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A Wear Detection System based on Machine Vision Technology

Ying Fang

Shanghai Maritime University, Shanghai ,201306 China.

645427874@qq.com

Abstract

At present, China has entered a period of comprehensive development of railway, which promotes economic growth to a great extent, facilitates people's transportation and production, and also puts forward higher requirements for the quality of rail. Rail welding base mainly uses mechanical contact measurement for rail shape detection, which not only has high labor intensity, low detection efficiency and poor working environment, but also has problems such as low reliability of measurement results and difficult to save data, which seriously affects the further development of railway. The existing image measurement method and optical measurement method improve the work efficiency to a certain extent, but the measurement accuracy and data reliability need to be improved. The purpose of this paper is to propose a rail profile measurement system based on machine vision technology.This paper first introduces the research background of the subject, then summarizes the composition and application fields of machine vision system, designs a rail surface wear detection system, and expounds some key technologies. Finally, the measurement results are compared with manual measurement, and the experimental results verify the accuracy of the system, which can meet the field requirements of rail wear measurement.

Keywords

Rail Profile; Wear Detection; Machine Vision Technology.

1. Introduction

Railway line equipment is the basic equipment of railway transportation industry. It is exposed in the nature all the year round. It is subjected to the effect of wind, rain, freezing and thawing and train load [1]. The track geometry is constantly changing, the subgrade and track bed are constantly deformed, and the rail, connecting parts and sleepers are constantly worn. As a result, the technical state of the line equipment is constantly changing. Therefore, the public works department should grasp the changes of the line equipment It is an important basic work to ensure the quality of the line and the safety of transportation to timely detect the line status and strengthen the line detection management. The more commonly used one is the static inspection, which refers to the inspection of the line with manual or light measuring car when there is no wheel load. It mainly includes the inspection of gauge, level, front and rear height, direction, empty hanging plate, rail joint, anti climbing equipment, connecting parts, sleeper and crossing equipment. With the development of computer technology and image processing technology, the railway track inspection will gradually develop to the direction of high efficiency and intelligence, and the current visual measurement technology will appear.

However, this manual measurement method needs to be operated by the staff, resulting in measurement error or reading error due to human reasons. At the same time, measuring instruments will also cause indirect damage to the rail. And the working place is generally in the field, some even on the viaduct, the working environment is bad, threatening the personal safety of the staff.

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Therefore, it is more and more urgent and necessary to design an efficient and intelligent non-contact rail loss measurement system. Its significance lies in that it can quickly and accurately detect the actual situation of rail wear, carry out real-time data processing, and greatly improve the work efficiency of workers. And the test results are analyzed and processed to provide data reference for the railway department, so as to facilitate the railway department to maintain and repair the line.

2. Rail wear detection system

2.1 Introduction of system composition

The technical problem to be solved in this paper is to overcome the defects of the existing technology, and to provide a wear detection system through machine vision technology. In order to solve the above technical problems, this paper proposes a wear detection system based on machine vision technology, including image acquisition module, photoelectric coding module, image processing module, image detection module, central processing module and database server. Among them: image acquisition module, photoelectric coding module and image processing module are all integrated equipment, image detection module is mobile equipment, central processing module and database server are fixed equipment, image acquisition module is connected with photoelectric coding module and image processing module respectively, image detection module is connected with image processing module, photoelectric coding module and central processing module respectively The CPU module is connected with the database module.The basic structure of the system is shown in the figure below:

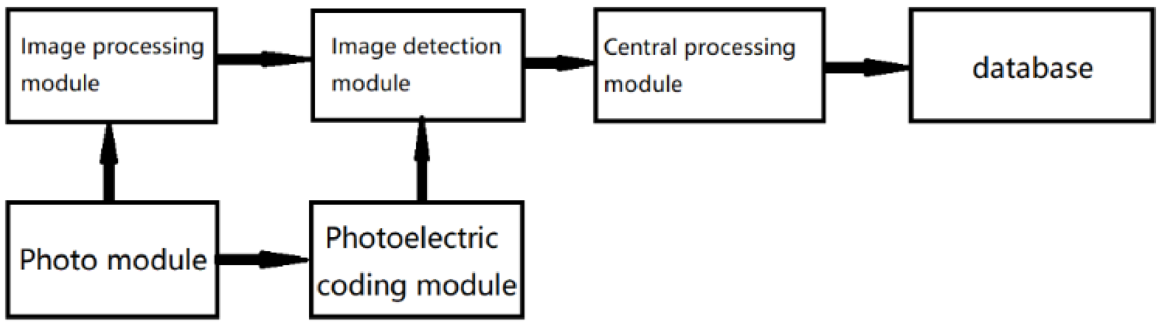

Fig. 1 System structure diagram

Fig. 2 Laser sensor

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The image acquisition module includes CCD industrial camera, exposure lamp, track detection vehicle and the first wireless transmission module; the photoelectric coding module includes photoelectric encoder, single chip microcomputer chip and laser sensor; the image processing module is realized by visual c + + programming software. The number of CCD industrial cameras is two, both of which are set at both ends of a single track, and are symmetrically set. The laser sensor module contains a laser transmitter, the number of laser sensors and CCD industrial cameras is the same, and the laser emission points are set at the center of the shooting range of the CCD industrial camera.

The laser transmitter adopts the online purchase of red light linear positioning lamp (model: ho-y650p5-f1240) and the overall dimension: 12 * 40MM. There are three kinds of light spot shapes: dot, straight line and cross line. The wavelength of the laser is red light 650nm, the power is 5MW, the working voltage is DC 2.8 ~ 5.2v, the structure features are imported laser diode + metal shell + high quality lens + constant power circuit board + plug wire or wire.

2.2 Principle of coordinate transformation

According to the above, the industrial CCD camera is placed above the rail side to shoot the laser on the rail, and the result of shooting must be an inclined contour line. In order to analyze the experimental data more intuitively, it is better to put the obtained wear profile and the standard profile in the same coordinate axis. Therefore, this section first briefly introduces the principle of coordinate transformation to be used in the experiment.

Coordinate transformation is the position description of spatial entity, and it is the process of transformation from one coordinate system to another. By establishing one-to-one correspondence between two coordinate systems. It is an essential step to establish the mathematical basis of map in various scale map survey and compilation. When two or more coordinates are transformed, the dimension space is determined by polar coordinate relative reference.

In order to get the transformation relationship between pixel and 3D coordinate, four coordinate systems are defined, namely world coordinate system, camera coordinate system, image coordinate system and pixel coordinate system. Let the world coordinates of any point P on the rail profile curve be (Xw, Yw, Zw), the camera coordinates be (Xc, Yc, Zc), the image physical coordinates be (x, y), and the image pixel coordinates be (U, V) [2]. The position relationship between the coordinate systems is shown in Figure 3.

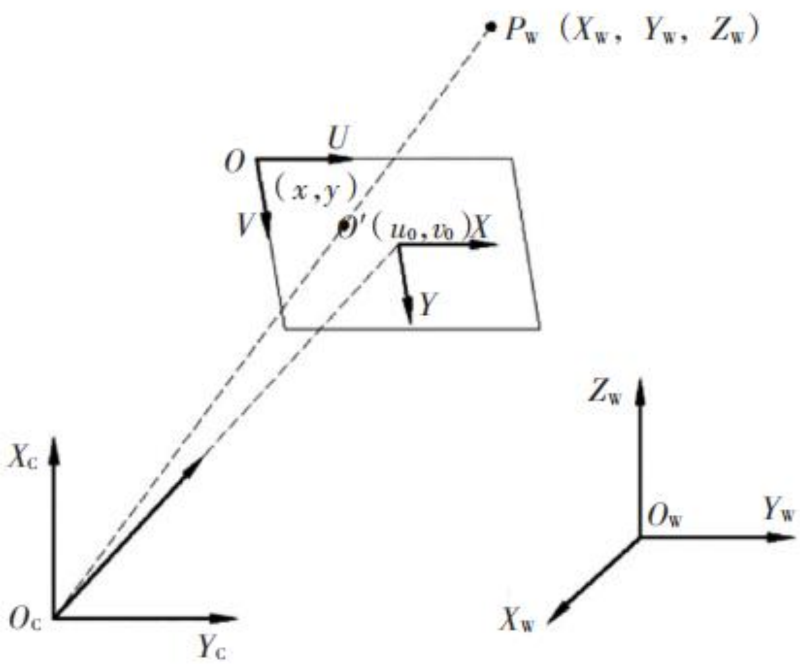

Fig. 3 The position relation of each coordinate system

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From the camera imaging relationship, the following formula can be obtained:

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x,0,u_0,0 \\ 0,f_y,v_0,0 \\ 0\ 0\ ,1\ ,0 \end{bmatrix} \begin{bmatrix} R,T \\ 0\ ,1 \end{bmatrix} \begin{bmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{bmatrix} = M_1 M_2 X = MX \tag{1}$$

In formula (1), M1 is the internal parameter matrix of the camera, which is determined by the camera itself; M2 is the external parameter matrix of the camera, which is determined by the position of the camera in the world coordinate system, and M is the camera parameter.

3. Image processing and analysis

3.1 The Subject of the experiment

First of all, this paper introduces the test object of the rail wear detection system, which is a 60kg / m heavy rail. It has been seriously worn under long-term bad working conditions and can not be used normally. Now it is transported back to the laboratory as the measurement object. See Figure 5 for the standard drawing of section size of 60kg/m.

Fig. 4 Damaged track

The inspection of rail type and size mainly includes the inspection of finished rail section size, such as rail height, head width, bottom width, waist thickness, concave convex degree and asymmetry degree at the bottom, etc. After analysis, it is obvious that it is difficult to measure the concave convex degree and asymmetry degree of the bottom, because the measured object is very bulky and the current laboratory equipment can not lift it. According to the railway line repair rules, when measuring the rail wear value, it is necessary to measure the side wear A_H and vertical wear A_V respectively. The vertical wear is measured at 1/3 of the rail top width (from the standard working side), and the side wear is measured at 16 mm below the rail tread (according to the standard section) [3]. According to the side wear and vertical wear, the total wear A_T is calculated as follows:

$$A_T = A_V + \frac{A_H}{2} \tag{2}$$

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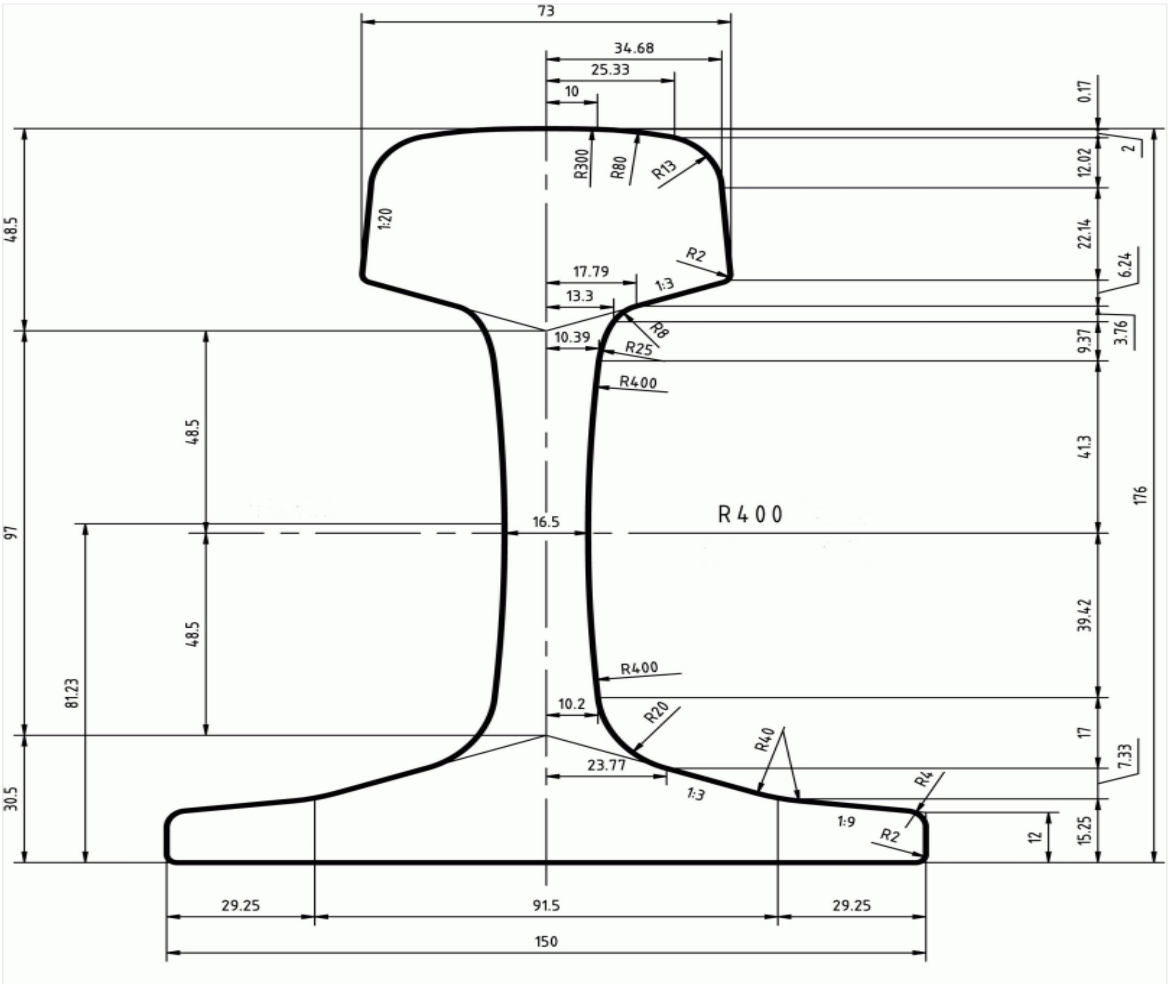

Fig. 5 Rail dimension drawing

Table 1. Comparison of both measurement results

Numble	A_{T1} Measure with caliper(mm)	A_{T2} Measure with system(mm)	Measure error (%)
1	1.638	1.642	0.244
2	1.653	1.649	0.241
3	1.636	1.639	0.183
4	1.644	1.641	0.182
5	1.653	1.649	0.242
6	1.665	1.661	0.240
7	1.634	1.639	0.301
8	1.643	1.648	0.234
9	1.649	1.653	0.242
10	1.658	1.662	0.243

3.2 Rail profile extraction

the profiles of 10 rail sections are randomly extracted. However, in order to analyze and calculate the error between the size of the worn section and the size of the rail delivery section more clearly and intuitively, it must be converted to the plane coordinate system by using the principle of coordinate transformation. The principle of coordinate transformation and related formulas have been described in detail in Chapter 2.2.

In this experiment, we also use vernier caliper to measure the wear of cross-section. Vernier caliper is a precise tool to measure the length. It can measure the length accurately to 0.01mm, and the

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measuring range is several centimeters. Although it is well known that the measuring accuracy of the micrometer is higher than that of the vernier caliper, considering the particularity of the size and shape of the experimental object, the vernier caliper is finally used to measure the second time to form the control data. The process of using vernier caliper is relatively simple, so this paper directly gives the measurement results of vernier caliper, and the measurement method and process will not be repeated.

Based on the measurement results of vernier caliper, formula (3) can be used to calculate the error of two measurements:

$$E_r = \frac{|A_{T1} - A_{T2}|}{A_{T1}} * 100\% \tag{3}$$

4. Conclusion

In this paper, a wear detection system based on machine vision technology is proposed. The system consists of image acquisition module, photoelectric coding module, image processing module, image detection module, central processing module and database server. Through the simple test, the stability of the system fully meets the requirements, and the measurement accuracy also reaches within 0.1mm, which basically meets the measurement requirements. This kind of rail profile measurement system based on machine vision plays an important role in the railway department, which can reduce the amount of labor, improve the efficiency and improve the quality of rail detection and maintenance work at the same time.

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