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Influence Analysis of Laser Spot Noise on the Measurement Accuracy of Laser Triangulation Method

Cao Miao[1], Wang Xiao[*1] andYao Qinghua[2]

[1]Changchun University of Science and Technology, Jilin Changchun, 130022, China
[2]Changchun University of Technology, Jilin Changchun, 130012, China
79816540@qq.com

Abstract

Laser triangulation method, widely used in modern industry, is able to meet the requirements of fast, real-time and on-line detection within non-contact measurement method. Laser triangulation method is affected by many factors, and the laser spot noise is the main factor to affect application field of the laser triangulation method directly. Based on the laser triangulation principle, this paper deeply analyzes the effect of laser spot noise on the measurement accuracy of laser triangulation method, such as signal flicker noise, background noise, dark current noise, thermal noise, amplifier noise and so on, and puts forward a new method to use the filtering algorithm to overcome the laser spot noise for improving the accuracy of laser triangulation.

Keywords*: laser measurement laser spot noise triangulation method*

1. Introduction

Laser triangulation method is widely used in the field of geometric measurement for its characteristic of non-contact, not easily damage surface, wide adaptability, simple structure, high measuring distance, anti-interference, small measurement point, high accuracy, real-time on-line measurement. The most modern science and technology are used to enrich and improve the way, and the structure is strived to further simplify, to improve accuracy, to broaden the scope of application to meet the needs of industrial production.

When the laser triangulation method is used to the measurement, the laser beam generated by the laser triangulation system is diffused by the detected target. When the laser beam from laser triangulation system is transmitted to the rough surface of the object, the shape of the reflected laser spot is relatively easier to produce distortion. If the laser spot distortion occurs, it will produce a large error in the subsequent laser triangulation, which directly affects the measurement accuracy of the measurement system.

2. The Measure Principle of Laser Triangulation Method

Laser is used as the emission light source in the process of laser triangulation method. the surface of the measured object is illuminated after the alignment and focusing of the optical system, so it will form a spot on the surface of the measured object. The laser beam reflected from the surface of the object is measured by the optical system in the light receiving plane of the CCD image sensor. The displacement of the object can be obtained with the change of the image point position of the CCD. When the object distance is changed, the image point position of the CCD is also changed correspondingly.

[*] Corresponding Author

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The incident and reflection of the laser constitute an optical triangle, so this method is named as optical triangulation method.

Optical triangulation, as one of the non-contact measurement methods, can be used to measure the distance of objects and the 3D shape of objects. Due to the laser collimation feature (faster speed, smaller measurement point and higher accuracy), this measurement method can be used for remote measurement. According to the different angle of incident light, optical triangulation method is divided into direct optical triangulation method and oblique optical triangulation method.

2.1. Direct Optical Triangulation Method

As shown in Figure 1, the laser beam passes through the alignment and focusing lens, and images in the surface of the detected object M, forms a laser spot. The reflected light passes an imaging lens L and is imaged on image sensor CCD of the receiving terminal. According to scheimpflug principle, locus of all image points fall on the receiving end of N, namely imaged on the CCD. When the measured object surface M moves downward certain distance D, the distance that imaging point moves synchronously is labeled as x. The mathematical relationship of its imaging can be obtained:

$$\frac{D\sin\theta}{S + D\cos\theta} = \frac{X\sin\varphi}{S' - X\cos\varphi} = tg\alpha$$

It can be deduced:

$$X = \frac{S'D\sin\theta}{D\sin(\theta+\varphi) + S\sin\varphi} = \frac{C_1 D}{C_2 + D} \tag{1}$$

$$D = \frac{SX\sin\varphi}{S'\sin\theta - X\sin(\theta+\varphi)} = \frac{C_2 X}{C_1 - X} \tag{2}$$

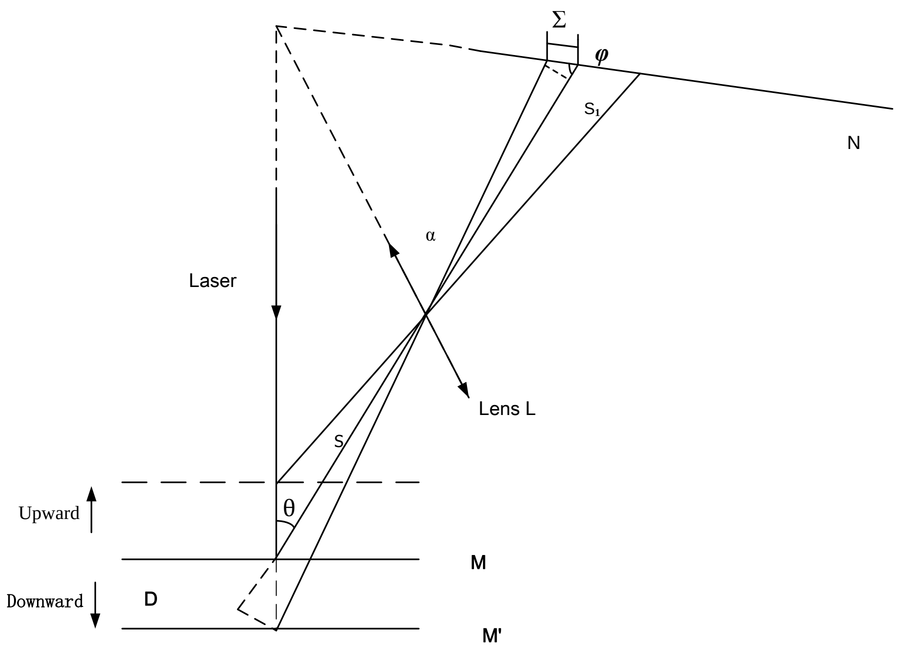

Figure 1. The Schematic Diagram of Direct Triangulation Method

Similarly, when the M surface of the measured object equivalently move the same distance D, it can be obtained:

$$X = \frac{S'D\sin\theta}{S\sin\varphi - D\sin(\theta+\varphi)} = \frac{C_1 D}{C_2 - D} \tag{3}$$

$$D = \frac{SD\sin\varphi}{S'\sin\theta + X\sin(\theta+\varphi)} = \frac{C_2 X}{C_1 + X} \tag{4}$$

In the formula, $C_1 = \frac{S'\sin\theta}{\sin(\theta+\varphi)}$; $C_2 = \frac{S\sin\theta}{\sin(\theta+\varphi)}$; D is the equivalent displacement of the object surface, X is the received light displacement of the image points on the image sensor CCD, θ is angle of incidence, φ is the angle between the receiving plane and the laser emitted beam.

From the formula (2) and (4) ,the displacement relationship between the measured object and the light spot image can be seen. When the displacement D is very small, it can be obtained:

$$D << S, |D\sin(\theta+\varphi)| << |S\sin\theta|$$

Similarly, according to the formula (1) and (3), can be obtained:

$$X = \frac{S'\sin\theta}{S\sin\varphi} D$$

It obtained from calculation:

$$D = \frac{S\sin\varphi}{S'\sin\theta} X = \frac{1}{m}\frac{\sin\varphi}{\sin\theta} X$$

Among them, m is the magnification of the lens L.

$$m = S'/S$$

2.2. Oblique Optical Triangulation Method

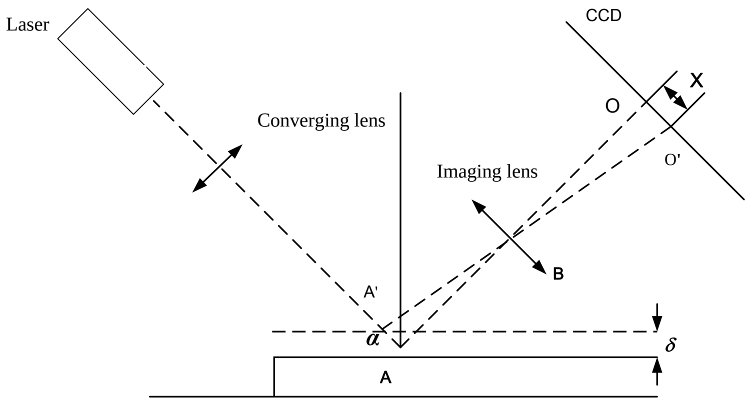

Figure 2. The Schematic Diagram of Oblique Triangulation Method

As shown in Figure 2, it is different from the direct optical trangulation method, the incident angle of laser emitted beam is α , the laser passes through a collimation focusing lens and incident to the point A of the object to be measured. The reflection light from the object surface can form image point on the CCD. It corresponds to A and is same as the direct mode. As the movement change quantity of object is δ , the incident light irradiates point A'. Corresponding image points on the photosensitive plane is labeled as O' , and the distance between O and O' is labeled as X. According to the mathematical relationship:

$$\frac{X}{OB} = \frac{AA'}{AB} = \frac{\delta / \cos\alpha}{AB} \quad (5)$$

$$\delta = X \frac{AB}{OB} \cos\alpha \quad (6)$$

From the above two formula, the position offset x in the light receiving plane and the change quantity of object distance is proportional relationship. If the initial height of an object is assumed as D_0 ,the amount of change can be expressed as:

$$D = D_0 + \delta = D_0 + X \frac{AB}{OB} \cos\alpha \quad (7)$$

In the above formula, α is the incident angle of incident laser; AB is the object distance of datum point; OB is the image distance of datum point; D is the height of measured object, D_0 is the initial height of measured object; X is the displacement of image points in the light receiving plane; δ is the height variation in measurement.

3. Analysis of the Influence of Laser Spot Noise on the Measurement Accuracy of Laser Triangulation Method

In the process of processing the return beam from the target, that is laser echo signal. In addition to carrying the reflected light from the information of the test piece, it also accompanied by a number of signal interference. Therefore, it is necessary to process the received optical signal, extract the target signal, and filter out the noise signal . There are many kinds of noise signals, such as background noise, dark current noise, thermal noise, signal noise and so on.

1) Signal Flicker Noise

Signal flicker noise is white noise, it is for the purposes of the detector, which is a kind of noise that is generated by the detector itself. Its output signal is:

$$i_{ns} = \sqrt{2ei_s^2 B_n G_d} \quad (8)$$

In the formula, e is the electron charge; i_s is the signal current; B_n is the system bandwidth; G_d is the detector power gain. The signal current can be obtained by formula (9).

$$i_s = \frac{P_r \cdot \eta \cdot e}{h \cdot \nu} \quad (9)$$

In the formula, ν is the optical frequency; h is Planck constant; P_r is the received power of detected photo surface; η is quantum efficiency of the detector.

2) Background Noise

When outside all the signal light, including natural light is received by the detector, will produce the corresponding noise, namely background noise.

$$i_{nb} = \sqrt{2ei_b B_n G_d} \tag{10}$$

In the formula, i_b is the background current, and it can be calculated by the following:

$$i_b = \frac{\eta \cdot e}{h \cdot \nu}\left(b \cdot \omega \cdot \Delta\lambda \cdot A_e\right) \tag{11}$$

In the formula, ω is the receiving angle of field of view; A_e is the equivalent aperture area of receiving optical system; b is background radiant flux; $\Delta\lambda$ is the optical bandwidth.

3) Dark Current Noise

When there is no background radiation and no receiving signal, it also produces noise. The noise is caused by the current itself, and thus is called the dark current noise. The calculation formula is as follow:

$$i_{nD} = \sqrt{2ei_D B_n G_d} \tag{12}$$

4) Thermal Noise

Thermal noise usually refers to the noise generated by the electronic components. The produced reasons are load resistance, electron thermal motion and so on. PIN photodiode is used in this paper. The thermal noise is mainly generated by the former, specific formula is as follows:

In the formula, R_1 is the resistance of detector load resistance; k is PohlSeidman constant; T is the temperature of detector load resistance.

$$i_{nr} = \sqrt{\frac{4k \cdot T \cdot B_n}{R_1}} \tag{13}$$

5) Amplifier Noise

Due to the presence of a large number of electronic components in the amplifier, these electronic components will generate noise at the output of the detector or the input of the current. These noises are collectively referred to as the amplifier noise, and the calculation formula is as follows:

$$i_{nA} = \sqrt{\frac{4(F_1 - 1)k \cdot T \cdot B_n}{R_1}} \tag{14}$$

In the formula, T is the reference temperature, R_1 is the equivalent input impedance of the amplifier; F_1 is the noise coefficient of amplifier. Formula (15) is used to calculate the total noise.

$$i_n = \sqrt{i_{ns}^2 + i_{nb}^2 + i_{nD}^2 + i_{nr}^2 + i_{nA}^2} \tag{15}$$

In the 3D measurement, it can make the target signal more prominent by reducing the influence of the optical background clutter and noise.

4. Using the Filtering Algorithm to Overcome the Noise of Laser Spot

In the course of measurement, the measurement system is in the case of various light pollution. According to influence of random noise on the accuracy of laser scanning measurement in this paper, the laser spot data signal of CCD is filtered and smoothed. It can reduce the interference of random noise and reduce the random error of the measurement system.

According to positioning, segmentation and processing of a frame CCD data signal in above paper, multiple measurement results of the same location can be measured. The mean filtering process is conducted after the central spot were obtained. This approach has good results in the light spot data signal approximation to the Gauss distribution, and for external complex measurement environment, signal noise may appear larger or noise irregularities. The noise can not be approximated to the Gauss distribution, this method continue to used will lead to lower measurement accuracy. In order to overcome this problem, this paper is improved from two aspects of hardware and software. Hardware, in the relevant circuit design, add Lens hood to overcome the influence of stray light, adjust the laser emitting position and intensity in real time. In software, the combination of median filter and Gauss filter is adopted, appropriate correction of the algorithm is carried out, and a simple and fast filtering method is obtained. Adopt the following steps to achieve:

1) Import raw CCD image data after hardware processing into a one-dimensional array c, construct an array interval, the radius of this interval assumes as d. A data c(1) in the array can obtain whole interval by adding and subtracting interval radius d, and its range is [c(1)-d, c(1)+d];

2) Comparing the data beyond the interval range with c(1). It is in the range of [c(1)-d, c(1)+d]. For instance, the n_1 number in the range of [c(1)-d, c(1)+d], so that the n_1 data is stored in a one-dimensional array e_1, and the other data stores and covers the array c.

3) Repeat steps 2) 3), obtain n_2 data in range of [c (1)-d, c(1)+d], and the n_2 data is stored in one-dimensional array e_2;

4) Repeatly execute 2) 3)step, until all the data in the array c are classified, so we get the corresponding n_1,n_2, n_3... , and array e_1, e_2, e_3... ,this moment, the elements in the array a are classified;

5) To find the maximum value in n_1,n_2, n_3...,then take the average value of the corresponding array.

After comparing and analysis the data by applying the above algorithm, it can be seen that the algorithm first found the range of the radius of the spot center is K. This range includes the data values that most probably occur. That is to control the measurement results in a range of close to real results. The average value of the data in the selected field is only selected, so as to get close to the center of the spot value. With the quantity difference of original sample data, and choosing different offsets d, the far or near degree that distant from laser spot is also different. Under the same circumstances, the more data quantity, the larger optional room, and the smaller generated offset. The result of this method is more close to the real spot center.

5. Conclusion

In various factors affecting the accuracy of laser triangulation method, laser spot noise is one of the main factors that directly affect the application area of laser triangulation. In the measurement process of laser triangulation, the laser echo signal is processed. In addition to carrying the reflected light from the information of the test piece, the signal is also accompanied by a number of signal interference. Therefore, it is necessary to process the received optical signal, to extract the target signal, and to filter out the noise signal. It based on the principle of laser triangulation in this paper, and the effect of laser spot noise on the measurement accuracy of laser triangulation method is deeply analyzed, such as signal flashing noise, background noise, dark current noise, thermal noise, amplifier noise and so on. It provides how to use the filtering algorithm to overcome the laser spot noise for improving the accuracy of laser triangulation.

References

[1] J. T. Bosiersa, I. M. Petersa, C. Draijera and A. Theuwissen, "Technical challenges and recent progress in CCD imagers", Science Direct, no. 1, **(2006)**, pp. 40-45.

[2] E. S. Bliss, D. R. S. Peek and W. W. Sinlnlons, "Direct interferometric measurements of the nonlinear index coefficient in laser materisalsm", Phys.Lett, no. 25, **(2004)**, pp. 728-730.

[3] J. Paul, B. Kevin and B. Ra, "Commereialisation of full depletion scientific CCDs", Proeeedings of SPIE, no. 6276, **(2006)**, pp. 604-627.

[4] Y. L. Zhao and Z. L. Xu, "The improvement of micro slit width laser measurement system based on the CCD",[J].Infrared and Laser Engineering, vol. 25, no. 1, **(2006)**, pp. 75-77.

[5] L. Mei, S. M. Ping, W. Lu and H. J. Huan, "High precision camera calibration in vision measurement", Optics&Laser Technology, vol. 9, no. 4, **(2007)**, pp. 35-40.

[6] Z. Yu, A. Zhi-yong and R. N. Yang, "The applications of CCD subdivision in the telescope exit pupil diameter and exit pupil distance measurement", Infrared and Laser Engineering, vol. 37 no. 5, **(2008)**, pp. 894-896.

[7] M. Ni, "The Research of Wheel-flange Measurement System Based on Optical Triangulation, Harbin University of Science and Technology, vol. 15, no. 2, **(2010)** April, pp. 39-42.

[8] Y.S. Jian, "Researchon Application of Analog-probefor Measuring Cente, Harbin University of Science and Technology", vol. 14, no. 4, **(2009)** August, pp. 121-124.