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A novel method for surface defect inspection of optic cable with short-wave infrared illuminance

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HIGHLIGHTS

- Novel method for surface defect inspection of optic cable.
- Implemented in the short-wave infrared illuminance.
- Effective on edge processing.
- Fast calculation speed of processing.
- Threshold window for the interaction framework.

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ABSTRACT

Intelligent on-line detection of cable quality is a crucial issue in optic cable factory, and defects on the surface of optic cable can dramatically depress cable grade. Manual inspection in optic cable quality cannot catch up with the development of optic cable industry due to its low detection efficiency and huge human cost. Therefore, real-time is highly demanded by industry in order to replace the subjective and repetitive process of manual inspection. For this reason, automatic cable defect inspection has been a trend. In this paper, a novel method for surface defect inspection of optic cable with short-wave infrared illuminance is presented. The special condition of short-wave infrared cannot only provide illumination compensation for the weak illumination environment, but also can avoid the problem of exposure when using visible light illuminance, which affects the accuracy of inspection algorithm. A series of image processing algorithms are set up to analyze cable image for the verification of real-time and veracity of the detection method. Unlike some existing detection algorithms which concentrate on the characteristics of defects with an active search way, the proposed method removes the non-defective areas of the image passively at the same time of image processing, which reduces a large amount of computation. OTSU algorithm is used to convert the gray image to the binary image. Furthermore, a threshold window is designed to eliminate the fake defects, and the threshold represents the considered minimum size of defects ε. Besides, a new regional suppression method is proposed to deal with the edge burrs of the cable, which shows the superior performance compared with that of Open-Close operation of mathematical morphological in the boundary processing. Experimental results of 10,000 samples show that the rates of miss detection and false detection are 2.35% and 0.78% respectively when ε equals to 0.5 mm, and the average processing period of one frame image is 2.39 ms. All the improvements have been verified in the paper to show the ability of our inspection method for optic cable.

1. Introduction

Along with the construction of broadband network, especially the vigorously deploy of the fourth and the upcoming fifth generation of networks, the market of optical fiber and cable industry has entered a period of vigorous development. During the manufacture process, surface defection of optic cable is a common technical difficulty caused by materials or improper workmanship. These defects not only affect the physical strength of the cables which may lead to the damage of internal fiber, but also make some optical properties changing, such as dispersion loss of fiber. Thus, the defects must be found out before the products are reached to the user. Traditional surface detection methods

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which used the spark detector are applicable to conventional metal sheathed cable. For the whole dielectric and alien surface structure cables (such as air-blowing micro-cables or fiber optic cables for access network), it can only be checked by means of manual rewind or human observation to detect the position of stripping or bulge defects. However, manual inspection in industrial manufacturing has low detection efficiency and costs a lot of manpower and resources. Therefore, it is of great practical significance to design a low cost, reliable, real-time and high veracity of automation method for defects inspection of optic cable. And the machine vision technology provides a viable solution to the issue.

Machine vision refers to the industrial application of vision technology. It describes the understanding and interpretation of technically obtained images for controlling production processes [1,2]. Currently, machine vision is widely used in industrial manufacturing, especially in quality detection, such as web [3,4], bottle [5], metallic strips [6], fabrication [7], and glass manufacture [8,9]. Ref. [10] designed two matched Gabor filters based on power spectrum of the textures of fabric, which was suitable for a regular texture images. Ref. [11] proposed an inspection algorithm based on contour comparison to satisfy the real-time and high accuracy defect inspection of printed circuit board (PCB) bare board, which was fit for standard shape defects in the target detection. However, for the optic cables making industry with high-automation, how to inspect the defective cables timely and effectively is a challenging work. And few researches of the image detection algorithms for the cables had been reported.

In this paper, we propose a new method for surface defects inspection of optic cable with short-wave infrared illuminance which is based on image processing. To detect cable's surface defects, we first need to choose appropriate illuminance to enhance the features of images. To the best of our knowledge, it has been rarely reported that defects detection system uses short-wave infrared illuminance. Compared with previously reported inspection methods based on visible light illuminance [16], our form of illuminance has the following advantages: first, it can provide illumination compensation under the weak illumination environment in order to ensure the correct detection. Second, it is a relatively stable form of illuminance. Therefore, it won't exist the case of exposure that appeared in visible light illuminance, which affects the veracity of inspection algorithm. Besides the accuracy of detection method, real-time performance is also highly desirable for industrial application. However, some existing algorithms generally focus on the defects with an active searching method, such as wavelet based techniques, the neural net algorithm, and statistical approach [1,12–17], which are time-consuming. For example, Ref. [9] classified two types of the blister based on information of area, boundary, length, etc., which were extracted from the binary images. Ref. [14] proposed the wavelet packet decomposition algorithm to solve the similar problem. In literature [18], Lin presented an automatic visual inspection of ripple defects using wavelet characteristic based multivariate statistical approach. He applied multivariate statistics of Hotelling T^2, Mahalanobis distance D^2, and Chi-square X^2, respectively, to integrate the multiple texture features and the three wavelet-based multivariate statistical models. This method was based on feature extraction from wavelet-domain images for defect detection. In contrast, our method is carried out in a passive detection way. We don't appreciate that what the defects are and the characteristics of them. We eliminate the non-defective areas while in image processing, and leave the considered defects finally. In addition to improve the processing speed of the algorithm, we also aim to eliminate fake defects such as edge burr on the edge of the cables, as shown in Fig. 1, where the edge burrs were mis-detected as defects marked by red-lines, and the true defects were circled by yellow[1]-lines.

The rest of the paper is organized as follows. In Section 2, preliminary principle of the newly raised inspection algorithm are introduced. Those include the analysis of performance requirements, and the detailed process of algorithm. In Section 3, experimental results on a large number of sample images are reported. Section 4 gives a conclusion, followed by future works.

2. Principle and process of inspection algorithm

2.1. The analysis of performance requirements of detection algorithm

Usually, a good optic cable has a stable reflection property. If defects appear, light path and light power will be changed due to the change of cable's optical character around defects. These changes lead to the variation of gray levels of image incepted by industrial cameras. During the manufacturing process, the conveyor speed of cable is generally 1–2.5 m/s. To ensure that all surface defects of the fiber photographed, the frame rate of cameras is set to 100 images per second. Our system uses four cameras which are simultaneously placed in the four directions of the fiber optic cables, then 400 images should be processed timely within one second. And the processing time of each frame should be controlled within 2.5 ms.

Consequently, detection algorithm should not only ensure the accuracy of the detection but also meet the requirements of real-time performance of the system. Considering from the image features and real-time processing, the image processing flow is illustrated in Fig. 2, which is composed of two parts of image segmentation and defect recognition. In this section, we will descript these two processes procedures step by step to illustrate the effect of our method.

2.2. Image segmentation

In this paper, we simulate the actual scene of industrial detection with short-wave infrared illuminance. Before extracting image features, we perform binary preprocessing with an appropriate threshold [11] to distinguish the foreground and background domain of image. We choose the OTSU algorithm [19] to convert the gray image to the binary image as the method of threshold segmentation [20–22] due to its good adaptability.

The OTSU algorithm uses the gray histogram of image to dynamically determine the optimal threshold segmentation through the maximum variance between the foregrounds and backgrounds, therefore a corresponding binary image could be obtained. The maximum variance means the minimum probability of misclassification. Suppose that L is the grayscale of image, then its pixels can be divided into two categories, C_0 and C_1, the probability of which can be described by the following equations respectively.

$$w_0 = P_r(C_0) = \sum_{i=0}^{t} p(i) \tag{1}$$

$$w_1 = P_r(C_1) = \sum_{i=t+1}^{L-1} p(i) \tag{2}$$

where $p(i)$ $(i = 0, 1, 2, \ldots, L-1)$ is the probability of pixels with ith grayscale. w_0 denotes the proportion of pixels that belong to foreground domain, while w_1 is that of background.

[1] For interpretation of color in Figs. 1 and 8, the reader is referred to the web version of this article.