

## MAIN IDEA

- Solder joint defect analysis is crucial for ensuring reliable PCB Assembly development. Among the various physical failure analyses, dye&pry relies on visual inspection.
- Problem 1:** Human labor is exhaustively spent to analyze defective types of dyed solder joints. Creating manual defect maps for a PCB Assembly takes about 3.5 hours.
- Problem 2:** Due to the relative bias among analysts, there exists variations between defect maps which needs to be eliminated and standardized.
- Solution:** Use of AI-driven techniques is highly necessary for efficient and fair investigation.

**Contribution 1.** We successfully apply an AI model to BGA PKG(Ball Grid Array Package) solder joint failure mode classification, which is accurate and significantly faster than visual inspection.

**Contribution 2.** The proposed correction method can be applied to other BGA PKG with various ball array.

## 2-STAGE DETECTION FRAMEWORK

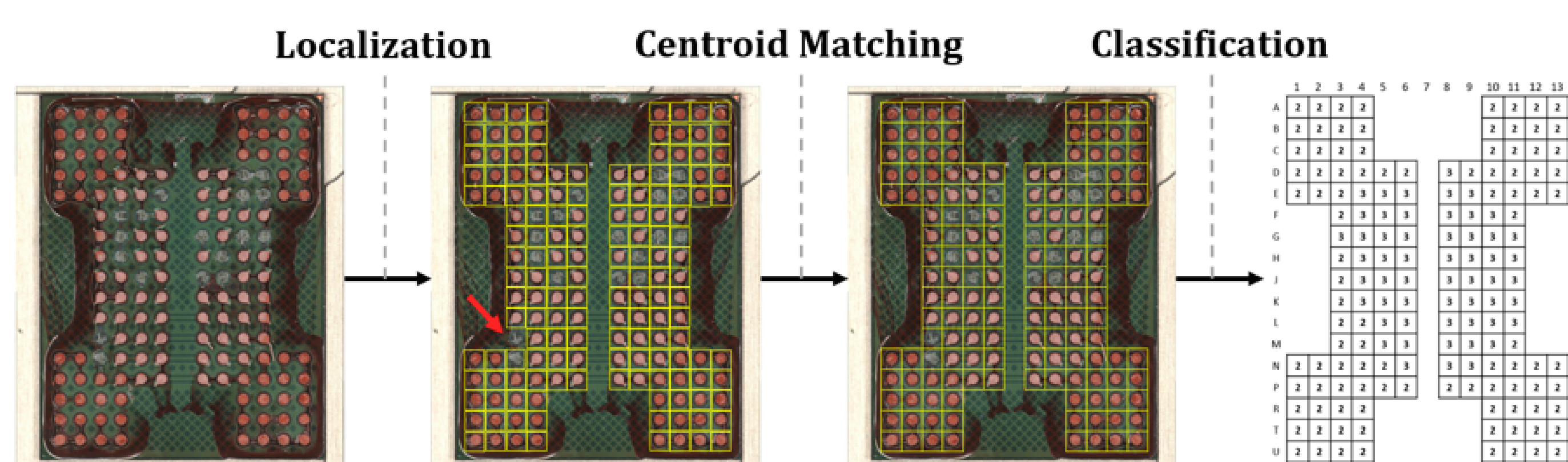


Figure: To utilize the post-training correction method after localization, we adopt a 2-stage detection framework consisting of localization and classification.

- Our framework follows a sequential process comprising solder joint localization and fail mode classification. Centroid Matching serves as an ad-hoc hedge for localization.

- Localization** finds the coordinates of each solder joint in given BGA PKG image.
- Centroid Matching** aligns the coordinates with fixed grid array.
- Classification** predicts the corresponding failure mode for each solder joint image cropped using its localized result.

## SOLDER JOINT LOCALIZATION & CENTROID MATHCING

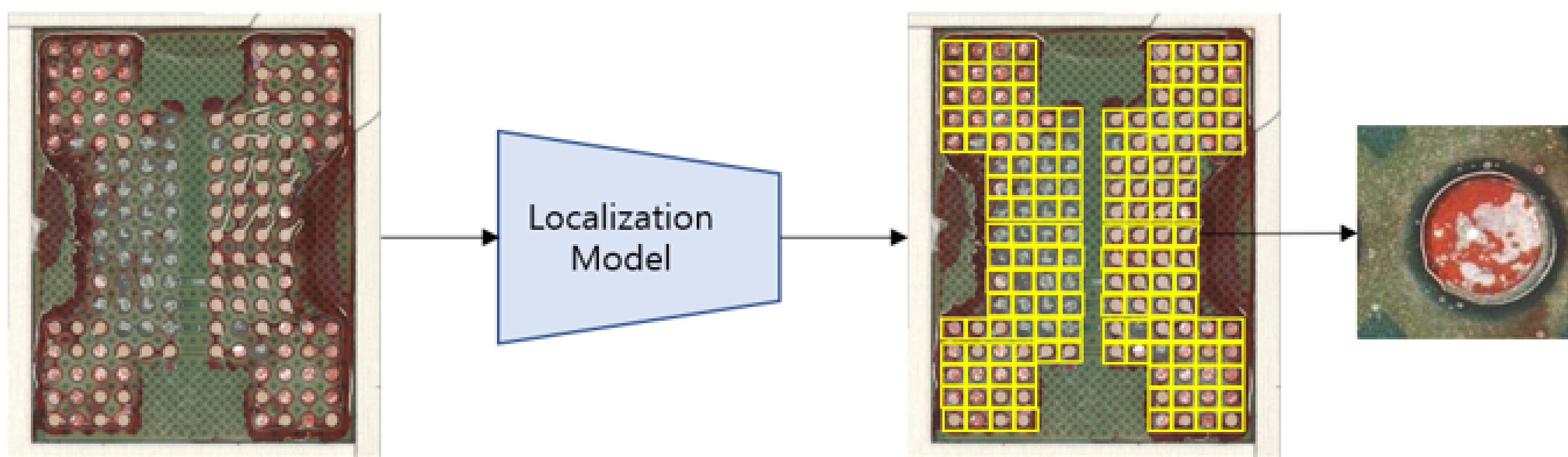


Figure: Qualitative result of Centroid Matching on Solder Joint Localization.

- Solder joint localization aims to identify the solder joints without classifying the fail type. In this regard, we label the solder joints as the foreground.
- We employ Faster-RCNN over YOLO due to accuracy being the primary issue in this domain rather than operation time.
- Since the number of solder joints is fixed for each PKG, the maximum prediction number is limited through confidence-wise order in prediction head.
- Even if the localization model shows high accuracy, false positives (e.g. wrongly defined as solder joints) or false negatives (e.g. missing solder joints) may occur.

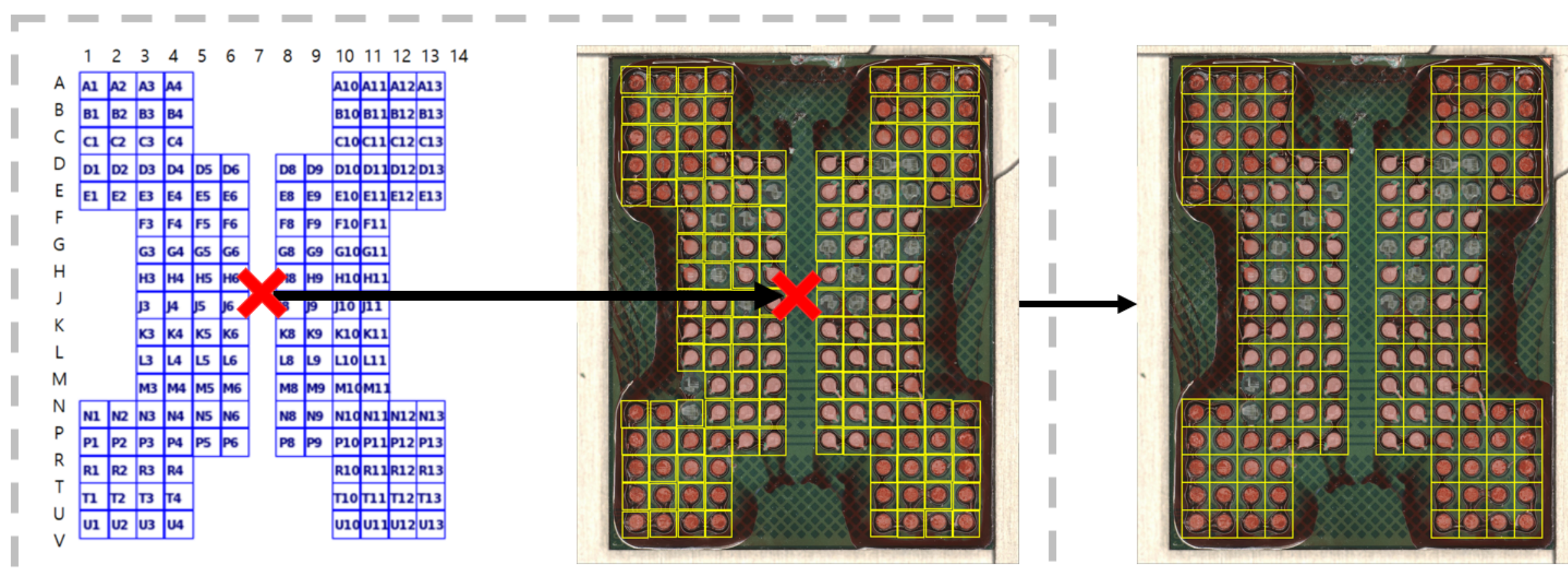


Figure: Description of Centroid Matching on PKG with 152 solder joints.

**Centroid Matching:** Even one false case is critical as the corresponding solder joint cannot be fed into a classification model. However, the remaining large number of true cases, combined with domain knowledge, allows us to cope with it. In the case of PKG with 152 solder joints, as shown in the Figure, few outliers out of 152 solder joints do not affect true centroid much. While each input images differ in margin outside of PKG, solder joints locate in fixed location inside the PKG like a grid. Simply moving the grid to match its centroid with predicted one can provide aligned localization and ensure every solder joint is identified.

## FAIL MODE CLASSIFICATION

- After the centroid matching, cropped solder joint images according to the aligned coordinates are fed to a classification model.
- There are 6 classes indicating the solder joint fail mode (e.g. 0: Solder Crack, 1: No Solder Crack, 2: PCB Cratering, 3: No PCB Cratering, 4: PKG Cratering, 5: No PKG Cratering).
- Due to the domain specificity, our training data is highly imbalanced due to different frequencies of defect types. To deal with this, we adopt focal loss in classification.

## DATASET & METRICS

### 1. Dataset

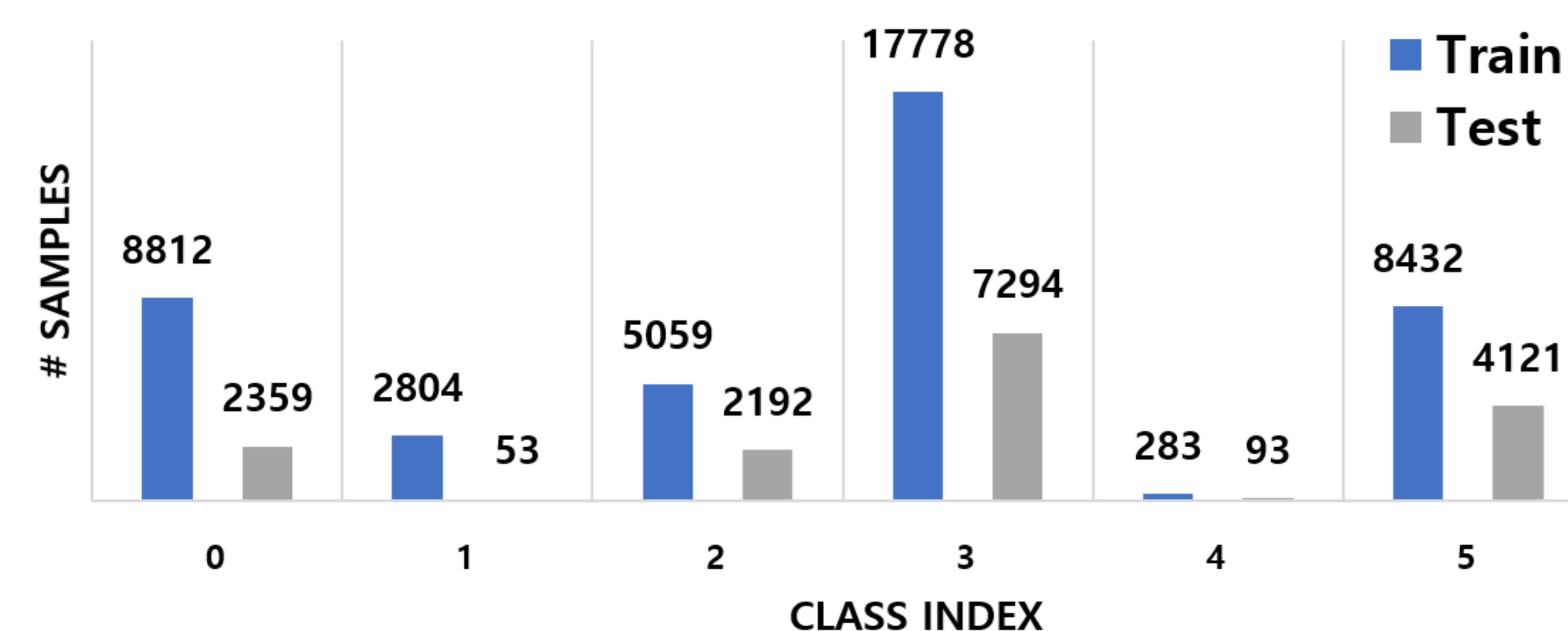


Figure: Fail mode distribution of solder joints in Train and Test data.

- The data is an image of the bottom side of the PKG, and to obtain the image, the PKG is mounted on the PCB surface and environment or mechanical test is performed. After test, detached the PKG from the PCB and take images.
- Both training data and test data are obtained by actual evaluation or harsh processing on SK Hynix to generate more defective data, as the data of pass modes are overwhelmingly large in a general evaluation situation.
- For localization, we prepared 284 PKG images for training, and 106 images for test. Corresponding solder joint images are cropped and used for classification as their distribution is visualized in the Figure.
- Among the fail modes, class 4 (PKG Cratering) has the lowest frequency of occurrence compared to other modes, causing data imbalance.

### 2. Metrics

- Since the maximum number of predictions was regulated in Section 2.1, we adopt the Accuracy@IoU=0.70 as the evaluation metric. If a ground truth solder joint overlaps more than 70% with any prediction, we regard it identified. Then, the metric can be formulated as  $\frac{\# \text{Identified@IoU}=0.70}{\# \text{Ground Truth}}$ .
- For solder joint classification, due to the skewed data distribution, the F1-score is adopted as the metric together with accuracy.

## EXPERIMENTAL RESULTS

### Experiment 1: Solder Joint Localization & Centroid matching

Table: Performance comparison on localization accuracy with and without Centroid Matching.

Method	Faster R-CNN	Faster R-CNN + Centroid Matching
Accuracy	0.980	1.000 (+0.020)

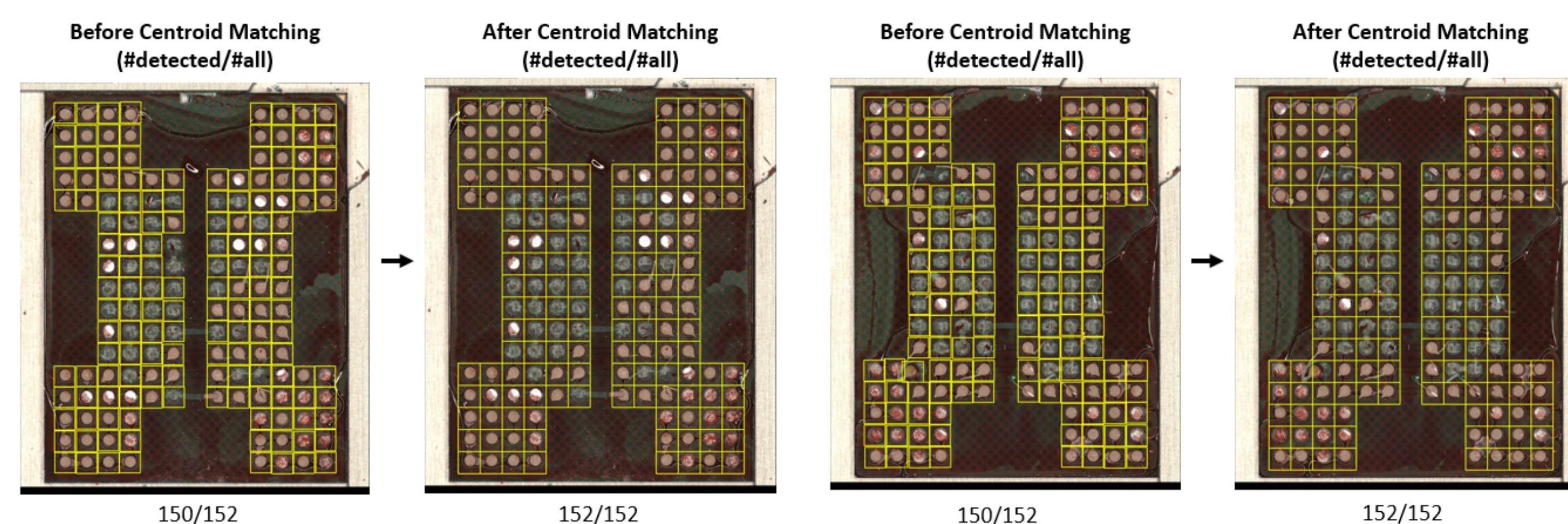


Figure: Qualitative result of Centroid Matching on Solder Joint Localization.

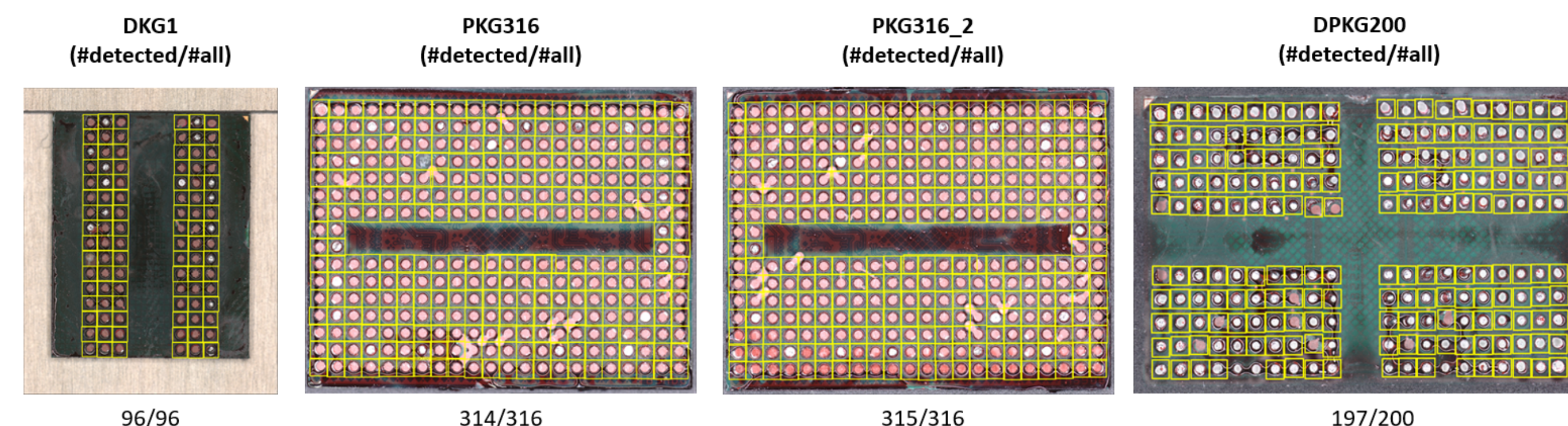


Figure: Results of various PKG types on Solder Joint Localization.

### Experiment 2: Fail Mode Classification

Table: Performance comparison on classification accuracy and F1-score between cross-entropy and focal loss.

Loss Function	Accuracy	F1-Score
Cross-Entropy Loss	0.9764	0.8943
Focal Loss	0.9741	0.9001

## ACKNOWLEDGMENT

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