



# IJRASET

International Journal For Research in  
Applied Science and Engineering Technology



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 13    **Issue:** V    **Month of publication:** May 2025

**DOI:** <https://doi.org/10.22214/ijraset.2025.71258>

[www.ijraset.com](http://www.ijraset.com)

Call:  08813907089

E-mail ID: [ijraset@gmail.com](mailto:ijraset@gmail.com)

# PCB Defect Detection Using Yolov5 on Raspberry-Pi

Archana Chaudhari<sup>1</sup>, Praveen Pol<sup>2</sup>, Parth Madnurkar<sup>3</sup>, Revati Pathak<sup>4</sup>, Ved Kapre<sup>5</sup>, Urvi Kshirsagar<sup>6</sup>

Department of Instrumentation Engineering Vishwakarma Institute of technology Bibwewadi, Pune, Maharashtra, India

**Abstract:** Conventional PCB fault detection are inefficient and error-prone, which tells us that automation is necessary. For this research, YOLOv5 is used on Raspberry Pi to detect six categories of PCB defects including Mouse Bites, Open Circuits, and Short Circuits in real-time. This system is offline capable and provides fast offline detection, accuracy, and low power optimization. Its accuracy is confirmed through precision, recall, and mAP performance measures. Findings indicate that AI defect detection improves defect detection significantly, and thus greatly increases PCB quality control while minimizing costs and reducing the inefficient manual inspections.

**Keywords:** PCB defect detection, YOLOv5, real-time detection, Raspberry Pi, Embedded system

## I. INTRODUCTION

Electronic circuits can interface with a device to send or receive signals through a PCB's connectors. This means that quality control is essential during the production stages since mistakes usually lead to problems. These problems include microcracks, shorts, and other soldering imperfections that are found within the PCB and lower the reliability of the device, increasing the cost of servicing it. For as long as one can remember, manual inspections alongside electrical probes had been the primary techniques applied to screen circuit boards and check them for faults. The many approaches tend to be inefficient because precisely judging their quality is very sensitive to human error, especially in detecting small damages concealed within elaborate multi-layered structures that are packed closely. Tiny cracks within intricate high-density layouts, misaligned components after reflow, and small solder bridges are just some of the possible errors that increase the expenses of this operation. The increased complexity in designs has created an urgent need for effective automated fault detection systems that are more efficient than current alternatives.

Recently, automated inspection techniques such as Automated Optical Inspection have gained momentum at a great speed and accuracy in fault detection. Artificial Intelligence and Machine Learning technologies, particularly deep learning algorithms such as Convolutional Neural Networks, have also gained ground to speed up this process. The latest major breakthrough in this area is the YOLO (You Only Look Once) algorithm, which has gained tremendous popularity, though for its fast detection of faults without sacrificing precision—this has proven to work best when rooting out faults in real time.

This study revolves around the application of YOLOv5, the most recent iteration in the YOLO framework, to develop a PCB defect detection equipment based on Raspberry Pi entrusted to real-time corrections. The general aim is to create a cheap and efficient method for the detection of six classes of PCB defects: Mouse Bites, Open Circuits, Short Circuits, Spurs, Misaligned Components, and Soldering issues. This paper describes the design and development of a user-friendly real-time fault detection system which takes in PCB images and highlights Defect Breaks by placing bounding boxes around them. The approach utilizes specific adaptations of pre-trained YOLOv5 models, customized with weights designed to detect PCB-related defects, ensuring operational efficiency on embedded systems like the Raspberry Pi without sacrificing accuracy. The architecture proposed has an image upload interface, a defect detection pipeline, and a module to display outputs, and the operation of the whole system on the Raspberry Pi would be seamless. Users can upload PCB images in JPG format and initiate defect detection immediately. A point of differentiation is that it is an offline solution and would thus work even in an environment with intermittent or zero internet following this approach. The application is designed to run on the Raspberry Pi as the local host to provide real-time feedback with lower operational latency while avoiding the security and data privacy concerns of cloud processing. It also allows processing of images locally while optimizing for the low processing power that is emanating from the Raspberry Pi.

## II. LITERATURE REVIEW

All The rapid advancement of deep learning and computer vision has led to significant improvements in object detection, pattern tracking, and defect detection across various domains. Systems operating independently, to industry specific uses, the YOLO (You Only Look Once) algorithm has proven its usefulness from balancing accuracy and speed in real-time tasks. This work synthesizes information from the supplied documents to evaluate their approaches, methods, applications, and scope in the specialization critically.

An important part of computer vision and object detection is essential in applications such as self-driving cars and security systems. TensorFlow which was used by Phadnis et al. (2018) [1] in the publication "ObjectsTalk - Object Detection and Pattern Tracking Using TensorFlow," showcasing its efficiency in real-time cases for object detection and tracking of patterns. The ability of TensorFlow to manage sizable and datasets while saving computing efficiency was highlighted by the authors. Their study demonstrated the benefits of these models for tracking and detection, laying the base work for contemporary frameworks like YOLO.

In "Blind Navigation Support System using Raspberry Pi & YOLO," Parvadhavardhni et al. (2023) [2] explained these concepts by combining YOLO and Raspberry Pi in a system intended to help the blind and visually impaired. This application of YOLO shows how adaptable it is to less-cost, resource settings. Because of the Raspberry Pi's portability and YOLO, visually impaired people can now see the real-world cases. This technique offered more precision in identifying obstructions than more conventional techniques like ultrasonic or infrared-based devices, particularly in modern environments.

The difficult nature of PCB and the need of high level precision, defect detection in PCB production is a significant task. Machine vision approaches, like rule-based and edge-detection systems, have frequently failed to handle faults in a variety of cases. Cai and Li (2022) [3] reviewed image-processing-based PCB defect detection techniques in detail in their paper "PCB Defect Detection System Based on Image Processing," pointing out important drawbacks such as noise sensitivity and lack of adaptability to changing conditions.

In "PCB Defect Detection Algorithm Based on YOLOv5," Chen et al. (2023) [4], an enhanced YOLOv5 algorithm designed for PCB fault identification in order to overcome these difficulties. The changes, which included using CSPDarknet53 as the backbone network and a CIoU loss function, resulted in insignificant increase in speed and mean average precision (mAP). Their research showed that YOLOv5 is reliable and can identify even the flaws, including misaligned tracks and missing parts, in a variety of scenarios.

Building on this work, Li et al. (2024) [13] created a YOLOv5-based model for PCB defect detection in "An Improved YOLOv5-Based Model for Automatic PCB Defect Detection," focusing on noise and real-time performance. Both Chen et al. (2023) [4] and Ling et al. (2023) [5] observed that YOLOv5 showed faster speeds than YOLOv4 while maintaining good accuracy in detecting faults. An analysis of YOLOv5 and its predecessors in PCB defect detection shows the importance of application necessities. YOLOv5 is adaptable for real-time, tasks owing to increased resilience and quick speed, while still maintaining better performance in defect detection accuracy. [4–8].

Another area where machine learning algorithms have shown good performance is facial detection. In the work by Singh et al. (2019) [6] used the Raspberry Pi to do facial recognition using machine learning-based techniques including Haar Cascade and Histogram of Oriented Gradients (HOG). These techniques poorly performance in low light and occlusion conditions, despite having a moderate level of precision and real-time results.

YOLO-based models are renowned for their precision in handling complicated situations, even though they were not examined in Singh et al.'s work. The use of hardware such as the Raspberry Pi for image processing was further given in the research by Marot (2020) [9]. Marot showed the ability of single-board computers to access to advanced technologies by developing a framework for learning image processing basics.

For autonomous directions and navigation to be safe and effective, object detection should be precise. According to Mohanapriya et al. (2021) [10], in their study of Object and Lane Detection for Autonomous Vehicle Using YOLOv3 Algorithm, YOLOv3 is effective in detecting objects and lanes for autonomous vehicles. Their research showed how YOLOv3 can interpret high-resolution images quickly, which makes it appropriate for different driving situations.

In the article "Detection of Missing Component in PCB Using YOLO," Chhetri et al. (2023) [11] used their YOLOv5-based model to detect missing components, which improved PCB defect detection. Their results showed how important datasets and structured training procedures are to improving performance. By experimenting with various target detection networks for PCB defects, Wu et al. (2023) [12] further gave YOLO's flexibility in their publication. Their results proved YOLOv5 is the leading algorithm for industrial use due to its accuracy and strength across various datasets.

Energy management and home automation have been completely transformed by machine learning into IoT devices. In their 2020 study, Raju et al. [14] explored how the integration of machine learning algorithms with Raspberry Pi would be able to maximize electricity consumption. They proved that significant energy efficiency can be achieved using demand-response mechanisms.

### III. METHODOLOGY

#### A. System Architecture

The process of the Raspberry Pi and YOLOv5 based flaw detection system is shown in Fig.1. The method starts with the user providing the Raspberry Pi system with an image of the PCB, then it runs the YOLOv5 model, which processes the image and detects defects. The identified faults are passed to the Defect Detection Module, which analyzes the results. Finally, the Storage Module saves the detection data for further review or quality control purposes.

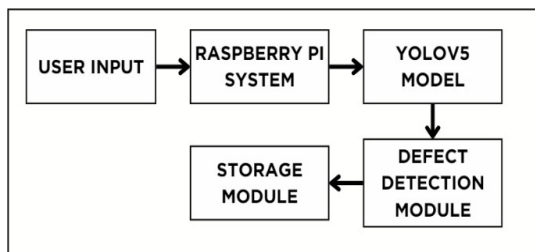


Fig.1 Workflow of the system

#### B. YOLOv5 Architecture

YOLOv5 uses the same head as YOLOv3 and YOLOv4. It consists of three convolution layers that predict the location of bounding boxes (x, y, width, height), objectness scores, and object classes. However, the equations used to compute the target coordinates for bounding boxes have changed from previous versions. The difference is shown below.

Equations (1) to (4) present the previous versions

(YOLOv2, YOLOv3) to compute the target bounding boxes and Equations (5) to (8) present the model used in YOLOv5 for computing the bounding boxes.

$$b_x = (t_x) + g_x \tag{1}$$

$$b_y = (t_y) + g_y \tag{2}$$

$$b_w = f_w \cdot e^{t_w} \tag{3}$$

$$b_h = f_h \cdot e^{t_h} \tag{4}$$

where:

$b_x, b_y$  → Predicted bounding box center coordinates  $b_w, b_h$  → Predicted bounding box width and height  $t_x, t_y, t_w, t_h$  → Model's predicted values

$g_x, g_y$  → Grid cell coordinates where the object is detected  $f_w, f_h$  → Anchor box dimensions for the detected object Center coordinates ( $b_x, b_y$ ) are obtained by adding the predicted offsets ( $t_x, t_y$ ) to the grid cell coordinates ( $c_x, c_y$ ), ensuring the bounding box stays within the grid but may cause localization instability.

Width and height ( $b_w, b_h$ ) are recomputed using an exponential transformation to keep them positive. However, this can sometimes result in oversized bounding boxes, leading to inaccurate predictions in edge cases.

$$b_x = (2 \cdot (t_x - 0.5) + c_x) \tag{5}$$

$$b_y = (2 \cdot (t_y - 0.5) + c_y) \tag{6}$$

$$b_w = p_w \cdot (2 \cdot (t_w)^2) \tag{7}$$

$$b_h = p_h \cdot (2 \cdot (t_h)^2) \tag{8}$$

By decreasing positional errors and ensuring that projected bounding boxes more closely match objects in the image, the improved transformations in YOLOv5 increase localization accuracy.

Loss Function in YOLOv5

YOLOv5 has three outputs, listed as following:

bounding boxes, objectness scores, and recognized object classes. To predict the overall loss, it uses Compound Intersection over Union (CIoU) loss for location regression while adding Binary Cross Entropy (BCE) loss for class and objectness predictions all under a single framework. Equation 9 provides the total loss as

$$\text{Loss} = \lambda_1 L_{cls} + \lambda_2 L_{obj} + \lambda_3 L_{loc} \tag{9}$$

Where

$L_{obj}$ -objectness loss (BCE loss).  $L_{loc}$ - localization loss (CIoU loss).  $L_{cls}$ -classification loss (BCE loss).

Each loss component is balanced by the weight of the parameters  $\lambda_1, \lambda_2,$  and  $\lambda_3$ .

With these enhancements, YOLOv5 is more precise and reliable, which makes it perfect for Raspberry Pi real-time PCB fault identification.

### C. YOLOv5 for Detecting Multiple Defects in PCB Using Raspberry Pi

#### 1) Environment Setup

Raspbian OS is installed on an SD card and configured on Raspberry Pi. Essential dependencies such as PyTorch, OpenCV, and TensorRT are installed to support deep learning-based image processing. This aligns with the step in the flowchart where dependencies and libraries are installed before running the detection model. Fig. 3 presents the flowchart of the proposed work.

#### 2) Model Training and Optimization

Since Raspberry Pi has limited computational capacity, model training is performed on a more powerful Windows system equipped with a high-performance GPU. The YOLOv5 model is trained on a dataset containing images of PCB defects, along with XML annotations specifying defect locations. After training, the model's weights (best.pt) are saved. This corresponds to the flowchart step where the model is trained and the optimized weights are stored.

To improve efficiency, the trained model is converted into a lightweight format such as TensorFlow Lite (TFLite) or ONNX. These formats reduce computational overhead, making the model suitable for real-time execution on Raspberry Pi.

#### 3) Hardware Acceleration and Deployment

To enhance inference speed, Raspberry Pi's GPU or an external Coral Edge TPU is used for hardware acceleration. The trained and optimized model is then imported into Raspberry Pi. At this stage, the system is ready for real-time defect detection. This is represented in the flowchart where the model is imported and prepared for execution.

A camera module is attached to the Raspberry Pi to capture live images of PCBs. The camera provides real-time input to the defect detection system, allowing automated inspection of PCB quality.

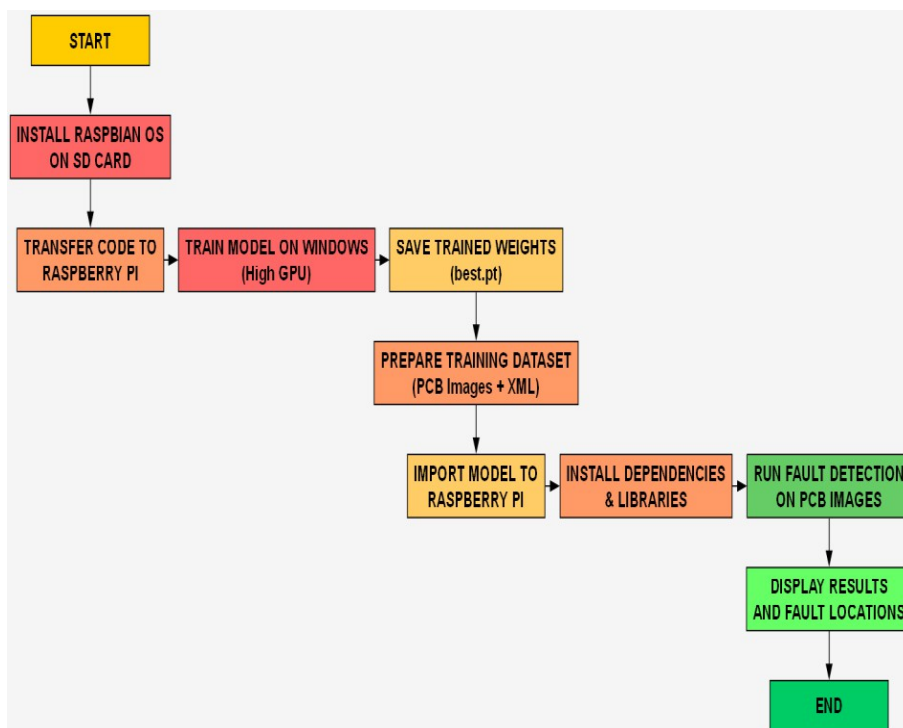


Fig.2. Flowchart of the system

#### 4) Fault Detection and Analysis

Once the setup is complete, the Raspberry Pi processes incoming PCB images using the optimized YOLOv5 model. The model uses bounding boxes to identify problematic areas in order to detect multiple problems. The results are shown instantly, giving users a sense of the PCB's status.

Defect data is also logged for additional examination. The Raspberry Pi either stores the identified errors and their locations locally or uploads them to a cloud-based platform for additional analysis. The flowchart's last steps, where detection findings are shown and saved for later examination, correspond to this.

#### 5) Evaluation Metrics for Performance Assessment

The following evaluation metrics are taken into consideration to guarantee the efficacy of the defect detection system:

- Precision and recall quantify the model's ability to identify flaws with the least amount of false positives and false negatives.
- Mean average precision (mAP) evaluates the model's performance across different types of PCB defects.
- Latency & FPS determine the system's ability to perform real-time detection by measuring inference speed and frames per second (FPS).

These evaluation criteria determine whether the system can effectively function in a real-world PCB quality control environment.

### IV. RESULTS AND DISCUSSIONS

Some important conclusions and illustrations of our system in operation are shown below.

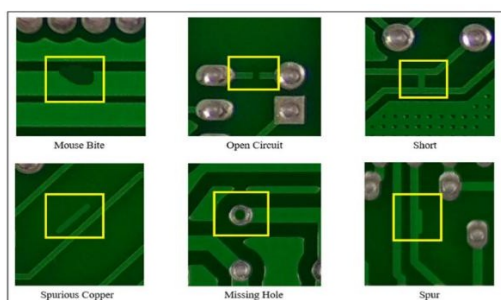


Fig.3.CommonPCBDefects

Some frequent PCB flaws are depicted in the above diagram. A "mouse bite," which resembles a nibble and is a tiny break in the copper trace, is what we have. A "open circuit" is a trace gap that interrupts the electrical flow. A "short circuit" occurs when traces accidentally connect to one another. "Spurious copper" refers to an overabundance of copper on the surface.

A "missing hole" reveals that there is no drilled hole, which affects the placement of components. Finally, a "spur" has a small unwanted protrusion of copper that might provide an unintended path for connections. These defects thus severely affect the functionality and reliability of electronic circuits.

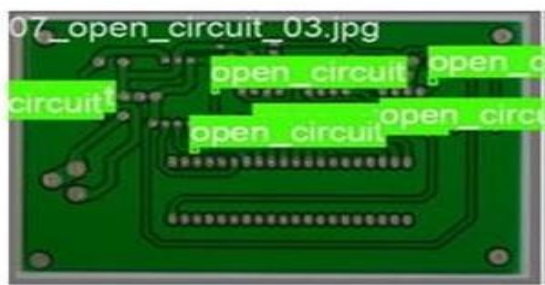


Fig.4.LabelledPCBDefects

The next figure depicts the power of our fault detection system. A close-up view of a PCB shows multiple "open circuit" defects with distinct labels marked on each. The breaks in the copper traces can severely affect electrical flow as determined by our advanced algorithm. The visual representation here shows that the system accurately pinpoints and classifies the critical defects that ensure the reliability and functionality of the manufactured PCBs.

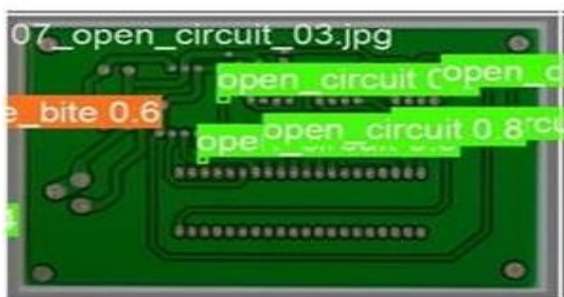


Fig.5.PredictedPCB Defects

This is the most exciting proof of the possibility of the concept of our system for the PCB defect detection mechanism. An image clearly shows what actually happens to be a zoom view of a circuit board with many kinds of defects properly identified and annotated. "open circuits," inside green boxes signify breaks in crucial electrical paths; a small irregular break in copper, that appears as "mousebite" was marked inside the orange box. This visual evidence underlines the system's impressive ability to not only detect but also accurately categorize various types of defects, ensuring the highest quality standards in PCB manufacturing.

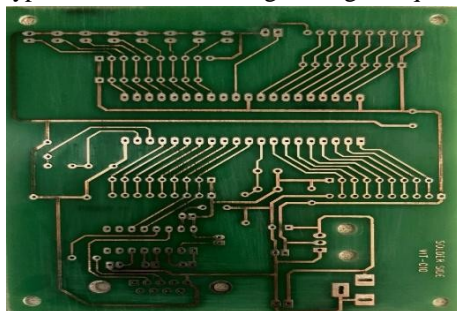


Fig.6.Real-timeinput

Our system has captured a live image of a double-sided PCB. The image shows the board's intricate design, with a dense network of copper traces etched meticulously onto its surface. This real-time input is currently being analyzed by the system to identify any possible flaws and guarantee that the highest quality standards are upheld throughout the manufacturing process. This live feed helps to proactively address issues as they arise and provides extremely important insights into the current production situation.

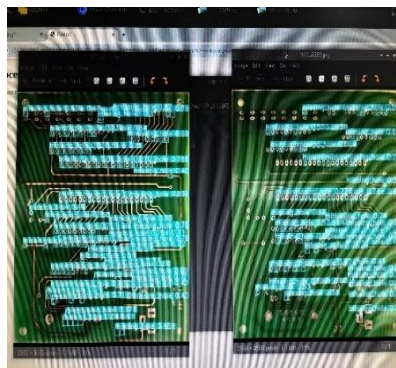


Fig.7.Realtimeoutput

Two PCB images are seen side by side in this picture fig.7. The potential flaws are shown in vivid blue in this figure on the left. Every board is thoroughly examined by the system, which highlights any irregularities it discovers, including open circuits, short circuits, and other serious ones. Visual comparison of the PCB enables prompt and effective evaluation and prompt remedial action to ensure that only flawless boards go to the final assembly stage.

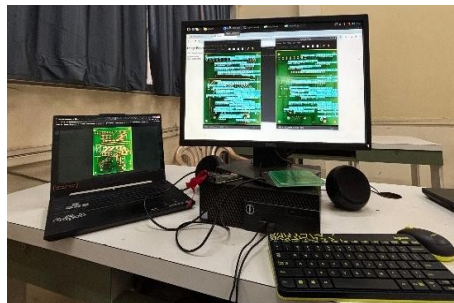


Fig.8.RealtimeSetupofthesystem

This is a picture of PCB fault detection system in operation. The system's real-time capabilities are demonstrated on a dedicated workstation. The system's output is shown on two computer monitors, one of which displays the original PCB image and the other, which uses vivid visual cues to show the errors that have been found. With this configuration, ongoing monitoring and analysis will be possible, guaranteeing that any possible problems are found and dealt with right away.

With increasing complexity in electronics manufacturing, PCB defect detection system is crucial. Our system not only identifies faults but also provides real-time insights for proactive quality control. By integrating such technology, manufacturers can significantly reduce errors and improve product reliability, reinforcing high industry standards.

## V. CONCLUSION

In summary, the YOLOv5 defect inspection system is a perfection for PCB manufacturing quality control through the assured detection of multiple defects within a single PCB. Identification of defects of both type and location by the system will thus be an enabling factor for manufacturers in quality control, particularly prioritizing repair attempts, hence keeping costs low while improving better product reliability.

Above all, predictive accuracy that captures the level of defect severity is the final piece of the puzzle missing, which is most needed to direct the production and also set priorities in addressing those issues which are great trouble for the production. In making the system foolproof and scalable at will to address industry needs, more optimizations to the system in the sense of affixing measures of confidence and thorough testing from real-world cases are required.

Since we intend to refine and test the system, we shall be emphasizing increasing its capability to support multiple designs and manufacturing condition for PCB. It is intended to improve reliability elimination of spurious positives, ease PCB manufacturing, and facilitate effective error-free E-manufacturing. The benefit of technology to the entire is vastly enormous for consumers and producers alike to witness improvements in product quality and the reduction of the overhead of production for the entire electronics sector.

## REFERENCES

- [1] Phadnis, Rasika & Mishra, Jaya & Bendale, Shruti. (2018). Objects Talk -Object Detection and Pattern Tracking Using TensorFlow. 1216-1219. DOI: [10.1109/ICICCT.2018.8473331](https://doi.org/10.1109/ICICCT.2018.8473331).
- [2] R.Parvadhavardhni, P.Santoshi, and A.M.Posonia, "Blind Navigation Support System using Raspberry Pi & YOLO," 2023 2nd International Conference on Applied Artificial Intelligence and Computing (ICAAIC), Salem, India, 2023, pp. 1323-1329. DOI: [10.1109/ICAAIC56838.2023.10140484](https://doi.org/10.1109/ICAAIC56838.2023.10140484).
- [3] Cai, Li, and Jingchuan Li. "PCB Defect Detection System Based on Image Processing." *Journal of Physics: Conference Series*, Vol. 2383, No. 1, IOP Publishing, 2022.
- [4] Chen, Shiqiao, Xiqing Liang, and Wenneng Jiang. "PCB Defect Detection Based on Image Processing and Improved YOLOV5." *Journal of Physics: Conference Series*, Vol. 2562, No. 1, IOP Publishing, 2023.
- [5] Ling, Q., & Isa, N. a. M. (2023). "Printed Circuit Board Defect Detection Methods Based on Image Processing, Machine Learning and Deep Learning: A Survey." *IEEE Access*, 11, 15921–15944. DOI: [10.1109/access.2023.3245093](https://doi.org/10.1109/access.2023.3245093).
- [6] Singh, S., Ramya, R., Sushma, V., Roshini, S., & Pavithra, R. (2019). "Facial Recognition Using Machine Learning Algorithm on Raspberry Pi." 2021 15th International Conference on Electrical, Electronics, Communication, Computer Technologies and Optimization Techniques (ICEECCOT), 197–202. DOI: [10.1109/iceecot46775.2019.9114716](https://doi.org/10.1109/iceecot46775.2019.9114716).
- [7] Chaudhari A., Uganlawar V., Barve T., Vaidya R. and Shelke D., "Analysis of YOLO V3 for Multiple Defects Detection in PCB," 2024 Parul International Conference on Engineering and Technology (PICET), Vadodara, India, 2024, pp. 1-6, doi: [10.1109/PICET60765.2024.10716153](https://doi.org/10.1109/PICET60765.2024.10716153).
- [8] Chaudhari, A., Manvatkar, V., Shinde, G. (2025). Analysis of YOLOv5 for Detection of Multiple Defects in PCB. In: Kumar, A., Pachauri, R. K., Mishra, R., Kuchhal, P. (eds) *Intelligent Communication, Control and Devices. ICICCD2024. Lecture Notes in Networks and Systems*, vol 1164. Springer,
- [9] Singapore. [https://doi.org/10.1007/978-981-97-8329-8\\_35](https://doi.org/10.1007/978-981-97-8329-8_35)
- [10] Marot, J., & Bourenmane, S. (2017). "Raspberry Pi for Image Processing Education." 2021 29th European Signal Processing Conference (EUSIPCO). DOI: [10.23919/eusipco.2017.8081633](https://doi.org/10.23919/eusipco.2017.8081633).



- [11] S, N. M., P, N. N., P, N. I., P, N. M. S. T., & R, N. M. (2021). "Object and Lane Detection for Autonomous Vehicle Using YOLO V3 Algorithm." AIP Conference Proceedings, 2387, 140009. DOI: [10.1063/5.0068836](https://doi.org/10.1063/5.0068836).
- [12] Chhetri, S. P., Bhat, S., Timalina, P., & Magar, B. T. (2023). "Detection of Missing Component in PCB Using YOLO." International Journal on Engineering Technology, 1(1), 62–71. DOI: [10.3126/injet.v1i1.60902](https://doi.org/10.3126/injet.v1i1.60902).
- [13] Wu, X., Ge, Y., Zhang, Q., & Zhang, D. (2021). "PCB Defect Detection Using Deep Learning Methods." 2022 IEEE 25th International Conference on Computer Supported Cooperative Work in Design (CSCWD), 873–876. DOI: [10.1109/cscwd49262.2021.9437846](https://doi.org/10.1109/cscwd49262.2021.9437846).
- [14] Li, Q., Zheng, Q., Jiang, S., Hu, N., & Liu, Z. (2024). "An Improved YOLOv5-Based Model for Automatic PCB Defect Detection." Journal of Physics Conference Series, 2708(1), 012017. DOI: [10.1088/1742-6596/2708/1/012017](https://doi.org/10.1088/1742-6596/2708/1/012017).
- [15] L. Raju, G. Sowmya, S. Srividhya, S. Surabhi, M.K. Retika, and M. Reshmika Janani, "Advanced Home Automation Using Raspberry Pi and Machine Learning," 2021 7th International Conference on Electrical Energy Systems (ICEES), Chennai, India, 2021, pp. 600-605. DOI: [10.1109/ICEES51510.2021.9383738](https://doi.org/10.1109/ICEES51510.2021.9383738).



10.22214/IJRASET



45.98



IMPACT FACTOR:  
7.129



IMPACT FACTOR:  
7.429



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24\*7 Support on Whatsapp)