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Fault Detection in Printed Circuit Board (PCB) using Image Subtraction Method

Avinash S, Prathapchandra, Ramachandra

***Abstract**: Fault detection in PCBs is a critical task in the electronics industry to ensure the consistency and performance of electronic devices. One common approach for detecting defects in PCBs is the subtraction method, which involves subtracting a reference image of a defect-free PCB from an image of a PCB with defects. The resulting image gives the differences between the two images, making it easier to detect and classify defects. In this work, a defect detection system for PCBs using the subtraction method in MATLAB is proposed. The research work uses publicly available PCB defect datasets to train and test the system. The work consists of image pre-processing, image subtraction, and defect detection.*

***Keywords:** Image Pre-Processing, Image Subtraction, Image Resizing, Threshold, Fault Detection*

I. INTRODUCTION

The uses of PCBs are numerous, with applications in a wide range of critical equipment and operations. Quality inspection in the PCB manufacturing industry is paramount for producing highly reliable components. The PCB production process contains several steps: (i) Starting with a Raw material preparation step, (ii) Exposure and development of the conductor step, (iii) material removal step through chemical or mechanical processes, (iv)Layering step, (v) Masking step for protection. Moreover, many manufacturers have inspection steps in between critical steps to remove nonconformities moving forward in production lines; a single undetected defect that passes through any one of these steps could make an entire PCB obsolete [7]. Defects are inevitable during the production of PCBs. This will significantly impact the functionality and performance of electronic components, and therefore, there is a need for effective techniques to identify these defects. Printed Circuit Board Manufacturing Flow Diagram is shown in Fig.1 [10]

A.Defects of the Printed Circuit Board

Imperfections on PCBs can be categorised into two sectors: Cosmetic defects and Functional defects. Cosmetic defects are imperfections that compromise the appearance of the PCB, such as pinholes, breakouts, over-etching, and under-etching. Cosmetic defects won't pose an immediate threat to the operation of the PCB, but can jeopardise its performance in the long run due to abnormal heat dissipation and current distribution. Functional defects are considered to be fatal issues, which means the PCB does not fulfil the objective for which they are designed; conductor breaking and short-circuit are some of the defects in this category [7]. PCB with a variety of Defects is shown in Fig.2

Fig.1: Printed Circuit Board Manufacturing Flow Diagram

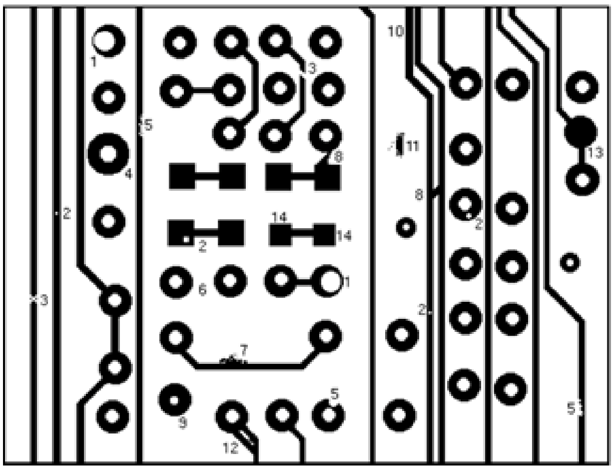

Fig.2: PCB with Defects

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1. Breakouts 2. Pinhole 3. Open circuit 4. Under-etch 5. Mouse bite 6. Missing conductor 7. Spur 8. Short 9. Wrong size hole 10. Conductor is tooclose to 11. Spurious copper 12. Excessive short 13. Missing hole 14. Over-etch.

PCB defects can be categorized into several types based on their nature and cause. Some common defects include [8]:

- Short Circuit: A short circuit occurs when two or more points on the PCB that are not intended to be connected become connected, resulting in a flow of current where there should be none. This can cause overheating, damage to components, and in some cases, a complete system failure.
- Open Circuit: An open circuit is the opposite of a short circuit. Instead of excessive current flow, there is a lack of current flow due to a broken connection or an open circuit. This can cause the PCB to malfunction or fail.
- Soldering Defects: Soldering defects can include incomplete soldering, insufficient or excessive solder, cold solder joints, and solder bridges. These defects can lead to poor electrical connections, resulting in intermittent or permanent failures.
- Component Misplacement: Component misplacement occurs when a component is placed in the wrong location or orientation. This can result in incorrect or failed connections, causing a range of problems, from intermittent failures to complete system failures.
- Copper Trace Damage: Copper traces on a PCB can be damaged by various means, such as scratches, nicks, or corrosion. This can lead to the loss of signal or power, resulting in a range of problems, from intermittent failures to complete system failures.

B. Printed Circuit Board with no defect

Imperfections. The following points can be considered for the PCB with no defects [9]

- Component Placement: All the components on the PCB should be placed in their respective positions and should be appropriately aligned with the design specifications
- Soldering: The solder joints on the PCB should be smooth, uniform, and free from any excess or inadequate solder material. There should be no visible solder bridges or solder balls
- Circuit connectivity: All the circuits on the PCB should be connected appropriately without any short circuits, open circuits, or other connectivity issues
- Electrical performance: The electrical performance of the PCB should be according to the design specifications and should not exhibit any unexpected behavior
- Physical integrity: The PCB should be free from any physical damage such as cracks, scratches, or deformation

Overall, an undamaged PCB should meet all design specifications, function properly, and be physically intact, with no visible defects. PCB with no Defects is shown in Fig.3

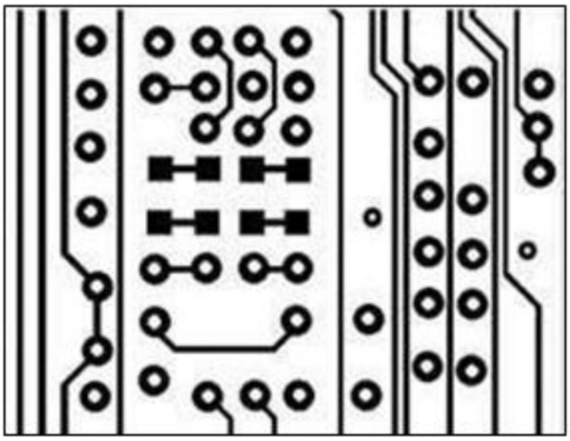

Fig.3: PCB with no Defects

In this work, the detection system for the final board is introduced, which is crucial to guaranteeing production quality. Electrical and optical inspections are the two types of quality inspections for PCBs. Visual detection technology based on image processing has become a key research aspect, offering advantages such as non-contact operation, high speed, and precise results. The image visual inspection system for PCBs can recognise defects such as bad welding points, breaking points, and short circuits through digital image processing and recognition technology.

II. LITERATURE SURVEY

A literature survey is a fundamental practice for understanding and developing ideas. A literature survey not only summarises the existing knowledge in an area or field. but also But also but also

M.H. Thigale, Shivani Gaikwad, Priyanka Nangare et.al [1] presented a PCB inspection system and the inspection algorithm, which mainly focuses on defect detection and defect classification. The Machine Vision PCB Inspection System is applied at the first step of manufacturing. In this work, the system's purpose is to automate the detection of defects in PCBs, thereby relieving human inspectors from the tedious task of identifying defects that may lead to electrical failure.

Neelum Dave, Vikas Tambade, Balaji Pandhare [2] focuses on more efficient techniques in the fabrication process. The objectives of this work are to provide an inexpensive and comprehensive method for defect detection. Introducing and implementing a PCB inspection system using image processing to remove the subjective aspects of manual inspection. At the same time, this system provides a real-time assessment of the PCB. The basic technique of the proposed system is to detect defects based on digital images of the PCB using image processing techniques.

The paper [3] proposes a deep learning-based image detection method for PCB defect detection, addressing the limitations of traditional methods in terms of template dependence, computational cost, and susceptibility to noise. The method introduces a new network based on Faster RCNN for improved performance. The proposed method utilizes a ResNet50 with Feature Pyramid Networks as the backbone for feature extraction.

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This choice enables better detection of minor defects on the PCB. Additionally, the method incorporates GARPN (Guided Anchoring Region Proposal Network) to predict more accurate anchors and merges the residual units of ShuffleNetV2. Experimental results demonstrate that the proposed method outperforms other PCB defect detection methods and is more suitable for deployment in a production environment. Furthermore, the method's effectiveness is validated across different PCB defects datasets.

Bing Hu and Jianhui Wang [4] aims to address the issues of low accuracy and efficiency in PCB defect detection using reference methods. The solution involves the use of a Transformer-YOLO network detection model. The approach begins by utilising an enhanced clustering algorithm to generate anchor boxes tailored to the PCB defect dataset. This step helps in accurately localizing and classifying defects. Instead of relying on traditional Convolutional Neural Networks (CNNs) for image feature extraction, the solution employs the Swin Transformer as the feature extraction network. The Swin Transformer is recognised for establishing effective dependencies between image features, resulting in improved detection performance.

Qin Ling And Nor Ashidi Mat Isa [5] provides a comprehensive review of defect detection methods in PCBs by analyzing over 100 articles published between 1990 and 2022. The aim is to address the need for high-precision and rapid defect detection in PCBs, given their increasingly small dimensions resulting from advancements in integrated circuits and semiconductor technology.

III. SYSTEM REQUIREMENTS

This journal employs a double-blind review process, which means that both the reviewer(s) and author(s) identities are concealed from the reviewers, and vice versa, throughout the review process. All submitted manuscripts are reviewed by three reviewers, one from India and the other two from overseas.

A. MATLAB Tool

MATLAB is a high-level programming language and interactive environment developed by MathWorks in 1984. It is widely used for numerical computation, data analysis, and visualization. MATLAB's strengths lie in its ability to perform fast and accurate numerical computations, with built-in functions for various mathematical operations and tools for handling arrays and matrices. It excels in data analysis and visualisation, offering extensive capabilities for importing, exporting, and manipulating data, as well as creating high-quality charts and graphs. MATLAB is flexible and extensible, with a vast library of built-in functions and toolboxes covering various domains. It also supports the development of custom functions and toolboxes. MATLAB is commercial software requiring a license, but a free trial version is available. Open-source alternatives, such as GNU Octave and Scilab, provide similar functionality.

B. Graphical User Interface (GUI)

The GUI provides easy access to all the features of the PCB defect detection system. Fig.4 shows the GUI in MATLAB

Fig.4: Graphical User Interface

GUI is a powerful tool in MATLAB that allows users to create interactive graphical interfaces for their applications. It enables users to design and build custom user interfaces with various components, such as buttons, sliders, menus, text boxes, and graphs, that can be easily accessed and manipulated by the user. The MATLAB GUI provides a platform for users to input data, perform computations, visualize results, and interact with the program. It simplifies the user experience and reduces code complexity. With the MATLAB GUI, users can easily create professional-looking interfaces, making it an essential tool for developing user-friendly applications across various fields, including engineering, science, finance, and education.

C. PCB Image Dataset

A PCB defect dataset for image processing is a collection of digital images of PCBs with various types of defects, used to test image processing algorithms for detecting these defects. PCB defect datasets for image processing typically contain high-resolution digital images of PCBs, captured using various imaging techniques. These images may include different types of defects, such as shorts, opens, misalignments, cracks, and delamination. In this paper, eight different reference PCB images, each with 10 test images that have defects, are collected. Fig. 5 shows a PCB with no defects that will be used as a reference image for defect detection, and Fig.6 shows a PCB with defects that will be used as a test image for defect detection.

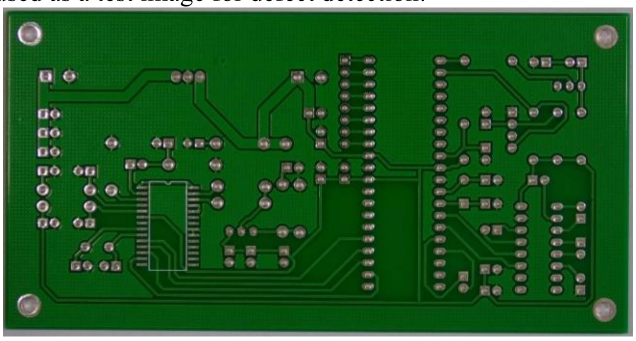

Fig. 5: PCB Reference Image

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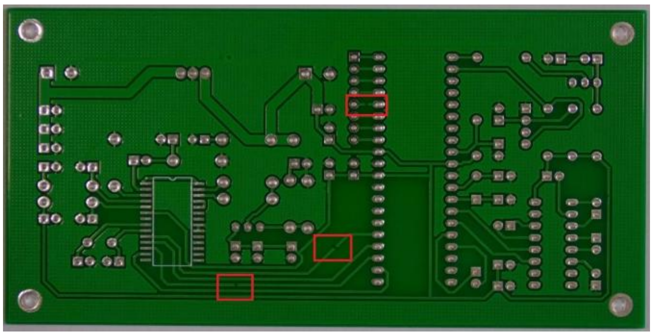

Fig. 6: PCB Test Image

IV. METHODOLOGY AND IMPLEMENTATION

A. Methodology

The proposed method for the system involves acquiring two PCB images: one is a reference image with no defects, and the other is a test image of the same design that may contain defects. Then, image pre-processing, image subtraction, thresholding, and defect identification are carried out. The resultant image is the defects present in the test PCB that can be located [6].

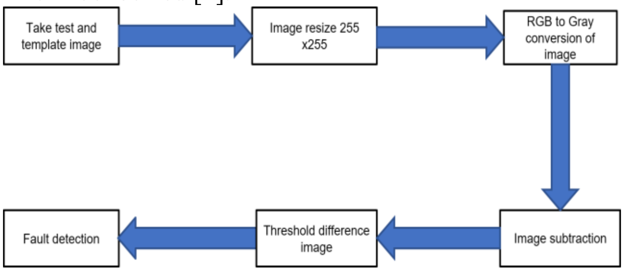

Fig.7: Block Diagram of the Defect Detection in PCB

To perform defect detection of PCB in MATLAB

- Import the image of the reference PCB and test PCB to be analyzed into MATLAB
- Implement an image processing algorithm on the PCB image, such as image resizing and RGB to grey conversion
- Perform Image subtraction between references and test PCB
- Threshold the difference image to get the image of defects in the PCB

B. Image Subtraction

The preprocessed inspection and reference images were compared using an absolute difference operation [6]. An XOR operation would be performed between the inspection image and the reference image, resulting in a temporary image that contains anomalies and/or defects. A pixel-to-pixel comparison would be performed, comparing the pixel in the reference image (x_r, y_r) with the corresponding pixel in the inspection image (x_i, y_i). The following table (Table I) depicts the logical operation of the XOR function.

Table I: Logical XOR Operation

Pixel (x_r, y_r) Reference Images	Pixel (x_i, y_i) Inspection Image	Output
0	0	0
0	1	1
1	0	1
1	1	0

According to the logic, If both pixels being compared are similar in value. (xr, yr) = 0 (black) and (xi, yi) = 0 (black) or (xr, yr) = 1 (white) and (xi, yi) = 1 (white), the resulting output value would be 0/black. This is not considered an anomaly or defect. If the pixels being compared have different values. (xr, yr) = 0 (black) and (xi, yi) = 1 (white) or (xr, yr) = 1 (white) and (xi, yi) = 0 (black)

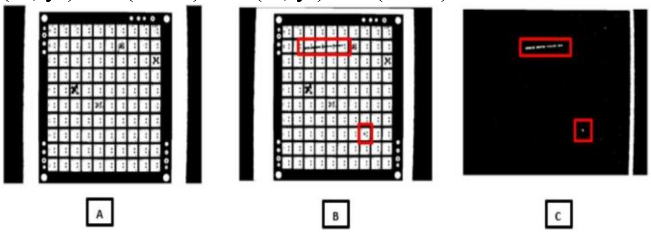

Fig.8: Reference Image A, Inspection Image B, the Output Image of the XORoperation C

The resulting output value would be a 1/white pixel. This is considered an anomaly or a defect. Fig.8 shows the process mentioned above. The reference image is "A" and the inspection image is "B". The red rectangles highlight the defects in the inspection image [8]. The output image with the anomaly/defect is shown in image "C" and is highlighted by the red rectangles.

V. RESULTS AND DISCUSSION

A. Detection of PCB Without Defects

The output obtained for defect detection in a PCB using MATLAB is shown in Fig., which indicates zero defects, meaning that the system has successfully detected that the PCB is free from any visible or measurable defects. The defects that can be detected through this process include open circuits, short circuits, and other manufacturing defects.

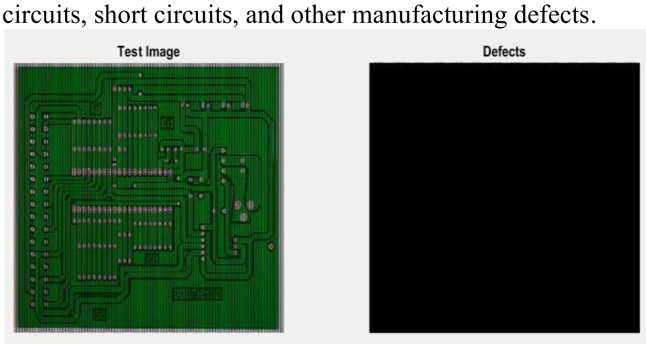

Fig.9: Output in MATLAB with No Defects

This result can assure the manufacturer and end-users that the PCB is of high quality and is less likely to fail or malfunction during operation.

B. Defect Detection in PCB

The output obtained for defect detection in a PCB using MATLAB is shown in Fig.10, where the system has identified one or more defects in the PCB. The defects can take the form of open or short circuits, as well as other manufacturing issues.

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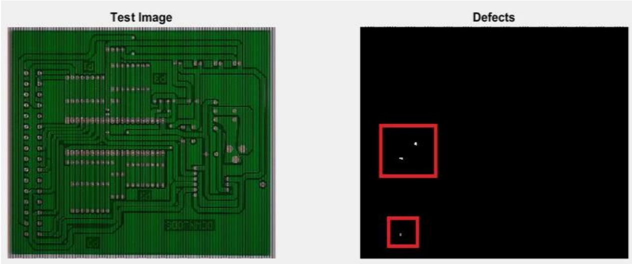

Fig.10: Defected Output in PCB

If the system's output indicates defects, it means the PCB has failed the inspection process and requires further analysis to identify the specific issue.

C.Defect Detection and Identification

The output obtained for defect location identification in PCB using MATLAB is shown in Fig. 11, indicating that the system has identified one or more defects in the PCB. Here, the location of the defects can be identified by clicking on the Defects in the Defect image and Test image [9].

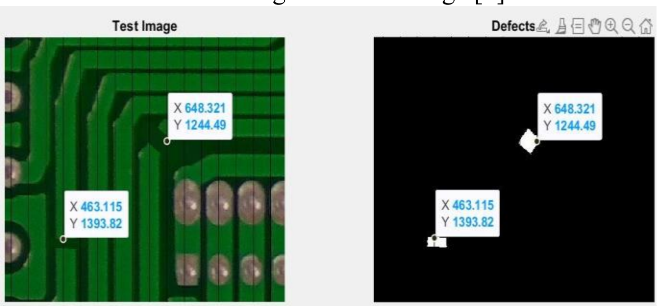

Fig.11: Defected Output in MATLAB with Location Identification

D.Output Analysis

Tested 60 PCBs for defect detection and observed the Run time and Number of defects in the PCBs as shown in Table II.

Table II: Output Analysis

Test PCB	Run Time	Number of Defects
01_open_circuit_01	5.74s	3
01_open_circuit_02	2.61s	3
01_open_circuit_03	2.01s	2
01_open_circuit_04	2.05s	3
01_open_circuit_05	1.38s	3
01_open_circuit_06	1.96s	3
01_open_circuit_07	2.21s	2
01_open_circuit_08	2.08s	3
01_open_circuit_09	1.90s	3
01_open_circuit_10	1.86s	3

Test PCB	Run Time	Number of Defects
04_open_circuit_01	1.97s	4
04_open_circuit_02	2.02s	3
04_open_circuit_03	1.70s	3
04_open_circuit_04	2.07s	3
04_open_circuit_05	2.17s	3
04_open_circuit_06	2.04s	3
04_open_circuit_07	2.07s	3
04_open_circuit_08	2.32s	3
04_open_circuit_09	2.39s	3
04_open_circuit_10	2.04s	3
05_open_circuit_01	2.08s	3
05_open_circuit_02	2.11s	3
05_open_circuit_03	2.05s	3
05_open_circuit_04	2.30s	6
05_open_circuit_05	1.93s	3
05_open_circuit_06	2.43s	3
05_open_circuit_07	2.21s	3
05_open_circuit_08	2.20s	3
05_open_circuit_09	1.98s	3
05_open_circuit_10	2.01s	3
06_open_circuit_01	2.27s	6
06_open_circuit_02	2.36s	5
06_open_circuit_03	2.22s	5
06_open_circuit_04	2.31s	5
06_open_circuit_05	2.03s	5
06_open_circuit_06	2.17s	5
06_open_circuit_07	2.20s	5
06_open_circuit_08	2.20s	5
06_open_circuit_09	2.36s	5
06_open_circuit_10	2.17s	6
07_open_circuit_01	2.23s	5
07_open_circuit_02	2.04s	5
07_open_circuit_03	2.28s	5

Test PCB	Run Time	Number of Defects
07_open_circuit_04	2.01s	5
07_open_circuit_05	2.07s	5
07_open_circuit_06	2.44s	5
07_open_circuit_07	2.26s	5
07_open_circuit_08	2.20s	5
07_open_circuit_09	2.30s	5
07_open_circuit_10	2.42s	5
08_open_circuit_01	2.17s	5
08_open_circuit_02	2.10s	5
08_open_circuit_03	2.14s	6
08_open_circuit_04	2.02s	5
08_open_circuit_05	2.42s	5
08_open_circuit_06	2.21s	5
08_open_circuit_07	2.21s	5
08_open_circuit_08	2.27s	5
08_open_circuit_09	2.28s	5
08_open_circuit_10	2.15s	5

VI. CONCLUSION

Defect detection in PCB using the subtraction method in MATLAB is a powerful technique that can help automate the PCB inspection process. The research involved the creation of a GUI that enabled users to load two images and perform image subtraction to identify any defects in the PCB board. The methodology involved several steps, including image acquisition, preprocessing, defect detection, and defect identification. The research successfully demonstrated the ability to accurately and efficiently detect defects in PCB images.

DECLARATION STATEMENT

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Conflicts of Interest	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval or consent to participate, as it presents evidence that is not subject to interpretation.
Availability of Data and Materials	Not relevant.
Authors Contributions	All authors have equal participation in this article.

REFERENCES

1. M.H. Thigale, Shivani Gaikwad, Priyanka Nangare, Nivedita Hule. 1996. " Defect detection and classification of PCB using MATLAB ". International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 02 | Feb -2017.

2. Neelum Dave, Vikas Tambade, Balaji Pandhare, " PCB Defect Detection Using Image Processing and Embedded System ", International Research Journal of Engineering and Technology (IRJET) Volume: 03 Issue: 05 | May-2016.
3. Bing Hu and Jianhui Wang, " Detection of PCB Surface Defects With Improved Faster-RCNN and Feature Pyramid Network ". IEEE Access May 24, 2020.
4. Wei Chen, Zhongtian Huang, Qian Mu, And Yi Sun, " PCB Defect Detection Method Based on Transformer-YOLO ", IEEE Access, November 19 2022. https://doi.org/10.1109/ACCESS.2022.3228206
5. Qin Ling and Nor Ashidi Mat Isa, "Printed Circuit Board Defect Detection Methods Based on Image Processing, Machine Learning and Deep Learning ", IEEE Access, February 8, 2023https://doi.org/10.1109/ACCESS.2023.3245093
6. Zheng, Jianfeng & Sun, Xiaopeng & Zhou, Haixiang & Tian, Chenyang & Qiang, Hao. (2022). Printed Circuit Boards Defect Detection Method Based on Improved Fully Convolutional Networks. IEEE Access. PP. 1-1. 10.1109/ACCESS.2022.3214306. https://doi.org/10.1109/ACCESS.2022.3214306
7. Liu, Chang & Zhou, Xiangyang & Li, Jun & Ran, Chuantao. (2023). PCB Board Defect Detection Method based on Improved YOLOv8. Frontiers in Computing and Intelligent Systems. 6. 1-6. 10.54097/fcis.v6i2.01. https://doi.org/10.54097/fcis.v6i2.01
8. Yang, Yujie, and Haiyan Kang. 2023. "An Enhanced Detection Method of PCB Defect Based on Improved YOLOv7" Electronics 12, no. 9: 2120. https://doi.org/10.3390/electronics12092120.
9. X. Hu, D. Kong, X. Liu, J. Zhang, and D. Zhang "Printed Circuit Board (PCB) Surface Micro Defect Detection Model Based on Residual Network with Novel Attention Mechanism," Comput. Mater. Contin., vol.78,no.1,pp.915-933.2024.https://doi.org/10.32604/cmc.2023.046376 https://doi.org/10.32604/cmc.2023.046376
10. Wujin Jiang, Taifu Li, Shaolin Zhang, Wenbin Chen, Jie Yang, PCB defects target detection combining multi-scale and attention mechanism, Engineering Applications of Artificial Intelligence, Volume 123, Part C, 2023,106359, ISSN 0952-1976, https://doi.org/10.1016/j.engappai.2023.106359.

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