Head gimbal assembly automated visual inspection by using digital image processing

Phonlawut Jaturawichanan\(^1\) and Somkiat Tangjitsitcharoen\(^2\)

Department of Industrial Engineering, Faculty of Engineering, Chulalongkorn University, Thailand

phonlawut.jaturawichanan@gmail.com\(^1\), somkiat.ta@eng.chula.ac.th\(^2\), +66865377322\(^1\), +66022186853\(^2\)

Abstract – This paper presented an approach of Digital Image Processing (DIP) and measurement properties of image region for inspecting the part in Head Gimbal Assembly (HGA) process. Current, the inspection process is performed by the skilled employee, which depends on employee experiences. The inspection method proposed by using digital image processing to do an image enhancement in order to detect the abnormalities and defects on part. The measurement properties of image region is proposed to identify the abnormality occurred on HGA part after image enhancement, in production process. This research aimed to develop the algorithm to inspected HGA part by considered the number of pads, convex area value, and eccentricity value. Then used measurement properties of image region to enhance the algorithm for classifying part in production process. This approach has been developed and proved with the real part in HGA production process. It’s proved that the algorithm and method proposed can be classified the part in HGA production process.

1. Introduction

The Hard Disk Drive (HDD) industry in Thailand is a large electronics industry. Thailand is the main production based of HDD industry. In addition, investment has been expanded as well as technologies transferred in Thailand. Hard Disk Drive has 2 major components, which are Head Gimbal Assembly (HGA) and accessory equipment for HDD. In this research will focus on the “Head Gimbal Assembly” or HGA. Head Gimbal Assembly process will consist of several processes, which are assembly, cleaning and inspection. Within HGA process, inspection process is the main process for capturing the defects occurring during HGA process. Inspection process required skilled employee to perform, which depends on the employee experiences. To train the new employee for inspection process, it take at least 1 month before working with a real part in production process. Hence, this research aim to develop the algorithm to help and reduce the operation cost in HGA production. It is leading to HGA manufacturing and inspection improvement.

For developed an algorithm for inspecting the HGA part, “Digital Image Processing” or DIP and “Measurement properties image of region” are the proposed methodologies to perform an inspection process. As many searches show the results that “Image Thresholding” can be used to detected or inspected an abnormality, which appear on an object, by converting grayscale image to binary image (black & white image). Hence, this technique is the most effective in image with high level of contrast [1] – [4]. Figure 1 is shown the result of input image after applied an image thresholding.
After applied image thresholding, “Morphology” is one of the DIP technique. It can be classified into 2 sub-techniques, which are “Dilation” and “Erosion”. Dilation is an expansion technique. It is used for fulfilled or expanded an interested area in a picture. This research also applied this technique after image thresholding in order to make an image suitable to process in the next step [5]. Erosion is a technique, which used for remove unnecessary area (size reduction) or collapse an object. Figure 2 is shown the result after applied dilation and erosion. Next step is about the justification process, whether this processed part is accepted or rejected? To justify the result, this research proposed “Measurement properties image of region” to identify the number of pad appeared in an input image, convex area value, and eccentricity value. These referred researches are evident that digital image processing and measurement properties of image region can be applied to classified part characteristics, part abnormality (appearance), and defects classification in HGA production process by using image thresholding, Morphology (dilation) techniques and measurement properties of image region.

2. Digital Image Processing (DIP) and Measurement properties of image region
In the research, DIP and measurement properties of image region are the techniques, which selected for performing an experiment. DIP is designed for image enhancement by using “Image
Thresholding” and “Morphology” in order to get a desired image. Image thresholding is one of the important technique in image segmentation, when T is the “Thresholding value”. This technique will replace each pixel in an image with a black color pixel, if the image density $I_{i,j}$ is less than some fixed constant T (That is, $I_{i,j} < T$), or a white color pixel, if the image density is greater than that constant [6]. Measurement properties of image region is the technique that use to measure a variety of image quantities ad features a black and white image. In this research, “Convex area” and “Eccentricity” are the properties, which using to determine the difference of an image after applied image thresholding as shown in the Figure 3-5.

![Accepted HGA part with convex area (5571) and eccentricity (8.10) value](image1)

| # of Pad_1 | Convex Area_1 | Eccentricity_1 |
|------------|--------------|----------------|
| 9          | 5571         | 8.1            |

**Figure 3:** Accepted HGA part with convex area (5571) and eccentricity (8.10) value

![Rejected HGA part with convex area (4721) and eccentricity (8.47) value](image2)

| # of Pad_2 | Convex Area_2 | Eccentricity_2 |
|------------|--------------|----------------|
| 9          | 4721         | 8.47           |

**Figure 4:** Rejected HGA part with convex area (4721) and eccentricity (8.47) value

![Rejected HGA part with convex area (2789) and eccentricity (7.69) value](image3)

| # of Pad_3 | Convex Area_3 | Eccentricity_3 |
|------------|--------------|----------------|
| 9          | 2789         | 7.69           |

**Figure 5:** Rejected HGA part with convex area (2789) and eccentricity (7.69) value

Convex area can be calculated by Number of pixels in “Convex Image”, returned as a scalar. Eccentricity of the ellipse that has the same second-moments as the region, returned as a scalar. The eccentricity is the ratio of the distance between the foci of the ellipse and its major axis length. The value is between 0 and 1. (0 and 1 are degenerate cases. An ellipse whose eccentricity is 0 is actually a circle, while an ellipse whose eccentricity is 1 is a line segment.) [7] – [8].
3. Experimental equipment and condition
This experiment performed by collected the sampling of the HGA in the production process. Then used the digital camera to capture HGA images, which stored in memory retrieved to computer and using digital image processing and measurement properties of image region to analyse an input image. Developing an algorithm, then load an image data in an algorithm. After input the digital image data in an algorithm, it will do the digital image processing, which will enhance an image, feature extraction, and calculated convex area value, and eccentricity value. Then used an enhanced images and calculated data to classify the HGA part. Figure 6 is demonstrated the algorithm of digital image processing and measurement properties of image region.

3.1 Equipment setup and condition
Digital Image Processing (DIP) is performed by digital camera with hi-power microscope (with illuminate controlled) and computer in order to take a picture of solder area on HGA part, then input into algorithm to process. Illuminate nearby inspection process has more influence to quality of a picture taken. Hence, during this experiment, the pictures data has collected under controlled environment.

3.2 Experiment performing
This experiment will be separate into 2 phases, which are digital image processing and measurement properties of image region. Digital Image Processing (DIP) is designed to process at the first phase of this experiment, in order to enhancement and prepare an image, then do a feature extraction in order to labeling a number on segmented objects. Next step is measurement properties of image region. This step will calculated the convex area value, and eccentricity value, which will use to identified the HGA part. The steps of experiment algorithm are consist of 7 steps (Figure 3). First step, take a picture of sample part, which collected in the real production process. Second step, load a picture in an algorithm. Third step, an algorithm will convert an original picture to grayscale picture. Fourth step, after getting a grayscale picture. The algorithm will do segmentation by checking each pixel, then compare to the target, which set at 250. If the value of pixel is less than 250, it will turn that pixel to 0, otherwise equal 255 (Figure 1). Fifth step, to removed noise after image thresholding by fulfilled an interested area with “dilation” 2 times (Horizontal axis and vertical axis). Sixth step, labeling each object and count on a labelled object in picture to check how many object(s) that algorithm can be detected? Last step, calculate the necessary parameters, which are convex area value, and eccentricity value.

4. Result and discussion
According to the DIP and measurement properties of image region, the result show that DIP can enhanced an image by using image thresholding technique in order to detect the number of HGA pads appeared in an image, then compare the result to the target, which is equal to 9 pads. After applied image thresholding, we observed that some image has an output of HGA pads equal to 9 pads as
accepted condition. Hence, measurement properties of image region will be the second condition that will make an algorithm more accuracy. Measurement properties of image region algorithm will be implemented after image thresholding. Figure 7 is illustrated the measurement properties of image region algorithm.

![Diagram of Measurement Properties](image)

**Figure 7**: Justification algorithm by using “Measurement properties of image region”

This algorithm will be set number of HGA pads, convex area and eccentricity value as target in order to distinguish HGA part. All conditions must be satisfy, then the result will be accepted. Otherwise, this algorithm will be rejected that HGA part.

### 4.1 Target value

To set the target values, which are number of HGA pads, convex area and eccentricity value. For number of HGA pads, it set by physical count the acceptable HGA part. To set the convex area and eccentricity value, we applied “Statistical Process Control” or SPC to establish the control limit, which included “Upper Control Limit” or UCL and “Lower Control Limit” or LCL [9]. Hence, after applied SPC to convex area and eccentricity value. The result show that convex area value has UCL equal to 5671 and LCL equal to 3838. Eccentricity value has UCL equal to 8.34 and LCL equal to 7.64. Figure 8 – 9 is demonstrated that convex area and eccentricity value can distinguish the rejected HGA part.
4.2 Algorithm verification
To verify the measurement properties of image region, we repeated an experiment by using the new set of data input in an algorithm, then see the result. Figure 10 is some of the result of the new data set.

5. Summary
As the result shown, Digital Image Processing (DIP) and measurement properties of image region can be utilized to detect a part characteristic, part abnormality (Appearance), and defect occurred during HGA production process by using image thresholding (Segmentation) in order to obtained the number of pad on HGA, then calculated the convex area value, and eccentricity value of each pad. The result interpreted by compared between the calculated results obtained from algorithm and target result. In the future, we can develop this algorithm by using a “Neural Network”. The neural network will help
this algorithm re-calculate the target values, which are convex area value and eccentricity value. And also detect the change in variation of HGA production process.

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