International Journal of Civil Engineering and Machinery Manufacture

Volume 4, Issue 4, December, 2019

Publisher: HongKong New Century Cultural Publishing House
Address: Unit A1, 7/F, Cheuk Nang Plaza, 250 Hennessy Road, Wanchai, Hong Kong
Tel: 00852-28150191
Fax: 00852-25445670

Contents

ISSN: 2518-0215, Volume 4, Issue 4, December, 2019

A Wheel Profile Fitting Method based on Discrete Points Weights of Wheel Tread Profile of Automatically Extracting Subsection Points

Qianyi Yu
Nanjing University of Science and Technology, Nanjing, 210094, China

Abstract: In order to better fit the contour of the wheelset tread, a method for fitting the contour of the wheel contour based on automatic segmenting by the weight of the contour point of the wheel tread was proposed. Firstly, the discrete points of the wheel tread contour were measured by the laser displacement sensor, and their weights were defined according to the importance of the scattered points. Then, the variable fitting iterative step size and error bounds were set to determine the piecewise points and the fitting function. The Lagrange multiplier method is used to solve the problem. The contour lines of each section of the wheelset tread with smooth connection can be obtained through the simulation fitting algorithm, which can be used in the fitting of the contour lines of the wheel tread with improved fitting accuracy and efficiency.

Keywords: Urban rail transit; Wheel set tread profile; Automatic piecewise fitting; Weight function; Lagrange multipliers

1. Introduction

As China's urbanization process continues to accelerate, the scale of urban rail transit continues to expand, and the speed of urban rail transit continues to increase, and the safety problem is also becoming increasingly prominent [1, 2]. Wheelset size is an important factor in representing the safety status of the wheel, and has a significant impact on vehicle related technical performance and driving safety [3]. Therefore, timely and accurate wheel pair size detection has very important practical significance. Engineering can use laser image sensor [4] or laser range finder [5] to scan the discrete points of the contour of the wheel pair, and then fit the scatter. Due to the complexity of its contours, the method of piecewise fitting [6] is generally used for fitting. In [7], a smooth element model based on the locally supported freeform parameter curve is proposed to determine the optimal value of the fitting break point. In [8], an adaptive node localization algorithm based on b-spline curve fitting is used to complete the curve fitting.

Since the measured discrete points are not the same as the "importance" of the position of the reference point, the importance of the discrete points at different distances from the reference point relative to determined the reference point's position should be different. According to this paper, a wheel-to-tread contour fitting method based on automatic segmentation of scatter weights is proposed in order to achieve a more accurate fitting of the contour of the wheelset, while shortening the fitting time and improving the fitting efficiency.

2. Wheel Pair Size Measurement Principle

The tread curve equation is obtained by curve fitting the known discrete points, and then the coordinate values of the reference points on the curve which can determine the relevant dimensions of the urban rail wheel pairs are obtained. The method of obtaining the reference point is as follows: the inner side end surface of the wheel is used as a reference surface, and a straight line (L2=70 mm) extending vertically 70 mm is made to the outer side side, and the intersection point of the straight line and the tread surface is used as the base point a, and the diameter of the wheel circle where the point a is located is Wheel pair diameter Dr. A horizontal straight line (L3=10 mm) is made from the base point position vertically upward 10 mm, and the inner side of the rim intersects the point g, and the horizontal distance from the point g to the inner side of the wheel set is the rim thickness Sd. The vertical distance between the rim apex n and the base point a is the rim height Sh. The 2mm downward line on the top of the rim has an intersection f with the inside of the rim, and the horizontal distance between point f and point g is the QR value [9].

As shown in Figure 1:

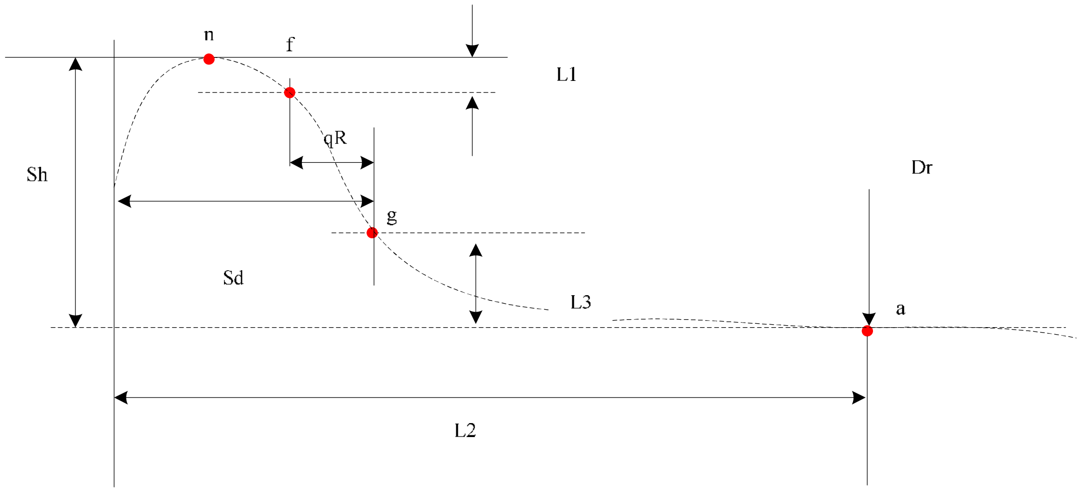

Figure 1. Schematic diagram of datum point

3. Wheelset Contour Contour Fitting Algorithm

Firstly, the weight function defines the weight of the discrete point, and then according to the set error threshold and the weight of the discrete point, the discrete points are segmented to determine the fitting segmentation point, and finally the Lagrangian multiplier method is used to solve the problem. The unknown parameters of the equation are combined to obtain a complete wheelset tread contour.

3.1. Weight function calculation

In order to achieve a more accurate fit to the wheelset contour curve, the importance of the different points is expressed, for the measured n discrete points $\{(x_1,y_1),...,(x_i,y_i),...,(x_n,y_n)\}$ .Their respective weights are defined by their relative positions from the reference point. First select the approximate position of the three reference points, and record the abscissa as: x_{b1} , x_{b2} , x_{b3} , Let the weights of the scatters in the neighborhood of length a on both sides of the three points be $w(x_i)=3$, The scatter point in the neighborhood of length b is $w(x_i)=2$, and b>a, $2\times b < x_{bm+1}-x_{bm}$, $m\in\{1,2\}$, The weight of the remaining scatter points is $w(x_i)=1$.

3.2. Determine the segmentation point

After determining the discrete point weights, determine the error threshold, starting from the left endpoint and fitting from left to right for least squares fitting [10],Each iteration of the iteration step is $s(w_i)$, $s(w_i)$ is a function of the discrete point weight, which is the sum of the point weights within the iteration step, expressed as :

$$s(w_i)=\sum_{n}^{m} w_i, i=n,n+1,...,m; \quad (1)$$

The number of fit points is n_p .At this time, the error threshold is a function of the number of fitting points and the scatter point, expressed as:

$$e(n_p,w_i)=\begin{cases} k_1 n_p, \max w_i=\{w_n,...,w_m\}=1; \\ k_2 n_p, \max w_i=\{w_n,...,w_m\}=2; \\ k_3 n_p, \max w_i=\{w_n,...,w_m\}=3; \end{cases} \quad (2)$$

Among them, k_1,k_2,k_3 is a different error constant set according to the measurement accuracy requirement. The specific segmentation method for determining the segmentation point is as follows:

Step 1: Starting from the left endpoint of the scatter, perform the first least squares fitting, $s(w_i)$ corresponds to the sum of the weights of the first point to the q1th point, Solving the normalized equations with weights, get the fitting equation $F_{D1}(x)$.

Step 2: Calculate the fitting error of this segment of the curve E_{D1}, expressed as:

$$E_{D1}=\sum_{i=1}^{q1} w_i \sum_{i=1}^{q1} |F_{D1}-y_i|; \quad (3)$$

Step 3: Compare the fitting error with the error function, if $E_{D1}< e(s)$,Then the curve is subjected to a second fitting, that is, starting from the end point of the first fitting and then iterating to the q_2 th point, At this point q_1 to q_2 is a step. The second time starts the fitting at point q_2 .Similarly, compare the size of the fitting error E_{D2} with the error function $e(s)$, if $E_{D2}< e(s)$,Then continue to increase the number of fit points. When fit-

ISSN: 2518-0215, Volume 4, Issue 4, December, 2019

ting to q_{n+1} points, if $E_{D(n+1)} > e(s)$, The fitting of the D segment ends. Otherwise, the fitting of the segment is directly ended, and D=1 is recorded. At this point, the number of points d1 is calculated. Get the first segmentation point (x_{d1}, y_{d1}) , And use this point as the starting point of the next fitting, let D=D+1, mark the segmentation point. Repeat the above steps until we find all the segmentation points $(x_{d1}, y_{d1}),...,(x_{dn}, y_{dn})$.

3.3. Data segmentation interval

After determining the segmentation point, all the discrete points of the wheel-to-tread profile of the urban rail train collected by the laser displacement sensor can be divided into n+1 segments by n segmentation points, thereby dividing the data points into n +1 group, remember m=n+1, The segmentation interval can be recorded as: $S_1, S_2,..., S_m$, Where is the number of data segments.

3.4. Fit equations for each interval

According to the segmented m data sets, the fitting equation f(x) on each data set is determined separately, and the fitting equation is selected as a polynomial form, and the form of each data set f(x) can be set as:

$$f_m(x) = \sum_{i=1}^{km} a_{mi} x_{mi}^n, (x, y) \in S_m; \quad (4)$$

Where: a is the undetermined coefficient, x^n is a linearly independent basis function, and the number of base functions and undetermined coefficients is m .

3.5. Fitting curve global continuous processing

After setting the fitting equation of each segment, e_i is used to indicate the fitting deviation at x_i , and the function S_e is the total deviation of the fitting segment. In order to make the fitting degree the best, the square sum of e_i should be as small as possible. In order to make the fitting curve of each segment smooth and continuous, there should be a constraint that the function value is equal to the first derivative at the end of the fitting curve. The mathematical model S_e is a solution to the multivariate extremum problem with a constraint condition, which is solved by the Lagrangian multiplier method [11]. Bring the solution into the fitting equation (4) to obtain a complete continuous contour of the wheel alignment.

4. Simulation Analysis

This paper uses the MATLAB programming fitting algorithm to fit the weight of the discrete points of the step as shown.

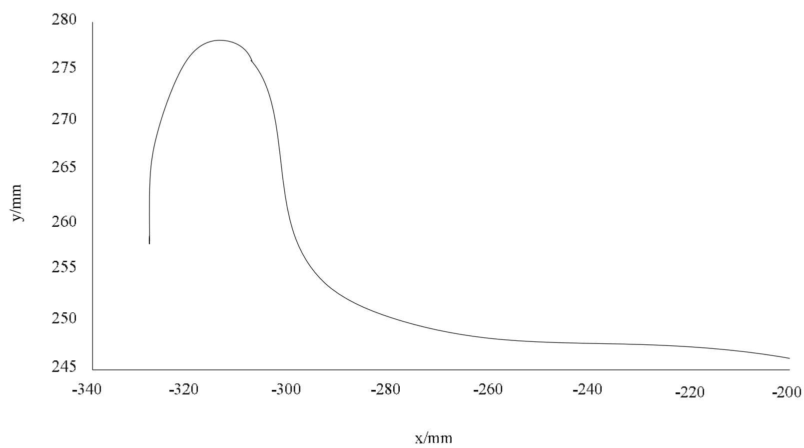

Figure 2. The algorithm in this paper fits the results

Compared with the curve fitting method of automatic segmentation, the scatter segment segmentation near the first reference point according to the method of the present invention is shown in Fig.2. The fitting result of the wheelset tread line based on the automatic extraction of segmentation points proposed in [12] is shown in Fig. 4.

According to the analysis, there are more segments in the region farther from the reference point. When there are more data points, the time is greatly increased, and the region closer to the reference point is longer, which is not conducive to improving the fitting accuracy. Use the method of this paper to obtain the segmentation point, automatically adjust the number of iteration points and the fitting threshold, take a shorter pre-measurement length near the reference point, reduce the fitting error threshold, and improve the fitting accuracy. At the same time, at a distance from the reference point, the advancement is longer and the fitting efficiency is improved.

The point measurement value of the rim segment with a large fitting error is randomly compared with the actual value. The analysis results are shown in Tab.1.

Table 1. Comparison of measured values and fitted values of data points

Data measurement value	Fitting value	Deviation size (E)
(115.022,12.988)	(115.022,13.021)	+0.033
(115.354,11.673)	(115.354,11.553)	-0.120
(117.598, 9.790)	(117.598, 9.853)	-0.063
(119.135, 7.690)	(119.135, 7.536)	-0.154
(120.237, 7.140)	(120.237, 7.207)	+0.067
(120.727, 6.484)	(120.727, 6.491)	+0.007
(122.682, 5.468)	(122.682, 5.410)	-0.058
(123.134, 5.023)	(123.134, 4.946)	-0.077
(125.604, 4.656)	(125.604, 4.634)	-0.022
(125.856, 4.605)	(125.856, 4.712)	+0.107

The maximum deviation between the fitted value and the measured value of the data is E=0.120mm, and the offset amplitude: the thickness of the rim is generally 30mm, so that the error caused by the fitting is $A = E / \sqrt{x^2 + y^2} \times 100\% = 0.104\%$, The offset error is: 0.0282mm. According to the national railway industry standard, the size error of the rim height and the rim thickness should be $\leq \pm 0.2mm$. It can be seen that the influence of the fitting error value on the measurement accuracy of the wheel pair can be neglected, and the detection requirement can be satisfactorily satisfied.

5. Conclusion

This paper introduces a wheelset tread contour fitting method based on automatic segmentation of scatter weights. By delineating the rough position of the reference point in advance, calculate the weight of the scatter in the curve fitting, and automatically adjust the iteration step and the error threshold when fitting according to the weight of the scatter, so that a complete smooth wheel can be obtained. For the tread contour, it also improves the fitting numerical accuracy and fitting efficiency of the wheel tread contour. The method can also be applied to the curve fitting of other engineering problems. As long as the weight of the data points is recalculated according to the actual problem, and the more perfect weight function is used, the related fitting problem can be better solved.

References

[1] Gao Y. Research on automatic and dynamic online measurement method of wheelset geometry. Beijing: Beijing Jiaotong University. 2014.

[2] Xie H.C. Design and research of portable metro wheel detection device based on laser sensor. Nanjing: Nanjing University of Science and Technology. 2016.

[3] Rovira, A. Roda, A. Marshall, M.B. Brunskill, H. Lewis, R. Experimental and numerical modelling of wheel–rail contact and wear.Wear. 2011, 271(5).

[4] Zhao Y. Dynamic measurement of wheelsets tread wear based on laser image. Laser and Infrared. 2012, 42(7), 743-745.

[5] Lu Y., Liu J.Z., Zhao W.J., Yang, T.T. Steady-state detecting method based on piecewise curve fitting. Journal of Instrumentation, 2012, 33(01), 194-200.

[6] Akemi G., Andrés I., Particle-based meta-model for continuous breakpoint optimization in smooth local-support curve fitting. Applied Mathematics and Computation. 2016, 275.

[7] Liu C. Research on detection technology of tread surface geometric parameters of train wheels. Changchun: Changchun University of Science and Technology. 2014.

[8] Wang L., Xing Z.Y., Chen S., Zhang Y. A wheel profile fitting method based on automatic extracting subsection points. Journal of Guangxi University (Natural Science Edition). 2017, 42(02), 618-626 .

[9] Wang L. On-line dynamic detection technology of wheelset size and research on wheel-making decision. Nanjing: Nanjing University of Science and Technology. 2017.