



# International Journal of Innovative Research in Computer and Communication Engineering

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# PCB Error Detection using IoT on a Conveyor Belt

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**ABSTRACT:** This paper presents a low-cost, IoT-enabled Automated Optical Inspection (AOI) system for detecting printed circuit board (PCB) manufacturing defects. To maximize system stability, the architecture divides the workload: an ESP32-S3 edge device handles real-time hardware actuation (ultrasonic proximity detection and conveyor motor control), while a local server handles intensive image processing. Overcoming the resolution limits and routing complexities of standard microcontroller cameras, the vision subsystem utilizes a commercial smartphone's high-resolution IP video stream. Upon detecting a PCB, the ESP32-S3 halts the conveyor and wirelessly triggers the server to capture an image and execute OpenCV-based image subtraction. This identifies defects like missing or misaligned components, demonstrating a highly scalable and budget-friendly machine vision solution for small enterprises.

**KEYWORDS:** Printed Circuit Board, Automated Inspection, Image Processing, Machine Learning, Deep Learning, Defect Detection Introduction

## I. INTRODUCTION

Printed Circuit Boards form the backbone of almost all electronic devices, providing mechanical support and electrical connectivity among components. As PCB complexity and production volume increases, ensuring defect free manufacturing has become a critical requirement. Defects such as missing components, short circuits, open circuits, solder bridges, and misalignments can significantly degrade system performance and reliability.

Conventional PCB inspection methods rely heavily on manual visual inspection and electrical testing. While these methods can detect certain faults, they are limited by human fatigue, subjectivity, and low scalability. Automated PCB Error Detection Systems aim to overcome these limitations by using computational techniques to identify defects quickly and consistently.

This survey reviews the evolution of automated PCB inspection methods, analyzes existing techniques, and highlights current challenges and future trends in the field.

## II. EASE OF USE

### Types of PCB Defects

PCB defects can broadly be categorized into the following types:

#### Structural Defects

These defects occur in the conductive tracks and include open circuits, short circuits, broken tracks, and excessive copper. Structural defects directly affect electrical connectivity.

#### Component Related Defects

These include missing components, wrong component placement, reversed polarity, lifted leads, and damaged components. Such defects are common in assembly stages.

#### Soldering Defects

Solder bridges, insufficient solder, cold solder joints, and voids fall under this category and mainly affect surface mounted devices.



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### III. TRADITIONAL INSPECTION TECHNIQUES

#### Manual Visual Inspection

Manual inspection is simple and flexible but suffers from low accuracy, high labor cost, and inconsistency due to operator fatigue.

#### Electrical Testing

In circuit and flying probe testing are widely used electrical methods. Although accurate for connectivity faults, they fail to detect visual defects such as misalignment or poor soldering.

### IV. IMAGE PROCESSING BASED PCB ERROR DETECTION IMAGE PROCESSING TECHNIQUES FORM THE FOUNDATION OF EARLY AUTOMATED INSPECTION SYSTEMS.

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### V. IMAGE PROCESSING BASED PCB ERROR DETECTION

Image processing techniques form the foundation of early automated inspection systems.

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### VI. MACHINE LEARNING BASED APPROACHES

#### Feature Extraction and Classification

Features such as texture, edge density, and shape descriptors are extracted and classified using algorithms like Support Vector Machines, k Nearest Neighbors, and Random Forests.

#### Advantages and Limitations

Machine learning methods provide better adaptability than rule based approaches but depend heavily on handcrafted features and quality labeled datasets.

### VII. DEEP LEARNING BASED PCB INSPECTION

Recent advances in deep learning have significantly improved PCB defect detection performance.

#### Convolution Neural Networks

CNNs automatically learn hierarchical features from raw images and achieve high accuracy in defect classification and localization.

#### Object Detection and Segmentation Models

Models such as YOLO, Faster RCNN, and UNet are used for real time defect detection and pixel level segmentation.

#### Challenges

Deep learning approaches require large annotated datasets, high computational resources, and careful model optimization for industrial deployment.

### VII. COMPONENT LIST WITH COST

1. ESP32-S3 Microcontroller: ₹ 750
2. ESP32-CAM Module with Programmer: ₹ 720
3. HC-SR04 Ultrasonic Sensor: ₹ 250
4. L298N Motor Driver: ₹ 220
5. 12V DC Adapter & Gear Motor: ₹ 600
6. Conveyor Belt Kit (Mechanical parts): ₹ 1200
7. Jumper wires & Headers: ₹ 100
- **Total Approximate Cost: ₹ 4000**



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### VIII. COMPARATIVE ANALYSIS OF EXISTING TECHNIQUES

Technique	Accuracy	Complexity	Robustness	RealTimeSuitability
ManualInspection	Low	Low	Low	No
ImageProcessing	Medium	Medium	Medium	Limited
MachineLearning	High	Medium	High	Yes
DeepLearning	VeryHigh	High	VeryHigh	Yes

### IX. CHALLENGES AND FUTURE DIRECTIONS

Key challenges include dataset scarcity, handling complex multilayer PCBs, reducing false positives, and ensuring real time performance. Future research may focus on transfer learning, synthetic data generation, hybrid models, and edge AI deployment.

### X. BLOCK DIAGRAM, HARDWARE DESIGN AND FLOW CHART

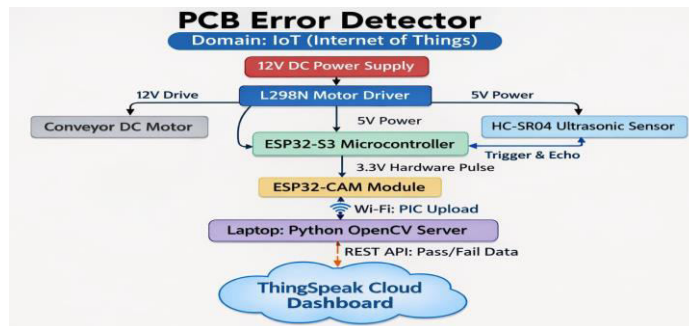


Fig 1:Block Diagram

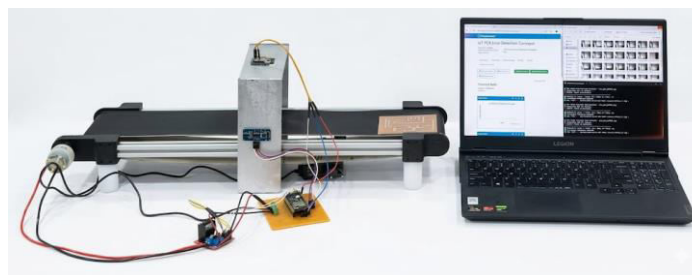


Fig 2:Hardware Design



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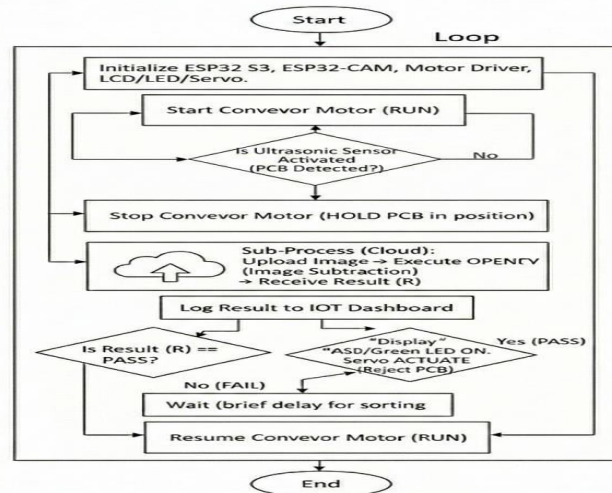


Fig 1:Flow Chart

### X. RESULT

The system was successfully deployed and tested. When a flawless PCB passes on the belt, the server registers a "PASS". When a defective PCB passes, the ultrasonic sensor halts the belt, the camera triggers flawlessly without DMA memory overflow, and the Python server successfully saves an image with a red bounding box explicitly highlighting the error. Simultaneously, the ThingSpeak dashboard updates in real-time, accurately reflecting the total number of inspected, passed, and failed boards on live graphical charts.

### XI. ADVANTAGES AND FEATURES, APPLICATIONS

#### Advantages

**High Speed:** Drastically faster than manual visual inspection.

**Cost-Effective:** Replaces expensive industrial cameras with low-cost IoT modules.

**High Accuracy:** Image subtraction ignores human fatigue and catches micro-defects.

**Wireless Data Logging:** Automatically saves photographic evidence of defective boards.

#### Features:

Automated stopping and starting of the assembly line.

Real-time computer vision bounding boxes.

Hardware noise filtering to prevent false camera triggers.

**Live Cloud Dashboard:** Remote monitoring of production statistics and defect rates using ThingSpeak.

#### Applications:

**SMT Production Lines:** Checking for missing Surface Mount Devices before soldering.

**Packaging Lines:** Verifying labels or ensuring pill bottles are fully populated.

**Quality Assurance:** Any manufacturing process requiring strict visual conformity.

### XII. CONCLUSION AND FUTURE SCOPE

Automated PCB Error Detection Systems have evolved significantly from basic image processing techniques to advanced deep learning models. Each approach has its strengths and limitations depending on application requirements. With continuous advancements in artificial intelligence and hardware acceleration, automated inspection systems are expected to become more accurate, efficient, and widely adopted in PCB manufacturing.



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The system can be upgraded by integrating a robotic arm or a pneumatic piston to physically push defective PCBs off the belt into a reject bin. Additionally, machine learning models (like YOLO) could be trained to classify the specific type of defect (e.g., "Missing Resistor" vs. "Solder Bridge") rather than just highlighting differences.

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