PCB Defect Detection and Classification

Introduction

Printed Circuit Boards (PCBs) are essential components in electronic systems, and ensuring their quality is critical for reliable device performance. Manual inspection of PCBs is time-consuming and prone to human error, especially in large-scale manufacturing. Therefore, an automated defect detection system is necessary to improve accuracy and efficiency.

This project presents a PCB Defect Detection and Classification System that combines image processing techniques and deep learning for automated inspection. The system detects defects by comparing a test PCB image with a defect-free template using image subtraction, thresholding, and contour detection. Detected defect regions are then classified into specific categories using a transfer learning-based deep learning model.

The application is deployed using a Streamlit web interface, allowing users to upload images, visualize detected defects, and download annotated results and reports. This end-to-end system provides an efficient and scalable solution for automated PCB quality inspection.

System Architecture

The PCB Defect Detection and Classification System follows a modular architecture consisting of four major layers: Input Layer, Image Processing Layer, Classification Layer, and Presentation Layer. Each module is designed to work independently while forming a complete end-to-end inspection pipeline.

1. Input Layer

The system accepts two types of inputs:

- Template PCB Image (defect-free reference)
- Test PCB Image (image to be inspected)

The test image is uploaded through the Streamlit web interface. Both images are resized to identical dimensions to ensure accurate comparison.

2. Image Processing Layer (Defect Localization)

This layer is responsible for detecting potential defect regions using classical computer vision techniques.

1. Grayscale Conversion
   Both template and test images are converted to grayscale to reduce computational complexity.
2. Image Subtraction
   Absolute difference is computed using:
3. Noise Reduction
   Gaussian blur is applied to smooth minor variations and remove noise.
4. Thresholding
   Binary thresholding converts the difference image into a defect mask.
5. Contour Detection
   OpenCV contour detection identifies connected regions that represent possible defects.
6. ROI Extraction
   Bounding boxes are generated around each detected contour, and defect regions are cropped for classification.

This layer outputs localized defect regions (ROIs).

3. Classification Layer (Deep Learning Model)

The extracted ROIs are passed to a trained deep learning model for classification.

Model Details:

- Base Model: EfficientNetB0 (Transfer Learning)
- Custom Dense Layers
- Softmax Output for Multi-Class Classification

Each ROI is classified into one of the predefined defect categories such as:

- Missing Hole
- Mouse Bite
- Open Circuit
- Short Circuit
- Spur
- Spurious Copper

The model outputs:

- Defect type
- Confidence score

4. Presentation Layer (Web Application)

The final results are displayed through a Streamlit-based web interface.

Features:

- Annotated image with bounding boxes
- Defect labels with confidence scores
- Total defect count
- Downloadable annotated image
- CSV log file export containing:
    - Defect ID
    - Type
    - Confidence
    - Coordinates
    - Area

5. Overall Data Flow

The complete system workflow is:

Image Upload → Preprocessing → Image Subtraction → Mask Generation → Contour Detection → ROI Extraction → Deep Learning Classification → Visualization & Export

6. Architectural Design Characteristics

- Modular structure (separate image processing, training, and UI modules)
- Reusable deep learning model
- Scalable for additional defect classes
- Suitable for real-time inspection scenarios

PCB Defect Detection System

Upload a PCB image to detect and classify defects automatically.

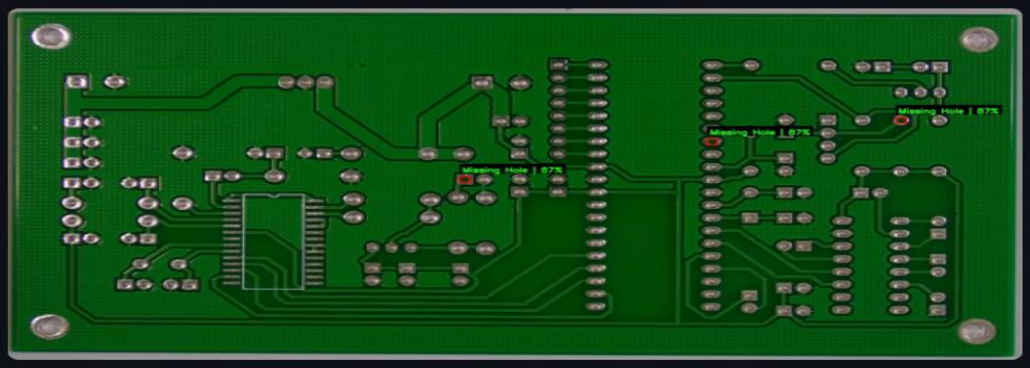
Upload PCB Image

Drag and drop file here
Limit 200MB per file • JPG, PNG, JPEG

Browse files

01_missing_hole_03.jpg 1.4MB

Detection Result



Total Defects Detected: 3

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Defect Type Distribution

- Missing Hole: 3

Average Detection Confidence: 87.0 %

Overall Model Accuracy: 85.0 %

Overall Timetaken to detect defect: 6 seconds

Detailed Defect Log

	Defect_ID	Defect_Type	Confidence (%)	X	Y	Width	Height	Area
0	1	Missing Hole	87	1351	759	31	26	806
1	2	Missing Hole	87	2091	589	29	26	754
2	3	Missing Hole	87	2655	493	31	24	744

⬇ Download Annotated Image

⬇ Download CSV Log

The PCB Defect Detection and Classification System generates both visual and structured outputs after processing a test PCB image. The primary output is an annotated image in which detected defects are highlighted with bounding boxes. Each bounding box is labeled with the predicted defect type along with its confidence score, allowing users to clearly identify the location and nature of defects on the PCB.

In addition to the visual output, the system generates a CSV log file containing detailed information about each detected defect. The log includes defect ID, predicted class, confidence score, bounding box coordinates, and defect area. These logs can be used for quality analysis, record keeping, and further evaluation.

During the model development phase, the system also produces training outputs such as the trained model file and accuracy/loss plots, which help assess the performance and reliability of the classification model. Together, these outputs provide a complete and structured inspection report for PCB analysis.

Drive link for demonstration of project:

https://drive.google.com/file/d/1vQESJ5N5T-jutDMxWDhQf_h8tWuM8y9w/view?usp=sharing