# Development Of Techniques to Determine Object Shifts for PCB Board Assembly Automatic Optical Inspection (AOI)

Resa Pramudita[1,2], Farkhad Ihsan Hariadi[1,2]
School of Electrical Engineering and Informatics, Institut Teknologi Bandung
Microelectronics Center, Institut Teknologi Bandung
Jl. Ganesha 10, Bandung 40132, Indonesia
hariadi@ic-proc.paume.itb.ac.id

***Abstract*— In this study, we try to propose and implement a solution to the problems that occur in automatic optical inspection (AOI) systems where problems occur with regard to object shifts when this visual inspection process occurs so this shift causes the inspection process to be hampered. In this research work, a low-cost machine vision based on an SBC (Single Board Computer) is developed. Where Raspberry-Pi as a popular SBC offers the capability of being interfaced with a camera and of running a Linux-based operating system such as Ubuntu. These capabilities enable this board to be used to run sophisticated image processing programs for machine vision. The output of this system is to determine whether the object under inspection is accepted if the value of the shift is still below the tolerance value or rejected if the value of the shift exceeds the tolerance value. We propose a method to measure the distance of object shift using the Euclidean distance method while to determine our key points we use the Oriented Fast and Rotated BRIEF (ORB) method to recognize the object.**

***Index Terms*— Automatic Optical Inspection (AOI), Single Board Computer (SBC), Euclidean Distance , Oriented fast and Rotated BRIEF (ORB)**

## I. INTRODUCTION

Visual Inspection is an important part of quality control in the electronics manufacturing industry, especially in the PCB assembly process. With the advancement of surface mount technology as a means to increase the level of automation in the electronic assembly line, with production volumes reaching thousands of boards per day, manual visual inspection is becoming more and more productive. For this purpose, Automatic Optical Inspection (AOI) based on machine vision can be used. However, this method requires consideration of the amount of investment that is not covered by small companies.

Ardhy. F and Hariadi F.I [4] in a previous study have developed a visual inspection system based on the adaptive Gaussian threshold, but in this study there are still deficiencies in which visual images are captured in the event of a shift and skew then the inspection results will be irregular due to the reference object and test objects are not matched because the system made is not sensitive to shift.

In this study, we will try to propose and implement a technique to overcome the shift and rotation problems, where this technique uses ORB to determine key points in reference images and testing images, in addition to determining the shift distance of objects we will use the Euclidean distance method.

## II. BASIC THEORY

### *A.* OpenCV

OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. Being a BSD licensed product, OpenCV makes it easy for businesses to utilize and modify the code. There is a lot of programming language supported by OpenCV such as C++, Python, etc. OpenCV has a complete documentation site and big community because of its simplicity and robustness [3].

### *B.* Automatic Optical Inspection

Automated optical inspection (AOI) is an automated visual inspection of a printed circuit board (PCB) (or LCD, transistor) manufacture where a camera autonomously scans the device under test for both catastrophic failure (e.g. missing component) and quality defects (e.g. fillet size or shape or component skew). It is commonly used in the manufacturing process because it is a non-contact test method. It is implemented at many stages through the manufacturing process including bare board inspection, solder paste inspection (SPI), pre-reflow and post-reflow as well as other stages [1].

Historically, the primary place for AOI systems has been after solder reflow or "post-production". Mainly because, post-reflow AOI systems can inspect for most types of defects (component placement, solder shorts, missing solder, etc.) at one place in the line with one single system. In this way, the faulty boards are reworked and the other boards are sent to the next process stage [2].

### *C.* Oriented Fast and Rotated BRIEF (ORB)

Feature points detection of ORB builds on FAST corner detector [5]. One pixel will be defined as the FAST corner if there are a certain number of pixels, in a circular ring about the corner candidate, all belonging to different regions compared with the corner candidate. In gray images, the different regions mean the larger difference between the intensity values. FAST corner detector has low computation cost but no scale and

978-1-5386-6670-8/18/$31.00 

rotation invariance, and the corners detected via FAST are considered to be feature points of ORB [6].

Feature points should be added an efficiently-computed orientation for the purpose of a rotation invariant descriptor of ORB, and ORB employs the intensity centroid. The intensity centroid assumes that a corner's intensity is offset from its center, and this vector may be used to impute an orientation. The moments of patch S, whose center is one feature point, is defined as. [7]:

$$M_{p,q} = \sum_{(x,y)eS} x^p y^q f(x,y) \ldots\ldots\ldots (1)$$

And with these moments, the centroid can be found :

$$C = \left(\frac{M_{1,0}}{M_{0,0}}, \frac{M_{0,1}}{M_{0,0}}\right) \ldots\ldots\ldots (2)$$

ORB constructs a vector from the feature point to the centroid. The orientation of the feature point then simply is:

$$\theta = \arctan\left(\frac{M_{0,1}}{M_{1,0}}\right) \ldots\ldots\ldots (3)$$

*D.* Euclidean Distance

Euclidean distance is the calculation of the distance from 2 points in Euclidean space. Euclidean space was introduced by Euclid, a mathematician from Greece around 300 B.C.E. to study the relationship between angle and distance. This Euclidean is related to the Pythagorean Theorem and is usually applied to 1, 2 and 3 dimensions. But it's also simple if applied to higher dimensions. in this study, the Euclidean distance used is 2 dimensions which are described in the following equation:

$$\mathrm{d}_{\mathrm{i,j}} = \sqrt{\sum_{\mathrm{k=1}}^{\mathrm{n}} (\mathrm{x_{ik}} - \mathrm{x_{jk}})^2 \ldots\ldots\ldots.(4)}$$

where $d_{ij}$ is the level of difference (dissimilarity degree), n is the number of vectors, $x_{ik}$ is the input image vector, and $x_{jk}$ is the vector of the comparison/output image.

## III. Specification and Design

In this research, so that the system can be applied correctly, there are several devices that are used including the following:

1. Raspberry Pi 3 Model B
2. HDMI Cable
3. Keyboard and Mouse
4. Digital USB Microscope
5. Board Place
6. 2A 5V adapter for Raspberry
7. Monitor for Display

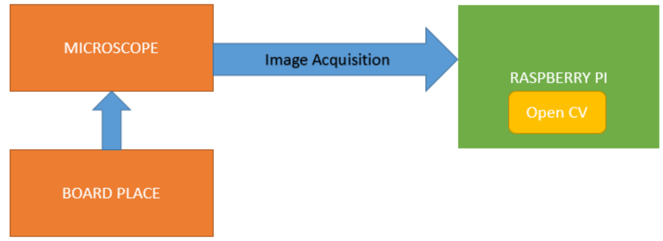


Figure. 1 The Proposed AOI Diagram Block

*A.* Image Acquisition

In this research, Picture saved in the Raspberry SDCard memory through our python program using OpenCV module 2 megapixels, for a camera we use Digital USB Microscope with built-in 8 controllable LED for taking the photograph of the board. We choose it because of it use USB connection, low price, up to 500 times optical zoom, and easy to mount.

*B.* Measurement Distance beetween 2 image

In this section, we will explain how to calculate distances between two points to get a shift value. The workings of calculating distance values are illustrated in Figure.2.

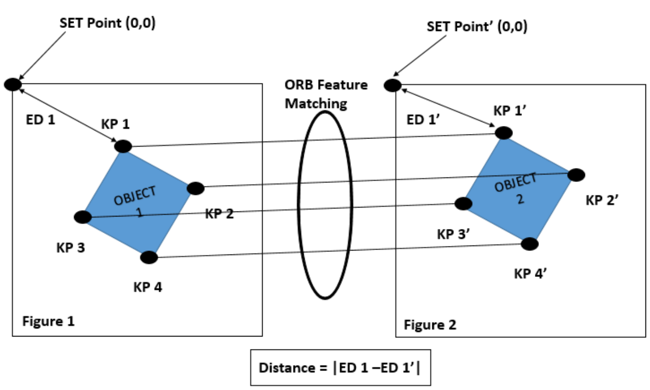


Figure .2 Illustration Distance Measurement Between 2 Image

Figure.2 shows how to measure the distance between Figure 1 and Figure 2, after determining the image to be compared we proceed to determine the key points (KP) using ORB where KP 1 to KP 4 is the key point in figure 1, while KP 1' to KP 4' is the key point in figure 2, after that each key point in figure 1 and figure 2 matches the similarity using the feature matching function, the next step is that the key points that have been mapped are measured the distance from the set point 0.0 using Euclidean distance so that the values ED 1 to ED 4 are obtained for figure 1 and ED 1' to ED 4' for figure 2, the next step after obtaining the ED value in Figure 1 and Figure 2, then the deviation value is found which is then used as the distance shift value of the two images.

*C.* Image Procesing

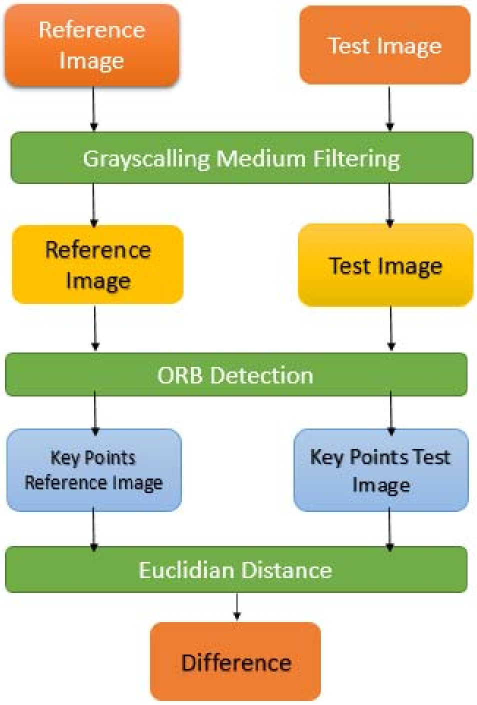


Figure.3 The Proposed Raspberry Pi Machine Vision

Figure. 3 shows the proposed system where this system has several stages including:

1. The first stage is Grayscaling from media image to facilitate the process of image processing.
2. After the image in grayscaling, the second step is to do ORB detection to get the key point from the image reference or image test.
3. After getting the key point from the reference image and test image the next step is to calculate the shift distance using the Euclidian distance method. Where if the difference between the two distances is zero then there is no shift and vice versa if the difference between the two distances is greater then the shift from the two images is farther away.

## IV. Implementation and Result

In this part, we will try to measure the image shift in the same image that is rotated in the range of 0 - 30 degrees. There are several measurements that can be displayed according to the degree of rotation.

*A.* Determine Shift the Overall Image

Before getting the overall image shift result, the first step we have to find the Euclidean distance value at each point of the key point in the test image or on the reference image that has been matched using ORB where it has been explained in the previous section and shown in Figure 4 below.

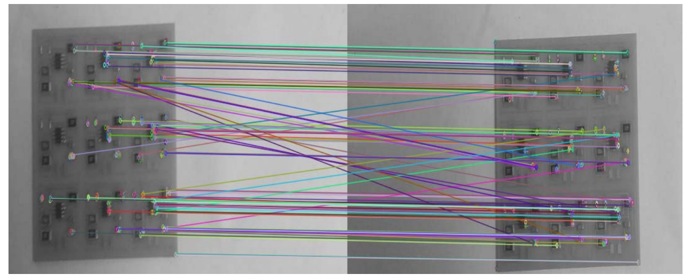

Figure. 4 Feature matching using ORB

After obtaining the Euclidean distance value at each point of the key point in the image reference and test image, we can calculate the average shift value of the two images using the following equation (5).

$$\text{Image Different} = \frac{\sum_{i=0}^{k} |ED1_k - ED2_k|}{k} \ldots \ldots \ldots (5)$$

In equation 5, $ED1_k$ is the Euclidean distance value in the first image or test the image point to k, while $ED2_k$ is the Euclidean distance in the second image or reference image at point k. Where we have to find the difference between the two values when the difference value is summed up with the values ED1 and ED2 next as much ask, where k is the number of keypoint matching of the two images. After we get the sum of the difference in Euclidean distance values, we divide again by k to get the image value different from the two images.

*B.* Results of image rotation measurements

We will try to measure the image shift in the same image that is rotated in the range of 0 - 30 degrees, where we use Figure 5 as the test image and rotation from Figure 5 using the PIL function in python as a reference image.

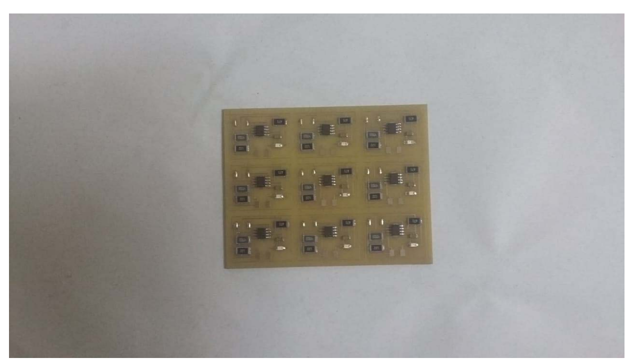

Figure.5 Test and Reference Image

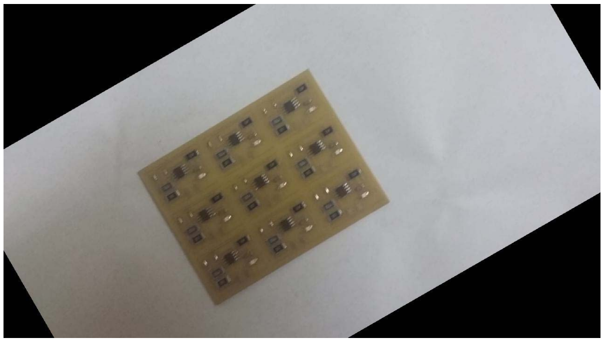

Figure.6 Image rotation $30^0$

The results of the measurements are in the form of pixel units where pixel coordinates are measured using Euclidean distance. The results of the measurement can be seen in table 1 below:

TABEL.1 RESULT OF MEASUREMENT DIFFERENT ROTATION

| Rotation | Key Point Matching (k) | Diff Image (in Pixel) |
|---|---|---|
| $0^0$ | 500 | 0 |
| $5^0$ | 384 | 22,356 |
| $10^0$ | 380 | 23,723 |
| $15^0$ | 368 | 23,315 |
| $20^0$ | 372 | 23,435 |
| $25^0$ | 385 | 22,522 |
| $30^0$ | 389 | 22,066 |
| $355^0$ | 395 | 22,114 |
| $350^0$ | 395 | 22,114 |
| $345^0$ | 376 | 23,853 |
| $340^0$ | 385 | 23,787 |
| $335^0$ | 388 | 22,773 |
| $330^0$ | 385 | 22,945 |

Table 1 shows the results of measuring pixel shifts from two different images with changing rotations. From this result, it can be seen if the image is not rotated or rotated by 0 degrees or 360 degrees, the point matching key value (k) is 500 and the difference image is 0 pixel, which means that there is no change in shift, whereas if the image is rotated then the value of k changes and image shift occurs.

## V. CONCLUSION

In this work, we try to propose and implement the technique used to calculate the shift distance in the AOI system, wherein checking this system we check when the image is rotated and then the distance of the difference in shift is measured, from the results of this implementation, the tool has been successfully implemented well, From the results of the rotation measurement, it can be seen that ideally the greater the rotation value, the greater the differential image value, but it does not occur. One of the causes is the unfavorable feature matching because there are the same points in several coordinates that cause keypoint matching differences in each image. rotation, so that the differential image becomes not ideal, besides the effect of light on the image also affects the image being processed.

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