J. Vis. Commun. Image R. 37 (2016) 70–77

Contents lists available at ScienceDirect

J. Vis. Commun. Image R.

journal homepage: www.elsevier.com/locate/jvci

Genetic algorithm and mathematical morphology based binarization method for strip steel defect image with non-uniform illumination

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ARTICLE INFO

Article history:
Received 11 January 2015
Accepted 8 April 2015
Available online 22 April 2015

Keywords:
Strip steel defect image
Mathematical morphology
Genetic algorithm
Image binarization
Non-uniform illumination
EOBMM
Top-hat transformation
Fitness function
Genetic operations

ABSTRACT

In order to precisely extract the image shape feature for the defect detection and classification, the strip steel image needs to firstly be binarized effectively. In this paper, the intelligent information processing, including mathematical morphology and genetic algorithm, is introduced to the strip steel defect image binarization. In order to eliminate the effect of non-uniform illumination and enhance the detailed information of the strip steel defect image, an enhancement operator based on mathematical morphology (EOBMM) is proposed firstly. And then, the binarization method based on genetic algorithm (BMBGA) is applied to the binarization of the strip steel defect image processed by EOBMM. The experiment results show that our method is effective and efficiency in the strip steel defect image binarization and outperforms the traditional image binarization methods, Otsu and Bernsen.

1. Introduction

The surface defect of strip steel will lead to the poor quality of strip steel, so it is very important to detect and classify the defect of the strip steel surface in the quality assurance of strip steel. On the other hand, the performance of the surface defect detector and classifier is also very crucial to not only the quality control in the strip steel product line, but also the real-time production process improvement of the strip steel.

Since the surface material of strip steel is metal, the light reflection and disparities will appear in the image sampling process, which will result in the low contrast and poor quality of the image. For example, a surface image from the strip steel product line, in Fig. 1(a), exists the non-uniform illumination phenomenon, and its corresponding histogram is shown in Fig. 1(b). In Fig. 1(a), we can find that the strip steel defect image holds dark edges, and in Fig. 1(b), its corresponding histogram shows that the dynamic range of the gray value of the image is narrow and the image contrast is low.

The non-uniform illumination and low contrast of the surface image will affect the strip steel defect identification and classification [9]. The image binarization processing can make the image edge contour clearer and improve the quality of the strip steel surface image. On the other hand, the image binarization can also be helpful for edge extraction, image segmentation and object recognition. Therefore, the binarization method for the strip steel defect image is worth further studying.

The image binarization methods [17,1] can be divided into two categories, the global threshold [25]and the local threshold [10]. Because the phenomena of non-uniform illumination and low contrast exist in the strip steel defect image, the image binarization methods using global threshold are not suit for the strip steel defect image. Although the benefit of the image binarization methods using local threshold for poor-quality image caused by non-uniform illumination is obvious, however, the local threshold usually requires to be dynamically determined, which leads to large amount of calculation and time consuming. Therefore, the local threshold method cannot satisfy the real-time requirement in the product line. Moreover, the local threshold method will also cause pseudo-shadow which will lead to the negative impact on image recognition.

To solve the problems mentioned above, a strip steel defect image binarization method is proposed in this paper. Firstly, in

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http://dx.doi.org/10.1016/j.jvcir.2015.04.005
1047-3203/

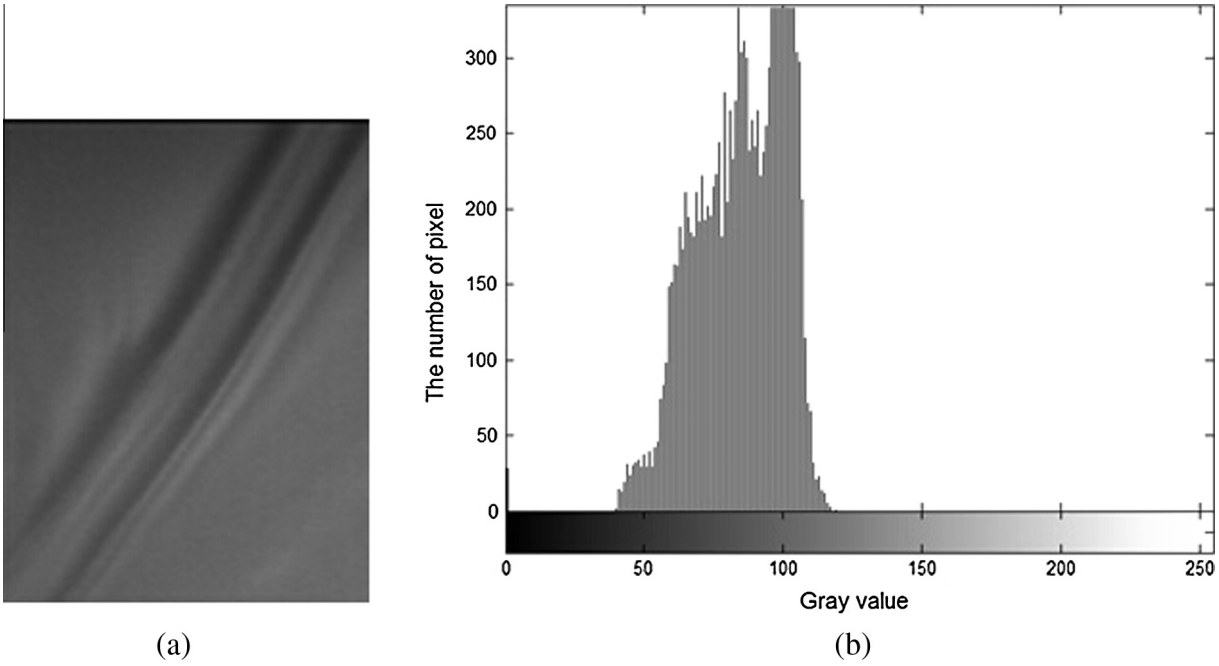

Fig. 1. A surface image and its corresponding histogram.

order to enhance the strip steel defect image and reduce the effect of non-uniform illumination, an enhancement operator based on mathematical morphology (EOBMM) is put forward. And then, the binarization method based on genetic algorithm (BMBGA) is proposed and used to binarize the image after the EOBMM processing.

The remainder of this paper is organized as follows. Section 2 reviews related work. Section 3 discusses the enhancement operator based on mathematical morphology. Section 4 proposes the binarization method based on genetic algorithm. Section 5 then presents experiments and discussions. Finally, Section 6 concludes the paper.

2. Related work

In this section, we will briefly discuss the related work on image binarization, including the strip steel defect image binarization. The image binarization has recently been paid more attentions. Yoshida and Tanaka [24] proposed a binarization method, in which fractal dimension was used to evaluate the fitness of binarized image locally and globally to decide the threshold value, for crack detection in road surface image. Su et al. [21] put forward a novel document image binarization technique by using adaptive image contrast which is a combination of the local image contrast and the local image gradient. An active contour based binarization method for document image was presented by Hadjadj et al. [6]. Zhang et al. [31,32] presented a weakly-supervised image segmentation algorithm that learns the distribution of spatially structural superpixel sets from image-level labels. In addition, Liu et al. [13] put forward an adaptively iterative method of document image binarization which began by defining a filter window length with initialized stroke width, and then transformed the document image into a feature space with Gaussian kerneled Bhattacharyya distance and set up a threshold with Ostu's method to temporarily binarize the image, and it used the stroke width extracted from the newly obtained image to update the filter window length until the iteration convergent. The binarization for strip steel defect image has also been paid more attentions. Yishu and Dewei [22] provided a novel segmentation model based on convex active for strip steel defects image. Yongmin et al. [23] presented a method in which excess entropy and fuzzy set theory were used to segment steel strip surface defectation.

Mathematical morphology [5,2] describes the essential shape morphological characteristics of the image through a series of operators using a certain form structural elements. Zana and Klein [26] presented an image segmentation algorithm based on mathematical morphology and curvature evaluation for the detection of vessel-like patterns. Koli et al. [12] put forward automatic blood vessel segmentation in retinal image based on mathematical morphology. The basic operators of mathematical morphology include erosion, dilation, opening and closing. In this paper, a kind of typical mathematical morphology operation, Top-hat transformation [3], is designed and used to enhance the strip steel defect image and reduce the effect of non-uniform illumination.

Machine learning [27,28] intends to make computer simulate and evolve human behaviors based on different types of empirical data. The machine learning methods can be divided into several types according to their mechanism, including supervised, unsupervised, semi-supervised, weakly supervised [29,30] and so on. The machine learning methods can be used to not only the image classification problem [27–30] but also the image binarization problem, mainly determining the threshold value. Heess et al. [8] introduced weakly supervised to image segmentation and proposed an extension of the Restricted Boltzmann Machine (RBM) allowing the joint shape and appearance of foreground objects in cluttered images to be modeled independently of the background. A new weakly supervised image segmentation model, focusing on learning the semantic associations between superpixel sets, was proposed by Zhang et al. [31,32]. In fact, the genetic algorithm [7], another kind of typical machine learning method, has recently been applied in image processing. Paulinas and Usinskas [15] gave a survey of genetic algorithms applications for image enhancement and segmentation and this survey drove the conclusion that the constant improvement of genetic algorithm would definitely help to solve various complex image processing tasks in the future. A determining optimal filters for binarization of degraded characters in color using genetic algorithms was proposed by Kohmura and