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Retraction

Retracted: Metro Wheel Set Size Measurement Method Based on CDD Image Recognition

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] J. Ma, C. Zhang, and B. Chen, "Metro Wheel Set Size Measurement Method Based on CDD Image Recognition," *Journal of Electrical and Computer Engineering*, vol. 2022, Article ID 9772436, 8 pages, 2022.

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Research Article

Metro Wheel Set Size Measurement Method Based on CDD Image Recognition

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In the process of train operation, the contact friction between wheel and track will change the size of wheel set. In order to ensure the safe operation of train, it is of great significance to detect the change of wheel set size timely and accurately. On the basis of summarizing the research at home and abroad, the online dynamic detection technology of wheel set size is studied. Firstly, the overall architecture of the wheel set size online detection system is studied, the working principle of each detection module is explained, and the installation parameters of the laser displacement sensor are designed. Secondly, the machine learning algorithm of online dynamic detection technology of wheel set size is studied. The passing wheel sets are photographed by CCD camera, and then the three-dimensional model is reconstructed by point cloud data, and then the parameters of each part are measured and calculated according to the model. The wheel set size can be obtained.

1. Introduction

Metro wheel set is a very important part of locomotive running part. The wheel set not only bears the whole weight of the subway and its own weight but also transmits the driving force and braking force between the subway and the rail. In addition, the wheel set needs to bear great static load and action force, assembly stress, thermal stress generated by brake shoe braking, frame force and guiding force when passing through the curve, centrifugal force of wheel set rotation, etc. Therefore, it is required that the wheel set must maintain a good technical state; otherwise, it will seriously affect the driving safety [1].

In addition, when the wheel passes through a curve or turnout, the wheel rim part rubs with the inner side of the rail, resulting in wheel rim wear. Tread wear and rim wear lead to changes in wheel dimensions, which greatly affect ride comfort and running stability. When the wheel wear exceeds a certain limit, it will cause major driving accidents. Therefore, the overall dimension of the wheel is an important index to measure the technical state of the wheel set. In recent years, with the continuous acceleration of subway, countries all over the world attach great importance to the detection of wheel sets. It is of great significance for subway safety to detect the wear parameters of wheel sets and ensure that the wear amount does not exceed the specified limit [2].

Static detection and dynamic detection are the main detection methods of wheel sets at present. The online dynamic detection for the wheel set in the driving state can understand the quality state of the wheel set in the driving state, which is real time and efficient. The online detection method of wheel set wear parameters based on photoelectric image has the advantages of noncontact, high precision, and fast speed. In this method, the laser is illuminated on the wheel set, the laser projection, that is, the contour curve of the wheel set, is obtained by the camera, the collected photoelectric image of the wheel set is processed by the image processing technology, and its wear parameters are deduced [3].

Digital image processing is an important part of the online detection of wheel set wear parameters of photoelectric image. The wheel set image obtained by CCD obtains the target curve through digital image processing to further obtain the wheel set wear parameters. In the process of image processing, due to the large number of wheelset images detected online, the large amount of data, and high complexity of image processing algorithm, the processing speed is slow and the efficiency is low. These problems affect the real-time detection and efficiency of wheelset online detection, so it is necessary to study relevant solutions. Since image processing is mainly realized by software and multicore processors are popular today, how to give full play to its computing and performance advantages through software has become one of the important problems faced by software development [4].

The online measurement system of wheel set geometric parameters needs to be installed at the track side, and the measurement conditions are extremely bad, which is reflected in three aspects.

First, the temperature changes greatly: the general conditions need to work normally under the ambient temperature of 25–50°, and some areas require a wider temperature range. The temperature change not only affects the measurement accuracy but also poses a challenge to the measuring device itself. In addition, the friction between the measuring wheel and the track for a long time causes a great difference between its own temperature and the ambient temperature, which brings great errors to the measurement results. Second, large vibration and deformation occur during measurement: the measuring device is generally fixed on the rail or subgrade. When the vehicle passes through the measuring system, due to the heavy vehicle and large vibration, it will have a great impact on the measuring system and measurement results. Third, the randomness of the measurement results is large: due to the different speed and load of the train during the measurement, the different conditions of each carriage and each wheel set, and the different subgrade and rail states, it brings great randomness to the measurement.

The online measurement of wheelset geometric parameters is a typical dynamic random measurement process, and its dynamic error has a great impact on the measurement results. At present, there is no research in this field at home and abroad. Therefore, the research in this field can not only improve the accuracy of wheel set geometric parameters measurement but also enrich the analysis theory of dynamic error.

2. Development Status at Home and Abroad

The train wheel set detection technology first came into being in the UK, the hometown of the train invention. It came into being almost at the same time with the emergence of the train. The first generation train technology has no modern rail, the iron bar was fixed on the hardwood bar, and the train wheel rolled on the rail. This kind of rail has great damage to the wheels, and the wheel speed of the train is not very high, which is not much faster than the horse drawn car. In order to detect the wear of wheels and the change of wheel set diameter caused by wear, a tool that can swim and display different data was designed by a railway engineer in Mantest, John Camano. Whenever the train stops at the station, the workers will hold this tool, measure all the wheels, and then record them all. This tool was later named cursor card. Foreign countries have been engaged in the research of wheel set automatic detection for many years. They have conducted in-depth research on the overall dimension detection of wheel set, possessed relatively mature detection technology, and developed dynamic and static automatic detection products suitable for different occasions. In China, the research on wheel set overall dimension detection is relatively late. Strictly speaking, it began in the 1990s. Before that, most of them introduced or copied the more mature technologies of developed countries. This introduction has many disadvantages. First, it is expensive. Second, most of these technologies are not used or will be eliminated by others [5].

2.1. Static Detection Technology

2.1. Static Detection Technology. Static detection technology originated from the traditional railway transportation countries, such as Britain and Germany. Its detection technology has advanced by leaps and bounds. Since the last century, the highway transportation technology, especially the expressway, in the developed countries led by the United States was only in its infancy, and most of the transportation of passengers and materials had to be undertaken by the railway. During this period, the railway technology of its country has developed vigorously, and the detection technology in vehicle operation has also developed rapidly. Therefore, railway transportation technology historians generally interpreted that the railway technology originated in Britain, improved in Germany, and developed in the United States.

Static detection refers to the detection conducted during train maintenance. Compared with dynamic detection technology, although this method has the disadvantages of occupying vehicle turnover time, it has the advantages of high precision, convenient equipment maintenance, and convenient storage of wheel information. In the 20th century, China mostly adopted this technology. Static detection technology has experienced the stages of mechanical measuring tool measurement, electronic measuring tool measurement, and noncontact measuring tool measurement. With the development of electronic technology, sensor technology, and optical technology, mechanical measuring tools have been replaced by electronic measuring tools and noncontact measuring tools [6].

CCD technology is the abbreviation of the English name of charge combining device in imaging technology. It used to be an important part of a digital camera. The structure of CCD the is like a row of buckets on the conveyor belt and filled with light. Light is like rain. The dots are scattered into each bucket, and each bucket is a pixel. When the technology works, the instrument itself emits a light beam to irradiate the detected body, and the two always maintain a certain distance, rather than scanning the detected body itself through various zero distance contact probes like electronic measuring tools to display the object image. CCD technology and image processing technology have been widely used not only in the dynamic detection of wheel set shape but also in the static detection. The service life of more than one measuring instrument can be extended, which means that the service life of one measuring instrument can be extended by dozens. Their economic and social benefits are very considerable [7].

2.2. Dynamic Detection Technology. Because the state of subway under dynamic conditions is not easy to determine, compared with static detection, the detection accuracy cannot reach the high-precision level of static detection in some cases. However, the dynamic detection method will not occupy the normal operation time of the vehicle and will not affect the operation cycle of the vehicle. At the same time, the parameter detection can be realized without dismantling the wheel set and transporting it to the designated place. It is convenient, fast, simple, and efficient, which can save a lot of manpower and reduce the labor intensity.

Based on the principle of eddy current testing, the former Soviet Union once developed a set of "wheel set wear eddy current testing conversion device." The device studies the corresponding relationship between the detection signal and wheelset wear, deduces the calculation formula of output signal value and wheel set wear parameters, and realizes the detection of wheel set. The "wheel set wear eddy current detection conversion device" based on eddy current method can realize the wheel set detection of vehicles running at various speeds. Through the research on electromagnetic ultrasonic technology, Franhoff Institute has applied this technology in detecting whether there are defects on the wheel set surface. The developed wheel set dynamic detection equipment has also been bought by German Hegenscheidt-MFD company and has been widely used. In addition, the "automatic wheel set parameter detection device" developed by Russia in the 1990s is also made based on this principle, which can detect the geometric parameters of vehicle wheel sets with slow running speed. The "Bobcats system," which appeared in the 1990s, was developed by the United States to detect the damage of vehicle wheel set tread. It is based on the principle of impact load method. During the detection process, it is necessary to design a special load circuit for the wheel set. When the subway passes, the circuit can transmit the load information in the vertical direction of the wheel to the core processing module of the system, calculate the impact load value of the wheel set, and compare the calculated value with the reference value in the database to judge whether the wear of the wheel set exceeds the specified threshold [8].

In the 1990s, Japanese researchers successfully developed the "wheel tread detection system" based on this method. As shown in the figure, when the vehicle enters the detection area, two acceleration sensors installed next to the track, respectively, detect the vibration of the tread arc with a quarter of the circumference of the wheel and then analyze and calculate the parameters of the wheel set according to the detected data. In the mid-1990s, Japan developed a machine vision wheel set detection device of "wheel tread shape detection system" based on the photoelectric detection principle. The components of the equipment mainly include laser light source, image sensor, positioning sensor, etc. In the acquisition process, two sets of light source laser beams are used to irradiate on the rim of the wheel set to form a wheel set section curve, respectively, and then the section curve formed by the light source on the wheel set is collected by two CCD devices [9].

However, the existing detection methods have defects of low precision and efficiency, and the proposed method in this research can effectively avoid the influence of environment, which has advantages in precision and efficiency.

3. Wheel Set Parameter Detection System

Compared with other existing online detection methods of wheel set wear, the detection technology using linear structured light imaging method has the advantages of simple structural design, low cost, and good repeatability. Therefore, the system uses this method to detect the wheel set parameters [10]. The detection system is mainly composed of three parts: sensor, laser, and CCD. In order to collect the complete contour curve of wheel set, the measuring device is installed on the inner side of two rails, respectively. In order to improve the accuracy of wheel set parameter detection, a set of detection units is used at the front and rear of each wheel. Such a pair of wheel sets adopts four groups of detection units to jointly complete the parameter detection of wheel sets. Each detection unit of the system is composed of linear laser source, CCD industrial camera, and positioning sensor. Each unit completes the acquisition of wheel set image independently. The inspection system of wheel set is shown in Figure 1, where L0–L7, R0–R7 are positioning sensors, Laser1–Laser4 are linear laser sources, CCD1–CCD4 are area array cameras, and DS1 and DS2 are laser displacement sensors; taking the left part of the detection unit as an example, the specific working process of the wheel set online detection system is described as follows.

When the train moves into the detection area, L0 and L1 trigger the central control unit to start supplying power to the positioning sensor, linear laser source, CCD camera, and laser displacement sensor to make the equipment enter the working state. After the detection of positioning sensors L2, L3, and L4, the speed information of wheel set operation is calculated. Combined with the horizontal distance between L4 and the detection point of CCD camera, the time required for the wheel set to reach the detection point is calculated. After the corresponding time delay, the wheel set just runs to the set detection position. At this time, the laser surface projected by the laser source forms a light cut curve on the wheel set surface, and the CCD camera completes the acquisition of the wheel set image by capturing this curve [11].

The image point coordinate used in the imaging plane coordinate system is $p = (x, y)$. In fact, the pixel can be regarded as a square block, and the length of the square block in the horizontal X and vertical Y directions is recorded as α and β, respectively. Therefore, the relationship between pixel coordinates and imaging coordinates can be calculated from the origin translation relationship and scaling coefficient between the two coordinate systems.

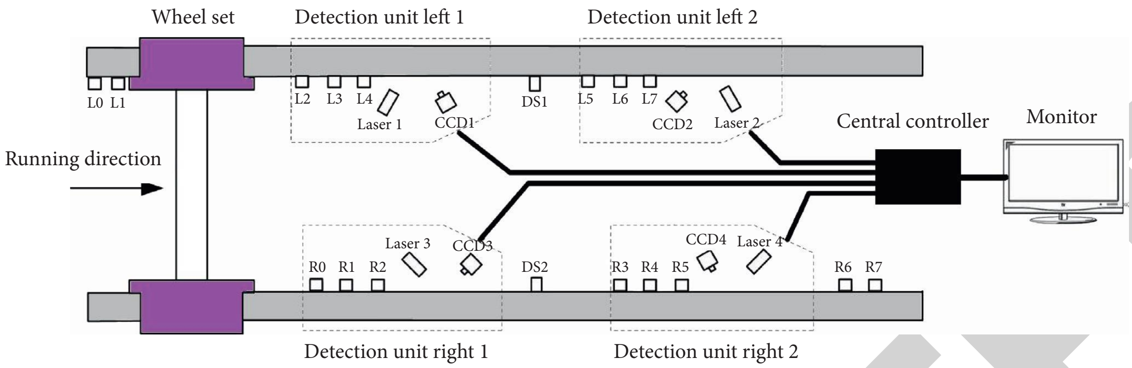


Figure 1: Diagram of inspection system of wheel set.

Note that the horizontal direction of pixel coordinates is σ and the vertical direction is v. The coordinates (σ, v) of the pixel coordinate system can be obtained by the formula (1) as follows:

$$\begin{aligned} \sigma &= \alpha \cdot x + c_x, \\ v &= \beta \cdot y + c_y, \\ \alpha \cdot x &= f_x \cdot \frac{X}{Z}, \\ \beta \cdot y &= f_y \cdot \frac{Y}{Z}. \end{aligned} \tag{1}$$

The formula of homogeneous coordinate can be obtained as follows [13]:

$$\begin{bmatrix} \sigma \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}. \tag{2}$$

The third-order matrix in formula (2) is recorded as H, which is expressed by

$$H = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}, \tag{3}$$

where f_x and f_y are related to the focal length of the camera and the size of pixels and c_x and c_y are translation distances that are related to the size of the camera imaging plane.

The process of camera calibration is the process of solving K. In order to get the relationship between the real wheel set tread in the three-dimensional coordinate and the tread image in the two-dimensional coordinate system, we must also know the external parameters of the camera. Its homography to the image plane is [14]

$$sm = A[R, t]M, \tag{4}$$

where s is the scale factor from world coordinate system to image coordinate system, R is the rotation matrix, t is the translation vector, and m is the number of pixels.

If the same camera is used to obtain n images of calibration plates under n different angles, then there are m pixels on each image. The three-dimensional point on the calibration plate corresponding to the jth image point on the ith image is represented by M_{ij}, and the following expression can be obtained:

$$\widehat{m}\left(K, R_i, t_i, M_{ij}\right) = K[R, t]M_{ij}, \tag{5}$$

where R_i is the rotation matrix of the camera corresponding to the i th image and t_i is the translation vector of the camera corresponding to the ith image.

Probability density function of m_{ij} is expressed by

$$f\left(m_{ij}\right) = \frac{1}{\sqrt{2\pi}} e^{\frac{-\left(\widehat{m}\left(K, R_i, t_i, m_{ij}\right) - m_{ij}\right)^2}{\rho^2}}. \tag{6}$$

The likelihood function is constructed that is expressed by [15]

$$L\left(K, R_i, t_i, M_{ij}\right) = \prod_{i=1}^{m} \prod_{j=1}^{n} f\left(m_{ij}\right). \tag{7}$$

the solution that makes the likelihood function obtain the maximum value is expressed as follows:

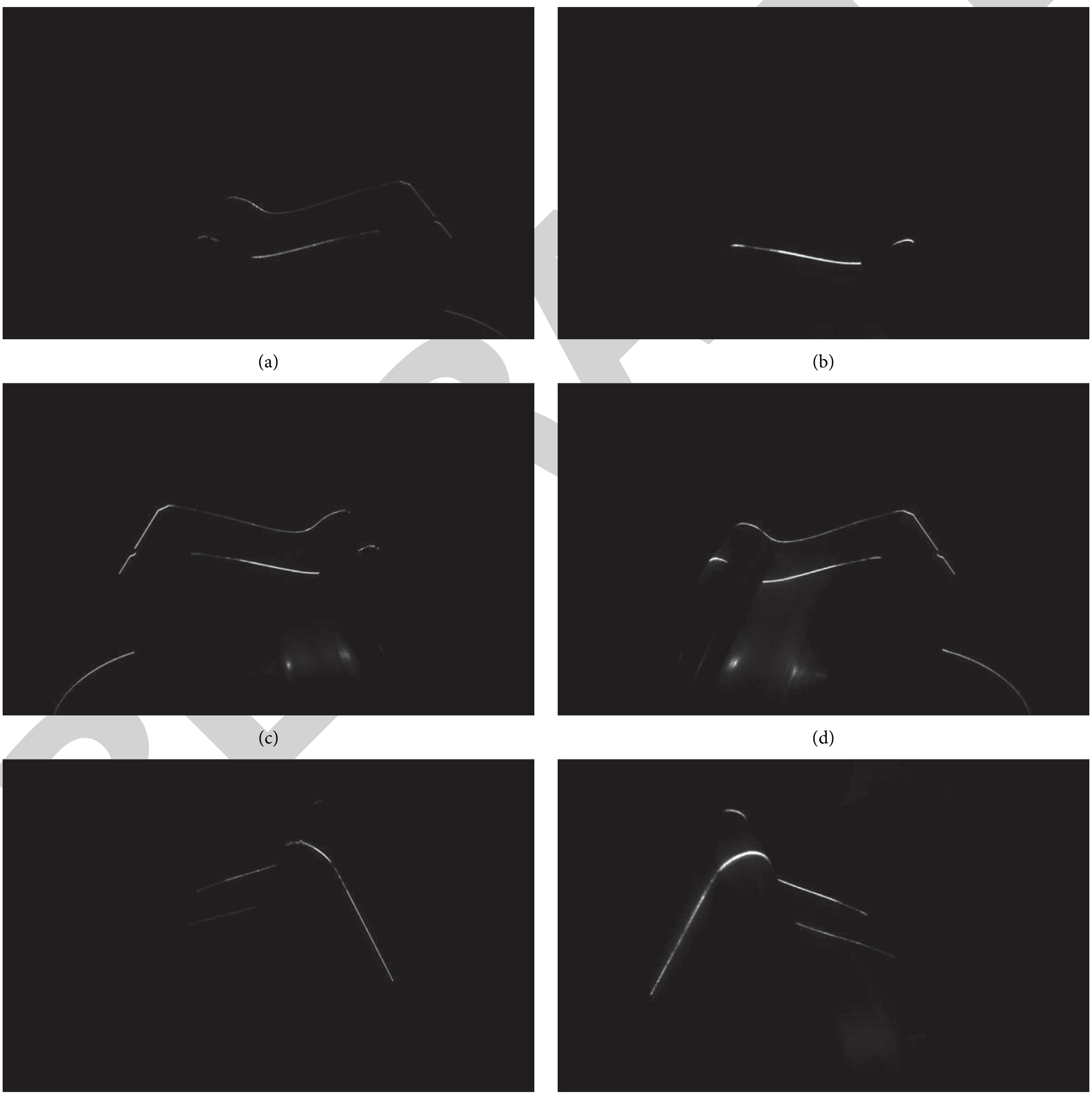
$$\sum_{i=1}^{m} \sum_{j=1}^{n} \left(\widehat{m}\left(K, R_i, t_i, M_{ij}\right) - m_{ij}\right)^2. \tag{8}$$

The solution process in this paper is a nonlinear optimization process: use the improved particle swarm algorithm, take the above solution as the initial value, substitute the solution into and complete the preset number of iterations, and finally find the optimal solution. The internal parameters of the camera are estimated by using the image coordinates, so as to complete the camera calibration.

4. Detection Case of Wheel Set Parameter

In order to verify the effectiveness of the detection system of wheel set parameters, the detection simulation analysis is carried out. According to the requirements of wheel set parameter detection indicators and combined with the

Figure 2: Diagram of CCD camera.



(a) (b) (c) (d) (e) (f)

Figure 3: Continued.

(g) (h)

Figure 3: Part of images obtained based on CCD camera for first group of wheel set.

Table 1: Main parameters of right wheel.

Number	Right rim height	Right rim thickness	Right wear right	Diameter of right wheel	Right felloe thickness	Right felloe width
1	28.34	31.76	1.14	840.08	27.5	136.13
2	28.08	31.96	1.15	840.17	27.6	136.12
3	28.24	31.81	1.12	840.14	27.6	135.93
4	28.18	31.74	1.12	840.17	27.6	136.08
5	28.36	31.77	1.1	839.99	27.5	135.85
6	28.24	31.75	1.09	840.2	27.6	136.07
7	28.38	31.94	1.12	840.57	27.8	136.02
8	28.48	31.78	1.07	840.56	27.8	135.94
9	28.16	31.76	1.12	840.01	27.5	136.02
10	28.28	32.07	1.17	840.35	27.7	136.01
11	28.42	31.86	1.11	840.64	27.8	135.92
12	28.14	31.72	1.13	840.18	27.6	135.81
13	28.17	31.93	1.09	840.18	27.6	135.79
14	28.31	31.71	1.12	840.1	27.5	136.16
15	28.44	32.1	1.12	840.46	27.7	135.95
16	28.32	31.74	1.11	839.99	27.5	136.09
17	28.38	31.82	1.19	838.11	26.6	135.82
18	28.32	31.43	1.17	839.04	27	135.87
19	28.45	31.4	1.14	838.66	26.8	135.89
20	28.3	31.87	1.15	839.99	27.5	135.82
21	28.03	31.75	1.09	840.17	27.6	136.06
22	28.49	32.02	1.12	840.29	27.6	136.04
23	28.25	31.88	1.12	840.45	27.7	135.95
24	28.32	31.75	1.05	840.01	27.5	135.9

actual situation of train vehicle wheel set detection, the progressive scanning area array CCD camera shown in Figure 2 is selected, and the type of it is JAI CM-140 GE [16].

During the collection process, the CCD camera is connected with the image acquisition card and computer and connected to the 100 m/s optical fiber network, and the camera acquisition action is controlled by software. For the above design requirements, the system selects the Helios image acquisition card made by Matrox, which uses the Inspector + MIL (Matrox Image Library) development platform, has various functions, and supports camera link communication. According to the actual situation and corresponding technical indicators, the system specially customized the semiconductor linear laser source. The light source parameters are as follows: the wavelength is 650 nm, divergence angle is 17°, rated line width is 0.5 nm, the rated voltage is 5 V, and the rated power is 50 Mw.

The wheel set image collected by the camera is an 8-bit gray image. If you want to extract the wheel set contour curve and separate the target curve from the image background, you need to segment the wheel set image. The segmented wheel set light cut curve has a certain width, which is not suitable for later parameter calculation. It must be refined to transform it into a single pixel line. For the discontinuous contour curve in some places caused by image thinning, pixel tracking search should be carried out on the image to connect the discontinuous image points to obtain a complete single pixel curve.

When the captured wheel set curve intersects the dynamic track at a point, the point is the imaging position of

Table 2: Main parameters of left wheel.

Number	Left rim height	Left rim thickness	Left wear right	Diameter of left wheel	Left felloe thickness	Left felloe width
1	28.54	31.11	0.91	840.54	27.8	0
2	28.24	30.96	0.85	840.49	27.7	0
3	28.28	31.16	0.91	840.39	27.7	0
4	28.27	30.96	0.91	840.35	27.7	0
5	28.23	30.83	0.99	840.46	27.7	135.13
6	28.26	30.59	1.15	840.76	27.9	0
7	28.27	31.18	0.9	840.92	28	0
8	28.34	31.04	0.83	840.52	27.8	0
9	28.34	31.04	0.91	840.06	27.5	0
10	28.29	30.78	0.41	840.76	27.9	0
11	28.29	31.21	0.96	841.17	28.1	0
12	28.28	31.11	0.88	840.61	27.8	0
13	28.46	31.11	0.93	840.42	27.7	0
14	28.23	31.19	0.82	840.46	27.7	0
15	28.59	30.73	0.92	841.14	28.1	135.23
16	28.16	30.59	1.16	840.47	27.7	0
17	28.3	31.41	0.92	838.34	26.7	0
18	28.1	31.16	0.97	839.42	27.2	0
19	28.19	31.5	0.93	839.07	27	0
20	28.27	31.07	0.88	840.46	27.7	0
21	28.52	30.41	1.01	840.17	27.6	0
22	28.25	31.34	0.86	840.92	28	0
23	28.53	31.08	0.88	840.46	27.7	0
24	28.35	30.6	0.36	840.77	27.9	135.25

Table 3: Comparison results of detection results.

Method	Detection time (s)	Detection precision (mm)
Traditional detection method	9.54	0.4
Proposed method in this paper	7.12	0.2

the wheel set base point. Similarly, on the other side of the wheel set curve, the dynamic trajectory of the key points on the inner side of the wheel set (the intersection of the straight line passing through the base point of the wheel set and parallel to the axle and the inner side) can also be determined. When the rim part of the light cut curve of the wheel set in the image is tangent to the connecting line between two points corresponding to a wheel diameter, the point is the rim vertex. The vertical distance between two points can be calculated by using the flange vertex coordinates and the base point coordinates. Determine the position of the base point of the wheel set in the image and then find out the intersection of the tread line of the wheel set and the rim part of the measured wheel set curve in the image. Then, the distance between the two intersections represents the image length corresponding to the rim thickness. The rim thickness of the measured wheel set can be calculated by using the geometric optics formula.

A group of wheel sets is used as research object to carry out size detection based on the proposed method. Part of images obtained based on CCD camera is shown Figure 3.

The main parameters of right and left wheels are obtained based on image are listed in Tables 1 and 2, respectively.

The measurement accuracy of metro wheel pair diameter is 0.2 mm in technical requirements. Through the statistical analysis of the test data, the root mean square error of each group of test results is less than 0.2 mm. The results of the main dimensional parameters of metro wheel set measured by the test method proposed in this paper meet the requirements of wheel set measurement accuracy, and the measurement error is within the allowable range. Therefore, the method can operate normally and measure the required main dimensional parameters. In addition, the average detection time for every group of data ranges from 6 to 8 s; therefore, the proposed detection method has higher detection efficiency.

In order to verify the effectiveness of the proposed method, the traditional detection method is used to detect the same wheel set, and the comparison results are listed in Table 3.

This proposed method can effectively detect wheel pair wear, which can get a lot of data, and has higher computing precision. This detection method can overcome the influence of environment effective based on analysis results.

5. Conclusions

The main size parameters of subway wheel set are detected based on CCD imaging technology, the corresponding image processing algorithm is designed, case study is carried out, results show that the detection precision is less than 0.2 mm, and the detection time ranges from 6 to 8 s; therefore, the proposed method can detect the size parameters of subway wheel set accurately and efficiently.

Data Availability

All data, models, and codes generated or used during the study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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