Geometric parameters measurement of wheel tread based on line structured light

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Abstract

The positioning precision is important in the processing of geometric parameters measurement technology of wheel tread. In this paper, a new method with no-contact measurement based on line structured light is given to solve this problem. Here traditional mechanical locating method is used as a rough reference. Moreover, some digital image processing techniques are developed for each of the key dimensions of measurement. According to the feature points (particularly, the key points that have not been worn) and lines extracted effectively on the wheel tread, precise positioning is realized. In this paper, the experiments show that the proposed method is feasible to implement non-contact measurement of the wheel tread, wheel flange thickness and rim width. It also ensures the accuracy of positioning and analyses the factors of measurement error.

Keywords: no-contact measurement, line structured light, wheelset tread, image segmentation

1. Introduction

With the rapid development of rail traffic, the issues of train safety are becoming increasingly prominent. A railway wheelset, which is indispensable and the most important component, bears all the static and dynamic load from the vehicle. Since it directly contacts with the rail, gradually and inescapably, the wheelset is worn down by the interactions between wheel and rail, which cause the undermining of critical dimensions. Moreover, the safety and operation quality are seriously affected. Hence, it is necessary to measure geometric parameters of train wheelset tread periodically[1].

At present, the wheelset detection method can be roughly divided into the contact and non-contact measurement. The traditional methods still depend on the special mechanic tools like artificial calipers. Albeit its simple principle, there are the problem of high labor intensity, low efficiency and low accuracy[2]. With the development of science and technology, non-contact measurement appears and is widely applied.

In this paper, the experimental model is established and the method with no-contact measurement is adopted which is based on line structure light. The problem, led by the precision of positioning between laser device and wheelset, is attempted to solve. The geometric

© The 2016 International Conference on Artificial Life and Robotics (ICAROB 2016), Jan. 29-31, Okinawa Convention Center, Okinawa, Japan

parameters, measured by using CCD to grab images and processing them with visual C++ and OpenCV, are flange height, flange width and wheel diameter.

2. Experimental principle

This part, the definition of wheelset's parameters and experimental principle are intuitively introduced.

2.1. *Definition of wheelset's parameters*

It is necessary to illuminate the definition of wheelset's parameters.

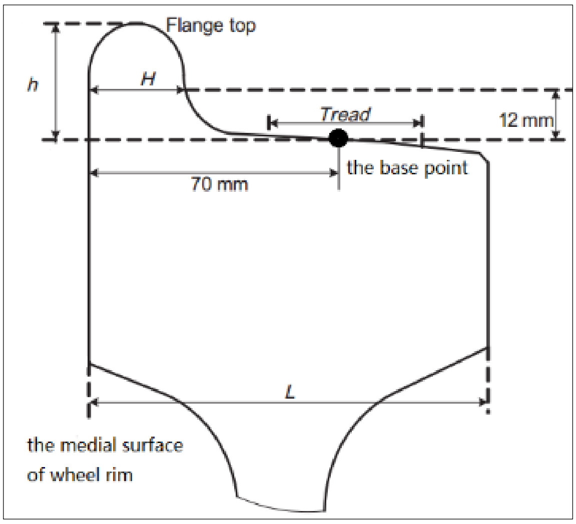

Fig. 1. the critical parameters

Fig. 1 shows the critical parameters of wheelset. the left is the medial surface of wheel rim (ostensibly, it is a line in the image). There is a point on the tread and the distance is 70mm to the medial surface of wheel rim, and it is customarily called the base point. Tread is the contacting area between wheelset and railway. Flange base line is the horizontal line 12mm above the base point. Flange thickness H is the horizontal thickness along flange base line. Flange height h is the height between flange base line and flange top. Rim width L is the distance between the medial surface and the lateral surface of wheelset[3].

Fig. 2 shows the rolling circle passing the base point on the tread. Wheel diameter D is the average diameter of rolling circle. In this paper, the key parameters H, h and D, are mainly concerned.

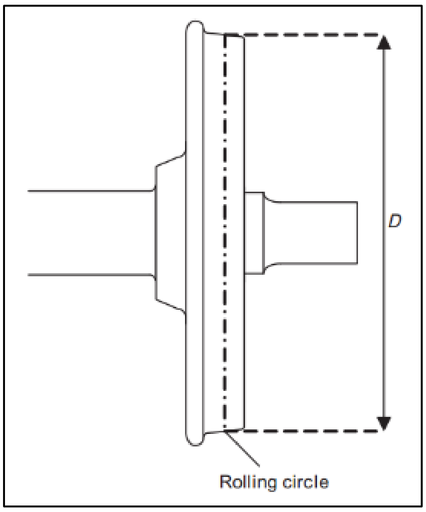

Fig. 2. one wheel of wheelset

2.2. *Experimental system and principle*

Fig. 3 shows the experimental device. The camera A and the camera C are used to positioning and the camera B is used to grab images of tread. Lasers and cameras are relatively fixed and calibrated.

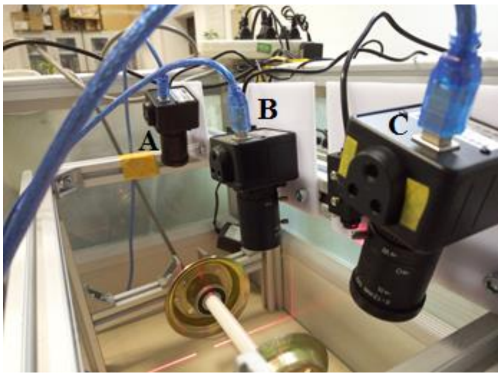

Fig. 3. The experimental device

The traditional method based on mechanism is regarded as slow and subjective to a great extent in the practical measurement. In order to ensure the light plane perpendicular to the tread, the more accurate method is proposed.

The geometric parameters of wheel tread are measured through laser scanning method in which linear light source is projected on the surface of work piece[4]. Laser vertical incidence and vertical imaging is applied to the measuring system.

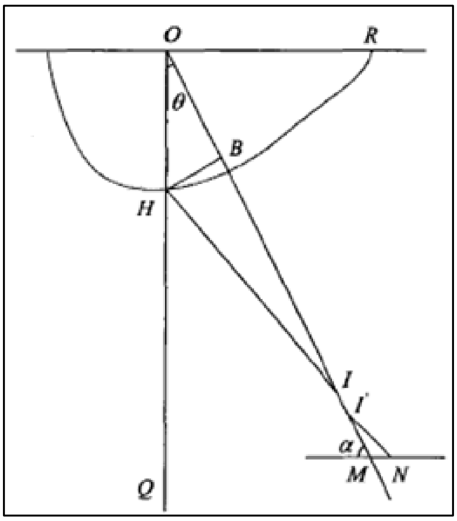

Fig.4. triangulation measurement

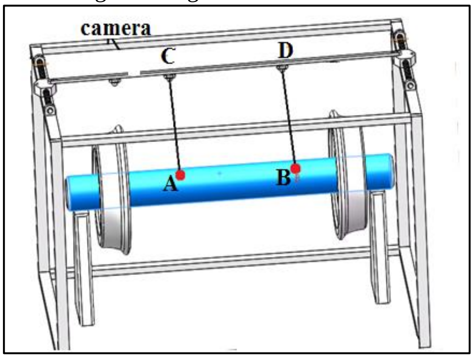

Fig.5. Diagram of positioning

According to Fig.4, θ is the angle between QO and PO, the height of point H on the work piece can be calculated as follows formula:

$$\mathrm{OH} = \frac{(OI - f)\Delta\sin\alpha}{f sin\theta + \Delta\sin\alpha\cos\theta}$$

In the above formula, f is the focal distance. The point on the surface of measured objects a three-dimensional coordinate reflected in the CCD's image plane, which presents as two-dimensional image, so the three-dimensional coordinates can be reconstructed by using the optical coordinate.

As Fig.5 shows, when the light is perpendicular to the axis, the distance between the highest point of axis and the optical center of camera can be obtained. If the distance AC is equal to BD, it can ensure two axes parallel. Besides, when AC or BD is minimum, the positioning is realized. Then we can use image processing to easily get the geometric parameters of wheelset. we assume that the distance between the optical center of camera and the center of axis is h_1, and to the base point is h_2, so the wheel dimeter D, as Fig.2 shows, can be got:

$$\mathrm{D} = 2(\mathrm{h}_1 - \mathrm{h}_2)$$

The flange width H and flange height h can be obtained after image processing. The key to implement the measurement as follows:

1) the collocation of the cameras and the linear structured light source.
2) calibration method
3) the extraction accuracy of light stripe.

3. Image processing

As Fig.6 shows, there are lots of noises. In order to remove noises, image segmentation is adopted. The principle of image segmentation is to separate out regions of an image corresponding to objects which we want to analyze. In this paper, this separation is based on the variation of intensity between the object pixels and the background pixels. To differentiate the pixels, we are interested in from the rest (which will be eventually rejected), we perform a comparison of each pixel intensity value with respect to a threshold.

Filtering is perhaps the most fundamental operation of image processing and computer vision. In the broadest sense of the term "filtering", the value of the filtered image at a given location is a function of the values of the input image in a small neighborhood of the same location. In the practical processing, sometimes, the filters do not only dissolve the noise, but also smooth away the edges. To avoid this, at certain extent at least, the bilateral filter is recommended. In an analogous way as the Gaussian filter, the bilateral filter also considers the neighboring pixels with weights assigned to each of them. These weights have two components, the first of which is the same weighting used by the Gaussian filter. The second component takes into account the difference in intensity between the neighboring pixels and the evaluated one.

Finally, the processing result is showed in the Fig.7. As it shows, image segmentation works well and bilateral filter makes a great contribution. Then, according to the result, we can get what we want to.

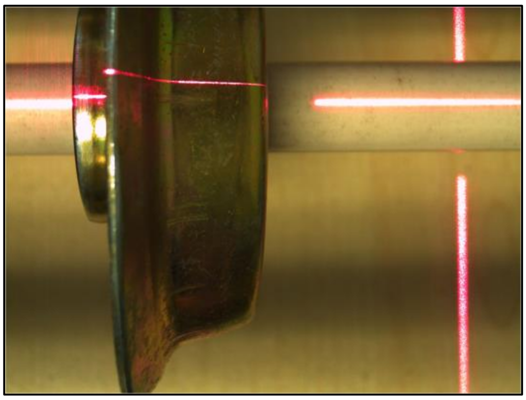

Fig.6. Wheel tread images: The initial image from camera.

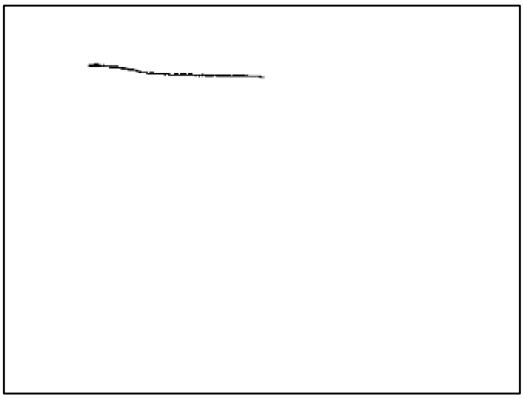

Fig.7. Wheel tread images after pre-processing

4. Error Analysis

In the process of measuring the wheel geometry parameters, the measurement precision is influenced by many factors. Usually, sensor position error, light angle error, the extraction accuracy of line structure light stripe, and so on.

All in all, errors include systematic errors and random errors. System error can be obtained by the structure parameters of the measurement accurate system calibration. Besides, it can be eliminated with the comparison between stand wheelset and measured result. Random error is mainly caused by laser sensor measurement error and the extracted line structured light stripe center, which can't be completely eliminated.

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5. Conclusions

The method based on line structured light with no-contact measurement is proposed. Some digital image processing techniques, such as image segmentation and bilateral filter which not only dissolve the noise, but also reserve the edges, are used to position and measure. The error also is analyzed in order to get higher accuracy.

Eventually, the experiments show that the proposed method turn out to be feasible to implement non-contact measurement of the wheel tread, wheel flange thickness and rim width.

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