Application of Image Processing to Laser Reflective Pattern for Multi-layer Auto-focusing System

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***Abstract*—It is very important for laser auto-focusing systems in the applications of precise machining. The reflective laser area which is a semi-circular pattern is usually used to estimate the degree of defocusing. As work piece surface may be different in reflective properties and not always smooth, the reflective pattern is usually not a perfect semi-circle. In this study, a novel image processing algorithm is proposed to overcome this fault. Comparing with the conventional method based on the bias of gravity center, the results indicate that the proposed method can not only reconstruct the desired semi-circle back but also calculate the defocusing distant individually. After we use microscope and obtain images and perform the binary-valued image processing, we can clearly discriminate the border and structure of semicircle images and reduce the complexity of the processing of product images. The purpose of binary-valued processing is to discriminate the objects and background of images, so as to obtain the information of objects. We observe the changes of eccentric distance among images with the increases of the focal distance of microscope to determine the accuracy of microscope. The experiment results have shown the superiority of the sharpness measurement scheme we proposed.**

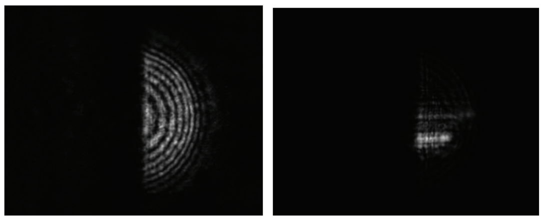
Keywords—Laser auto-focusing; Reflective pattern; Semicircle; Defocusing distance; image processing

I. INTRODUCTION

Laser machining applies widely to the production of panel module in recent years. Therefore, a reliable laser auto-focusing system detects the focusing condition on the surface of work piece is very important [1-7]. As the surface position significantly affects the focusing condition, the surface position is estimated based on the projection pattern on the work piece surface. If the work piece surface is not at the focal position, the energy shortage will cause the defocusing of surface projection and make the area of projection too large. Under this circumstance, we then have to refocus the surface position again.

For the optical focusing system, the work piece surface lay further than the focal point will generate a semi-circular reflective pattern on the right side while the surface lay nearer than the focal point will generate the same pattern on the left side. The radius of the semi-circular pattern will get larger when the surface is with a larger distance away from the focal point.

The algorithm of conventional focusing estimation computes the mean coordinate of points with intensity information on x-axis which crosses the center of semi-circular pattern; it calculates the summation of each position multiply by its intensity and subsequently divided by the intensity summation. There are single layer and complex layer on the work piece. The algorithm works on the reflective pattern of single layer, as Figure lea); however, it does not work on the pattern which usually shows the imperfect semi-circle obtains from the reflection of complex layer, showing as Figure 1(b). Therefore the estimation based on gravity center is greatly deviated from the ground truth when the work piece surfaces are complex.



(a) (b)

Fig 1. The reflective pattern of different types on the work piece. (a) On the single layer. (b) On the complex layer

II. MATERIALS AND METHODS

In this section, we will introduce the hardware and software algorithm respectively. The hardware part consists of two systems, the laser focusing system and the optical imaging system, as shown Figure 2. The laser focusing system was used to produce the semi-circular reflective pattern which was shaded with a blade on the path of laser beam. It makes the reflective pattern becoming a semi-circular pattern. The optical imaging system was used to acquire the clear images of work piece surface in real time from which we can see the position of laser point on the work piece. As mentioned previously, we propose an algorithm which provides a faster and more accurate estimation of focusing on work piece surface. Figure3 is the flow chart of the algorithm.

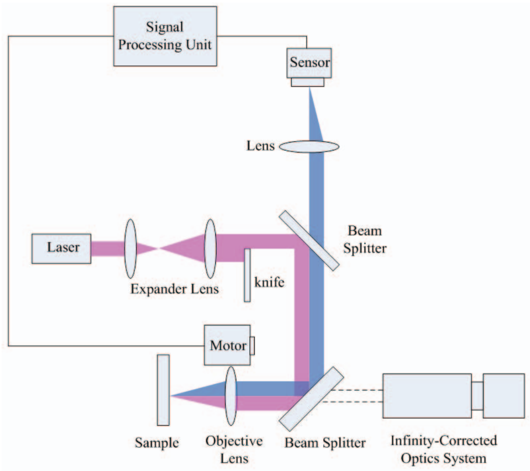


Fig. 2. The integrated optical system with laser focusing subsystem and optical imaging subsystem.

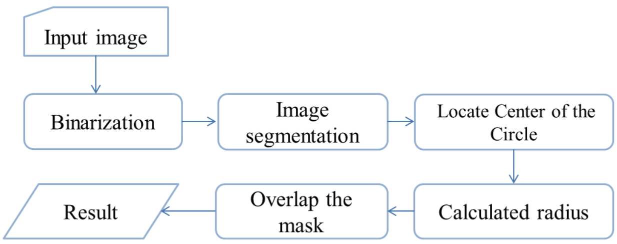


Fig. 3. The flow chart of our algorithm

Figure 4 illustrates the shape of the laser spot on them CCD sensor given various defocus distances [8, 9]. Note that in the figure, points (Xc, Yc) and (xcentroid, ycentroid) represent the positions of the geometrical image center and the centroid of the image captured by the CCD sensor, respectively. The image centroid coordinates can be expressed as follows:

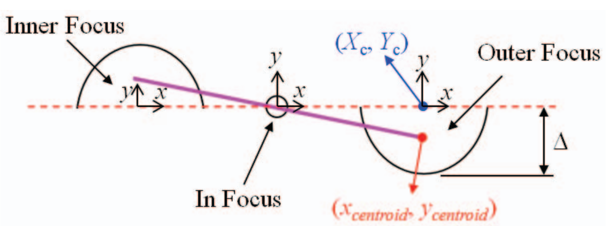


Figure 4.Schematic representation of laser spot on CCD sensor given different values of the defocus distance

To observe the image changes under different focal lengths of optimal microscopes. After the image processing of semi-circle, we can make out the center of a circle and radius length. We can use the center of circle and its radius to draw out a complete semi-circle mask (as auxiliary), so as to view the experimental result and the its coincidence with the original image. To judge the center-of-gravity position of each pixel with the weighted calculation and cross comparison, we can make out the defocus value and the xy axis relationship curve of the heart-to-heart distance.

A. Intensity Normalization

Gray-scale histogram is a kind of frequency degree distribution figure which can makes use of showing the amount of pixels and make use of corresponding to an image, which is composed of bright objectives in the background with shadows.

B. Selecting a Thresholding

The value used to do clustering is called threshold value. The purpose of threshold value is usually to extract the objectives or defective areas, and once the gray-scaled colors of these objectives or defective areas are different from the background, we can use thresholding method to separate this objectives or defective areas from the background.

- The characteristic quantity distribution figure can show several peaks, so we can easily make decisions according to the numbers of peaks of the quantity distribution figure, and the position of threshold value is set in the valley between peaks.
- To use the valley value of histogram to decide the threshold value to make out the threshold value having the optimal segmentation effect.

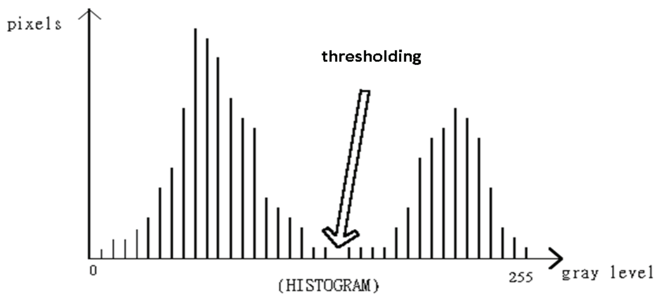


Fig. 5. The graph chart of Gray-scale Histogram

C. Locate Center of the Circle

This method is to use "row" to search the first pixel as A and the middle left pixel as B to be the reference point, and calculate the center point and get the radius.

D. Graphics Function Library

To use e->Graphics->FillRectangle & e->Graphics->FillEllipse in the C++ function library.

• Appearance: After setting the position of the center of circle and the radius length, there shows a virtual full complete semi-circle. After covering the complete semi-circle on the original image, we can see the chromatic aberration, and view the extent of graphical changes (eg: loose, expanded).

- Statistics: To calculate the 180 degrees on the semi-circle, and make 10 degrees as a single unit, then there show totally 19 points on the circumference. To overlap these virtual experimental semi-circles and detect whether there are superimposed images on these 19 points, and take the coincidence rate as the reference of accuracy.

E. The Calculation Method of Heart-to-Heart Distance

To use the pixel weight to make out the focus of figure and central point of circular border, and calculate the focus of figure (direction X) and the distance of circular border, so as to make out the heart-to-heart distance. The focus of the semicircular area is as shown in figure, and it can be known from the focus formula of fan-shaped area that:
Central angle =180°, θ = (Central angle / 2) = 90° = π, and the distant of the center of a circle *O* and the center of semi-circle *G* can be calculated by:

$$\overline{OG} = \frac{2}{3} + \frac{r\sin\frac{1}{2\pi}}{\frac{1}{2}\pi} = \frac{4r}{3\pi} \qquad (1)$$

Central coordinates (X. Y) : $\overline{X} = \frac{4r}{3\pi},\ \overline{Y} = 0$

Due to the asymmetrical situations of image luminance are very common, for example, training data are the interfered images of optical microscopes. While the focal length is small, the image luminance value is the greatest and the structure is closer, on the contrary, the image luminance value is smaller and the structure is loose, and the edges are more blurred. This is to accurately find out whether the binary-valued method which decides the threshold value is a key step of the success of experiment. The binary-valued threshold values are related to whether the target objects can be correctly segmented. Generally speaking, the histogram of intensity can be the basis of the selection of threshold values. If the histogram of intensity shows bimodal shape, then the intensity values corresponded by the valley points between two peaks are the appropriate two-valued threshold values. If the intensity of image is asymmetrical, there will be several blocks which show multiple peaks on the histogram. If the object is bright and the background is dark, the only use of binary-valued threshold value may cause the objects and background unable to distinguish. Therefore, we must use dynamic threshold values, and use high threshold values in bright areas and low threshold values in dark areas, and obtain a good binary-valued result.

The thresholding method which has been implemented is showed in section.

1) *Manual threshold value*: to use the artificial way to select threshold value, and directly judge which threshold value has the binary-valued effect beneficial to the operations of experiments.
2) *Otsu method*: to use the statistical principle of gray-scaled histogram to find out the best threshold value to segment the pixels of two clusters in the images, which divide the image into background and objectives. While the average value between background and objectives are greater, the maximum value is greater. This explains the difference of two parts which compose the image is great.
3) *Mode method*: While two peaks are not far apart to each other, we can use the way of finding peaks and valleys to set the threshold value at the valley position, especially when the areas of background and objectives are the same. There is a fairly small probability of misclassification if using this method to select the threshold value.
4) *Discriminant analysis*: to find out the primary valley to be threshold value from the smallest gray-scaled values through the primary peaks. If there are several peaks, it means an inaccuracy threshold value. Discriminant analysis usually makes out the best separated threshold value according to the covariance of two groups of gray-scaled average values.

III. Experimental Results

All images we use are captured by the laser imaging system. The image size is 1200xl040. The relationship between defocusing distance and the radius is linear and symmetric for the further and nearer defocusing cases. The defocusing distance can be calculated by interpolating two of the known radii.

In order to effectively resolve the image projected by microscope, after the binary-valued processing, we retain the image structure and edge detail, and take the pixel as the basic unit to actually classify the black and white blocks, and use the intensity values of pixels to do calculation. Figure 6 (a) is the original image, and (b) is the image processed by binary-valued segmentation with discriminant analysis, and it can be clearly seen the black and white blocks. Then we can perform the experimental operation, and (c) is the simulated standard semi-circle based on the obtained data.

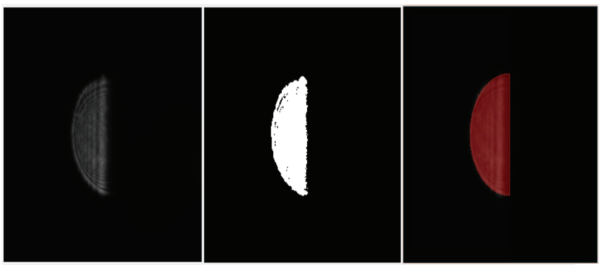


Fig. 6. Experiment results for proposed method: (a) Original image; (b) Image binarization; (c) The proposed method

IV. CONCLUSIONS

We propose a novel method to compute the defocusing distance based on the radius of semi-circular pattern with the corresponding relationship between defocusing distance and radius. We can accurately estimate the defocusing distance based on the obtained radius. The proposed system can calculate the defocusing distance precisely not only for single layer but for complex ones with the specifically designed image processing system. It provides great potential in the industrial auto-focusing applications. The gray-scaled changes of edges are continuous, so there are easily errors in the calculation of threshold value, and this will directly affect the actual structures of segmented images. How to select the binary-valued method depends on the use situation and the disturbance degree of image processing.

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