Automating the Visual Classification of Metal Cores

In-Gyu Park, Kyung-Ho Song, and Tae-Joong Ha
Dept. of Electric & Control Eng.
Hong Ik University

ABSTRACT

An automatic visual classification system is introduced which provides for measuring the length and diameter of coilform cores and dividing them into 5 different classes in terms of how far their length be from the desired length. This task is fully automated by controlling two STEP motors and by using image processing techniques.

The classification procedure is broken into three logical parts. First, cores in the form of randomly stacked bundle are lined up one by one so as to be well captured by a camera. The second part involves capturing core image. Then, it enters the measuring process. Finally, this machine would retain all the information relating to the lenghth. According to the final result, cores are sent to the corresponding bin.

This considerably simplifies the selecting task and facilitates a greatly improved reliablity in precision. The average classifying capability is about 2 pieces per second.

1. Introduction

During the manufacturing process, the classification in quality and the shape inspection are, still, being done, mostly, not by an automatic machine, but by human beings. If the manufacturing process be performed manually, the results would be plagued with several serious drawbacks including inconsistence, poor performance, inefficiencies and inadequacies due to boredom and fatigue. However, it may be anticipated to take time to realize automaization. Here, let us examine closely the cause of the retardation toward automation. First, on considering the technical point of view, without fully understanding a lot of essential technologies, it can not be done well to develop an automatic manufacturing system. Second, it is not easily acquired to possess capabilities of integrating and harmonizing several technologies, referring to the system integration technology. Finally, most managers are too often disposed to have the short-sighted view on automation.

The main subject of this research is to develop an automated classifing system to be capable of measuring the size of several types of metal coilform cores, and classifing the parts into five different grades. The essential technologies which have to be employed to achieve this goal, are listed as followings: Motor Control, Image Processing, Computer interface, Sensor, and Software, etc.. One of the accompanying effects of this project is to understand more or less those technologies.

The classifying process can be performed either by contact inspection or by non-contact(visual) inspection. Non-contact (visual) inspection offers over traditional contact inspection is the opportunity to produce parts with consistent accuracy and quality. Industrial inspection is an area in which the application of machine vision technology shows exceptional promise. Intense competition and stringent product reliabilty requirements often made inspection the single most important and sometimes the most expensive stage in a production stage. A great deal of this expense is due to the labor intensive nature of most inspection tasks.

The classification is of great importance to metal cores production and is considered to be one of the most difficult tasks. It was found that precise performance statistics for human inspectors were not available, but estimates of top performances in the range of 70 percent efficiency for this classifying inspection. These figures drop considerbly with inspector fatigue. In adition, it is likely that a significant number of classified parts will be incorrectly selected. Such misclassifications often lead to unnecessary rework and ultimately to the degradation of their quality. Therefore, one of the prime motivations for developing this machine is to ensure that the classification of parts is rapid, efficient and reliable.

This sytem is designed for measuring the length of coilform cores, very accurately, without contacting of part under test, and divide into five different classes with the test result as required for the assigned criteria, and finally, the classified cores are stored into the pertinent box. the quantity to be stored in a box can be, of cource, changed and by setting initial input data at any time. Also, all informations which are occurred during the process, are memorized. If necessary, sometimes later, these inormations could provide with data for quality control, and printer output to be adhered on the surface of a cartoon package.

2. Automated Process

The following is a concise description of sequences of classifying process used in this system. An outline of the classification algorithm involves six stages on the sequence of working. The steps are as follows.

1) Supply Process: Finished products are transported to this system for inspection. At this stage, it is assumed that parts are scattered randomly.
2) Line-up Process: Its role is to transform the randomly scattered parts into the well standing state in line. For this, it demands a highly-precision mechanical mechanism.
3) Image Grab Process: At this stage, the image to be used for applying image processing techniques are acquired.
4) Measuring Process: The next task is to manipulate images,and to extract information from them.
5) Classifying Process: The subject of this stage is to classify a part as belonging to one of five classes, and then to store that into the corresponding bin.
6) Count and Statistics: It is designed to memorize all informations occured during the classifying procedure on the secondary storage, Hard disk. These informations wil be used for quality control.

3. System Configuration

An automated cores clasification system has been developed accoring to the above-mentioned sequences. It consists of five main blocks (Fig. 1): a system for handling the parts to be classified, the IBM-compatible PC which include the image frame grabber board and the control interface board, the sensor which detects the flow of the parts, the camera set, and the system control board.

For the purpose of image processing, the handling system should allow a good repeatability of the part's position. The image frame grabber board converts the analog signal of the CCD camera into a digital data stream.

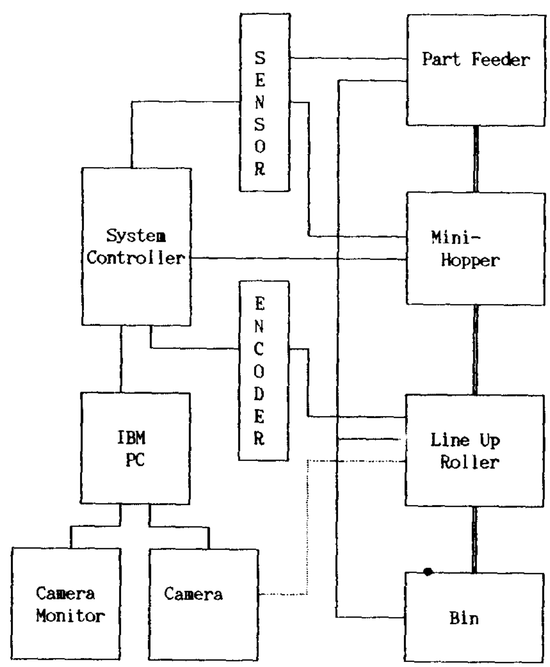


Figure 1 : System Configuration

4. System Structure

In the paragraphs below, each of major components will be discussed in the context of the interaction as a complete system. Figure 2 is a photograph of this system. The overall system dimension are 2 m wide by 1.5 m long by 1.5 m height.

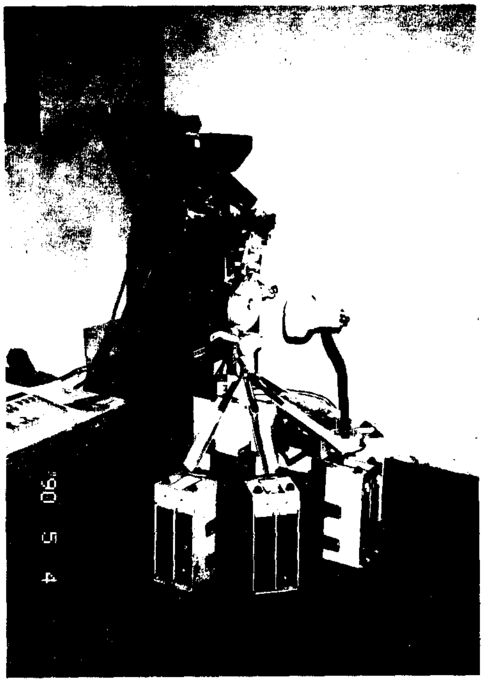


Figure 2 : System Overview

1) Parts Feeder & Mini-hopper

Their role is to transform randomly scattered parts into well standing in line.

A vibrator is located at the center of the Parts Feeder. While the vibrator keeps vibrating, the parts start to be scattered into the outside direction, actually having a spiral curve. Several metal plates are sticked to control the pace of flowing of the path, and to make the parts stand in a line.

Randomly scattered parts should be positioned on the specific fixed point for the purpose of capturing the image of the parts. Therefore, it is highly desirable to take care to ensure that a sophisticated system allow a good repeatability of the part's position and a regular presence of tha parts on the grooves carved on the circumference of the wheel. For this objectives, the Mini-hopper should have the path of the parts to be able to transport only one core without being blocked. Two sensors are installed at the entrance of the path and at the end of the path for the purpose of never being blocked. It is also maintained that the gap space of the flow always has to be a regular interval of 2 mm.

2) Measurement System

Measurement system consists of the camera set and the Line-up Roller. A relatively simple wheel was used to make the Line-up Roller. The step motor rotates the Line-up Roller around its axis. Thirty six grooves are carved on the circumference of the Line-up Roller.

It is designed that the Line-up Roller starts to rotate slowly from the fixed reference point of the wheel. Also, the current position is always detected from Encoder.

3) Sorter

The measured part falls down to the circular cone. After that, immediately, the circular cone is rotated to the nearby of the entrance of the pertinent pipe. After the part crosses the pertinent pipe, it reaches a bin.

5. Image Processing System

5.1 Image Processing system Organization

It consists of the image frame grabber board additioned to a IBM-compatible 286 PC for image capture and display, the camera set and a software package which runs under the DOS. A comprehensive set of commands is available for interactive use to generate and manipulate images, and to extract information from them. The software is written in C language and can be readily extended to incorporate new routines.

- The Location of Camera

The camera is located in the upper portion of the Line -up Roller, and is installed so that the direction of projection may be accorded with the center point of Line -up Roller. No reflected light is detected by the CCD

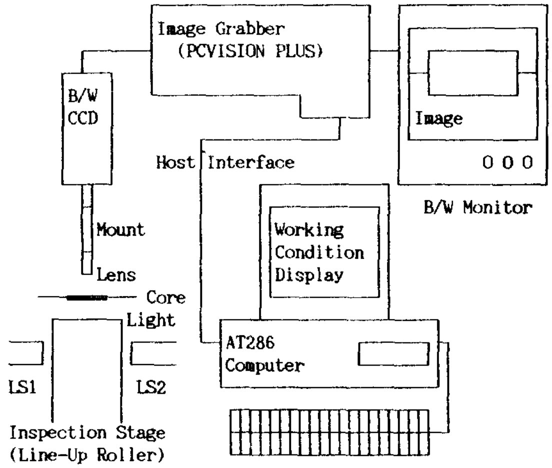


Figure 3 : Image Processing System

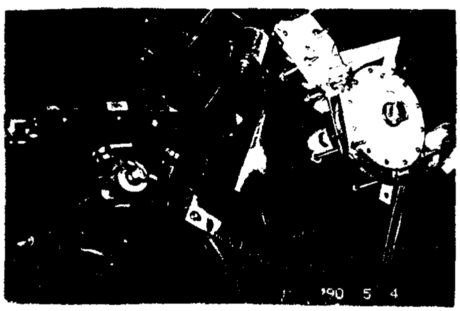


Figure 4 : The Location of Camera

camera because the material of the Line -up Roller is Tepron, which has the semitransparent characteristics for light.

5.2 Image Capture

The video signal from an OPC B/W video camera, which has an iris and a solid state MOS sensor. It is digitized to a 8-bit number and stored in the picture memory using the Truevision Image Frame Grabber Board. After that, several basic image operations could be implemented very

- Image Quality

The lighting arrangement is very important. For this work, it will be, first, discussed what factors have an effect on the image.

1) Illumination

It is no question that the illumination may have an effect decisively on the image. Here, let us consider the causes of affecting illumination. First, it is due to the neighborhood's lighting. Second, it is whether the projected light may be reflected or no reflected.

It was verified by so many experiments that this should be the most, decisively important factor. Therefore, It is beyond description to emphasize that the status of illumination must be checked before/during the working.

2) Lined-up Roller

Since the image must be captured on the condition that parts are mounted on the groove surface of the Line -up Roller, the image always consists of that of core itself, and that of background. So, the captured image may be easily affected by the surface state. In order to take the accurately clean image, special care has to be taken to keep the groove surface clean.

Also, another important factor is that the Line -up Roller must be stopped completely in order to take image. However, it is not easy to be stopped without any vibration, because there is a tendency to keep vibrating by inertia.

3) Vibration

It is really unavoidable that the Lined-up Roller keeps to feel shock/vibration from the Parts Feeder, vibrator, and other vibrating sources.

6. System Controller

- Hardware Organization

The sytem control is composed of the interface circuit, the control circuit, the sensor circuit.

For interfacing the automated cores classification sytem to a IBM-compatible PC, the interface circuit was designed to transfer command or data each other, to send the status of the controller.

Next, the control circuit contains the main controller circuit, the motor control circuit, the sensor driver, the solenoid driver,and the LED driver. In this Board, the circuit for inputing from three sensors are provided.

The first one is a encoder which reads out the position of a stepper motor, The second one is a photo interrupter to detect the zero point of a sorter. The last one is a photo sensor to detect the accumulation status through the path of Mini-hopper.

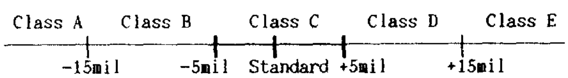
7. Classifying Algorithm

7.1 Specifications

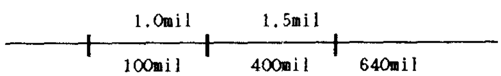
1) Specifications of CF Core

Length of CF Core : 100mil - 650mil
Diameter of CF core : 40mil - 300mil

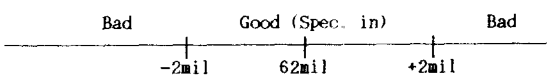
2) Classes by Length



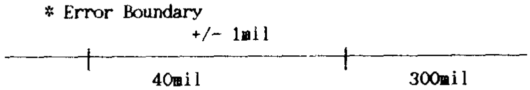
* Error boundary



3) Classification by Diameter



* Error Boundary



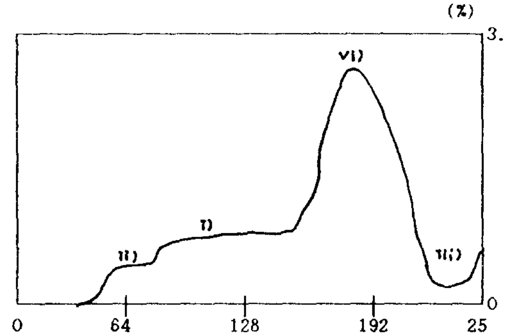
7.2 The Algorithm for Image Inspection

If the complex algorithm were used, too much waste time would be expected. For this reason, we developed a new simple algorithm, which can measure the length by cleaning, if possible, the image captured by camera.

1) Binarization

The catured image is composed of metallic lead, body, dust/noise and lighting table. From the histogram, we can predict the gray level on each part of the core. Also, from the above informations, the threshold level can be automatically decided for image binarization.

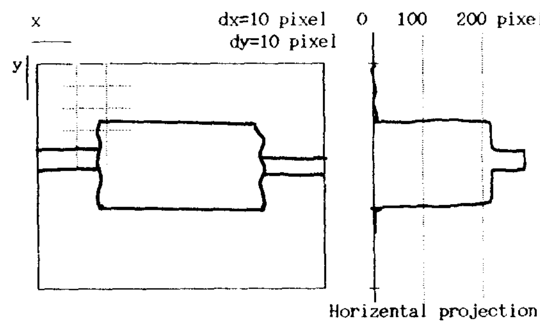
From the above histogram, we can get the solution of the method to get image and to install illumination.

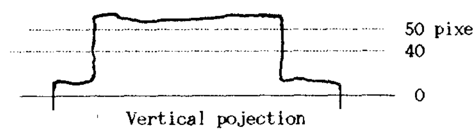


i) core body
ii) the shadow of core
iii) the highlight of metallic lead and core body
vi) lighting table

2) Identification of cores

The identification of cores is performed by tracing pixels both from the top to the down vertically and from left to right horizontally. By the below algorithm, the center of core body is detected.

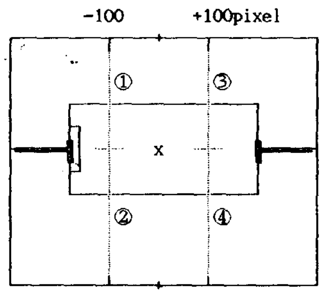




We can detect the core position within the error boundary +/- 10 pixel. At the same time we get the identification of core body, we can get another accompanying decision of the unacceptable one.

3) Length and Diameter Measurement

After the center of core body is detected, two vertical samping lines are decided at 100 pixel distance of both sides from the core center. We can check the line pixel data of the two sampling lines.



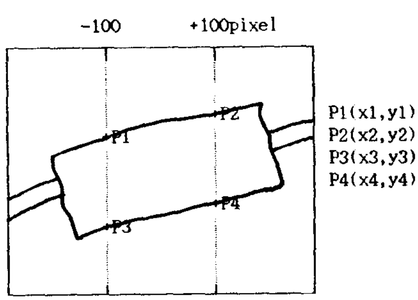
By follwoing four different lines on sequence of 1,2,3,4 in turn, counting of pixels will be continued until the background image is met. During the counting, the noises should be cleaned up by applying the noise cleaning algorithm because the number of counting can not be trusted due to dust and noise.

The cleaning algorithm is concerned with spacial median filter as follows;

x,y-2 x,y-1 x,y x,y+1 x,y+2 line pixel

$$p(x,y) = \frac{1}{5} \left(\sum_{i=-2}^{2} f(x,y+i) \right)$$

where if $p(x,y) > 128$: background
< 128 : Core body



- After the slope of core is obtained, that can be applied to the sampling line equation.

$$\text{slope} = \frac{(y2 - y1)}{(x2 - x1)}$$ if $(y2 - y1) - (y4 - y3) > 40$ then the measurement of length and diameter of core can be disregarded

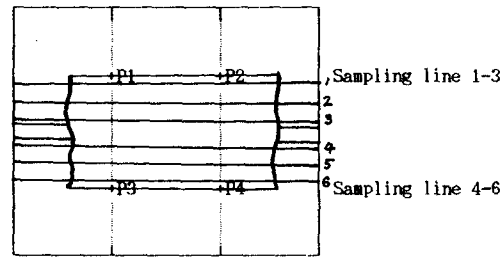
- Six sampling line equations for length measurement.
- Line Equation 1-3

L1 - L3 : $y = slop * (x - x1) + y1 + (dy * i)$
$dy = (y3 - y1) / 13$

- Line Equation 4-6

L4 - L6 : $y = slop * (x - x1) + y3 + (dy * (i-5))$
$dy = (y3 - y1) / 13$

- Obtain the values of y, when x=0,x=511.



Determine the location of the first point and the last point beloning to each sampling line.

- Since the data obtained by the sampling lines includes the unwanted data due to noise/dust scattered on the background, the algorithm to eliminate the effects by some noise should be applied as followings:

x,y-2 x,y-1 x,y x+1,y x+2,y

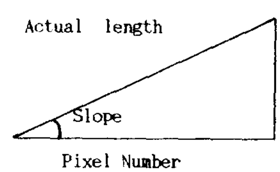
$$p(x,y) = \frac{1}{5} \left(\sum_{i=-2}^{2} f(x+i,y) \right)$$ if $p(x,y) > 128$, background
< 128, Core Body

- Considering P(x,y), the length of body can be only calculated.

4) Conversion to actual length

Next, it is needed to get the actual size from the measured information.

- Actual length



$$\text{Actual length} = \text{pixel number} * \sqrt{X_s^2 + (Y_s * \text{slope})^2}$$

where X_s/Y_s: the actual horizontal/vertial length corresponding to one pixel image

8. Conclusion

Experimental results indicates that the average classifying capability is about 2 or 3 pieces per second. Based on this result, it is confirmed that the classifying algorithm suggested in this paper provides high accuracy and appears to much improvement over human inspector performance.