A Novel Approach to the PCBAs Defects Detection Using Background Algorithm

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Abstract—Currently the AVI systems expand so much time to realize the inspection of PCBAs (Printed Circuit Board Assemblies) component by component. In this article, we focused to provide a solution that can supply a widely inspection area of a PCB (Printed Circuit Board) using an image processing algorithm developed in MATLAB (Matrix Laboratory) to realize the visual inspection of missing or misaligned components in PCBAs during the run-time of the assembly process. Hence, this novel approach is performed to detect those defects using the concept of background subtraction, capturing the PCB image of reference and a testing PCB image (with defects), then showing the missing or misaligned components in the foreground plane (FG) and the defects in the PCB surface in the RGB loaded image on MATLAB. In addiction, also is described the background modeling concepts using the Mixture of Gausian (MoG) classical method. Results involving compression image average and detection efficacy also are presented in this work.

Keywords—*computer vision; PCBA defect detection; PCB assembly; PCBA inspection process; backgorund subtraction; image processing*

I. INTRODUCTION

Various concentrated algorithms of background subtraction have been proposed in the recent literature. All those proposed methods have tried effectively to estimate the background model of the frames temporal sequence in the image processing technique [1]. One of the simplest algorithms is the “frame differencing” [2]. In this algorithm, the actual frame is subtracted from the previous frame, and this method was extended in such a way that reference frame is obtained by the estimative of a certain period of frames [3] [4], being this method also known as median filter.

Still according to [1], variations in the types of defects belonging to a PCB assembly and the numerous fabrication technologies of electronic components have been done the development of AVI systems a challenge question in the ultimate decades. In the development of such systems, many studies [5] [6] have delineated the missing components as one of the five common types of defects and the necessity for AVI systems to obtain appropriate algorithms for the detection of those defects. Have been founded in those studies that about 20% of defects were missing electronic components, missing ball-grid matrix was about 5% and missing ICs were about 11%. This question has become the approach for the missing and misaligned components detection in their works [7].

Taking into account those aspects, and the necessity to develop robust algorithms for the AVA systems inspection quality in the industry of PCBs assembly, in this work a background algorithm capable to detect missing or misaligned components in RGB images of PCBAs was developed in MATLAB, aiming to classify and identify the main failures occurred during the run-time inspection in a high volume assembly line in the industry. Also, a red marker was embedded to this algorithm, identifying in the RGB PCB image the failures of missing or misaligned components in the red color.

A compression tax also is implemented to the algorithm, indicating the average compression of the reading PCB image, testing image, background test image and RGB red color testing image in the GUI developed using the MATLAB. Hence, those compression tax indicators are indeed to classify the minimum average for that a PCBA could be identified as defected, being in this work the minimum compression tax about 70:1 during the run-time test of the background testing image in the experiment 2. That means the all the background images about a compression tax up to 70:1 tested in this novel algorithm will be considered as a defected PCBA image.

According to [1], about the mathematic model utilized in this work, the main techniques for the background modeling, can be classified into two main categories: non-recursive and recursive. Non-recursive techniques requires a widely space storage quantity, and because this reason, do not seems to be an interesting option, hence, in the mathematic model, was choose a recursive technique. Into the various recursive techniques, was decided to use the classical model of Mix of Gaussian (MoG), being this the more widely utilized technique for the background modeling into the area of PCBs inspection in a high volume assembly line in the industry.

Therefore, in the next topics of this work, is represented the main research methods utilized to the development of the background algorithm in MATLAB capable to detect defects as missing and misaligned components in PCBAs.

II. LITERATURE REVIEW

According to [8], AVIs are often used to check the functionality of a PCB assembly. Today, PCBs have evolved to become more complex in design, multi layered and are assembled with increasingly miniaturized components. This has made quality control of PCBs more challenging and demanding. Currently, AVIs combined with in-circuit-testers (ICT) are the most prominent systems that are used to check the functionality of a PCB assembly. This is because AVI systems provide better quality control at lower costs. Inspection systems placed at appropriate sections along an assembly line will reduce rework cost which would eventually provide better results during the electrical testing phase.

As cited in [9], Printed Circuit Board is a backbone of all of the electronic products used in various sectors such as Automotive, Medical, Aerospace, and Defense etc. Manufacturing of complete PCB involves two processes i.e. manufacturing of Bare PCB and manufacturing of assembled PCB. The manufacturing processes for both are unique and follow their own stages. Assembling of electronic components onto the bare PCB plays a major role and is application specific. Each stage in the assembly process possesses its unique steps and are defined based on design specifications of the end product.

An automatic visualized inspecton system [10] is used for fault identification of the assembled PCB. Different techniques are used for detecting the defects such as missed components, wrong polarity, and breaks in circuits. Specifically, fault-detection method involves the conversion of RGB to Gray, thresholding, Bit-wised XOR operation on the reference & test image. Then contour analysis technique is used for training and labeling the obtained defects that result in identifying the defects. Further canny edge detection technique is applied. Finally, the resultant image obtained with the highlighted name of the faulted components.

The authors in [11] have made an estimated study on different automated defect detection techniques for inspecting the PCBs. The morphological segmentation of image is extracted to expect the maximum identification of defects in PCB image, this result in increased speed and accuracy. Initially the source image is captured in full color then it is converted into gray scale. Various filtering methods are applied to remove noise, the histogram view of the resultant image is stretched and equalized to fine tune it. Then wavelet transform and subtraction of images are implemented to identify the defects. They concluded that the specified technique performs faster compared to other techniques.

The authors in [12] have successfully experimented for detection of defects by applying template matching, background subtraction, and wavelet transform algorithms. They found the identification of misaligned component by using background subtraction algorithm. In this, the RGB image is converted into HSV and then it is converted to gray image. The median filter is applied to the gray image by tracing the boundary region and then in the resultant binary image the defect has been detected. For template matching algorithm the image is converted into gray scale image, then for both the images normalized cross correlation is calculated. Next, by combining the defect has been detected. Later for detecting the upside placed component, the median filter is applied by the conversion of the RGB format of PCBA image to gray. The difference in the images is identified and morphological operation is performed for finding the defects by applying the wavelet transform technique.

III. MATHEMATICAL MODEL

The main techniques for background modeling can be classified into two main categories; non-recursive and recursive. Non-recursive techniques require a huge storage space and hence do not seem to be an interesting option. Hence, we opted for a recursive technique. Within the various recursive techniques, we decided to use the Mixture of Gaussian (MoG) method. This is probably the most widely used technique. A density function that is a combination of different Gaussian components, each with mean intensity, standard deviation and appropriate weights, is maintained for each pixel.

In the MoG technique, we first need to decide on the components of the pixel vector which are going to be observed. From the sensors of the camera, the output vector at pixel level is as follows:

$$I = (R, G, B) \tag{1}$$

which separates the red (R), green (G) and blue (B) channels coded in a (8:8:8) ratio. Thus, we have 8 bits of color information for each of the three channels. This will become our vector which we will learn by observation. The variation in the observed vectors at pixel I, can be modeled separately by a mixture of K Gaussians. The probability P then of a pixel I belonging to the background is given by:

$$P(I) = \sum_{i=1}^{K} \omega_i \, f(\, I, \; \mu_i \,, C_i \,) \tag{2}$$

where K denotes the number of Gaussians, μ the mean value of the Gaussian and C the covariance matrix associated with this Gaussian. Since we have chosen a single Gaussian to model the background, $K = I = \omega = 1$. This model is will be used to learn the input vector from the camera sensors during run-time.

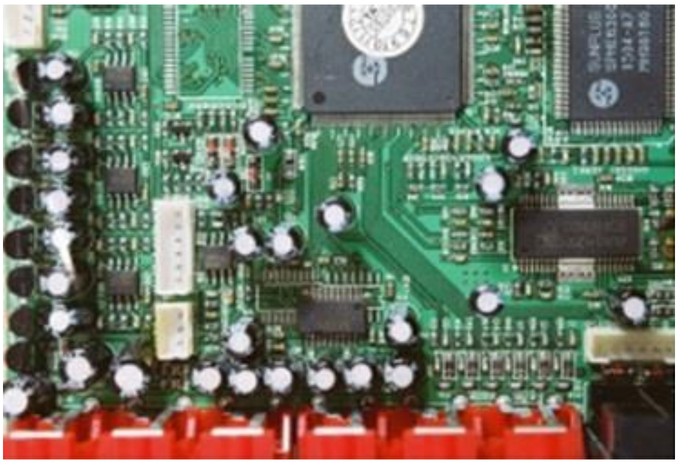
Having chosen a suitable mathematical model, we can proceed to describe the background subtraction process during run-time. We assume that all required memory for image processing has been allocated sufficiently. From Equation (2), we can see that in order to use a Gaussian density function, we need to obtain the mean value μ and the covariance matrix C for each pixel.

IV. RESEARCH METHODOLOGY

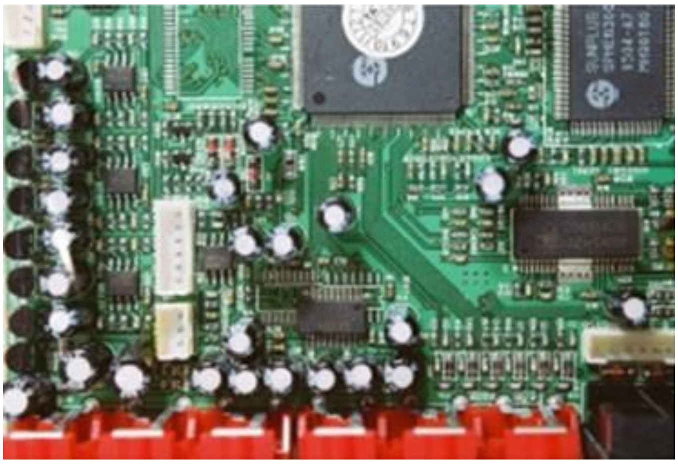
During the experiments with PCBAs of this work, the assembled PCB was warranted to contain various electronics components of widely types, sizes, colors and shapes. In this novel experiment, first of all, free PCBs defects assembly were utilized in the learning process to obtain the reference image of the background utilized in the developed algorithm.

A. Bench of testing and reference PCBAs images

A bench of 4 images was composed to test the novel algorithm of image subtraction developed in MATLAB. There are images related to ICs and capacitors positioned correctly in the PCB assembled board.



(a)



(b)

Figure 1: Good reference of a PCBA without misaligned components (a) and PCBA with misaligned components (b)

(c)

(d)

Figure 2: Good reference of a PCBA without missing IC (c) and PCBA with missing IC (d)

(e)

(f)

Figure 3: Good reference of a PCBA without misaligned capacitor (e) and PCBA with misaligned capacitor (f)

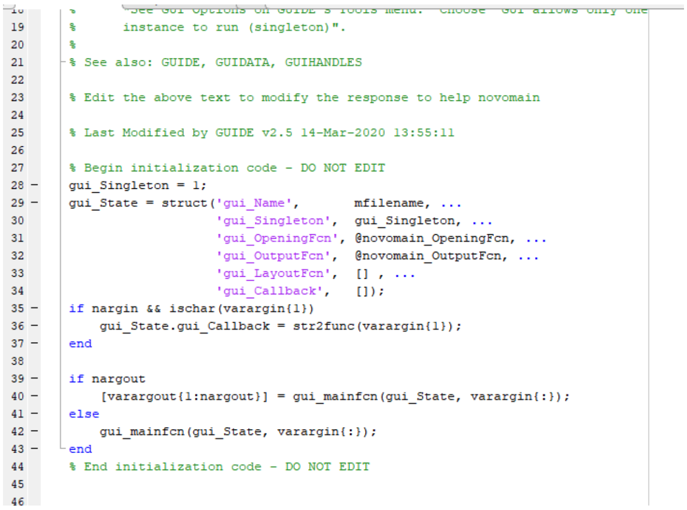
(g)

(h)

Figure 4: Good reference of a PCBA without missing SMT IC (g) and PCBA with missing SMT IC (h)

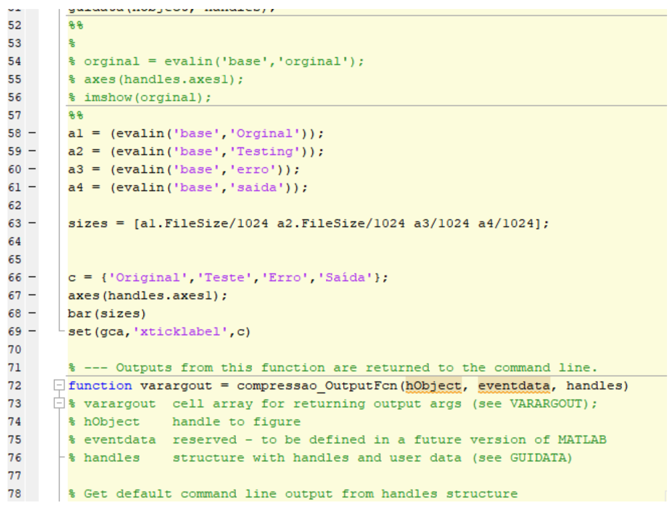
B. Algorithm of background subtraction developed in MATLAB

The following images shows the screen of algorithm developed in MATLAB for the PCBA background subtraction operation also capable to mark in red color the defects of the PCBs RGB image indicating missing or misaligned electrical components such as IC, capacitors or SMT devices. The compression tax screen developed using a GUI interface in MATLAB also is shown in the Figure 6 of this subsection.



```
%      instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help novomain

% Last Modified by GUIDE v2.5 14-Mar-2020 13:55:11

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @novomain_OpeningFcn, ...
                   'gui_OutputFcn',  @novomain_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT
```

Figure 5: Code script interface of the novel background algorithm



```
%%
%
% orginal = evalin('base','orginal');
% axes(handles.axes1);
% imshow(orginal);
%%
a1 = (evalin('base','Orginal'));
a2 = (evalin('base','Testing'));
a3 = (evalin('base','erro'));
a4 = (evalin('base','saida'));

sizes = [a1.FileSize/1024 a2.FileSize/1024 a3/1024 a4/1024];


c = {'Original','Teste','Erro','Saída'};
axes(handles.axes1);
bar(sizes)
set(gca,'xticklabel',c)

% --- Outputs from this function are returned to the command line.
function varargout = compressao_OutputFcn(hObject, eventdata, handles)
% varargout  cell array for returning output args (see VARARGOUT);
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
```

Figure 6: Code script interface of the compression tax algorithm

C. Capacity of compression tax of the algorithm

The following Table 1 gives a summary of all the values of compression tax in the background subtraction algorithm for the original, testing, error and output images loaded in the GUI interface of this algorithm. The bench of images used to calculate the compression tax is the PCBAs images of Figure 1, Figure 2, Figure 3 and Figure 4.

TABLE I. COMPRESSION TAX SUMMARY

Figure	*Original*	*Testing*	*Error*	*Output*
Fig. 1	50:1	50:1	150:1	180:1
Fig. 2	50:1	50:1	70:1	170:1
Fig. 3	40:1	40:1	150:1	160:1
Fig. 4	30:1	30:1	105:1	110:1

D. Comparison with previous studies and improved GUI interface developed in MATLAB to mark in red color the defects detected in RBG PCBA image

Compared to the work [1] related in this article, we can see that the new background subtraction algorithm proposed for detecting missing or misalignment electronic components has a optimized interface with Original, Testing, Error, Output and Compression Tax buttons implemented to this GUI interface. Also can be observed the novel algorithm can detect in the RGB PCBAs images the defects as cited above during the run time process in MATLAB software.

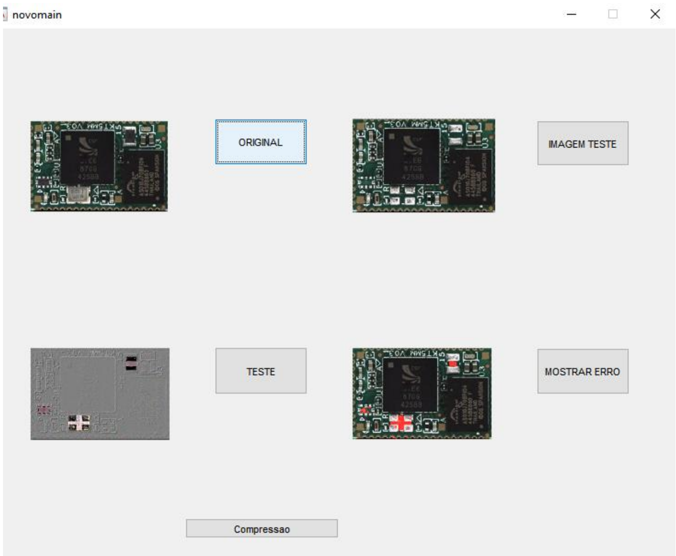


Figure 7: GUI interface of the novel background algorithm

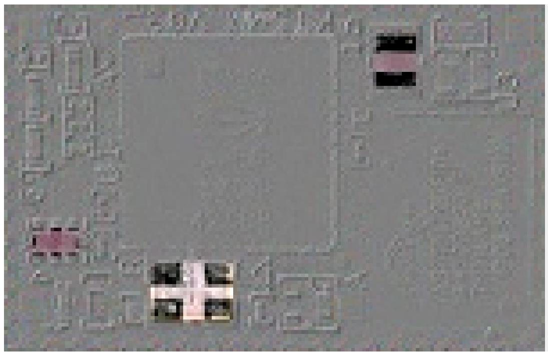


Figure 8: Background subtraction

Figure 9: Missing SMT component detected in red color

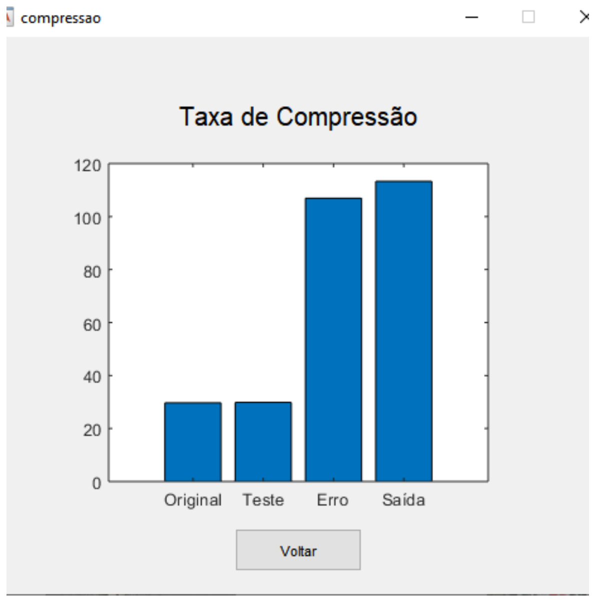


Figure 10: GUI interface of the compression tax

V. RESULTS

The results appoint a minimum compression tax about 70:1 related to the background subtraction image compression tax during the experiment 2 (Figure 2). That means all the background subtraction images of PCBAs loaded in this novel background subtraction algorithm, that shows a compression tax up to 70:1, certainly will present some kind of defect in the mounting board: misaligned or missing electronic components.

The Graphics 1, 2, 3 and 4 indicated in the Figures 11, 12, 13 and 14 shows the compression tax capacity of the PCBAs tested in the Figure 1, Figure 2, Figure 3 and Figure 4. Now the Graphics 2, indicated in the Figure 15, shows the minimum average curve in relation to the compression tax of background subtracted images in the Figure 1, Figure 2, Figure 3 and Figure 4 subtitled in the GUI experiment as "Error" for a PCBA can be considered as a defect board (see Table 1).

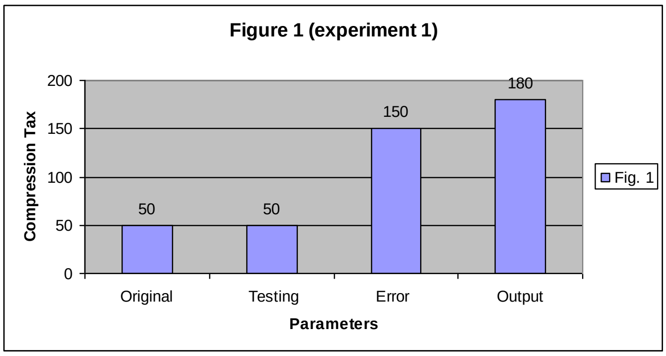


Figure 11: Compression tax of Figure 1 experiment

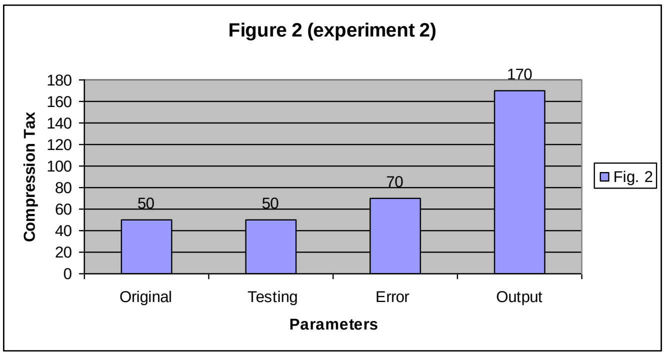


Figure 12: Compression tax of Figure 2 experiment

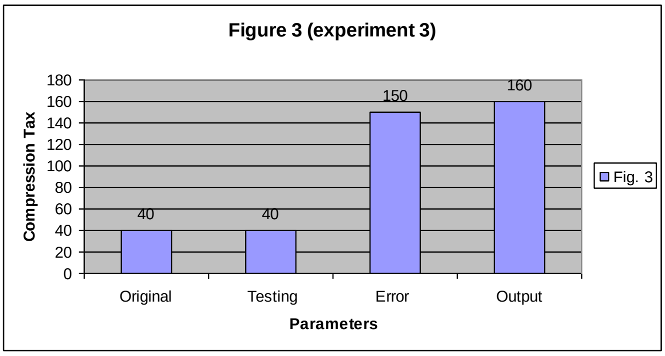


Figure 13: Compression tax of Figure 3 experiment

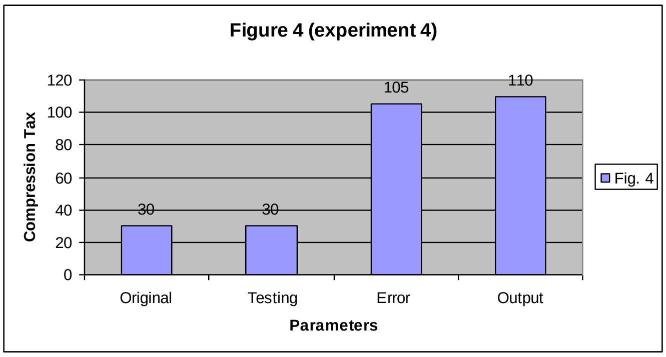


Figure 14: Compression tax of Figure 4 experiment

A minimum curve of the compression tax for "Error" parameters in the experiments 1, 2, 3 and 4 also can be plotted in the Graphic 5:

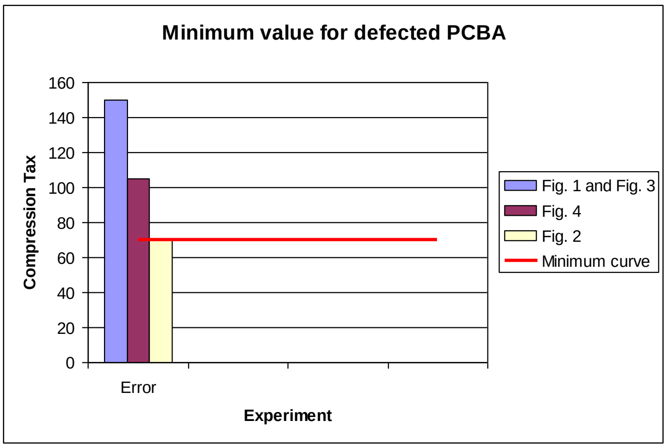


Figure 15: Minimum value for a defected PCBA

V. DISCUSSION

The idea of this article is to provide to the reader a general vision about the basics phenomena involved in the background subtraction images of four main PCBAs tests using MATLAB software. It is important that reader has a basic knowledge about the background image processing techniques, because those are the elements responsible for the PCBs assembled defect detection image processing generation. The presentation of the elements related to the background subtraction technique in this paper allows that your modeling can be incorporated to the other techniques of image subtraction, utilizing estimative parameters such as Kalman filters and Mohalanobis distance to average the distribution of RGB colors along the PCBA board. The literature regarding to the background subtraction techniques is very vast.

VI. CONCLUSION

In this work was deduced a model commonly utilized in the field of image processing to represent a pattern detection (background subtraction) of a bench composed by four main images (reference and testing images) of PCBAs with misaligned and missing components. Once defined the novel algorithm, also capable to identify the defects of those PCBs in the red marker in the RGB test images into a GUI window in MATLAB, were defined optimized implementation strategies to account the minimum compression tax in the "Error" classified images by the compression tax algorithm.

After a definition of an optimization metric through the novel algorithm for background subtraction detection, was verified the occurrence of minimum compression tax in the Figure 1, Figure 2, Figure 3 and Figure 4 experiments. The Graphics of average shows that a minimum compression tax for a assembled PCB can be classified as defected is about 70:1 is the "Error" parameter of the novel algorithm. With those results, was possible obtain a pattern referential able to detect missing or misaligned components in PCBAs in function of the developed algorithm in MATLAB.

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