Automated Visual Inspection for Magnetization Process

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Abstract

This paper presents the automated visual inspection method for classifying a magnet in the magnetization process of a spindle motor manufacturing. The original inspection process is performed by a trained human inspector. When an inspector handles the part manually, the risk of contamination in the process is usually high. The proposed automated visual inspection process will be integrated into the fully automated magnetizing machine that is currently developed in order to reduce the problem of contamination in the existing process. In this paper, the gray level image is converted to binary image using the thresholding level which is automatically calculated based on the principle of optimal thresholding histogram. Furthermore, two classification methods: the neural network approach and the template accumulator approach are proposed. These two methods were applied to this specific application and the results were compared.

Introduction

Hard disk drive industry has been growing quite rapidly in the recent years. The new HDD products are developed to be smaller such that the record intensity of the media disk becomes higher, read/write head is smaller and the gap between read head and media disk is closer. Thus, the production technology has to achieve high precision in well controlled environment which means the clean room needs to be a class 100 standard (JIS) or higher. Moreover, other industries related to hard disk drive production such as spindle motor manufacturer has to follow the same standard.

DC brushless Motor is the foundation structure of a spindle motor manufacturing (Kenjo and Nagamori, 2003). There are many production processes in the making of a spindle motor. These processes are complicate and required to be performed with high precision. Moreover, inspection has to be performed 100 percents for all parts during the entire production. The magnetization process which is performed within the spindle motor assembly process required to have a visual inspection of the magnetized parts by a trained inspector using a test sheet. Although the current method of inspection gives good result, there is a risk of contamination that could occur during human handling procedure. Therefore, a fully automated process of magnetization and inspection is necessary for reducing the risk of contamination in the production.

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This paper will discuss about the theory and previous research in image processing such as the method of selecting the appropriate thresholding level and the classification method. Then, we will propose the method for finding the appropriate threshold level automatically. After that, we will explain about two different classification methods and show the experimental result of each classification method and compare both methods considering the correctness of the classification result and the computation time.

Automated visual inspection

As previously explained in section 1, the current inspection method by a human inspector risks with contamination. Thus, in order to prevent the problem to occur, this paper proposes the autonomous visual inspection method that does not required the inspector to touch the magnet as shown Figure1. The system comprises of 2 sections. First, the image acquisition subsystem that uses a CCD camera to capture an image into the system. Second, the defect detection subsystem which is an image processing and a decisioning methods that classifies the type of defect on an inspected part.

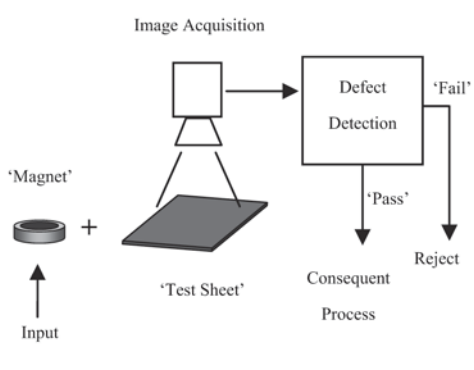


Figure 1. Automated Visual Inspection System

Image acquisition

The image acquisition subsystem consists of a CCD camera and a light source. In this application, the position of a camera and light source is fixed at the position that minimize shadow and reflection. However, the image condition will be further improved by image processing in the defect detection subsystem. Two images are acquired in this applications. The first one is the image of the magnet. The second one is the image of a magnetized test sheet.

Defect detection

Defect detection section use image processing together with a decisioning algorithm to classify the defected part from the good part. There are two steps in the process: image segmentation by thresholding and object classification.

Gray level thresholding

An image is acquired as a 8-bit gray levels (0-255) from a green channel of a 320x240 pixels RGB image from a CCD camera, then is converted to a binary image using thresholding method. Selecting an appropriate threshold level is very important. If the binary image that is created from thresholding is not well-segmented, the recognition process will be affected. As shown by the sample in Figure2, when the selected threshold level is too high, some pixels that represent an object is disappear as shown in Figure2 c. In contrary, if the selected threshold level is too low, the pixels that represent an object are mixed with the back-ground. Moreover, a fixed value of threshold level will not be applicable when there are changes of object color or brightness. Thus we should find the way to adapt this threshold value dynamically.

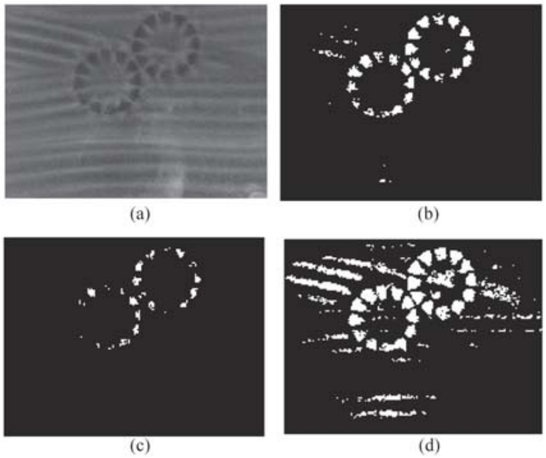


Figure 2. a) The image of a magnetized test sheet
b) a binary image with the proposed thresholding method
c) a binary image when the thresholding level is too high
d) a binary image when the thresholding level is too low

Object Classification

The object classification subsystem is the decisioning algorithm that can classify between the good and the defected product. The thresholded image is the input of the object classification process. There are different approaches for object classification in an automated visual inspection system such as pattern matching, rule based decisioning, neural networks and feature detection. The general Hough Transform (Gerhard et al., 2001) is one of the powerful feature detection algorithm based on an accumulator concept that considers lines, shapes, and other parameters such as radius and center. In this research, two methods of object classification: a multilayer neural networks and a template accumulator are applied and tested as will be explained in more detail in section 4.

Finding an appropriate thresholding level

The optimal thresholding method (Sonka et al., 1999) assumes that the gray level histogram is a combination of two normal distribution functions, the thresholding level is then selected based the difference between these two functions. Otsu (McAndrew, 2004;Otsu, 1979) also proposed another method that follows the same principle as the optimal thresholding method. For the image that have variations of lighting throughout the image, thresholding can be applied locally within the small section of the image (Jahne, 2005). Yanowitz and Bruckstien (1998) also suggested the thresholding surface based on the gradient of a gray scale image. In this research, the proposed thresholding algorithm is based on the principle of optimal thresholding on the gray level histogram, however it is slightly different from the methods described in (McAndrew, 2004;Otsu , 1979) and (Sonka et al., 1999).

The thresholding method proposed in this research is considered two different cases of the gray level histogram. The first case is applied on the magnet image, while the second case is applied on the image of a magnetized sheet.

Case 1: The gray scale histogram feature can be observed as a combination of two normal distribution functions as shown Figure 3a. The thresholding level can be solved from a derivative of the histogram after applying a low pass filter and smoothing function to the gray scale image. The optimal threshold is chosen at the place where the derivative of the histogram is zero and in between the negative and positive value as shown in Figure3b.

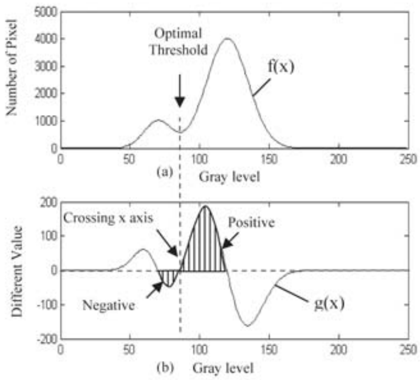
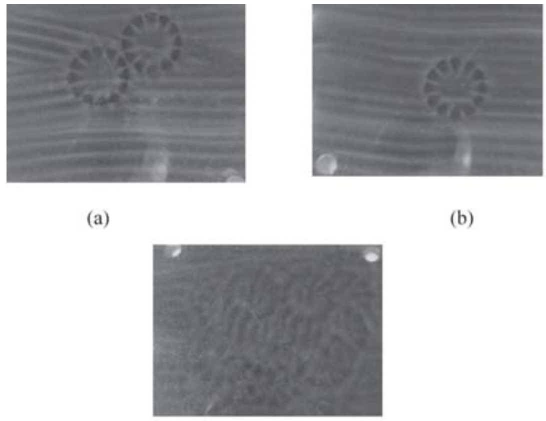


Figure 3. a) the smoothed histogram and optimal threshold
b) the derivative of histogram and the selected threshold level

Case 2: In the case of a magnetized sheet image, there are no clear separation between the two normal distribution functions of a gray scale histogram like in case 1. Therefore, the thresholding level can be approximated by a multi-derivative histogram. The derivative of the gray level histogram is taken twice. The maximum of this second derivative will be chosen as the thresholding level for this case.

Experiments and Discussion

This inspection and classification process is experimented using Matlab 7.1 program with 15 samples of a 320x240 pixel image. (1 sample consists of one image of a magnet and one image of a magnetized testsheet) The sample images are classified into 3 groups: two magnets, one magnet and none. The one magnet and none cases are considered a 'fail' case as shown in Figure4 .



(a) (b)

(c)

Figure 4. image of the magnetized test sheet
a) group1: two magnetized objects (pass),
b) group2: one magnetized object (fail),
c) group3: no magnetized object (fail)

Experiment of classification with the neural network

The binary input image is preprocessed before entering the neural network module by a translation and rotation to a standard configuration and follows by a thinning process and a chain code conversion and normalization. The chain code used in this method is the eight direction chain code as shown in Figure 5c. which has the benefit of being location invariant. The three layer neural network with one hidden layer is used for classification. 120 input nodes of the network receive the chain code of the image. Output nodes are the 3 classified cases. There are 20 nodes in the hidden layer. 45 samples were used for training. (15 samples for each group) The training iteration are 300 epochs with the learning rate of 0.4. The target output is 1.0.

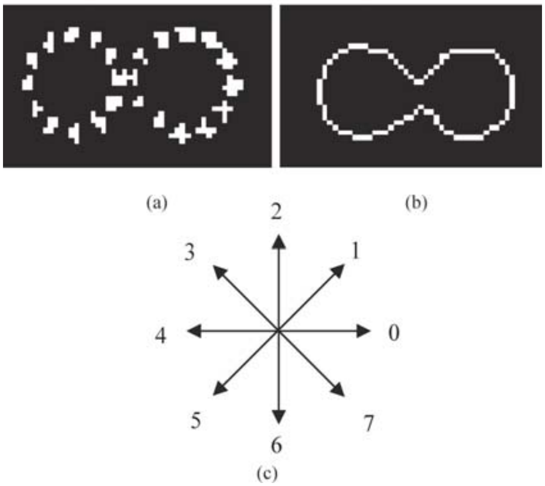


Figure 5. a) Binary image of the magnetized test sheet
b) Binary image after thinning process
c) 8-direction chain code format input

The result of the experiment from 15 test samples shows 100% accuracy of the classification method by the proposed neural network. The average computation time of the process (including preprocessing and classification) is 0.358 seconds.

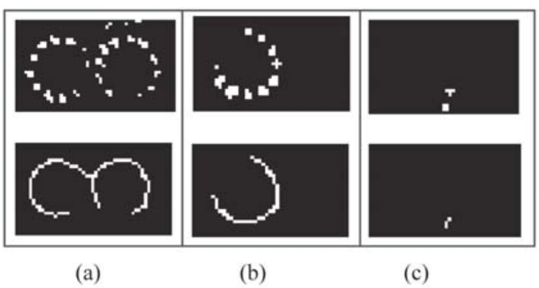


Figure 6. The binary image after thresholding and thinning for each group as an input to the neural network method a) group 1, b) group 2, c) group 3

Experiment of classification with the template accumulator

The template accumulator approach doesn't require training. This method uses an 'and' operation between the binary image of the magnet image (template image) and the binary image of the magnetized test sheet. The white pixels that are within the template are accumulated as shown in Figure7. If the accumulated output is higher than the set threshold of 84 then the object is detected.

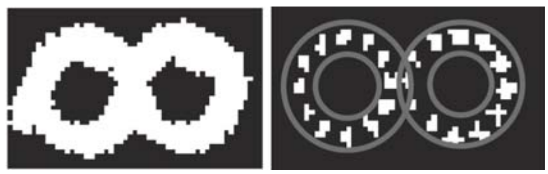


Figure 7. a) Image template from the magnet image
b) Input for the Template Accumulator

This second experiment used the same set of test samples as the previous experiment. The result of the experiment shows that 126 pixels is the minimum accumulated value of the detected magnetized object and 41 pixels is the maximum accumulated value when there is no magnetized object. With the threshold of 84, all samples are classified correctly with 100% accuracy. The average processing time for this method is 0.181 second which is almost 3 times less than the neural network approach.

Table 1. Experimental result of two classification methods

Method	Accuracy (%)	Average Computation time (sec.)
Neural network	100	0.358
Template accumulator	100	0.181

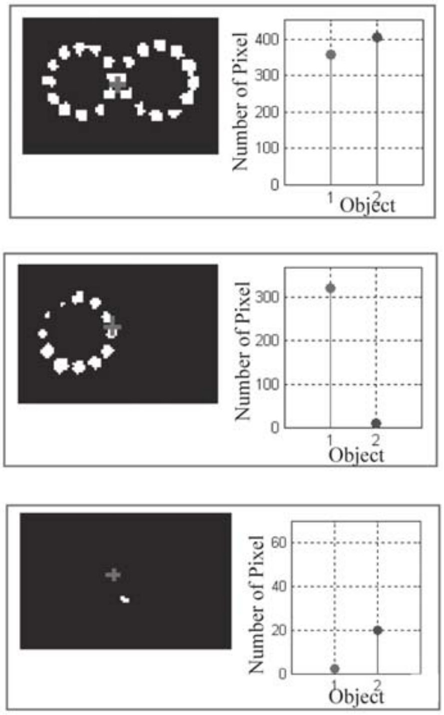


Figure 8. Classification by template accumulator

Conclusions

The image processing technique is applied to the magnetic inspection system for a spindle motor manufacture. The gray scale images of the magnet and the magnetized test sheet are used as input for an automated defect detection. An adaptive thresholding algorithm is applied to the image in order to convert from a gray scale image to a binary image. Two classification methods: neural network and template accumulator are proposed and applied to the binary image. Both methods can successfully detect the defect parts from the good parts with 100% accuracy using 15 test samples. The template accumulator approach does not require a training step and the average computation time is only 0.181 seconds which is much smaller than the neural network approach. This visual inspection system will be integrated into the automated magnetizing system.

Acknowledgements

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