Arrangement and Processing Algorithm of Monitoring Sensors for Cargo Over-limit Status

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Abstract: There is a large number of large-scale freight transport demand in the railway freight transport. Because of its overweight and over large characteristics, large-scale goods in process transport have possibility to colliding facilities and equipment along the line or too close to the risk of transport. The existing technical cannot handle the railway large cargo over-limit status real-time monitoring and management. In order to solve this problem, it is proposed to use infrared distance sensor as the data collection terminal, and present a rotation displacement judgment method based on the sensor's real-time acquisition data is proposed.

1. Introduction

In order to ensure the safety of the railway transport, it is necessary to limit the horizontal size of the cars and goods running on the line[1,2]. It can prevent the railway vehicles, cargos and equipments on the line such as platforms, bridges, tunnels, signal machines, contact networks, etc.

In order to find the change of the position of the goods in the process of transport in time and avoid the adverse effects caused by it, real-time monitoring of the excess status of goods in the course of transport is a problem to be considered in the transport of goods by railway[3].In this paper, it is proposed to use infrared ranging sensor as the real-time acquisition end of the raw data of the over-limit state.

2. Sensor arrangement and correction of cargo loading position

Set two infrared distance sensors in the direction of the vehicle's horizontal center line and the vehicle's vertical center line. The four sensor numbers are S_1, S_2, S_3, S_4. Where the connection of S_1, S_2 parallel with vehicle horizontal center line, the connection of S_3, S_4 parallel with vehicle vertical center line. The four sensors measure distance from the sensor itself to cargo l_1, l_2, l_3, l_4.

The right-angle coordinate system is established with S_1, S_2 connection as the coordinate system y axis, the two sensor coordinates are $(0,b_1)$, $(0,b_2)$, and the S_3, S_4 connection as the coordinate system x-axis, two sensor coordinates are $(a_3,0)$, $(a_4,0)$, as shown in Figure 1.

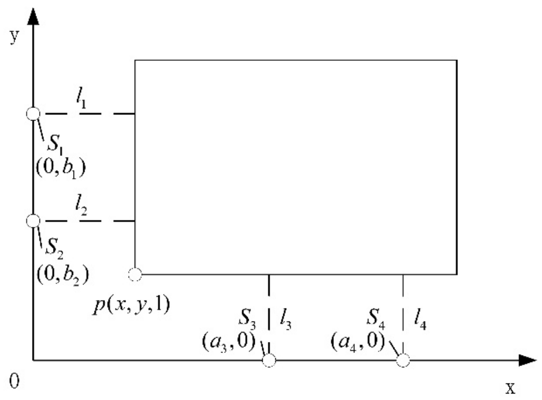

Fig. 1 Sensor layout

Set the coordinates of the calculation point before position change of the goods due to external factors be $p(x,y,1)^T$, and the coordinates of the calculated point after the location change is $p^{'}(x^{'},y^{'},1)^T$. Set the rotation displacement matrix is $R=\begin{pmatrix}\cos\Delta\theta & -\sin\Delta\theta & 0\\ \sin\Delta\theta & \cos\Delta\theta & 0\\ 0 & 0 & 1\end{pmatrix}$ and the translation matrix is $M=\begin{pmatrix}1 & 0 & \Delta x\\ 0 & 1 & \Delta y\\ 0 & 0 & 1\end{pmatrix}$. In the matrix, $\Delta\theta$ is rotation angle, with the cargo itself as the stationary reference system not considering rotation, and the goods moving distance of each point along the horizontal and vertical direction of is Δx and Δy respectively. Because the goods under the external force in the horizontal direction will produce two movements: rotation and translation, the position change before and after the calculation point coordinates of the relationship can be expressed as:

$$p^{'}=MRp$$

$$p^{'}=\begin{pmatrix}1 & 0 & \Delta x\\ 0 & 1 & \Delta y\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\cos\Delta\theta & -\sin\Delta\theta & 0\\ \sin\Delta\theta & \cos\Delta\theta & 0\\ 0 & 0 & 1\end{pmatrix}p \tag{1}$$

$$p^{'}=\begin{pmatrix}\cos\Delta\theta & -\sin\Delta\theta & \Delta x\\ \sin\Delta\theta & \cos\Delta\theta & \Delta y\\ 0 & 0 & 1\end{pmatrix}p$$

As shown in Figure 2, the angle of measuring point connection corresponding to vertical center line of vehicle before rotation of S_3 and S_4 is θ.After rotation S_3, S_4 corresponding measuring point connection and vehicle vertical center line angle is $\theta^{'}$. The rotation angle is $\Delta\theta=\theta^{'}-\theta$. After the rotation, sensor S_3, S_4 measures the distance from itself to cargo is $l_3^{'}$, $l_4^{'}$.

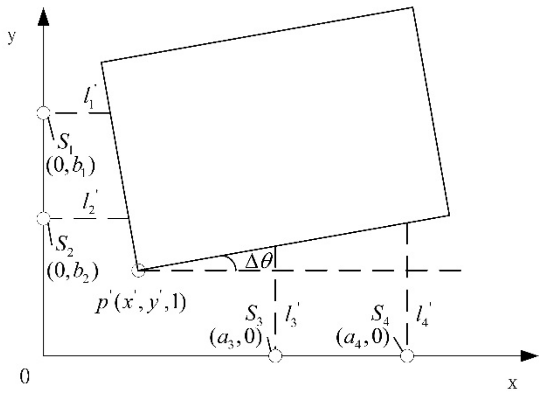

Fig. 2 Illustration after rotation

Then:

$$\begin{cases} \theta = \arctan\left(\dfrac{l_4 - l_3}{a_4 - a_3}\right) \\ \theta' = \arctan\left(\dfrac{l_4' - l_3'}{a_4 - a_3}\right) \end{cases} \tag{2}$$

$$\Delta\theta = \arctan\left(\frac{l_4' - l_3'}{a_4 - a_3}\right) - \arctan\left(\frac{l_4 - l_3}{a_4 - a_3}\right) \tag{3}$$

After calculating the rotation angle of the cargo, on this basis, calculate the cargo calculation point. After the translational movement, use the horizontal and vertical center lines of the vehicle as the reference system coordinates.

$$\begin{cases} \dfrac{\Delta x - l_1}{l_2 - l_1} = \dfrac{\Delta y - b_1}{b_2 - b_1} \\ \dfrac{\Delta x - a_3}{a_4 - a_3} = \dfrac{\Delta y - l_3}{l_4 - l_3} \end{cases}$$

$$\Rightarrow \begin{cases} \Delta x = \dfrac{l_1 - l_2}{b_2 - b_1} \cdot \dfrac{\dfrac{l_2 - l_1}{b_2 - b_1} - l_1 + a_3 - \dfrac{a_4 - a_3}{l_4 - l_3} \cdot l_3}{\dfrac{l_2 - l_1}{b_2 - b_1} - \dfrac{a_4 - a_3}{l_4 - l_3}} + \dfrac{l_1 b_2 - l_2 b_1}{b_2 - b_1} \\ \Delta y = \dfrac{\dfrac{l_2 - l_1}{b_2 - b_1} - l_1 + a_3 - \dfrac{a_4 - a_3}{l_4 - l_3} \cdot l_3}{\dfrac{l_2 - l_1}{b_2 - b_1} - \dfrac{a_4 - a_3}{l_4 - l_3}} \end{cases} \tag{4}$$

Since:

$$p^{'}=\begin{pmatrix}\cos\Delta\theta & -\sin\Delta\theta & \Delta x\\ \sin\Delta\theta & \cos\Delta\theta & \Delta y\\ 0 & 0 & 1\end{pmatrix}p$$

$$\begin{pmatrix}x^{'}\\ y^{'}\\ 1\end{pmatrix}=\begin{pmatrix}\cos\Delta\theta & -\sin\Delta\theta & \Delta x\\ \sin\Delta\theta & \cos\Delta\theta & \Delta y\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}x\\ y\\ 1\end{pmatrix} \quad (5)$$

$$\begin{cases}x^{'}=x\cos\Delta\theta-y\sin\Delta\theta+\Delta x\\ y^{'}=x\sin\Delta\theta+y\cos\Delta\theta+\Delta y\end{cases}$$

The position of the available cargo changes under external force is:

$$\begin{cases}x^{'}=x\cos\left[\arctan\left(\frac{l_4^{'}-l_3^{'}}{a_4-a_3}\right)-\arctan\left(\frac{l_4-l_3}{a_4-a_3}\right)\right]-y\sin\left[\arctan\left(\frac{l_4^{'}-l_3^{'}}{a_4-a_3}\right)-\arctan\left(\frac{l_4-l_3}{a_4-a_3}\right)\right]\\ \quad+\frac{l_1-l_2}{b_2-b_1}\cdot\frac{\frac{l_2-l_1}{b_2-b_1}-l_1+a_3-\frac{a_4-a_3}{l_4-l_3}\cdot l_3}{\frac{l_2-l_1}{b_2-b_1}-\frac{a_4-a_3}{l_4-l_3}}+\frac{l_1b_2-l_2b_1}{b_2-b_1}\\ y^{'}=x\sin\left[\arctan\left(\frac{l_4^{'}-l_3^{'}}{a_4-a_3}\right)-\arctan\left(\frac{l_4-l_3}{a_4-a_3}\right)\right]+y\cos\left[\arctan\left(\frac{l_4^{'}-l_3^{'}}{a_4-a_3}\right)-\arctan\left(\frac{l_4-l_3}{a_4-a_3}\right)\right]\\ \quad+\frac{\frac{l_2-l_1}{b_2-b_1}-l_1+a_3-\frac{a_4-a_3}{l_4-l_3}\cdot l_3}{\frac{l_2-l_1}{b_2-b_1}-\frac{a_4-a_3}{l_4-l_3}}\end{cases} \quad (6)$$

Where $y^{'}$ is included in the calculation of half-width of the actual cargo as a lateral offset caused by the change in the loading position.

3. Summary

This article is based on the practical problems encountered in the process of over-limit cargo transportation. In order to timely monitor the situation that over-limit state changes due to the displacement of the cargo caused by train during the journey. Reduce the errors and related workload caused by manual secondary measurements in traditional mid-way inspections. A real-time monitoring of the cargo using an infrared ranging sensor is proposed, and a complete algorithm for judging the overrun situation based on the monitoring data is proposed.

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References

[1] Jovanović D, Avramović Z Ž, Arsić S, et al. Safety of railway transport of dangerous cargo[J]. JTTTP-JOURNAL OF TRAFFIC AND TRANSPORT THEORY AND PRACTICE, 4(1-2).

[2] Yang Y, Zhu X. A Railway Transportation Safety Assessment Method Based on Safe State Index[C]//2015 International Conference on Electromechanical Control Technology and Transportation. Atlantis Press, 2015.

[3] Yang F, He D, Wang T, et al. The real-time safety monitoring of railway condition by FBG sensor[C]//2009 9th International Conference on Electronic Measurement & Instruments. IEEE, 2009: 2-1032-2-1035.

[4] Jicha T R, Lokken R W. Remotely operated rail car status monitor and control system: U.S. Patent 6,175,784[P]. 2001-1-16.

[5] Feng F, Guo X. Robust Overbooking Strategy of Railway Cargo Transport[M]//CICTP 2014: Safe, Smart, and Sustainable Multimodal Transportation Systems. 2014: 842-852.

[6] Kit I, Fomenko A, Vyshnia V, et al. Computer Tools for Cargo Thefts Fighting on Railway Transport[C]//2019 10th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS). IEEE, 2019, 1: 172-175.

[7] Yoon S C, Kim Y S. A Study on the Safety of Carbody for Railway Vehicles[C]//Key Engineering Materials. Trans Tech Publications, 2015, 627: 409-412.

[8] Pu L, Jiang X, Wang C, et al. Research on Railway Transportation and Loading Reinforcement of the Special Purpose Vehicle[C]//6th International Conference on Electronic, Mechanical, Information and Management Society. Atlantis Press, 2016.

[9] Ulianov C, Hyde P, Shaltout R. Railway Applications for Monitoring and Tracking Systems[M]//Sustainable Rail Transport. Springer, Cham, 2018: 77-91.

[10] Niezgoda T, Krason W. Prototype Railway Wagon with Rotatable Loading Platform and Concept of Innovative Intermodal System Usage[C]//4th International Conference on Road and Rail Infrastructure. 2017.