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Image processing method for multicore fiber geometric parameters

Chuanbiao Zhang, Tigang Ning, Jing Li *, Chao Li, Shaoshuo Ma

Institute of Lightwave Technology, Beijing Jiaotong University, Beijing 100044, China
Key Lab of All Optical Network & Advanced Telecommunication Network of EMC, Beijing Jiaotong University, Beijing 100044, China

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ABSTRACT

An image processing method has been developed to obtain multicore fiber geometric parameters. According to the characteristics of multicore fiber, we using MATLAB to processing the sectional view of the multicore fiber (MCF), and the algorithm mainly concludes the following steps: filter out image noise, edge detection, use an appropriate threshold for boundary extraction and an improved curve-fitting algorithm for reconstruction the cross section, then we get the relative geometric parameters of the MCF in pixels. We also compares different edge detection operator and analyzes each detection results, which can provide a meaningful reference for edge detection.

1. Introduction

In recent years, the development of traditional single-core optical fiber has into a bottleneck period [1,2], and because of its potentially huge transmission capacity, multicore optical fiber have attracted more and more attention [3–5]. With the deepening research of the multicore fiber, it has been widely used in many fields, like the light sensor, light detection, optical fiber transmission system, etc [6–8].

In the fiber transmission network with multicore fiber, the connection between the fiber bundle will directly impact on the performance of the whole system, how to connect optical fiber with the control of connection loss is very important [9]. Therefore, as a connection reference of the optical fiber, it is necessary for us to understand the geometric parameters of the multicore optical fiber cross-section. Traditionally, there have some method to get geometry parameters of fiber cross section, including near-field image method, refractive near-field method, side-looking method [10,11]. But these measuring methods are complex, and expensiveness of instrument. Application of image processing technology to processing the collected optical fiber end-face images and get the parameters of the optical fiber is the current development trend.

In this paper, we use 36-core optical fiber as the research object. According to the characteristics of multicore fiber end-face, which obtained by high resolution CCD camera, we put forward that use image processing method to process the sectional view of the multicore fiber. Through the noise processing, boundary detection, bit-manipulation, we used geometric fitting to reconstruction the geometric parameters of the fiber cross section, and a curve-fitting algorithm are improved to adapt to the characteristics of multicore optical fiber end-face. Then through image recognition, we can recognition the shape and test the size of the optical fiber end-face under the premise of retain original features of the physical information. In addition, we also compared and analyzed different edge detection operator.

2. Principle analysis

The end-section image of MCF were processed using image processing software (MATLAB). According to processing sequence, the method can be divided into four parts: image preprocessing unit, image segmentation unit, image edge detection unit, fitting and calculate unit. Principle block diagram is shown in Fig. 1.

Known by the principle block diagram, first we preprocessing the RGB image which recorded by a CCD camera. Although CCD camera can get high quality, high resolution image, however, due to the influence of the external environment image may have many noise, if make the direct detection and analysis on the acquired images, will unable to get accurate result, so prior to the detection and analysis, need to preprocessing the image, aims to improve image quality.

Here, we pretreat the RGB image obtained by the camera into the gray image. Gray image means divided black to white into 256-order according to the logarithmic relationship, and correspond each pixel of the original RGB image to a gray scale. Due to

* Corresponding author at: Institute of Lightwave Technology, Beijing Jiaotong University, Beijing 100044, China.
E-mail addresses: cbzhang@bjtu.edu.cn (C. Zhang), Lijing@bjtu.edu.cn (J. Li).

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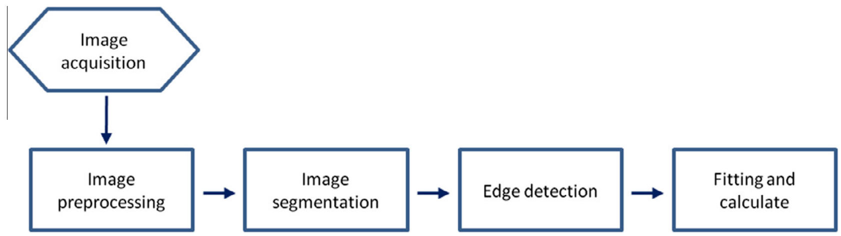

Fig. 1. Principle block diagram.

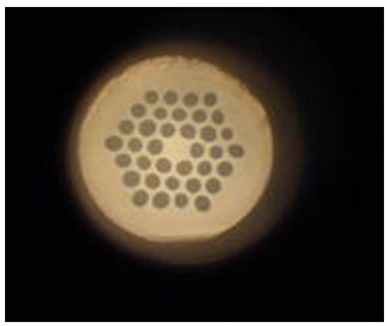

Fig. 2. RGB image of MCF collected by camera.

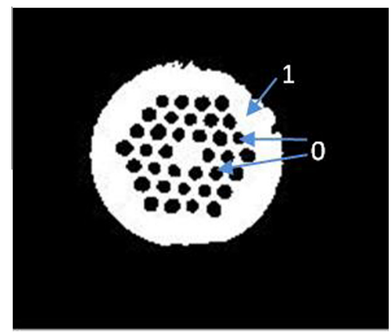

Fig. 5. Binary image.

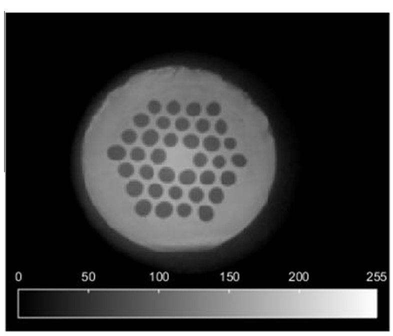

Fig. 3. Gray image.

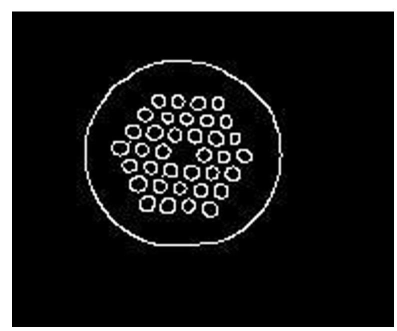

Fig. 6. Detect edges from the fiber end-face with Canny operator.

its protection of edge information, we use Median Filter to filt Gaussian white noise. RGB image and gray image after preprocessing as shown in Figs. 2 and 3, respectively.

After image preprocessing, then second step is segmentation the image, mainly include binarization processing. Image segmentation is to separate the target image from the background. Defined the gray image as $f(x,y)$, the gray scale ranged is $[0, L-1]$, then choose a suitable threshold 'T', and the image segmentation can be described by the following formula,

$$g(x,y) = \begin{cases} 1 \; f(x,y) \geqslant T \\ 0 \; f(x,y) < T \end{cases} \tag{1}$$

where g(x,y) is a binary image. In the process of segmentation, the key is the selection of threshold 'T'. Here we defined n_k as the pixels of gray scale for k, so the total pixels 'N' can be described by,

$$N = \sum_{i=0}^{L-1} n_i = n_0 + n_1 + \ldots + n_{L-1} \tag{2}$$

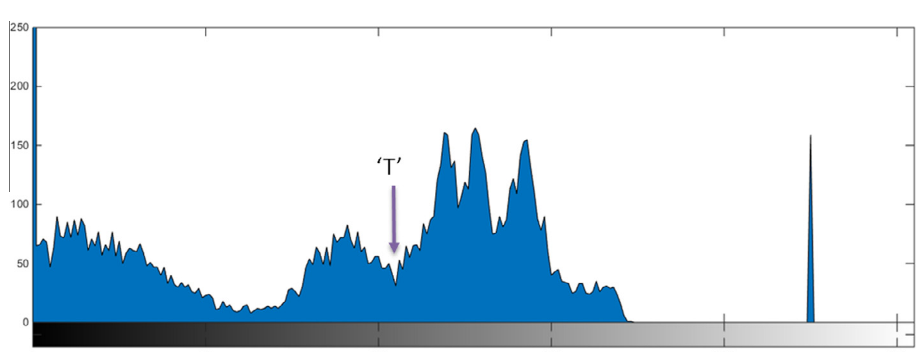

Fig. 4. Gradation histogram.

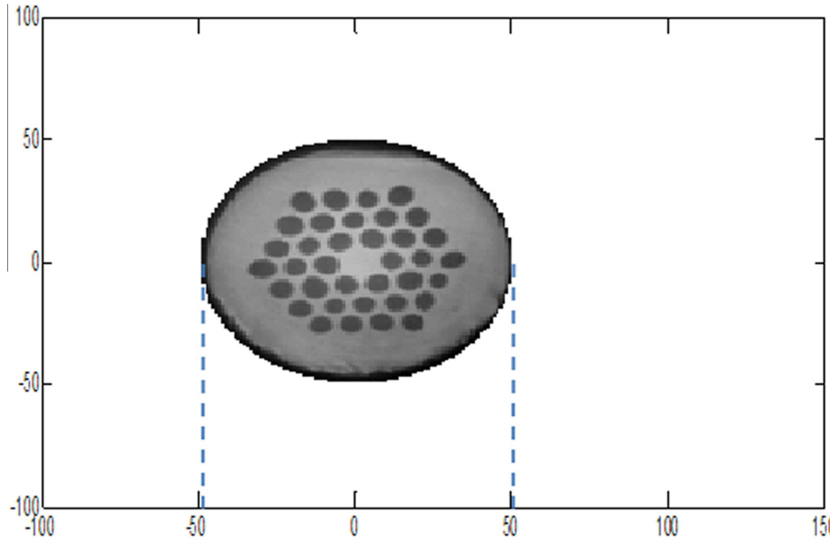

Fig. 7. Separate an outline of the cladding with a larger radius <50 (pixels).

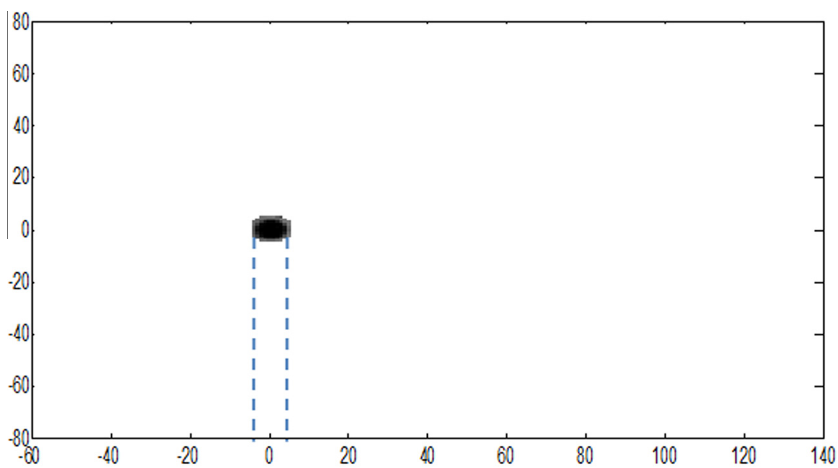

Fig. 8. Separate an outline of the core with a smaller radius <6 (pixels).

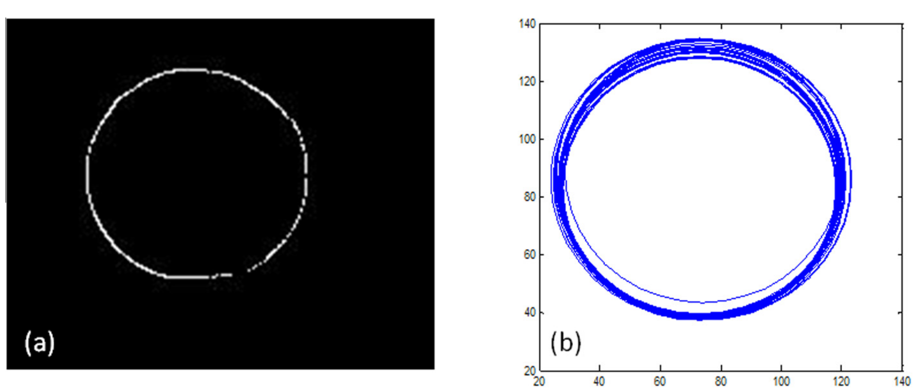

Fig. 9. (a) Fitting the outline of cladding, (b) drawing the fitting circle graph.

As we can see in the gradation histogram (GH), shown in Fig. 4, two peaks in the GH, because of the simple of image elements, we choose the minimum value between two peaks as the threshold '*T*', and obtained binary image shown in Fig. 5.

During the processing method, the important part is edge detection unit, which directly affect the fitting and calculation. In order to get smooth and clear edges information, we here use Canny operator for detection. In the detection algorithm, threshold selection is also very important, if the threshold is too small, it will detect some of the edge formed by the uneven brightness of image. If the threshold is too large, it can only detect high contrast edge, lost part of the actual target edge. After the edge detection, as shown in Fig. 6.

Table 1
The fitting circle's center and radius for cladding, default unit is pixels.

Center (pixels)	Radius (pixels)
(73,83)	4.53×10^1
(73,83)	4.55×10^1
(73,83)	4.56×10^1
(73,83)	4.58×10^1
(73,85)	4.71×10^1
(74,85)	4.71×10^1
(74,85)	4.73×10^1
(74,87)	4.73×10^1
(73,87)	4.73×10^1
(74,86)	4.77×10^1
(74,87)	4.78×10^1
(73,86)	4.79×10^1

Table 2
The fitting circle's center and radius for core, default unit is pixels.

Center (pixels)	Radius (pixels)
(54,67)	3.2
(47,74)	3.2
(91,95)	3.2
(56,92)	3.3
(55,88)	3.3
(48,94)	3.3
(70,54)	3.4
(57,107)	3.4
(70,56)	3.5
(99,79)	3.5
(65,92)	3.5
(82,101)	3.5

Finally, we analysis and recognition the extraction image. For multicore fiber, round is the mainly recognition geometry, using the curve fitting equation, calculate the geometric parameters of and fiber core. After preprocessing and feature extraction, then using Canny edge detection method, we obtained contour grayscale of the 36-core fiber's end-face. However, the edges of the image is fuzzy, the graphical outline is not a smooth round, so we adopt Hough circle fitting method which has a better anti-interference.

In the fitting process of the round-image, we separate the core and cladding by Shear-Function. Separate outline of the cladding with a larger radius, shown in Fig. 7, and we got the radius of cladding <50 (the unit is pixels). Separate an outline of the core with a smaller radius, shown in Fig. 8, the radius of core <6 (the unit is pixels).

Based on the parameters of core and cladding as we estimated before, then we targeted to detect their geometric parameters respectively. We fitting and calculate the cladding firstly use Hough-circle fitting function, as shown in Fig. 9(a). In the process of fitting, we join the drawing function at the same time, so that we can restores the graphics with a proper accuracy, the results of the real-time drawing shown in Fig. 9(b) and return parameters shown in Table 1. By the way, we have to say that an optimal parameter was using in this fitting process, so the testing result becomes more reliable and rational. To ease the discussion of the results, we here use the Pixels as data unit, and we can transform into standard unit according to the proportion of camera.

By similar process, we got a fitting image of the fiber core and a real-time drawing, as shown in Fig. 10(a) and (b). In this process, the result of core's real-time drawing is more sensitive to the algorithm parameter, because each core is very close. Then we get the results of the core, shown in Table 2. As the table shows, the calculation of the parameters is not unique value, this because of the influence of the non uniformity geometric parameters of fiber core and other factors, there is a certain error. It is worth noting that the data in the table is only part of the fitting data, and we select some of the relative parameters in the table to indicate the algorithm, then we calculate the average value of all data, obtained 47.2 (pixels) for cladding, 3.2 (pixels) for core.

3. Discussion

The essence of edge detection is use some kind of algorithm to extract the boundary line of the target and the background. The change of image grayscale can reflect by the gray gradient distribution, so we can use partial differential technology to gain an edge detection operator. Classical edge detection method is to construct edge detection operator in a small area of the original image pixel. Here, in the process of image edge detection, we also have four additional edge detection algorithm, we compared and analyzed this five different edge detection operator, and the contrast effect shown in Fig. 11.

Compare this five different edge detection operator, we can see that canny operator has a better edge detection effect, with complete and smooth marginal information. Next is prewitt operator and sobel operator, the edge is relatively continuous, means that they also have certain smooth function to noise, but more rough than canny operator, their accuracy is not high enough. Then roberts operator and log operator, roberts operator has the advantage that processing speed is fast, but the edge it detected is very coarse, and the precision is low, could not locate the details, not applicable, log operator is also not ideal. By the analysis of the edge detection operator, we chose canny operator to process the image and got a better effect.

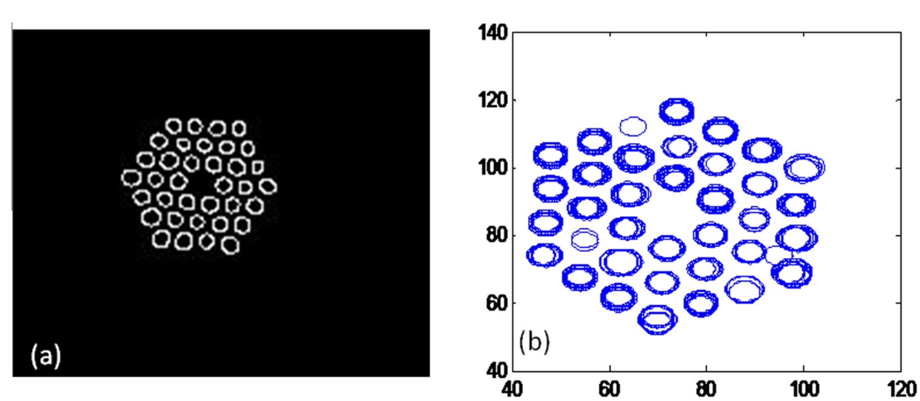

Fig. 10. (a) Fitting the outline of core, (b) drawing the fitting circle graph.

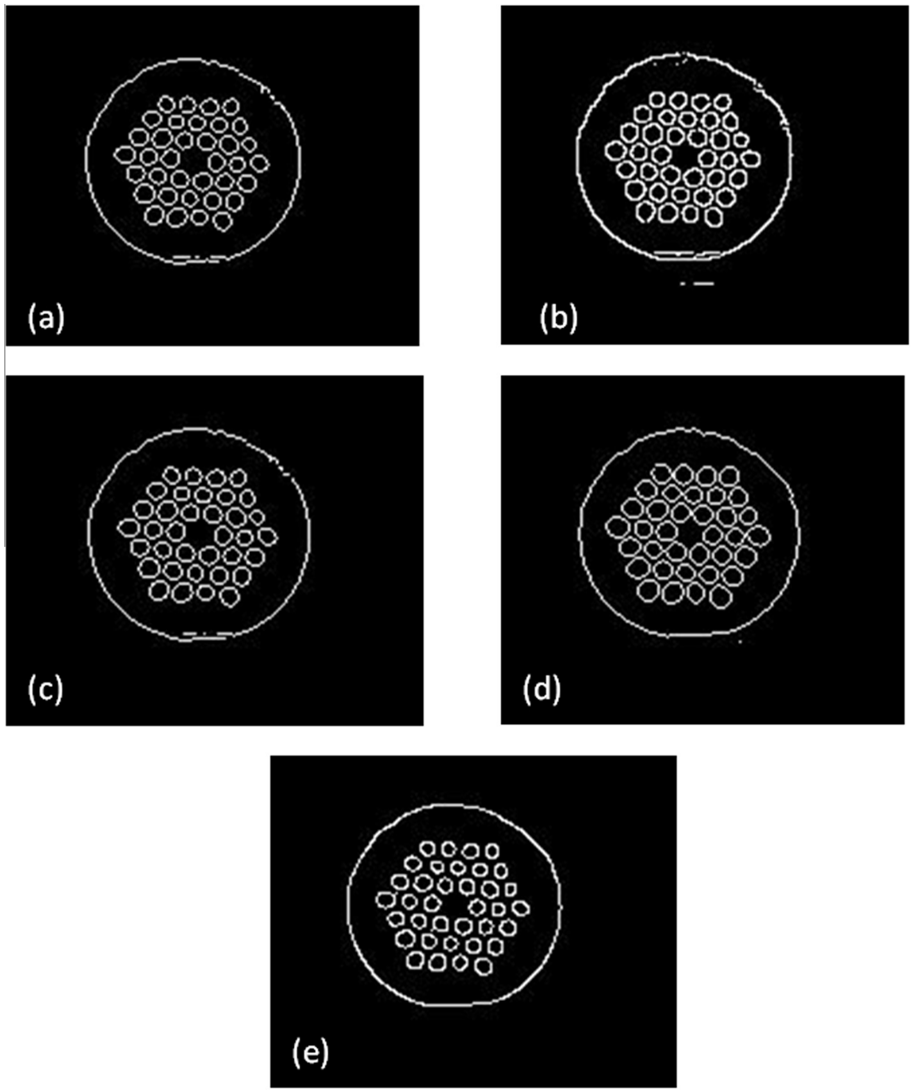

Fig. 11. Detection results by different edge detection operator (a) Sobel operator, (b) Roberts operator (c) Prewitt operator (d) Log operator (e) Canny operator.

4. Conclusion

We present that use MATLAB to process the sectional view of the MCF, through the image preprocessing, image segmentation and optimized image feature extraction algorithm, we got the image of the fitting parameters. Then calculated by the proportion, geometric parameters of the multicore optical fiber can be obtained. Due to the influence of the non uniformity geometric parameters of fiber core, the result of fitting calculation has some errors, which needs further improvement. We also compared the treatment effects of five different edge detection operator, proved that canny operator is the optimization of edge detection operator. Digital image processing method can not only used to measure the geometric parameters of multicore fiber, also expected to be used for measuring more important parameters of multicore optical fiber, such as refractive index distribution, and provides an economic and convenient method to the research of modern optical fiber communication system.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.yofte.2016.04.005.

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