Mura Region Detection by Using 2D FFT with Exponential Kernel for Black Resin-Coated Steel

Nam Kyu Kwon, Jong Seok Lee, and PooGyeon Park

***Abstract*—This paper proposes mura region detection algorithm by using two-dimensional fast Fourier transform (2D FFT) with exponential kernel for black resin-coated steel. If the mura exists in the black resin-coated steel image, the image has large low-frequency component. To improve accuracy, multiply exponential kernel to low frequency region. The simulation results show improved performance.**

***Index Terms*—2D FFT, defect detection, black resin-coated steel, mura.**

I. INTRODUCTION

Black resin-coated steel is a colored steel which is coated with ARD paint, one of high polymer series, on electrolytic galvanized iron(E.G.I). Since this steel sheet has good ability to dissipate heat to the outside, this is widely used in the exterior materials of video output device. For this reason, demand and coverage of black resin-coated steel will increase gradually in the steel-making industry. So, it is important to improve quality of the black resin-coated steel. Good equipments and high quality materials are one of the factors to affect the quality of the black resin-coated steel. However, the defects occur when producing the black resin-coated steel even if no matter how good equipments are used. Therefore, defect detection algorithm is necessary for high quality black resin-coated steel.

Currently, defect detection algorithm for the black resin-coated steel is almost non-existent. Instead of the black resin-coated steel, however, many defect detection algorithms for TFT-LCD have been studied [1]-[8]. Wavelet transform [1], [2] and level-set method [3] are representative method. Based on regression diagnostics algorithm [4] and using adaptive thresholding algorithm to detect defect in TFT-LCD are proposed [5], [6]. Minimum error thresholding algorithm is presented by J. Kittler [7]. Also, defect inspection algorithm for steel products which is available in real-time is presented [8]. It is worth applying these algorithms to the black resin-coated steel because the defect which exists in TFT-LCD panel is similar with defect which exists in the black resin-coated steel.

The proposed algorithm consists of three parts: image segmentation, two-dimensional fast Fourier transforms (2D FFT) and multiplying the exponential kernel to low frequency region of segmented image. First, for efficient inspection, image segmentation is necessary with appropriate window size. Second, in order to determine whether there is a defect in segmented image, 2D FFT is used in the algorithm. Finally, multiply the exponential kernel to low frequency region. Through this process, we can expect good effect which is similar with contrast compensation, so accuracy of defect detection algorithm would increase.

This paper is organized as follows. Section 2 introduces system architecture of obtaining the black resin-coated steel image. Section 3 presents explanation of basic theory of the proposed algorithm. Section 4 explains overall algorithm of the proposed algorithm. Section 5 provides the simulation results and shows the performance of the proposed algorithm. Finally, Section 6 presents the conclusion of this paper.

II. SYSTEM ARCHITECTURE

Line scan camera and area scan camera are types of cameras which are widely used in machine vision. Area scan camera transmits image by scanning one frame at a time. So, area scan camera can capture only stationary state objects. Sensor of line scan camera is composed of pixels only horizontally. So, line scan camera can capture moving objects only with constant speed.

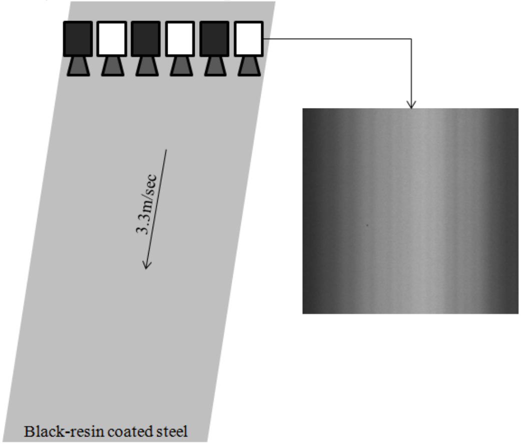

Fig. 1. System architecture

Fig. 1 shows system architecture of obtaining the black resin-coated steel image. The black resin-coated steel

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The authors are with the Division of Department of Electrical and Computer Engineering and IT Convergence Engineering, Pohang University of Science and Technology, Pohang, Gyungbuk, Republic of Korea (e-mail: kwunnam@postech.ac.kr, jongseoklee@postech.ac.kr, ppg@postech.ac.kr).

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production line moves at a constant speed. So, line scan camera is useful for the black resin-coated steel production line. The black resin-coated steel image is obtained by several line scan cameras. Because there could be defect in the acquired image, defect inspection is necessary.

III. BASIC THEORY

A. 2D fast Fourier Transform

Fourier transform is one of spatial transform. By using Fourier transform, frequency response of any signal can be obtained. Since image is two dimensional signals, two-dimensional Fourier transform is necessary. In addition, in order to reduce the simulation time, we use fast Fourier transform. The equation of 2D FFT is following as

$$F(u,v)=\frac{1}{NM}\sum_{x=0}^{N-1}\sum_{y=0}^{M-1} f(x,y)e^{-2\pi i(xu/N+yv/M)} \quad (1)$$

x, y are the coordinates of 2D image signal, $f(x,y)$ is gray-level of coordinates (x , y). u , v are the coordinates in frequency domain. M , N are the horizontal size and vertical size of image, respectively. We can get frequency response of original time domain signal using above equation. Existence of defect in image means existence of low-frequency component. So, if the defect exists in black resin-coated steel image, the image has large low-frequency component. From this information we can determine whether the presence of defects.

B. Exponential Kernel

In this paper, the proposed algorithm does not have contrast compensation part. So, it is difficult to detect the inconspicuous defects (mura) using only 2D FFT. In order to detect these defects, multiply the weight in the low frequency region. The weight which is multiplied in the low frequency region is exponential kernel. By setting higher weight to lower frequencies, it becomes possible to detect the inconspicuous defects without contrast compensation. Results are almost same as algorithm using contrast compensation, but a lot of time can be shortened.

IV. DEFECT DETECTION ALGORITHM

Black resin-coated steel images are obtained from multiple line scan cameras. Size of image is 2048-by-2000.

Fig. 2 shows overall process of the proposed algorithm. First, the image is segmented into 128-by-128 sized image. 2D FFT has a bad performance if the image size is too large or small. For this reason, image segmentation with appropriate size is important. The proposed algorithm uses a 128-by-128 size window that works best experimentally. For efficient inspection, each segmented image is overlapped nearby segmented image at least 12 pixels in the horizontal and vertical direction. If segmented image is not overlapped other segmented image, performance of the proposed algorithm tries to defect inspection for each segmented image. Fig. 3 shows the order of inspection of segmented image.

And then, perform 2D FFT to each segmented image and calculate *comp* that is mean of low frequency region which is multiplied exponential kernel. In order to calculate *comp*, we have to define low frequency region. The low frequency region is defined as 9-by-9 upper left side except first rowand first column and 9-by-9 lower left side except first column. Exponential kernel is defined as follows:

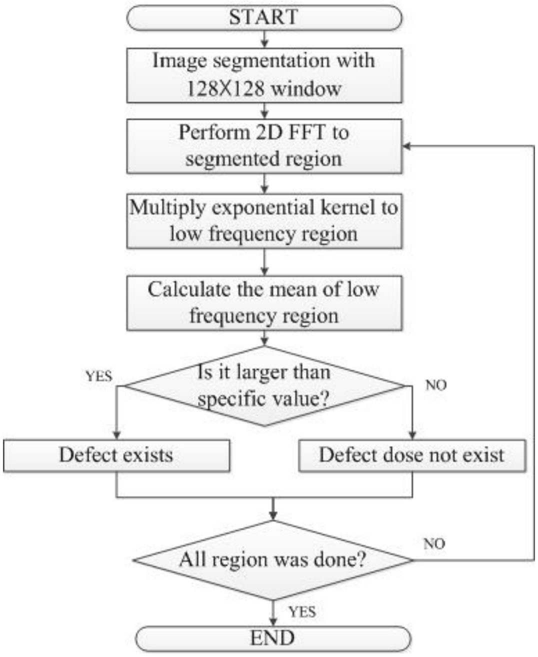

Fig. 2. Overall process

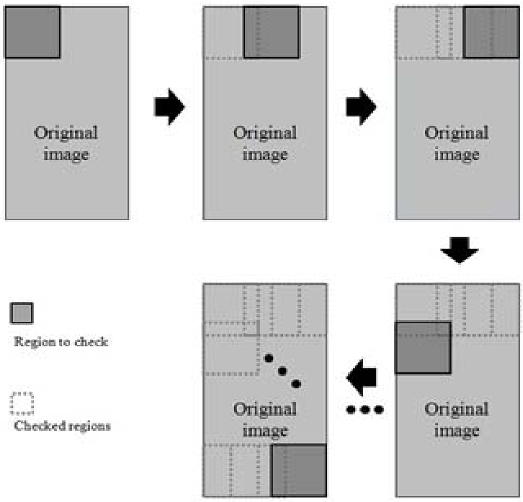

Fig. 3 The order of inspection of segmented image

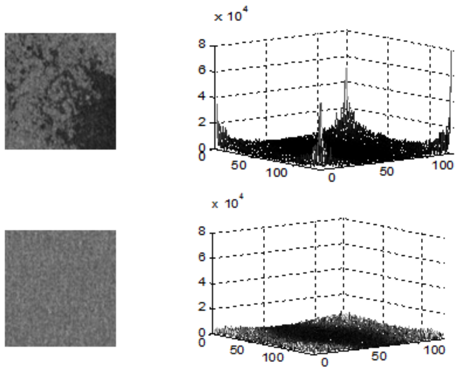

Fig. 4. Frequency domain of defective image comparing with no-defective image

$$C(u,v) = 300 \times e^{-(u+v)}, \qquad for \quad 1 \le u,v \le 9 \qquad (2)$$

If u and v are small, the value $C(u,v)$ is larger. Small u, v means low frequency region. So, the more low frequency value is multiplied by the larger value. Through this process, the more low frequency component is to put a high proportion.

$$F(u,v) = \frac{1}{NM} \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} f(x,y) e^{-2\pi i (xu/N + yv/M)}$$

$$A(u,v) = F(u+1, v+1) \times C(u,v), \qquad for \quad 1 \le u,v \le 9$$

$$B(u,v) = F(u+1, 129-v) \times C(u,v), \quad for \quad 1 \le u,v \le 9$$

$$comp = \frac{1}{162} \sum_{u=1}^{9} \left(\sum_{v=1}^{9} |A(u,v)| + \sum_{v=1}^{9} |F(u,v)| \right) \qquad (3)$$

The value *comp* is obtained from (3). If this value larger than specific value *th*, we determined that the segmented image has defect. In the opposite case, we think that the segmented image does not have defect. Fig. 4 shows low frequency component of segmented image which has defect is larger than that of segmented image which has not defect. The specific value *th* is defined as follow

$$th = \gamma \times m \times W \qquad (4)$$

γ=0.01, m is gray level mean of the segmented image and W is window size 128. The constant value γ is obtained experimentally.

V. SIMULATION RESULT

To evaluate the performance of the proposed algorithm, the defect detection accuracy was measured. 200 black resin-coated steel images were used to verify the performance of the proposed algorithm. Also, to confirm difference according to the presence or absence of the exponential kernel, comparison results are presented.

Simulation results of the proposed algorithm are shown Fig. 5-8. Fig. 5-8 shows difference according to the exponential kernel. (a) is original image, (b) is simulation result which was not applied exponential kernel and (c) is simulation result of the proposed algorithm including exponential kernel. Red square is defect region which is detected by the defect detection algorithm. The defect of Fig. 4 is more conspicuous than that of Fig. 5, 6. Through the simulation results, the conspicuous defect can be detected by the defect detection algorithm which does not include exponential kernel. However, the inconspicuous defect, we say mura, can be detected only by the proposed algorithm including exponential kernel.

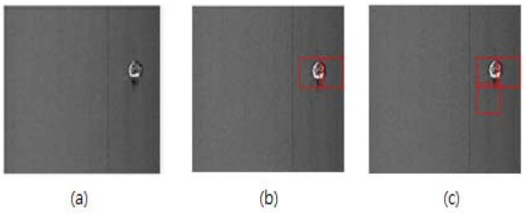
(a) (b) (c)

Fig. 5. Simulation result

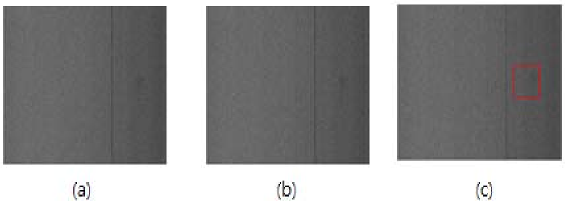
(a) (b) (c)

Fig. 6. Simulation result

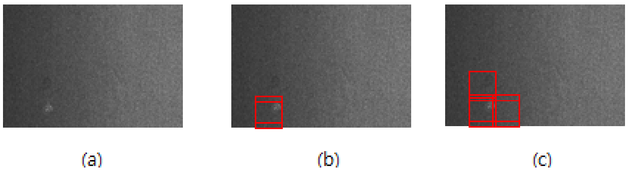
(a) (b) (c)

Fig. 7. Simulation result

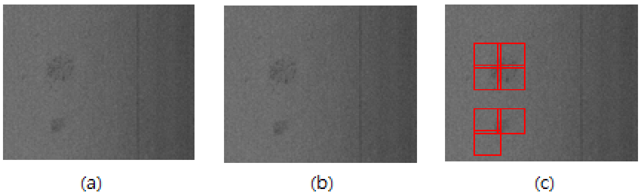
(a) (b) (c)

Fig. 8. Simulation result

Table I and II show difference according to the presence or absence of the exponential kernel by showing accuracy of the algorithm. The accuracy of defective, no-defective of the algorithm using only 2D FFT is 85.1, 78.9 percent, respectively and total accuracy is 84.5 percent. The accuracyof defective, no-defective of the proposed algorithm is 95.6, 89.5 percent, respectively and total accuracy is 95 percent. The proposed algorithm guarantees defect detection rate of high accuracy.

The simulation was performed using a system based on a Intel Core i5-2500K (3.30 GHz) CPU. Operation system is windows 7 and simulation program is Matlab R2009B.

TABLE I: ACCURACY OF THE ALGORITHM USING ONLY 2D FFT

Algorithm	Success	Fail	Accuracy (%)
Defective image	154	27	85.1
No-defective image	15	4	78.9
Total	169	31	84.5

TABLE II: ACCURACY OF THE PROPOSED ALGORITHM

Algorithm	Success	Fail	Accuracy (%)
Defective image	173	8	95.6
No-defective image	17	2	89.5
Total	190	10	95

VI. CONCLUSION

This paper has presented a mura region detection algorithm by using 2D FFT with exponential kernel. The proposed mura region detection algorithm for the black resin-coated steel image consists of three part: image segmentation, 2D FFT and multiplying exponential kernel.

For efficient inspection, image segmentation is necessary. Low frequency information is obtained by 2D FFT. Finally, multiply exponential kernel to low frequency region. Using this information, proposed algorithm finds mura region. The simulation results show that the proposed algorithm satisfies high detection accuracy even if defect is inconspicuous.

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Nam Kyu Kwon received his BS in electrical engineering from Pohang University of Science and Technology (POSTECH) in 2010. He is currently studying toward a PhD at POSTECH. His current research interests include image processing, robust and Linear Parameter Varying(LPV) .

Jong Seok Lee received his BS in electrical engineering from Kyungpook National University in 2010. He is currently studying toward a MS at POSTECH. His current research interests include image processing and control.

PooGyeon Park received his BS and MS in control and instrumentation engineering from Seoul National University, Korea, in 1988 and 1990, respectively, and his PhD in electrical engineering from Stanford University, in 1995. Since 1996, he has been affiliated with the Division of Electrical and Computer Engineering at Pohang University of Science and Technology, where he is currently a professor. His current research interests include robust, Linear Parameter Varying(LPV), Receding Horizon Control (RHC), intelligent, and networkrelated control theories, signal processing and wireless communications for a personal area network