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The improved defects detection method of optical fiber winding

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ABSTRACT

The paper discusses mainly how to check the defects such as fiber-stacking fiber-cut and fiber-uneven with an improved method in the process of fiber optic gyroscope coil winding. In the paper, it is aimed at the gray level image of optic fiber coil winding to get binary image using mathematical morphology and to get optic fiber position image using the improved moving target detection algorithm, on the base of the optic fiber position image, to figure out the relative position of adjacent optic fiber. Through the value of the relative position of adjacent optic fiber, the status of optic fiber winding can be estimated. Experimental results show that the entire image processing and defect detection method can effectively distinguish the defects in the process of optical fiber coil winding.

1. Instruction

Among the many factors contributing to FOG performance, the quality of the sensing coil is one of the most important [1]. Fiber placement is known to be important factor in winding a hign performance. The Sagnac effect relies on the fact that the shift in the phase of the light beams is due solely to the rotation of the coil. Fiber sensing coil must undergo a rigorous process of winding, that is, these fibers on the same layer or on the different layers should closely packed around, not to appear fiber-stacking (in Fig. 3), fiber-cut (in Fig. 4) and fiber-uneven (in Fig. 2), winding optic fiber like that can reduce the optical loss and depolarization caused by the environmental change [2]. One of the greatest challenges is to be able to wind an entire coil with few or no errors. Therefore, the winding process of the fiber sensing coil needs to be real-time detection, in order to trace and exclude the various defects that may occur in the process of optic fiber winding.

Machine vision technology is applied to monitor the process of optic fiber winding in the paper. The images collected by machine vision are analyzed and processed by some algorithms to determine the status of the fiber winding. The machine vision technology is the use of optical devices for non-contact perception, automatic acquisition and interpretation of the image of a real scene, to get the information and control the machine [3]. The pretreated images are processed by using target detection algorithm to identify the detected target in the process of fiber winding. The position and status of the detected optical fiber is always changing, so the moving target detection method is applied to processing and detection of fiber winding images.

In the applications environment of defect detection in fiber winding, image processing and target detection should be fast, accurate and robust. This paper applies mathematical morphology directly on the gray level image of the collected images by machine vision, which can greatly reduce image preprocessing time. On the base of traditional moving target detection algorithm, an improved algorithm is proposed, which is suitable for detecting the defect of fiber winding. After the images are processed by the above process, the images show the position of every fiber. On the base of the processed images, the fiber pixel location in difference images can be calculated by combining the pixel size of the chosen CCD industrial cameras with related position of fiber in qualified fiber coil to determine whether there are defects such as fiber-stacking, fiber-cut and fiber-uneven in the process of fiber winding. The clarity of the fiber winding images shows that the methods used in the paper are effective and correct.

2. The application and the basic idea of mathematical morphology

Mathematical morphology is one kind of new method used in the field of image processing and pattern recognition [4]. The basic idea of using mathematical morphology for performing image processing is that there is a certain specific shape of the structural elements such as rectangle, circle, or diamond of a certain size detection target image, by checking the validity of the structural elements of caving and fill method in the target area of the image to obtain information about the image morphology, and thus achieve the purpose of analysis and recognition image.

The morphology operation is a collection of object shape and the interaction between the structural elements, which is not sensitive

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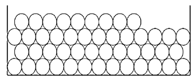

Fig. 1. Regular status.

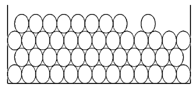

Fig. 2. Fiber-uneven.

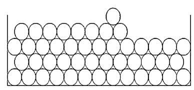

Fig. 3. Fiber-stacking.

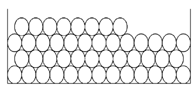

Fig. 4. Fiber-cut.

to the edge direction, but which can detect the true edge of the image and the noise of the image can be largely suppressed [5]. So, the morphology operation has unique advantages in the description of the characteristics of the object in the image. Therefore, the mathematical morphology for edge detection can effectively filter out the noise and retain the original details in the image with better edge detection effect.

This paper applies opening and closing operation of mathematical morphological to extract the outer contour of optical fiber winding image. The closing operation generally will narrow the gap linking and fill the hole smaller than the structural elements. The opening operation can remove the object area that cannot contain the structure elements and can remove the small protruding portions. The method is characterized by the following formula, where formula (1) is opening operation expression and formula (2) is closing operation expression.

$$A \circ B = (A \Theta B) \oplus B \quad (1)$$

$$A \bullet B = (A \oplus B) \Theta B \quad (2)$$

The experimental results show that the application of mathematical morphology for processing Fig. 8, that is gray level image of original image of optic fiber winding to get binary image of optical fiber winding, that is Fig. 9. As can be seen from Fig. 9, the image fully meets the needs of the subsequent analysis.

3. Improved moving target detection algorithm for optical fiber winding

3.1. Traditional moving target detection algorithms

Moving target detection algorithms are diverse. Every algorithm is different in its specific application environment. In a static context, traditional moving target detection algorithms are mainly optical flow field method, inter-frame difference method and background difference method. These moving target detection algorithms depend on the range of applications, each with its own advantages and disadvantages.

Optical flow field method is represented by a two-dimensional image of the velocity field in the three-dimensional motion of the object point, which uses the optical flow characteristics, that is moving target changing over time to create the optical flow constraint equation for target detection, the calculation method of optical flow field is proposed in reference [6], but due to the complexity of the calculation formula, under the conditions without special hardware support, it is difficult to achieve real-time requirements, so its poor application and poor real-time are not suitable in defect detection of fiber winding.

There is a small amount of calculation in the inter-frame difference method, easy to implement, which use two or three adjacent frames of video sequence to get time difference threshold to extract the target. So it has strong adaptability in dynamic environment [7]. However, this method cannot completely extract the relevant characteristic pixel point, and the feature of depending on the selection time interval also becomes the drawback of this method. The method is characterized by the following formula:

$$D_k(x, y) = |I_{k+1}(x, y) - I_k(x, y)| \quad (3)$$

where $D_k(x, y)$, $I_{k+1}(x, y)$, and $I_k(x, y)$ are respectively difference image, the $k+1$ original image, and the k original image.

The defect detection of fiber winding needs to detect the exact location of each optical fiber, so the inter-frame difference method is not suitable for the application environment.

Like inter-frame difference method, the background difference method also extracts the target region using different image. But its difference to the inter-frame difference method is that the background difference method is not the difference image of the current frame image with the adjacent frame image, but is the difference image of the current frame image with a continuously updated background image [8]. The method is characterized by the following formula:

$$D_x(x, y) = |I_{k+1}(x, y) - B_k(x, y)| \quad (4)$$

where $D_x(x, y)$, $I_k(x, y)$, and $B_k(x, y)$ are respectively the difference image, the current frame image, and the background image.

In the defect detection of fiber winding, each frame image is different and the difference image of the adjacent frame image is not the detected target. So using background difference method for defect detection of fiber winding will cause larger detection error, it is not suitable to the detection environment of fiber winding defect.

In view of the above analysis, the traditional target detection algorithms exist their shortcomings in the defect detection of optical fiber winding. The improved algorithm was forwarded for the particularity of the detected targets in the paper.

3.2. Improved moving target detection algorithm based on inter-frame difference method

For fiber winding process, the interval of adjacent frames is very short; there is a strong correlation and continuity on adjacent frame image. Using the inter-frame difference method alone to detect target will be missed target. Due to the limits of fiber winding speed, there are more than two images on the interval of two fibers appearing on the same end respectively. For background difference method alone there are similar problems to inter-frame difference method, and the background difference method needs to constantly update the background image that causes the heavy workload. Therefore, in fiber winding, in order to obtain fast detection speed, according to the speed of optical fiber winding and the FPS of chosen CCD industrial cameras, the images of the input images collected by machine vision are sampled to meet accurately detected defect of fiber winding.

Based on the basic principle of the inter-frame difference method, the images formed in the process of fiber winding will be re-combinated to form a new sequence of images, which are suitable for the application of defect detection and moving object detection method. There are lots of video images in the process of fiber winding, but in the judgment of the winding defect, need to select an image with a new and entire fiber on the end, as Fig. 5.