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Feature Point Extraction Model for Improving Semiconductor Package Inspection Efficiency

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Abstract
Background/Objectives: With the development of IT, the manual work has been changed to the mechanical work. As smart factories have been spread widely, there has been on the sharp increase in the demand of applying vision system to automation process. In particular, the semiconductor production process utilizes vision system as an image processing and image analysis technology in order for efficient control and processing. Accordingly, it is necessary to develop the vision system that makes it possible to inspect whether products pass or fail accurately and immediately.

Methods/Statistical analysis: With the high density and minimization of such products as semiconductors, the human inspection with the naked eye can cause a slow inspection speed and low efficiency and accuracy. In addition, since the inspection criteria for products are ambiguous in such an inspection way, it is impossible to guarantee product quality. This study implemented the model that makes it possible to extract feature points of objects through ORB algorithm to inspect whether products pass or fail in the BGA of semiconductor package, to classify and save image data through SVM algorithm, and thereby to improve product inspection efficiency through vision system.

Findings: IC logic used in semiconductor manufacturing is an expensive chip with high performance. Therefore, if a package defect is found in the middle of manufacturing, it causes a lot of losses. Removing defected products in the production line through vision inspection system can greatly influence improvements in the final value and reliability of products. The proposed system is the SVM algorithm based semiconductor package inspection model that makes it possible to classify and save the semiconductor package images put in by probe with the application of pre-processing process and ORB algorithm for feature point extraction. In the experiment of the proposed model, when one obtained image was learned, recognition rate was about 28%; when 14 images were learned, recognition rate was 97%. If the proposed model is applied to vision system as semiconductor inspection equipment, it is expected to inspect products more quickly and accurately.

Improvements/Applications: The proposed model makes it possible to not only inspect semiconductor package, but extract feature points. Therefore, it is possible to apply the model to text or symbol recognition. In the future, it will be necessary to research how to apply a different algorithm to extract feature points, and how to shorten the time taken to detect defected products in order to inspect products immediately and accurately.

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1. Introduction

With the rapid development of IT(Information Technology) and the advent of the 4th industrial revolution, the manual work has been changed to the mechanical work. In particular, as more attention has been paid to computer based convergence technologies, it has been possible to obtain video images from CCD (Charge Coupled Device) based sensors and to process the images, and consequently the computer based machine vision system tends to develop quickly [1]. Vision system is capable of obtaining, analyzing, and judging an image. With the spread of smart factories, the demand for applying a smart factory to automation process has been on the sharp increase, and thus vision system is widely used for quality management process and inspection in industries [2] and serves as a guide for a robot [3]. In addition, since vision system is applied much to inspect products in the industrial area, the big issue of product manufacturers is the introduction of vision system. Thanks to the accurate recognition of vision system in production process, the system is greatly effective at detecting defected products and is very excellent at detecting the defected products that are hardly identified with the naked eye. In the semiconductor area, vision system is applied to almost all inspection processes, such as lead frame inspection and BGA(Ball Grid Array) inspection. Generally, machine vision is referred to as the combination of measurement, analysis, and geometry. Since it needs connection with such multiple technologies as image processing, computer graphics, pattern recognition, and machine learning, it is expected to develop further [4]. In terms of the machine vision system, there has been the sharp increase in the demand for measuring a shape of the fine pattern processed through special processing, and the computer-camera convergence technology for measuring the shape has drawn more attention. In addition, semiconductor manufacturing is efficiently processed and controlled with the use of machine vision system as an image processing and analysis technology [5]. IC logic used in semiconductor manufacturing is an expensive chip with high performance. Therefore, if a package defect is found in the middle of manufacturing, it causes a lot of losses. Removing defected products in the production line through vision inspection system can greatly influence improvements in the final value and reliability of products. With the high density and minimization of the products related to the area, the human inspection with the naked eye can cause a slow inspection speed and low efficiency and accuracy. In addition, since the inspection criteria for products are ambiguous in such an inspection way, it is impossible to guarantee product quality. Therefore, this study proposes the model that makes it possible to extract feature points of objects through ORB algorithm to inspect whether products pass or fail in the BGA of semiconductor package, to classify and save image data through SVM algorithm, and thereby to improve product inspection efficiency through vision system. If the proposed model is applied to vision system as semiconductor inspection equipment, it is expected to inspect products more quickly and accurately.

2. Related Works

2.1. ORB Algorithm

Oriented FAST and Rotated BRIEF(ORB) is an algorithm of extracting feature points, using Features from Accelerated Segment Test Corner Detection(FAST) algorithm [6]. As typical algorithms of recognizing a particular object automatically, there are Speeded Up Robust Features(SURF) [7] and Scale invariant Feature Transform (SIFT) [8]. However, since these algorithms require a lot of operations, it is hard to recognize an object in real time. ORB [9] developed to overcome the disadvantages of conventional algorithms can quickly extract feature points from an object, and can generate Descriptor fast with the use of Rotation BRIEF algorithm.

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Therefore, ORB can extract features points from an object accurately, can match fast on the basis of information on the extracted feature points, and is robust for blur. [Figure 1] illustrates the ORB algorithm process [9] in which Harris Corner Detection is applied to extract feature points of corner [10], Intensity Centroid is applied to determine a direction [11], rBRIEF algorithm is used to generate Descriptor, and Hamming Distance algorithm is applied for matching.

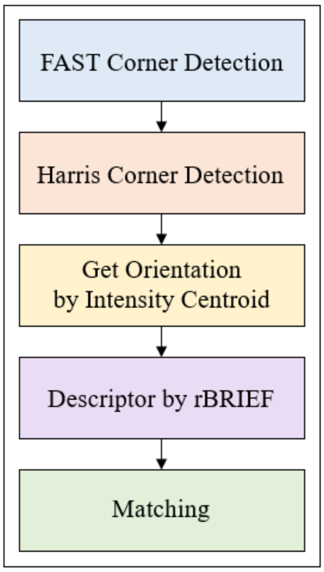

Figure 1. ORB Algorithm Process.

2.2. SVM

Support Vector Machine (SVM) is much applied to many classification problems, for it has efficient calculation, flexibility and processes high-dimensional data. Like many other classifiers, SVM can greatly influence system performance factors such as calculation efficiency and classification accuracy if it fails to remove the functions irrelevant to many supervised learning problems, and it has the following three characteristics [12]. Firstly, the function of classifier is improved through feature pruning that makes it possible to exclude unnecessary nodes. Secondly, if irrelevant functions are used, it takes long to calculate. Thirdly, since many functions are unable to converge, classification is determined randomly. For these reasons, SVM has been applied to a variety of areas, including vision system, statistics, signal processing, pattern recognition, machine learning, and neural network. Typically, the feature point extraction based selection is independent on learning classifier parameters[13-16]. If the two steps are taken separately, a lot of information can be lost in classification. Therefore, various approaches for SVM structure have been proposed[17-19]. Such SVM is a new learning approach based on statistical learning theory in order to minimize the structural risk[20]. Using learning data, it maps an original input space into a high-dimensional feature space and maximizes the margin of class boundary[21] in the feature space so as to determine an optimal hyper plane. At this time, the training point that is closest to the optimal hyper plane is called a support vector. If the determined plane is obtained, it can be used for the classification of new data[22]. [Figure 2] illustrates Linear SVM Model. In the figure, when a straight line is moved in the direction of support vector, the distance between its original straight line and its moved straight line is called a margin. The linear SVM model tries to find the straight line to maximize the margin[23,24].

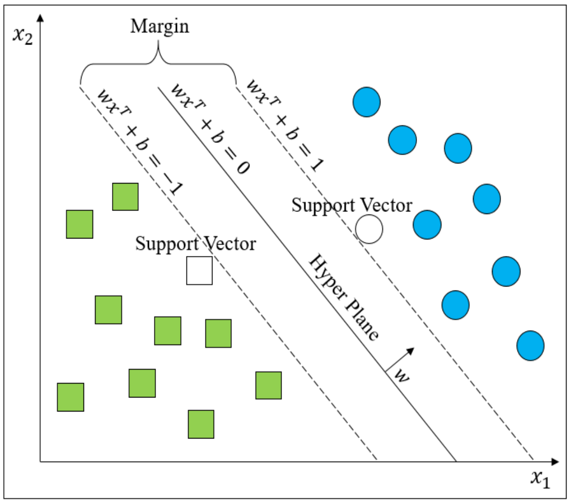

Figure 2. Linear SVM Model.

Being very robust for classification, the SVM is aimed at creating a boundary determined between two classes to predict a label in at least one feature vector. Fox example, if a set of learning data with a given label is offered, it can be presented with the

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formula (1). In the formula, x_i represents a feature vector, and y_i is the positive or negative class label of training compound i.

$$(x_1, y_1), \dots, (x_n, y_n), \quad x_i \in R^d \text{ and } y_i \in (-1, +1) \tag{1}$$

An optimal hyper plane is defined in the formula (2), where w means a weight vector, x is an input feature vector, and b is a bias.

$$wx^T + b = 0 \tag{2}$$

As for all factors of training set, w and b satisfy the inequality as shown in the formula (3).

$$wx^T + b \ge +1 \text{ if } y_i = 1, \quad wx^T + b \ge -1 \text{ if } y_i = -1 \tag{3}$$

3. Proposed Model

3.1. Model Configuration

[Figure 3] illustrates the configuration of the model for detecting defected products in semiconductor manufacturing, which consists of two parts. The first one is CCD camera and light for extracting semiconductor images through Probe. The second one is machine vision system that pre-processes the images extracted from Probe with the use of OpenCV, extracts feature points with ORB algorithm, and makes classification with SVM algorithm.

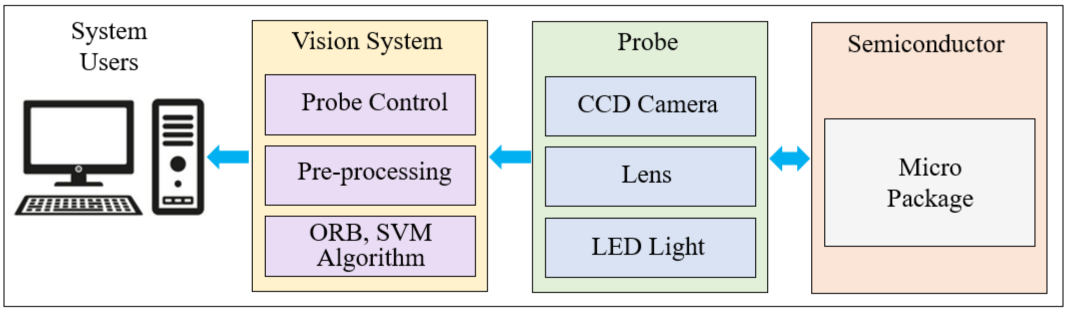


Figure 3. Proposed Model Configuration.

3.2. System Process

As shown in [Figure 4], the proposed model process consists of five steps. In the first step, the image extracted by Probe is set as Region of Interest, and only the regions necessary to extract feature points are left, and other regions are removed.

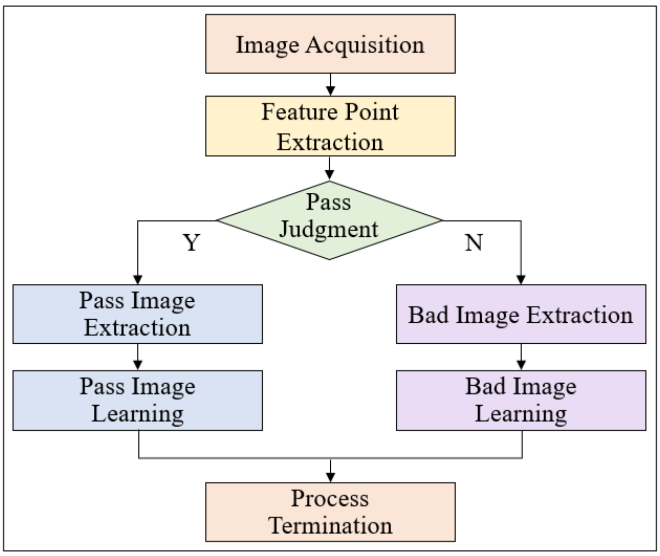


Figure 4. Proposed Model Process.

In the second step, feature points are extracted. The image obtained through image pre-processing is used by ORB algorithm to extract feature points. In the third step for classification, the extracted feature point data are used by SVM algorithm to judge if the image passes or fails. In the fourth step for image learning, based on the extracted feature point data by SVM algorithm, images are classified in ‘Pass’ image and ‘Fail’ image. The feature points of each image are learned. In the fifth step, the feature point data for Pass and Fail images are saved in DB.

3.3. ROI Setting

[Figure 5] presents (a) an original image and (b) an ROI(Region of Interest) setting image.

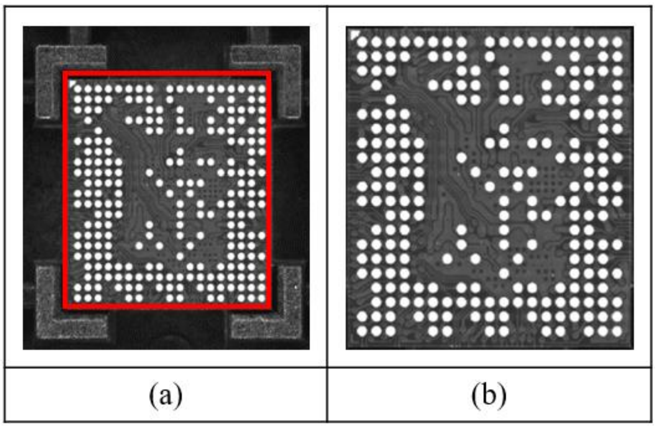


Figure 5. ROI Setting Image.

In terms of the Probe based feature point extraction, unnecessary regions can cause a problem at the time of judging if an image passes or fails, and thus it is hard to judge the image accurately. For this reason, the proposed model applies ROI to set up actual inspection regions only in semiconductor package, and thereby performs inspection continuously.

3.4. Feature Point Extraction

[Figure 6] shows the detailed feature point extraction procedure.

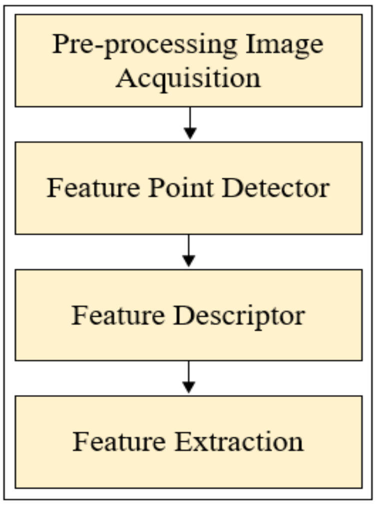


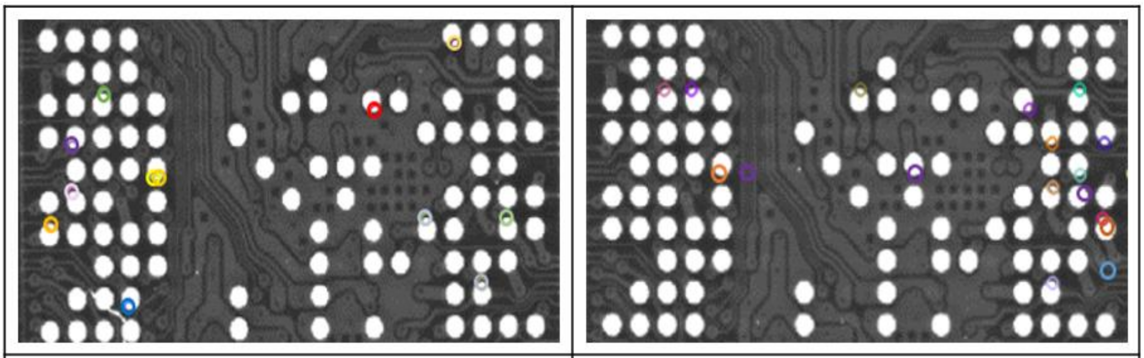
Figure 6. Feature Point Extraction Process.

The pre-processed image is obtained, and feature points are extracted by feature point detector and feature descriptor. The proposed model utilized ORB algorithm that includes both feature point detector and feature descriptor. The feature point detector of ORB algorithm detects a feature point according to the threshold variance of the image pixel used by FAST algorithm, and ORB algorithm utilizes Feature Descriptor for similarity conjecture and matching even if an image size changes or an image rotates. With the uses of the feature point detector and feature descriptor, feature points are extracted. [Figure 7] shows a part of the algorithm for extracting feature points with the use of ORB algorithm.

```
cvtColor(Original Img, PreProcesstin Img, COLOR_BGR2GRAY);
detect.detect(Preprocess Img, dector Pixel);
descrip.compute(Preprocess Img, dector Pixel);
```

Figure 7. Feature Point Extraction Algorithm.

[Figure 8] illustrates the images with the feature points which were extracted from the original image with ROI. In the figure, (a) shows Pass image, and (b) Fail image. Their feature points are extracted in different positions.



(a) Pass Image (b) Fail Image

Figure 8. Feature Point Images (Pass/Fail).

3.5. Image Classification and Learning

[Figure 9] illustrates the image classification and learning process. After feature points are extracted, SVM algorithm is applied to judge if the image passes or fails. The judged images are classified in Pass image group and Fail image group.

The images are learned through the classification, and data are saved in database. [Figure 10] shows a part of the algorithm for learning images with the use of SVM.

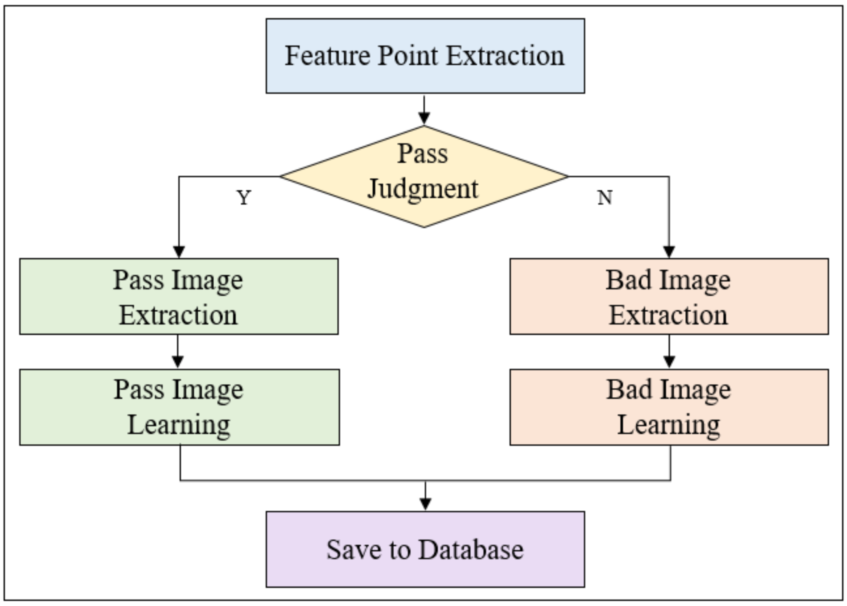


Figure 9. Image Classification and Learning Process.

```
if(OK)        groups.push_back(1);
else if(NG)   groups.push_back(2);

CvSVMParams params = CvSVMParams(CvSVM::C_SVC, CvSVM::LINEAR, 0, 1, 0, 1, 0, 0, 0,
cvTermCriteria(CV_TERMCRIT_ITER+CV_TERMCRIT_EPS, 100, FLT_EPSILON));

//Training classifier
SVMtrain(samples, groups, Mat(), Mat(), params );
Database.INSERT(samples);
```

Figure 10. SVM-based Image Learning.

If the image with the extracted feature points passes, it is classified in Pass image group; if it fails, it is classified in Fail image group. SVM algorithm learns images by setting parameter values. After learning is complete, data are saved in database.

[Table 1] shows the table of the database in which learned data are saved. In the table, attributes are result and feature point (detector) data.

Table 1. Learning Data Table.

No.	Result	Detector Data
1	Pass	1100110101
2	Fail	1000111011

4. Results and Discussion

To experiment the proposed model, this study designed the probe with the use of CCD camera that has FOV (Field of View) 70x70, resolving power 10 µm lens and light. To pre-process an input image, obtain the pre-processed image, and implement a machine learning algorithm, it made the model with the use of dialog box based MFC in Visual Studio 2017. [Figure 11] illustrates the screen for judging the semiconductor status with the use of SVM algorithm. In the screen, a Pass or Fail test image is selected, and ROI for the test image is set up. From the converted image, feature points are extracted by ORB algorithm.

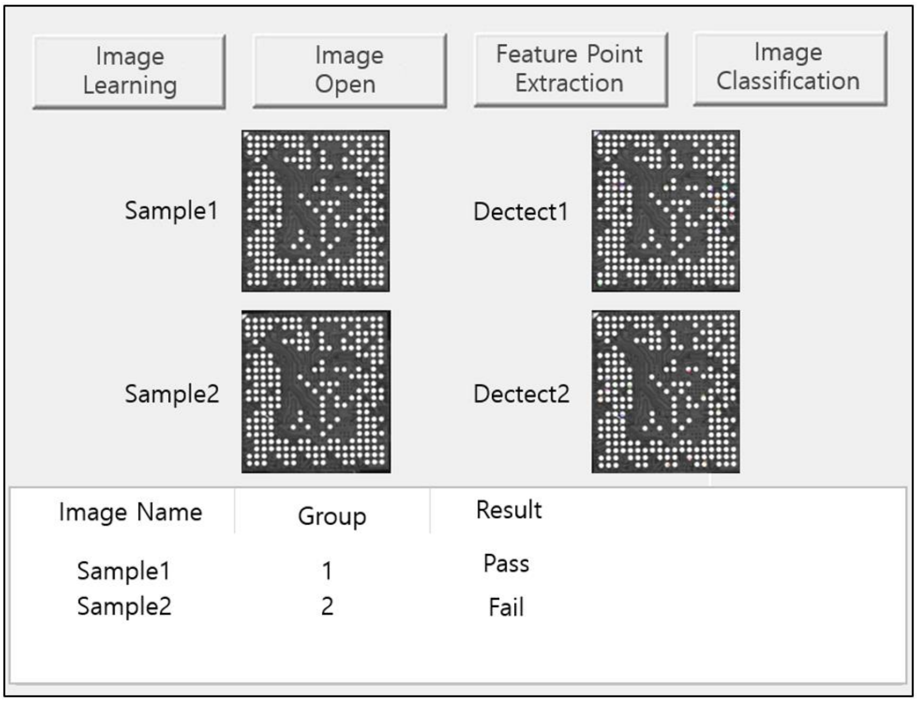


Figure 11. SVM-based Image Learning.

[Figure 12] presents recognition according to image learning. Images are learned according to the number of images. When one image was learned, recognition rate was about 28%. When 14 images were learned, recognition rate was about 97%.

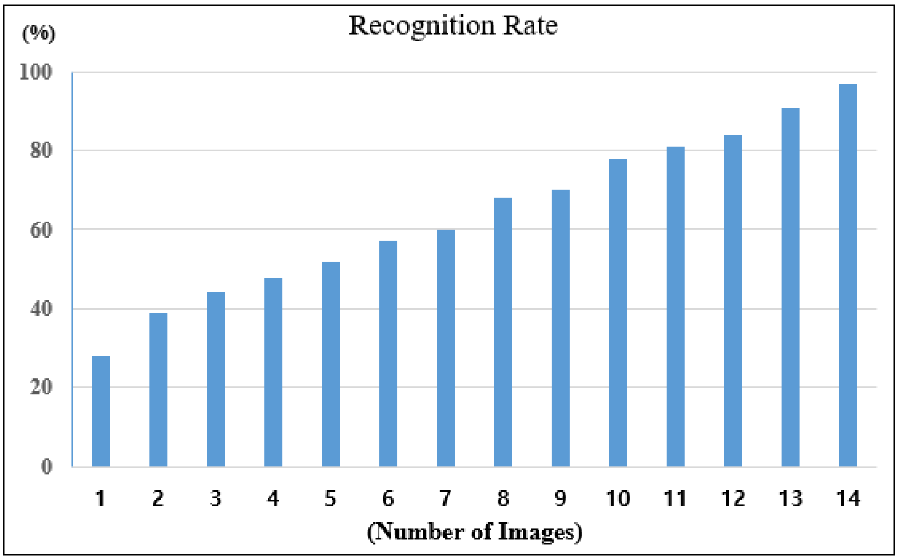


Figure 12. Recognition Rate Result.

5. Conclusion

The development of IT leads to a lot of changes in all industrial areas. Accordingly, vision system has rapidly been introduced in industries. In the semiconductor area, machine vision system is applied to many inspection processes, including BGA inspection and lead frame inspection. Vision inspection system has been more developed in combination with such multiple technologies as image processing, computer graphics, pattern recognition, and machine learning. In particular, it is much applied to classify semiconductor products in good and bad products. IC logic used in semiconductor manufacturing is an expensive chip with high performance. Therefore, if a package defect is found in the middle of manufacturing, it causes a lot of losses. Classifying and removing defected products in the production line through vision inspection system can greatly influence improvements in product value and reliability. In this sense, vision system is essential in the semiconductor manufacturing process. Therefore, this study proposes the model that makes it possible to extract feature points of objects through ORB algorithm to inspect whether products pass or fail in the BGA of semiconductor package, to classify and save image data through SVM algorithm, and thereby to improve product inspection efficiency through vision system. According to the experiment of the proposed model, when one obtained image was learned, recognition rate was about 28%; when 14 images were learned, recognition rate was 97%. If the proposed model is applied to vision system as semiconductor inspection equipment, it is expected to inspect products more quickly and accurately. In the future, it will be necessary to research a method of securing feature point extraction data, a scheme of applying a different algorithm, and a way to shorten the time taken to detect a defected product in order for fast product inspection.

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