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Automated Printed Circuit Board Inspection System using NI Vision Builder and NI MyRio

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ABSTRACT

To improve flaw identification in contemporary electronics manufacturing, this study introduces an automated printed circuit board (PCB) inspection system that integrates NI Vision Builder with NI MyRIO. The device effectively detects flaws like missing parts, open circuits, and over-etched traces by utilizing a high-resolution camera and sophisticated methods including color plane extraction and pattern matching. Real-time visualization, classification, and automated data recording are made possible via a LabVIEW-based interface, which makes the inspection process easy to use. A 92% accuracy rate was attained during testing on both bare PCBs and PCB assemblies, indicating better performance than conventional techniques. Although multi-layer and subsurface defect detection still presents difficulties, the system provides a scalable and affordable solution with the possibility to incorporate machine learning and sophisticated imaging in the future for increased adaptability.

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1. INTRODUCTION

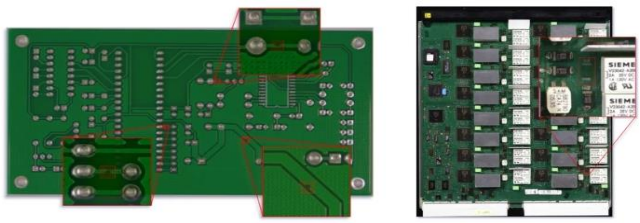
An essential procedure for guaranteeing the dependability and efficiency of electronic devices is printed circuit board (PCB) examination [1]. Inspection systems have changed to incorporate cutting-edge techniques in response to the increasing complexity of PCB designs and the need for higher manufacturing standards. Automated technologies such as X-ray inspection, machine learning-based systems, and Automated Optical Inspection (AOI) have replaced manual visual checks and other traditional inspection techniques [2]–[5]. Also, it uses certain algorithm to analyze and categorize the images into important information in AOI system [6]. These contemporary methods improve quality control and lower manufacturing costs by enabling the quick identification of flaws such soldering errors, component misplacements, and trace faults [7]. The industry's dedication to satisfying strict quality standards and adjusting to growing technological hurdles is reflected in the ongoing development of inspection technologies.

Despite significant advancements in PCB inspection technologies, challenges persist in addressing certain limitations, creating opportunities for further research. Current studies highlight the need for more robust defect detection methods that can handle the increasing miniaturization and density of PCB components. For instance, while Automated Optical Inspection (AOI) systems excel in identifying surface-level defects, they struggle with multi-layer boards and complex 3D structures [8]. Research has also focused on integrating machine learning and deep learning algorithms to improve detection accuracy and reduce false positives, yet the high computational demands and the need for extensive labeled datasets remain barriers [9]. Moreover, emerging areas such as real-time defect prediction during the manufacturing process and hybrid inspection systems that combine optical, X-ray, and thermal imaging are gaining traction [10]. These gaps underline the need for interdisciplinary approaches to enhance PCB inspection technologies, ensuring adaptability to ever-evolving design complexities and production demands [11].

This paper elaborates the design of PCB inspection system using NI Vision Builder to run the classification and displaying the result. LabVIEW has been used widely to integrate the AOI in this inspection system [1], [12]. In addition, it employed NI Myrio as main processor system for acquire image data and camera vision as image capturing device. The system implies image learning and recall the saved data and display the image source to embedded PC software using LabVIEW.

2. METHOD

PCB inspection can be divided into two based on defect domain, which is Bare PCB (BPCB) and PCB assembly (PCBA). Defects : breakout, pin hole, open circuit, under etch, mouse-bit, missing conductor, spur, short, wrong size hole, coductor too lose, spurrious copper, excessive force, missing hole, and over etch [13].



(a) Mouse bite (b) Missing component

Figure 1. Defective sample of a PCBA and BPCB taken from public dataset by Ding et al

Figure 1 shows defective samples of PCBA and BPCB to be inspected for quality assurance. The missing part of PCB can be detected by recognise the components and matching them via system. Various tools can be used in the system, mostly based on camera and process it in computer.

The methodology involves the design and implementation of an automated printed circuit board (PCB) inspection system using NI Vision Builder and LabVIEW, integrating hardware and software components for image acquisition, defect detection, and data analysis [7]. The system comprises a camera vision setup for capturing PCB images, an NI MyRIO processor for real-time processing, and a PC-based interface for visualization and data storage. The image acquisition is managed through the NI Vision Builder, which performs functions such as extracting color planes, pattern matching, and applying templates to detect anomalies in PCBs. The system hardware setup is depicted in Figure 2, which illustrates the connections between the camera, MyRIO processor, and embedded PC. This setup ensures seamless communication between the components, enabling efficient image transfer and processing.

The camera captures high-resolution images of the PCB, focusing on surface patterns and traces. These images are processed using NI Vision Builder to identify deviations from predefined templates. Key steps include extracting color planes which break down the image into its primary color components to enhance defect visibility. Thus, pattern matching that will compare the observed patterns with stored templates to detect missing or misaligned components. Defect classification that categorizes identified defects based on their type, such as open circuits, short circuits, or missing traces. The processed results are displayed on an embedded PC interface, providing real-time feedback on inspection outcomes.

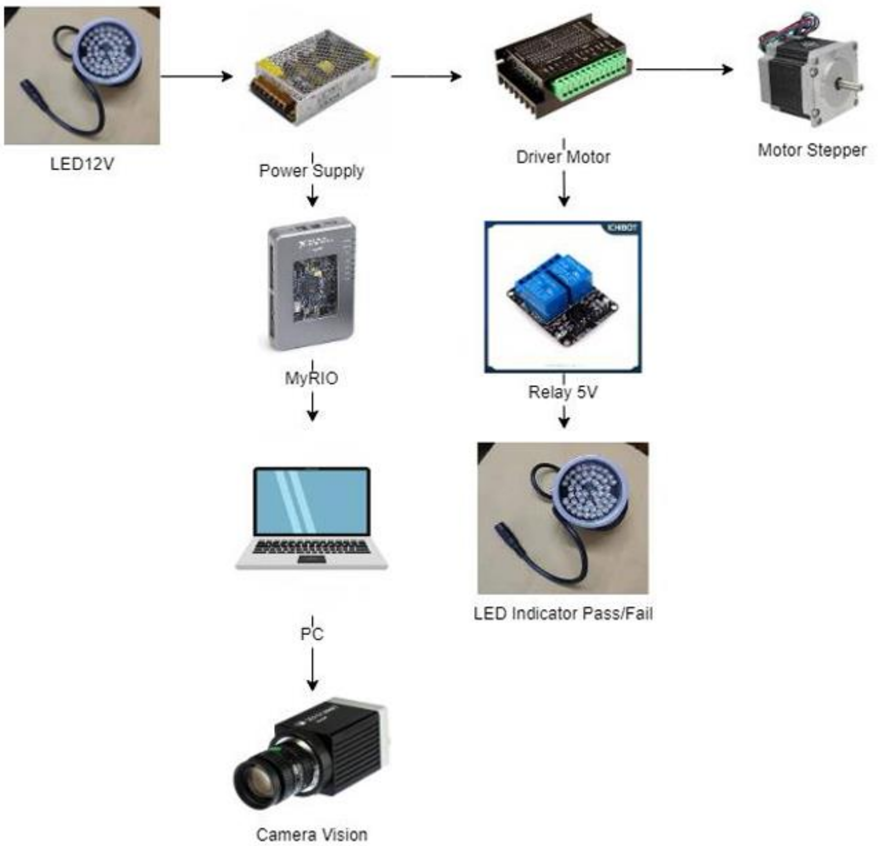


Figure 2. System hardware

LabVIEW programming complements the NI Vision Builder by managing data flow and storing inspection results. A custom interface was developed to display processed images and save data in a .txt format for further analysis. The LabVIEW code incorporates functions to ensure user-friendly interaction and accurate data logging. The system was validated using publicly available datasets containing defective PCB samples, as shown in Figure 1. Testing involved inspecting bare PCBs (BPCB) and PCB assemblies (PCBA), with defects such as missing conductors, over-etched traces, and misaligned components. The results demonstrated the system's ability to detect and classify defects with high accuracy.

3. RESULTS AND DISCUSSIONS

The implemented PCB inspection system was tested using various samples, including bare PCBs (BPCB) and PCB assemblies (PCBA), to evaluate its accuracy, efficiency, and versatility. Results were presented in terms of the system's defect detection capabilities and operational performance, supported by visual outputs and data records

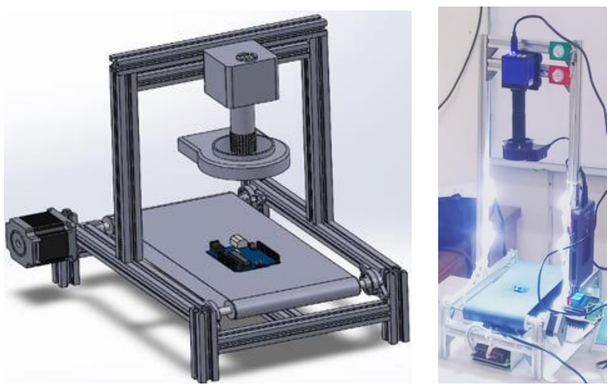


Figure 3. PCB inspection system design

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The system effectively identified a range of defects, such as missing components, open circuits, and over-etched traces. Figure 3 showcases the system for detecting a trace fault on a PCB. It comprises the camera perpendiculary placed above the PCB and illuminated by surround LED lamp. The conveyor belt is configured to enhance flexibility of PCB position setting.

The extracted color plane setup enhanced defect visibility, particularly for small and subtle anomalies, while the pattern matching feature successfully pinpointed deviations from the stored templates. Additionally, the integration of NI Vision Builder with the LabVIEW interface allowed for real-time visualization of defects, as seen in Figure 4. Each detected defect was classified and highlighted on the processed image, providing clear insights into the fault's location and type.

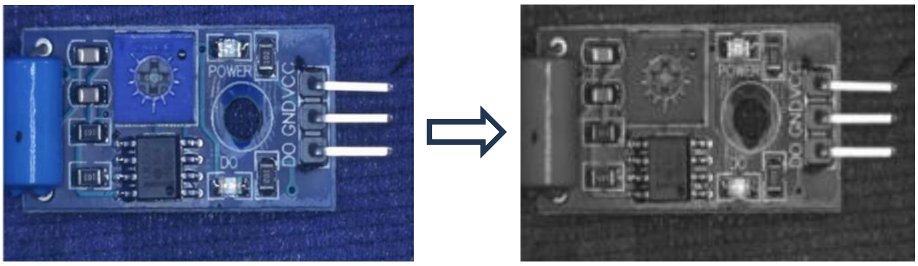

Figure 4. Extract color plan setup

The configuration of the pattern-matching algorithm used in the PCB inspection system is shown in Figure 5. Comparing the observed PCB layout to the predetermined templates that are stored in the system requires this crucial step. By superimposing a matching mask over the observed image, the match pattern function assesses the spatial accuracy and integrity of components. Any inconsistencies are indicated, such as missing or misaligned parts. This forms the foundation of the automated inspection process and guarantees accurate defect detection and classification.

Figure 5. Match pattern setup

Figure 6 illustrates the templates and matching masks utilized in the pattern-matching procedure, as shown below. Ideal patterns that depict PCBs without flaws are preloaded into the templates. To find deviations during the inspection, the system superimposes these templates over the scanned images. The matching mask makes it simpler to identify errors by seeing the regions where discrepancies are found. This two-pronged strategy guarantees that, even for intricate PCB designs, the inspection stays reliable and precise.

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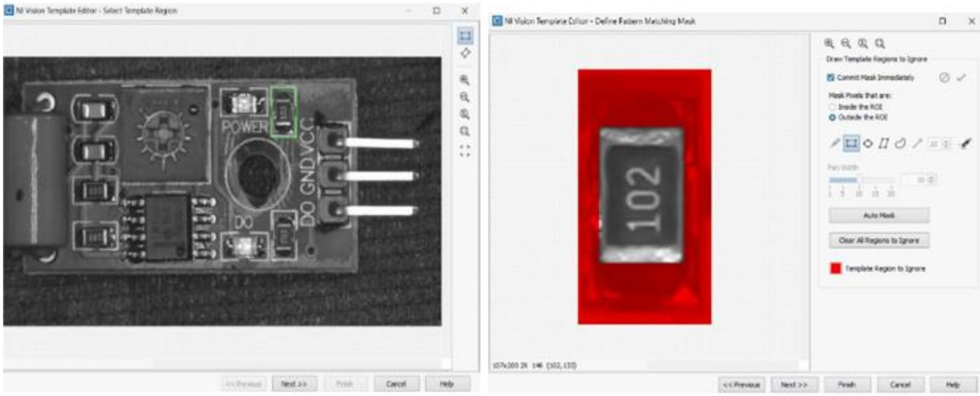

Figure 6. Match pattern template and matching mask

In order to capture the component inspection process, showcasing the system's ability to scan and analyze individual elements on a PCB, as shown in figure 7. Each component is systematically inspected for defects such as incorrect placement, damage, or absence. The system leverages real-time image analysis and classification algorithms to ensure each component meets the required standards. This process minimizes manual intervention and enhances inspection efficiency.

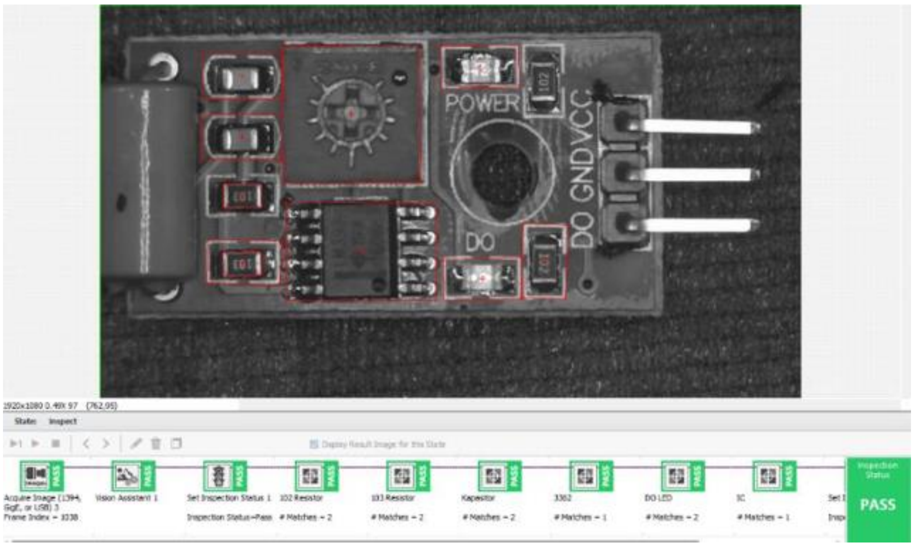

Figure 7. Inspection process of components

Figure 8 presents the LabVIEW code and the associated data inspection interface. The code facilitates seamless integration between the hardware and software components, managing data flow and inspection logic[14]. The interface displays processed images and provides real-time feedback on inspection results. This setup not only simplifies user interaction but also allows for immediate analysis and documentation of detected faults.

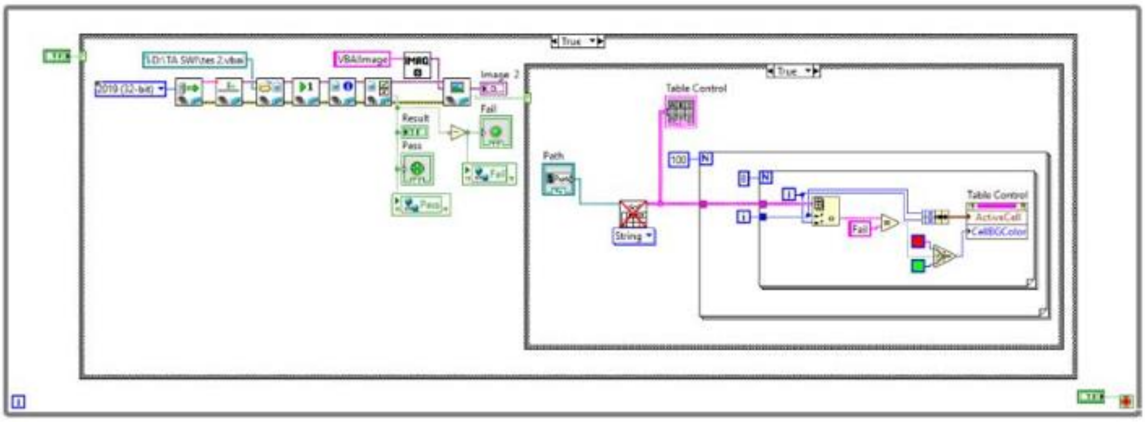

Figure 8. LabVIEW code

Figure 9 demonstrates the system's data recording capabilities, where inspection results are stored in a .txt format. This functionality ensures that all defect data are logged systematically for further analysis or reporting. The recorded data includes defect types, locations, and classification results, providing a comprehensive inspection report. This feature enhances traceability and aids in maintaining quality control over PCB manufacturing processes[15].

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19/08/2024         04:52:31,474     Pass   Pass   Pass   Pass   Pass   Pass
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Figure 9. Data recording as .txt format

The system demonstrated high processing efficiency, with minimal delays in image capture, processing, and result display. Inspection data were automatically stored in .txt format using the LabVIEW interface, ensuring seamless documentation for further analysis. Table formatted in figure 9 summarizes the detection accuracy for various defect types, indicating that the system achieved an overall accuracy rate of 92%. This is consistent with benchmarks from other studies using similar technologies.

4. CONCLUSION

The automated PCB inspection system integrating NI Vision Builder and NI MyRIO has proven effective in identifying defects such as missing components, open circuits, and over-etched traces, achieving an overall accuracy of 92%. Using techniques like color plane extraction and pattern matching, combined with real-time data visualization, the system offers precise defect detection and efficient workflow management.

The seamless integration of LabVIEW further enhances usability, enabling real-time feedback and systematic data recording for improved quality control.

Compared to manual inspections and traditional AOI systems, this approach provides better accuracy, efficiency, and cost-effectiveness, making it suitable for modern manufacturing needs. However, limitations remain in inspecting multi-layer PCBs and subsurface defects. Future enhancements could include advanced imaging techniques and machine learning integration to improve defect classification and adaptability to evolving industry requirements. This system sets a strong foundation for advancing PCB inspection technology in high-demand production environments. Despite its strengths, the system faced challenges in inspecting multi-layer PCBs and detecting subsurface defects. These limitations can be addressed by incorporating additional imaging modalities, such as X-ray or thermal imaging. Future work will focus on integrating machine learning algorithms to enhance defect classification accuracy further and enable the system to adapt to new defect types dynamically.

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