Algorithm Analysis on Extracting the Information of Central Fringe of Low-Coherence Interference Image of CMOS Camera

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Abstract Complementary metal-oxide-semiconductor (CMOS) transistor cameras instead of conventional photoelectric detectors are used to obtain planar information and can improve the tolerance of electromagnetic interference and measurement precision. Three algorithms are proposed to extract central finges. With a proper design of low-coherence Young's fiber interferometer, these algorithms are tested experimentally. The result shows that covered area comparison algorithm is most efficient and the central fringe is marked accurately. In addition, it is suitable to real-time information display systems.

Key words image processing; CMOS cameras; low coherence; central fringe

OCIS codes 100.3008; 100.3175; 110.2350; 110.2650

基于 CMOS 相机的低相干图像中心条纹提取的算法分析

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摘要　利用 CMOS 相机而非常规光电探测器来获取平面信息能够提高抗电磁干扰能力以及测量精度。提出 3 种算法来提取中心条纹，并通过设计低相干杨氏干涉仪对 3 种算法进行了实验比较。结果显示面积比较法最有效，能够准确标记中心条纹。此外，它还适用于实时信息显示系统。

关键词　图像处理；CMOS 相机；低相干；中心条纹

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1 Introduction

Complementary metal oxide semiconductor (CMOS) image sensors are now the device of choice for most imaging applications because of their multiple functionalities and easy serial fabrication[1]. CMOS cameras approach can be used to find the position and orientation of objects in the image plane[2]. So it is common to use CMOS cameras instead of conventional photoelectric detectors to record images, which can obtain planar information and improve the tolerance of electromagnetic interference and measurement precision.

In this case, image luminance instead of light intensity is to be measured, which can make it easier, faster and effective in extracting and more processing interference central fringe. At the same time, however, it enhances the demand of image processing algorithm, so that three algorithms are used to gain the information of central fringe of low-coherence interference in this article.

Low-coherence interferometer[3,4] is a type of interferometer based on low-coherent light sources. The character of the light intensity distribution is that there is a fixed position where the optical path difference (OPD) is

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zero[5]. The central fringe is exactly located at this fixed position with highest light intensity. Furthermore, the extraction of low-coherence central fringe influences the precision of physical quantities to be measured greatly[6].

2 Experimental system

Low-coherence Young′s fiber interferometer is one of the efficient methods to measure fiber optic delay. The advantage of the structure of Young′s interferometer is that the passing light is partial coherence and can reflect the coherence of the source. Algorithms are proposed to extract the central fringe. And then, by calculating the difference between zero-order light fringes, the delay time in fiber can be ottained.

The system is built to analyze fiber optic delay, as shown in Fig.1. Light sources pass different paths (two single-mode optical fibers coupling with the output ports of a 3 dB directional fiber coupler). Road 1 is the fiber delay line under test and Road 2 is a variable delay line to provide a measuring basis. And then the coherent fringes are obtained and processed in personal computer (PC).

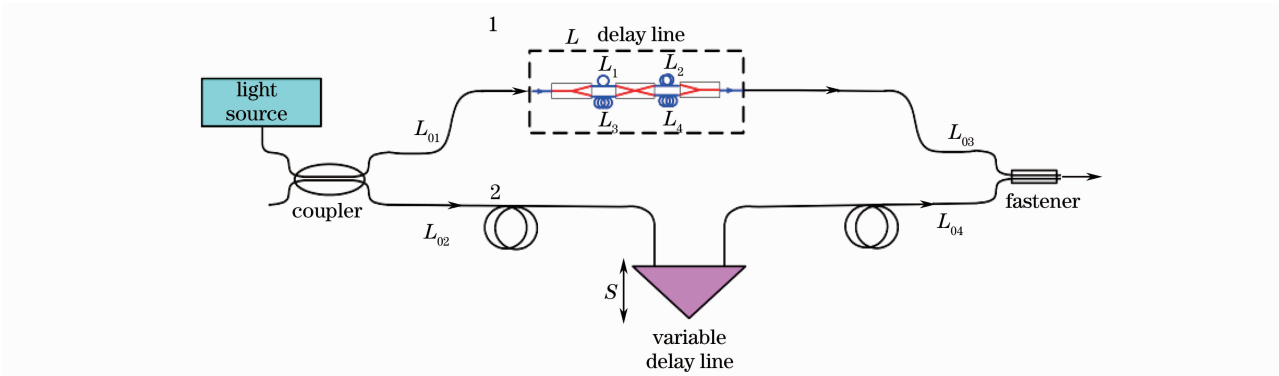

Fig.1 Experimental system

The fringes curve because the out of fibers cannot be perpendicular to the screen rigorously[7], but the central fringes don′t change and the location of central points can be ottained to measure fiber delay.

3 Algorithms analysis in low-coherence fringes

The information of central fringe here is referring to the coordinates of central point of certain central fringe. Luminance extremum, point number comparison and covered area comparison algorithms are used to gain the information and to make experiments[8]. The results are compared to get the most suitable algorithm.

In actual Young′s interferometer, shapes of some fringes are changed because of different observed positions. Because of the different placing of two fiber ends each time, both straight lines and curves can be observed. But from images it can be known that the nearer to the central is, the less offset is, when it is compared with the straight condition on each fringe. Central coordinates of the central fringe are required to eliminate errors caused by this reason.

3.1 Luminance extremum algorithm

The central fringe is of the largest light intensity in low-coherence interference image. So that luminance extremum algorithm is designed to get the coordinate of highest brightness point of each line by getting the brightness data of the binary image line by line[8]. The process of information extraction is shown as the flow chart in Fig.2.

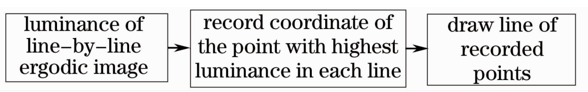

Fig.2 Flow chart of luminance extremum algorithm

3.2 Point number comparison algorithm

Point number comparison algorithm is baseed on the opinion that the point number of the contour of central fringe is maximal. So that point numbers of each contour are calculated and compared. The fringe with maximal point number is the central fringe[8]. The process of information extraction is shown in Fig.3.

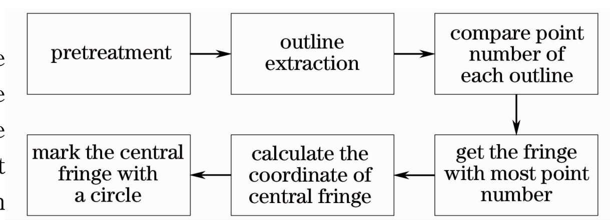

Fig.3 Flow chart of point number comparison algorithm

3.3 Covered area comparison algorithm

Covered area comparison algorithm is based on the idea that central fringe covers maximal area. The areas of different fringes are compared with an approximation outlining method. The central fringe is with the max area[8]. Coordinates of all points of the central fringe area covered are averaged, and then the mean value is defined as the coordinate of central fringe. The process of information extraction is shown in Fig.4.

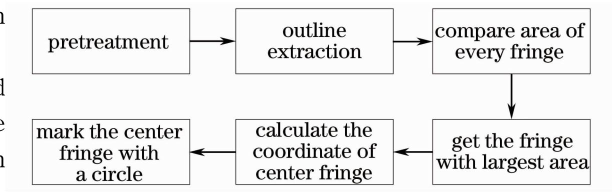

Fig.4 Flow chart of covered area comparison algorithm

3.4 Central-point location

According to the information of central fringe, a circle is marked at central point $P(x_{\mathrm{r}}, y_{\mathrm{r}})$. The coordinates of central fringe are given by

$$\begin{cases} x_{\mathrm{r}} = \dfrac{x_1 + x_2 + \cdots + x_{N-1} + x_N}{N} \\ y_{\mathrm{r}} = \dfrac{y_1 + y_2 + \cdots + y_{N-1} + y_N}{N} \end{cases},$$

x_i, y_i ($i = 1, 2, \cdots, N$) are coordinates of points which are obtained by each of these three algorithms; N is the total number of points.

4 Experiments and results

With the proper design of low-coherence Young′s fiber interferometer, these algorithms are tested experimentally. The result shows that covered area comparison algorithm is most efficient and the central fringe is marked accurately. With this algorithm, the information of low-coherence interference images central fringes in CMOS cameras is obtained quickly and accurately.

The original image binarization is made for further processing, as shown in Fig.5.

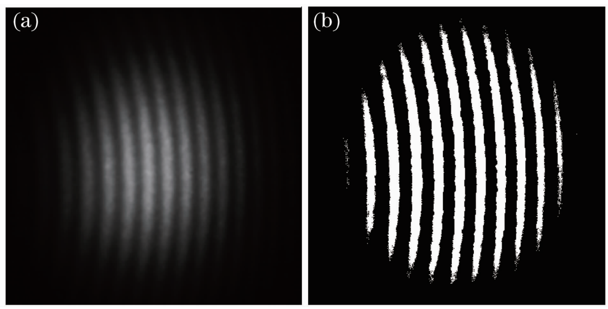

Fig.5 Original image (a) and processed image (b)

The image processed with luminance extremum algorithm is shown in Fig.6. All the maximal intensity point is not the position of central fringe in each line and therefore this algorithm cannot obtain the central fringe availably.

Point number comparison algorithm is used to process image and the result is shown in Fig. 7. A contour extraction is done first. It is obvious that marks are not located at the central of central fringes, which means this algorithm is not effective to extract central fringe.

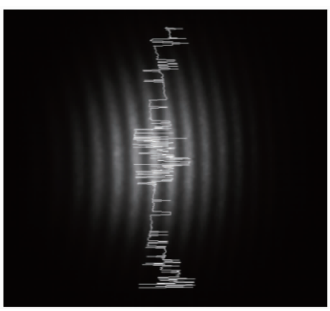

Fig.6 Image processed with luminance extremum algorithm

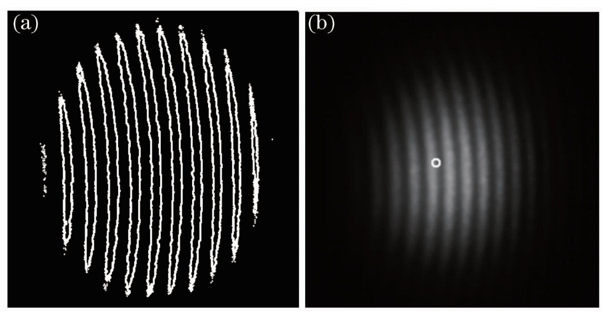

Fig.7 Image with contour extraction (a) andimage processed with point number comparison algorithm (b)

Four low-coherence interference images are dealt with covered area comparison algorithm. From the result shown in Fig.8, it can be known that central points of central fringes are obtained accurately in all images. This algorithm, hence, is suitable to extract low-coherence interference images.

5 Conclusion

With a proper design of a low-coherence fiber interferometer, these algorithms are used experimentally. The result shows that covered area comparison algorithm is most efficient and the central fringe is marked accurately. In

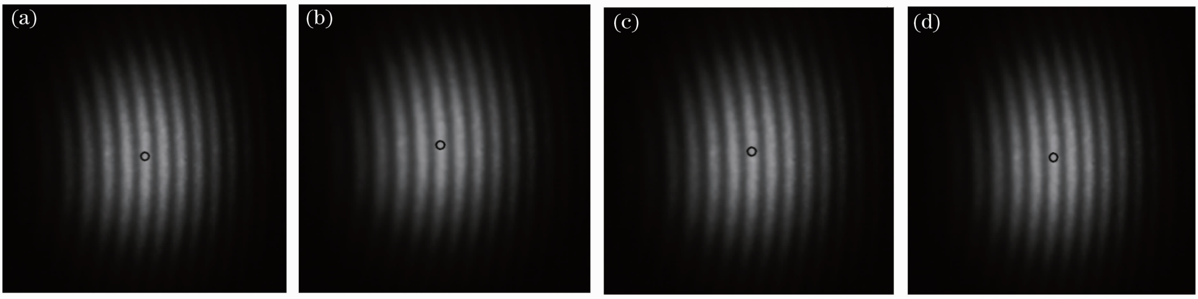

Fig.8 Images processed with covered area comparison algorithm

summary, CMOS cameras can record images fast and comprehensively, while covered area comparison algorithm is proved efficient and exact to gain the information of the central fringe. With this algorithm, the information of low-coherence interference images central fringes of in CMOS cameras is obtained quickly and accurately. In addition, it is suitable to real-time information display systems.

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