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# Development of Surface Inspection System for Wire Rod

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**Abstract:** This paper introduces the surface inspection system for wire rod in steel-making industry. The inspection system is based on vision technology. We have developed illumination system with blue LED lighting sources to get best quality of surface image. And we have implemented defect detection algorithms based on block sigma transform which can recognize wire rod objects and segments defect candidates from images in robust and efficient manner. We have installed the inspection system in production line and have good detection rates.

## 1. INTRODUCTION

In this paper, we introduce the surface inspection system for wire rod. The wire rod is one kind of the products in steel industry. The product is made by rolling billets. During the rolling process, defects may be created by various reasons. The inspection of wire rod in rolling process is very difficult because rolling is done with being covered by guide devices at very high speed of 17 meter per seconds. It is dangerous for operator to access the product during rolling process. The convectional method of automatic inspection for wire rod in rolling process is ECT (Eddy Current Test) system. The system is based on electromagnetic induction to detect flaws in conductive materials. However, it is very weak against noisy environments and highly dependent on its configurations. Moreover, it only gives simple electronic signals to operators, which are too few information to recognize defects of wire rod.

We have proved those algorithms give very stable segmentation results. We have developed inspection system based on vision technology. The wire rod is very small with its diameter of maximally 36 mm and runs fast in high temperature. So it is considered that applying measurement system with vision technology is impractical to inspect defects on wire rod. We compactly designed the illumination system that has equipped with lighting sources and CCD cameras that cope with environmental difficulties. To detect flaws on the surface of wire rod, we analyze surface images and apply image-processing algorithms that are fast enough to get real-time results. The surface of wire rod is highly noisy with scales, oil, and water vapour and looks like textures. There are many image-processing algorithms that can segment flaws in textures (D.F. Dunn et al., 1995, T.Chang et al., 1993). However, those are not well applicable for these kinds of targets. We have developed defect segmentation algorithms based on block sigma transform that measures local variations with given block size.

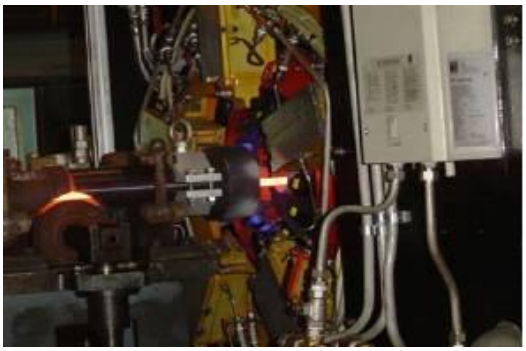

Fig. 1. Surface inspection system for wire rod at production line (blue LED lighting sources and CCD cameras)

## 2. THE SURFACE INSPECTION SYSTEM

### *2.1 surface Inspection system*

In this inspection system, we use CCD cameras to get surface images of wire rod. Because the wire rod is long thin round object, we can get completely connected surface images by total five cameras that are placed circularly surrounding it. The CCD sensors are line scan types so that we can continuously grab images without skip a portion of them by using double buffering grabbing technique where two buffers are allocated and images are grabbed asynchronously.

The Illumination is one of the most important and critical parts in the surface inspection system. We have developed the patented oblique lighting system that is optimized for this application, which use blue LED as lighting source. The lighting system depresses the bright field reflection

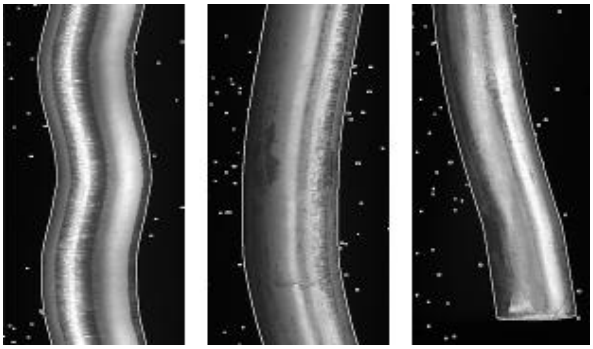

Fig. 2. Examples of OD (Object Detection) algorithm

on the centre of image so that the captured images have uniform illumination distribution. Figure 1 shows our illumination system that is installed at production line.

### *2.2 Defect detection algorithms*

The wire rod in the production line moves fast with high speed and high temperature because it is made by rolling process. And the surface of wire rod is highly corrupted by scale, oil, dust, water vapor and etc. Therefore, it need more efficient and robust defect detection algorithms than other defect segmentation applications. The algorithms we have developed in this paper consist of OD (Objection Detection) and DD (Defect Detection).

The OD algorithm recognizes the wire rod from image and extracts the wire rod object from background. The algorithm mainly depends on the block sigma transform, which is defined by following equations.

$$f_m(x,y) = \frac{1}{MN} \sum_{i=-\frac{M}{2}}^{\frac{M}{2}} \sum_{j=-\frac{N}{2}}^{\frac{N}{2}} f(x+i, y+j).$$

$$f_{\sigma^2}(x,y) = \frac{1}{MN} \sum_{i=-\frac{M}{2}}^{\frac{M}{2}} \sum_{j=-\frac{N}{2}}^{\frac{N}{2}} (f(x+i, y+j) - f_m(x,y))^2.$$

$$f_\sigma(x,y) = \sqrt{f_{\sigma^2}(x,y))}.$$

Then the block sigma transformed images are segmented by predefined threshold value. The maximum object is selected by using connected components analysis and holes, if they exist, in the object are filled in the object. Finally, erosion morphology operation is applied with corresponding block size M and N.

The DD algorithm is applied on the object founded by OD algorithm. The base algorithm is also depends on the block sigma transform but with different block size M and N. For determining threshold, we calculate the mean sigma value on the object, wire rod. Then the object image is segmented by using weighted mean sigma value. The segmented regions are where the local block variation is higher than mean variation. The segmented pixels are connected as blobs by connected neighbouring analysis.

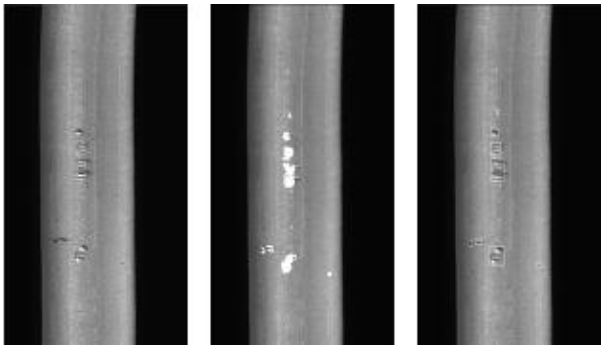

Fig. 3. Examples of DD (Defect Detection) algorithm (Left: original image, Centre: segmented image, Right: connected components of defects)

## 3. EXPERIMENTAL RESULTS

We have installed the surface inspection system at production line. The maximum line speed is 17 meter per second. We use line scan CCD cameras of specification with 512 pixels per line and 70 kHz data rates. And the image data from each camera are captured by frame grabber board and processed by computer processor. The detection algorithms are solely implemented by software without using any hardware-dependent processors.

The images are captured by installed system and processed on the production line. Figure 2 shows wire rod segmentation results by OD algorithm. The White lines are the boundaries of wire rod we have founded by the algorithm. The white spots in the images are water drops in air. Although the spots are supposed to be removed by selecting maximum area object in the OD algorithm, we have showed them only for illustration purpose.

Figure 3 shows a series of processed images applied by DD algorithm. The test image has scab-like defects on the surface of wire rod. The left of Figure 3 is input image and the middle is the segmented image in that white regions are defects found by the detection algorithm, and the right image shows connected components of defects. The results show the critical defects are successfully detected.

## 4. CONCLUSION AND FUTURE WORKS

In this paper, we have introduced the surface inspection system for wire rod product in steel industry. The developed system overcomes the environmental difficulties and opens a new visual way to inspect the surface of wire rod. The project is ongoing. We are in progress to improve detection algorithms, and will add classification algorithm to complete the inspection system.

## REFERENCES

D.F. Dunn and W.E. Higgins Optimal Gabor filters for texture segmentation IEEE Trans. Image Process., vol. 7, pp. 947-964, 1995.

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