

Laser Spot Center Detection and Comparison Test

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Abstract: High efficiency and precision of the spot center detection are the foundations of avionics instrument navigation and optics measurement basis for many applications. It has noticeable impact on overall system performance. Among them, laser spot detection is very important in the optical measurement technology. In order to improve the low accuracy of the spot center position, the algorithm is improved on the basis of the circle fitting. The pretreatment is used by circle fitting, and the improved adaptive denoising filter for TV repair technology can effectively improve the accuracy of the spot center position. At the same time, the pretreatment and de-noising can effectively reduce the influence of Gaussian white noise, which enhances the anti-jamming capability.

Keywords: Spot; TV repair technology; spot center

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1. Introduction

The laser spot images still have various challenges. Although the center can be seen with naked eyes, it has not high accuracy. By physical means, the middle point of the spot can be accurately found, but it needs more time and requires a high degree of precision for the physical equipment. Relatively, faster positioning algorithm using software has higher speed and accuracy for finding the spot center position. High efficiency and precision of the spot center detection, which are the foundations of avionics instrument navigation and optics measurement basis for many applications, have a noticeable impact on the overall system performance. Reference [1] presented an algorithm of laser spot detection based on circle fitting with a

high precision, which has a high degree of accuracy. Reference [2] compared circle fitting and traditional algorithm of laser spot position, and the algorithm of circle fitting has advantages of high precision and efficiency. Reference [3] proposed a new algorithm of the image filters, and its performance was proved to be also very good. Reference [4] presented an algorithm of adaptive median filtering, which could automatically find and remove cycle disturbances. Yet, the laser spot has noise and other interference in real optical measurement, resulting in uneven distribution of spot signal strength. In general, the above algorithm does not meet requirements of accuracy or speed, and its anti-jamming ability is poor [5–9]. Therefore, the improved algorithm is based on the original circle fitting. Before circle fitting, the algorithm has pretreatment to solve

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various interferences, and then an improved TV filtering algorithm can have better filtering for Gaussian white noise and finally pinpoint the spot center.

2. Theoretical analysis

Fitting is based on least squares (smallest residual sum of squares) guidelines for mathematical methods [10–12]. By fitting the target coordinates or grayscale, you can get the form of continuous functions, so that you can determine the values that describe each parameter object [13–15]. When the target is characterized by round or ellipse, we extract a set of points of the target circle fitting, whose method is the laser beam profile.

The equation of a circle is as follows:

$$(x-a)^2 + (y-b)^2 = r^2. \quad (1)$$

At this point, take the residuals as follows:

$$\varepsilon_i = (x_i - a)^2 + (y_i - b)^2 - r. \quad (2)$$

Above, a and b represent a collection of all the boundaries, and x_i represents a sharp point coordinates.

Residual sum of squares function is calculated as

$$a = \frac{(\overline{x^2x} + \overline{xy^2} - \overline{x^3} - \overline{xy^2})(\overline{y^2} - \overline{y^2}) - (\overline{x^2y} + \overline{yy^2} - \overline{x^2y} - \overline{y^3})(\overline{xy} - \overline{xy})}{2(\overline{x^2} - \overline{x^2})(\overline{y^2} - \overline{y^2}) - 2(\overline{xy} - \overline{xy})} \quad (11)$$

$$b = \frac{(\overline{x^2y} + \overline{yy^2} - \overline{x^2y} - \overline{y^3})(\overline{x^2} - \overline{x^2}) - (\overline{x^2x} + \overline{xy^2} - \overline{x^3} - \overline{xy^2})(\overline{xy} - \overline{xy})}{2(\overline{x^2} - \overline{x^2})(\overline{y^2} - \overline{y^2}) - 2(\overline{xy} - \overline{xy})^2} \quad (12)$$

$$r = \sqrt{a^2 - 2\overline{xa} + b^2 - 2\overline{yb} + \overline{x^2} + \overline{y^2}}. \quad (13)$$

As can be seen by the above formulae, the algorithm is derived by the least squares circle fitting. Our algorithm can calculate each parameter, but its calculation speed is quick because it only calculates the central parameter.

3. Test programme

3.1 Process

The flow chart of the improved algorithm is shown in Fig. 2.

follows:

$$Q = \sum_{i \in E} \varepsilon_i^2 = \sum_{i \in E} [(x_i - a)^2 + (y_i - b)^2 - r^2]^2. \quad (3)$$

By the least squares method, we can get the following equation:

$$\frac{\partial Q}{\partial a} = \frac{\partial Q}{\partial b} = \frac{\partial Q}{\partial r} = 0 \quad (4)$$

which is simplified by

$$a^2 - 2\overline{xa} + b^2 - 2\overline{yb} - r^2 + \overline{x^2} + \overline{y^2} = 0 \quad (5)$$

$$\overline{xa^2} - 2\overline{x^2a} + \overline{xb^2} - 2\overline{xyb} - \overline{xr^2} + \overline{x^3} + \overline{xy^2} = 0 \quad (6)$$

$$\overline{ya^2} - 2\overline{xya} + \overline{yb^2} - 2\overline{y^2b} - \overline{yr^2} + \overline{x^2y} + \overline{y^3} = 0. \quad (7)$$

Parameters satisfy the following formula:

$$\overline{x^m y^n} = \sum_{i \in E} x_i^m y_i^n / \sum_{i \in E} 1. \quad (8)$$

Then, we can get

$$(\overline{x^2} - \overline{x^2})a + (\overline{xy} - \overline{xy})b = \frac{1}{2}(\overline{x^2x} + \overline{xy^2} - \overline{x^3} - \overline{xy^2}) \quad (9)$$

$$(\overline{xy} - \overline{xy})a + (\overline{y^2} - \overline{y^2})b = \frac{1}{2}(\overline{x^2y} + \overline{yy^2} - \overline{x^2y} - \overline{y^3}). \quad (10)$$

Lastly, we can combine the expression parameters with the formula parameters:

3.2 Improved algorithms and performance analysis

White noise is a constant power spectral density of random signals or stochastic process. In other words, the signal powers are the same in all frequency bands, as white light is made up of frequency (color) of light mixed together. This flat nature of the power spectrum of the signal is said to be “white”, and thus this signal is called white noise. When being obtained from Gaussian distribution of the random sample values, samples consisting of random process is the “white Gaussian noise”.

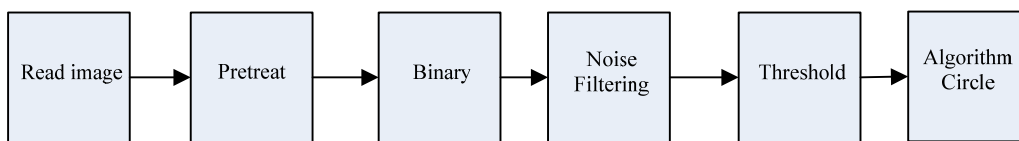


Fig. 2 Processes of improvement algorithm.

Firstly, we deal with the noise around image. Then, the improved TV filtering method is used to remove spots of Gaussian white noise. We test Gaussian

white noise filtering and median (median filtering, MF) in order to verify the effectiveness of adaptive TV. The results of comparison are shown in Fig. 3.

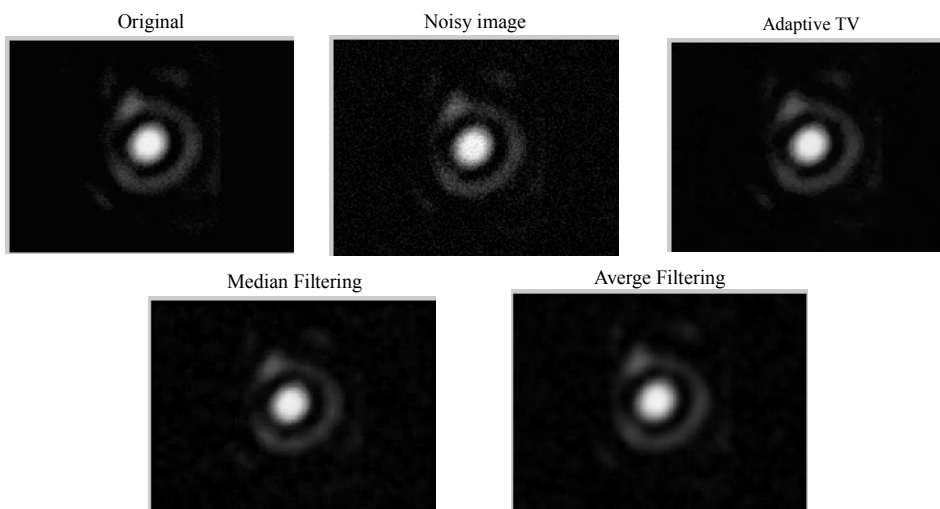


Fig. 3 Results of our algorithm.

3.3 Results and analysis

As we can see from Fig. 4, our method can better protect spot edge and traditional round edge in the

process of detecting image. Also, we discover that the algorithm tends to lose some real information, which is not good for research of spot.

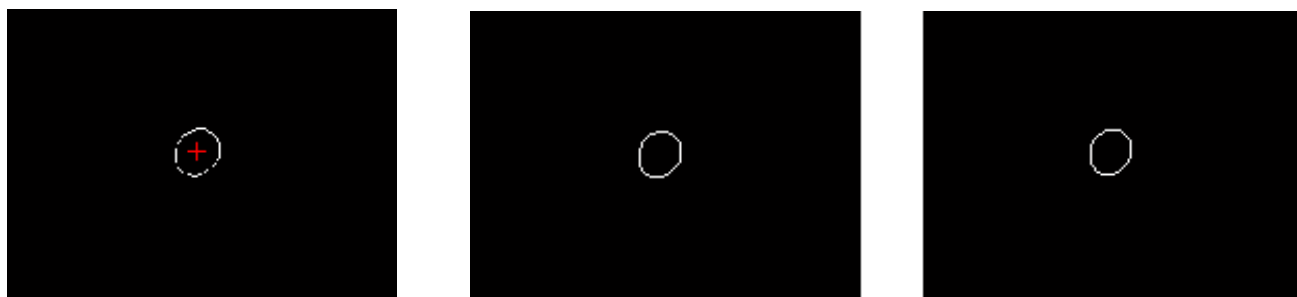


Fig. 4 Process of detecting image.

4. Conclusions

Based on the experimental results, we can conclude that the improved algorithm of laser spot center detection on circle fitting is better than the original method. The performance of the improved algorithm for noise immunity is better with the

high accuracy. Therefore, studying on the algorithm of follow-up research on the spot is important.

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