



Design of High Speed Railway Turnout Structural Damage Identification System Based on Machine Learning

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Abstract. In order to improve the damage detection and identification ability of high-speed railway turnout structure, a machine learning-based damage identification method for high-speed railway turnout structure is proposed, and the computer vision image analysis method is used to detect the damage of high-speed railway turnout structure. The super-linear segmentation and feature recognition of the damaged parts of high-speed railway turnout structures are realized by means of active contour detection, and the feature segmentation and localization of high-speed railway turnout structures are carried out in the damaged areas. According to the result of feature matching, the machine learning algorithm is used to identify the damage of high-speed railway turnout structure. The simulation results show that the accuracy of the proposed method for damage identification of high-speed railway turnout structure is high, and the ability of damage detection and identification of high-speed railway turnout structure is stronger than that of high-speed railway turnout structure.

Keywords: Machine learning · High speed railway · Turnout structure · Damage identification · System design

1 Introduction

In recent years, with the increasing development of railway construction in China, high-speed railway has become an inevitable trend of railway development in the future. The traditional ballastless track has the advantages of convenient laying, low cost and easy maintenance, but with the increase of train speed, the deformation of ballaststone track bed, ballastless spatter, all kinds of irregularity of track, affecting the comfort and safety of high-speed train, the traditional ballastless track has the advantages of convenient laying, low cost and easy maintenance. It also makes it difficult to maintain the track. Ballastless track has the characteristics of high smoothness, high stability and less maintenance, and has gradually gained obvious advantages in railway operation [1]. The practice shows that both kinds of track structures can ensure the safe operation of high-speed trains. However, due to the differences in technical and economic aspects between the two types of track structures, it is necessary to select the railway reasonably according to its own national conditions

in order to obtain the best technical and economic benefits. It is of great significance to study the damage identification method of turnout structure of high-speed railway [2].

The damage monitoring and identification of high-speed railway turnout structure is the basis for the maintenance of municipal bridges. Through the optimization detection and real-time identification of high-speed railway turnout structure damage, the causes of high-speed railway turnout structural damage are analyzed. It is of great significance to study the damage monitoring and identification methods for turnout structure of high-speed railway, which can promote the development of intelligent maintenance of municipal bridges. With the development of computer vision information processing technology, the computer image processing technology is used to monitor the damage of high-speed railway turnout structure, and the topological distribution structure of high-speed railway turnout structure damage is analyzed, combined with the image processing method. High-speed railway turnout structure damage monitoring, the related high-speed railway turnout structural damage identification methods have been paid great attention to [3].

In the traditional method, the manual detection method was mainly used to monitor the structural damage of high-speed railway turnout, and the intelligent machine vision method had not been widely used [4]. However, the damage identification method of high-speed railway turnout structure was studied in relevant literatures.

In view of the above-mentioned problems, this paper proposes a damage identification method of high-speed railway turnout structure based on machine learning. Firstly, the feature extraction of the high-speed railway turnout structural damage monitoring image is carried out by the fusion spatial relation transformation, and the spatial position information of the high-speed railway turnout structural damage monitoring image is sampled based on the block region segmentation technique. The super-linear segmentation and feature recognition of the damaged parts of high-speed railway turnout structures are realized with active contour detection method, and then the feature segmentation and localization of high-speed railway turnout structures are carried out in the damaged area. The feature matching and template registration are carried out in the block area of high-speed railway turnout structure image, and the damage identification of high-speed railway turnout structure is realized according to the result of feature matching. Finally, simulation experiments are carried out to show the superior performance of the proposed method in improving the damage identification ability of turnout structure of high-speed railway.

2 Image Acquisition and Feature Extraction of Spatial Position Information

2.1 Image Acquisition and Preprocessing for Structural Damage Monitoring of High-Speed Railway Turnout

In order to identify the structural damage of high-speed railway turnout, the effective feature extraction method of monitoring image, bridge damage detection and multi-level and multi-direction decomposition method are used to detect the damage of

high-speed railway turnout [5]. The spatial position location model of high speed railway turnout structure damage monitoring is constructed, the characteristic quantity of high speed railway turnout structure damage is extracted, and the profile image block feature matching technology is used to monitor the damage of high speed railway turnout structure. According to the results of regional fusion, the dynamic monitoring of high speed railway turnout structure is carried out. It is assumed that the image of high speed railway turnout structure to be identified is that the uniform point on each basis function of $f(x, y)$. The multi-profile feature decomposition technique is used to detect the damage profile of high-speed railway turnout structure in $g(x, y)$, and the block feature quantity of high-speed railway turnout structure damage is analyzed, and the sub-region segmentation technique is adopted. The template matching of high-speed railway turnout structure damage monitoring is carried out. The image to be extracted is divided into $\eta(x, y)$ topology structure, and four extraction channels for damage monitoring of high-speed railway turnout structure are set up. The multi-modal feature component of high-speed railway turnout structure damage analysis is described as $\hat{f}(x, y)$. The edge pixel feature extraction of high-speed railway turnout structure damage is carried out in the connected region of the image. The multi-level feature component estimation value $\hat{f}(x, y)$ of the image is defined as follows:

$$\hat{f}(x, y) = \begin{cases} g(x, y) - 1, & \text{if } g(x, y) - \hat{f}_{Lee}(x, y) \geq t \\ g(x, y) + 1, & \text{if } g(x, y) - \hat{f}_{Lee}(x, y) < t \\ g(x, y), & \text{else} \end{cases} \quad (1)$$

Dynamic feature matching is carried out in the center pixel distribution zone of high speed railway turnout structure damage monitoring. By using visual reconstruction method, the entropy information characteristics of high speed railway turnout structure damage are obtained as H and η , and the more information $\hat{f}(x, y)$ and $f(x, y)$ information are, the more the entropy information of high speed railway turnout structure damage is K . The stronger the information degree of high-speed railway turnout structure damage monitoring is, the closer the $\hat{f}(x, y)$ will be, and the closer the $f(x, y)$, will be to enhance the gray-scale information according to the damage intensity of high-speed railway turnout structure. The binary treatment process of high-speed railway turnout structure damage monitoring is as follows:

$$g(x, y) = h(x, y) * f(x, y) + \eta(x, y) \quad (2)$$

The feature extraction of the high-speed railway turnout structural damage monitoring image is carried out by the fusion spatial relation transformation [6], and the three-dimensional point position is obtained as follows:

$$g(x, y) = f(x, y) + \eta(x, y) \quad (3)$$

Where, $\eta(x, y)$ is the sub-band characteristic distribution set of high-speed railway turnout structure image monitoring. The image extraction results of high-speed railway turnout structure are as follows:

$$T(x_{i+m}, y_{i+n}) = \begin{cases} 1 & \text{if } r(x_{i+m}, y_{i+n}) > s \\ 0 & \text{if } r(x_{i+m}, y_{i+n}) \leq s \end{cases} \quad (4)$$

According to the analysis, the space position matching and the information feature extraction of the high-speed railway switch structure damage monitoring are carried out by adopting the block region segmentation technology, and the statistical feature quantity is extracted, so that the high-resolution identification of the high-speed railway switch structure damage monitoring image is realized.

2.2 Feature Extraction of Structural Damage Monitoring Image for High Speed Railway Turnout

The feature extraction of the high-speed railway turnout structural damage monitoring image is carried out by the fusion spatial relation transformation [7]. The multi-resolution high-speed railway turnout structural damage monitoring image is extracted by the Harris corner detection algorithm, and the local beam adjustment analysis method is used to analyze the damage of the high-speed railway turnout structure. The damage characteristics of high-speed railway turnout structure are obtained at each scale $\sigma^{(n)}(1, 2, \dots, n)$ The information entropy distribution is expressed as follows:

$$H(x, y, \sigma) = JJ^T = \begin{pmatrix} 1 + L_x^2(x, y, \sigma) & L_x(x, y, \sigma)L_y(x, y, \sigma) \\ L_x(x, y, \sigma)L_y(x, y, \sigma) & 1 + L_y^2(x, y, \sigma) \end{pmatrix} \quad (5)$$

Dense texture rendering is used as a segmented pixel for damage identification of high speed railway turnout structure, and multi-level texture segmentation of high speed railway turnout structural damage monitoring image is carried out. The output is expressed as follows:

$$\begin{cases} \frac{\partial R}{\partial x} = 2ax + cy + d = 0 \\ \frac{\partial R}{\partial y} = 2by + cx + e = 0 \end{cases} \quad (6)$$

The adaptive weighting algorithm is used to modify the contour of the high-speed railway turnout structural damage monitoring image extraction process. According to the location and orientation of the shot, the correction process is described as follows:

$$R(x, y) = x^2 + y^2 + dx + ey + f \quad (7)$$

In the search area of the maximum distortion coefficient, the sub-pixel coordinates of the damage corner (x, y) of the high-speed railway turnout structure are obtained, and the multi-resolution image information fusion processing of the damage monitoring

image of the high-speed railway turnout structure is carried out [8]. The damage feature extraction and output of high-speed railway turnout structure are obtained:

$$\begin{cases} \frac{\partial R}{\partial x} = 2x + d = 0 \\ \frac{\partial R}{\partial y} = 2y + e = 0 \end{cases} \quad (8)$$

According to the result of error analysis, the feature extraction of the high-speed railway turnout structural damage monitoring image is carried out by the fusion spatial relation transformation, and the spatial position information of the high-speed railway turnout structural damage monitoring image is sampled based on the block region segmentation technique. Locate the damage point [9].

3 Damage Identification and Optimization of Turnout Structure for High Speed Railway

3.1 Division of Damaged Parts of Turnout Structure in High-Speed Railway

Based on the feature extraction of the high-speed railway turnout structural damage monitoring image by the fusion spatial relation transformation, the computer vision image analysis method is used to detect the high-speed railway turnout structural damage [10]. The block area reconstruction model of high-speed railway turnout structural damage monitoring image is constructed, and the characteristic resolution intensity of the high-speed railway turnout structural damage monitoring image is obtained as follows:

$$\begin{aligned} I_{GSM} &= I(C^N; D^N | s^N) \\ &= \sum_{i=1}^N I(C_i; D_i | s_i) \\ &= \sum_{i=1}^N (h(D_i | s_i) - h(D_i | C_i, s_i)) \\ &= \sum_{i=1}^N (h(g_i C_i + V_i | s_i) - h(V_i)) \end{aligned} \quad (9)$$

The damage identification method of high-speed railway turnout structure based on machine learning is constructed. Considering the intensity of affine region in the image, combined with the distinguishing features of the high-speed railway turnout structure image, the three-dimensional model reconstruction is carried out. The edge scale of the damage site is obtained by the beam adjustment method of the correlation frame:

$$p(x, t) = \lim_{\Delta x \rightarrow 0} \left[\sigma \frac{u - (u + \Delta u)}{\Delta x} \right] = -\sigma \frac{\partial u(x, t)}{\partial x} \quad (10)$$

The dynamic feature analysis of high-speed railway turnout structure damage monitoring is carried out in the block area of high-speed railway turnout structure image [11]. Combined with dynamic segmentation technology, the regionalized feature segmentation of high-speed railway turnout structure damage is carried out. Get the merge set of a large number of mismatched points:

$$L(a, b_m) = \sum_{V_m \in P_{res}} \frac{|V_m|}{|V|} \log \left(\frac{|V_m|}{|V|} \right) + \sum_{V_n \in P_{true}} \frac{|V_n|}{|V|} \log \left(\frac{|V_n|}{|V|} \right) \quad (11)$$

The Harris corner of the high-speed railway turnout structure damage monitoring image is calculated, and the segmentation results of the damaged part of the high-speed railway turnout structure are obtained after removing the mismatched points [12].

3.2 Feature Matching and Damage Detection Output

Based on the active contour detection method, the super-linear segmentation and feature recognition of the damaged parts of high-speed railway turnout structure are realized. The feature segmentation and localization of the high-speed railway turnout structure are carried out in the damaged area. The segmentation function of the image is expressed as follows:

$$u(t) = \frac{1}{\sqrt{T}} \text{rect}\left(\frac{t}{T}\right) \exp\{-j[2\pi K \ln(1 - \frac{t}{t_0})]\} \quad (12)$$

Where $\text{rect}(t) = 1$, $|t| \leq 1/2$, the gray histogram is extracted in the block area of high speed railway turnout structure damage monitoring, and the multi-layer wavelet decomposition results are obtained as follows:

$$\theta(t) = 2\pi \int_{-T/2}^{t/a} \left(\frac{K}{t_0 - t'} \right) dt' = -2\pi K \ln(1 - \frac{t}{at_0}) + \theta_0 \quad (13)$$

The feature matching method is used to extract the segmentation line and contour of the damaged part of the turnout structure of high-speed railway, and the robust feature points of the image frame are obtained as follows:

$$w_{sij}(n_0 + 1) = w_{sij}(n_0) - \eta_{sij} \frac{\partial J}{\partial w_{sij}} \quad (14)$$

The feature points for image frame matching are:

$$x(n) + \sum_{k=1}^p a_k x(n-k) = \sum_{r=0}^m b_r u(n-r) \quad (15)$$

The feature matching and template registration are carried out in the block area of high-speed railway turnout structure image. According to the result of feature matching, the damage identification of high-speed railway turnout structure is realized. The realization process is described as follows.

Input: To identify the damage monitoring image of high-speed railway turnout structure y and training sample set D , and get the characteristic distribution set $\alpha^{(l)} = [\frac{1}{l}, \frac{1}{l}, \dots, \frac{1}{l}]$ of high-speed railway turnout structure damage monitoring. l is a series of damage samples of high-speed railway turnout structure.

Output: The classification function set of damage feature matching for turnout structure of high-speed railway G. Initialization parameters, self-adaptive optimization of high-speed railway turnout structure damage monitoring starting from SDF, three-dimensional spatial reconstruction and fusion space region location, adaptive optimization process of damage characteristics of high-speed railway turnout structure satisfies the convergence condition $\sum_{i=1}^n \rho_\theta(e^{(t)}) < \sum_{i=1}^n \rho_\theta(e^{(t-1)})$.

Based on the above analysis, the feature extraction of the high-speed railway turnout structure damage monitoring image is realized. According to the feature extraction result, the feature matching result is carried out and the damage identification of the high-speed railway turnout structure is realized [13].

4 Simulation Experiment and Result Analysis

In order to verify the application performance of this method in the detection and identification of high-speed railway turnout structure, the experimental analysis shows that the high-speed railway turnout structure is divided into cross-high-speed railway turnout structure and longitudinal high-speed railway turnout structure, as shown in Fig. 1.

According to different types of high-speed railway turnout structure, the sampling pixel intensity of image for damage detection of high-speed railway turnout structure is 2000, the gray value is 0.24, and the characteristic matching degree is 0.19. According to the above simulation parameters, the image sampling pixel intensity is set to 0.24, and the characteristic matching degree is 0.19. High-speed railway turnout structure detection and identification is carried out, and the results of high-speed railway turnout structure detection with detailed information are shown in Fig. 2.



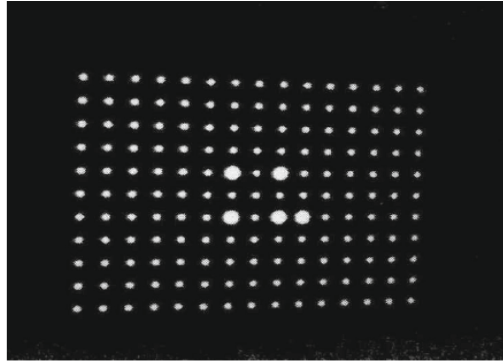
(a) Longitudinal high-speed railway turnout structure



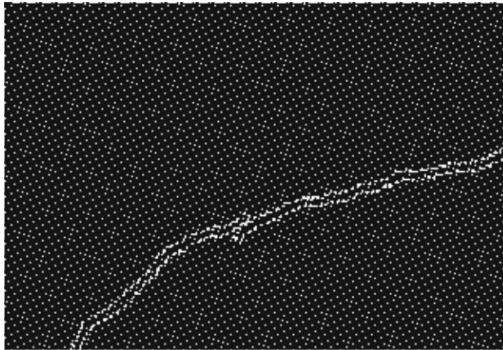
(b) Cross-high-speed railway turnout structure

Fig. 1. High-speed railway turnout structure category

According to Fig. 2, the proposed method can effectively identify the damage of high-speed railway turnout structure, the damage identification parts are continuous, and the important information of high-speed railway turnout structure can be identified. In traditional methods, only key points are identified, which is not comprehensive enough. It shows that the design method in this paper can retain more details of the image and the recognition result is more reliable. The test results of cross-high-speed railway turnout structure detection and identification are shown in Fig. 3.



(a)Traditional method



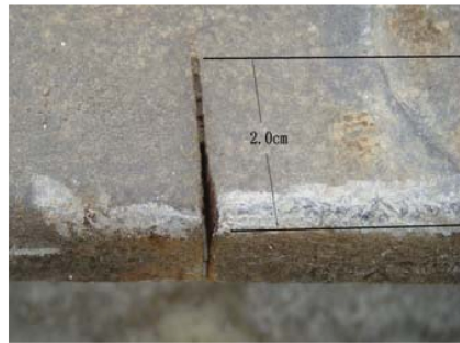
(b)Proposed method

Fig. 2. Inspection results of turnout structure in high-speed railway

Analysis of Fig. 3 shows that when the traditional method and the proposed method are used to detect the damage structure of the same high-speed railway turnout, the traditional method only detects the damage length of 1 cm, while the proposed method detects the damage length of 2 cm, which shows that the proposed method can effectively detect some hidden structural information of the high-speed railway turnout with high accuracy.



(a)Traditional method



(b)Proposed method

Fig. 3. Check and contrast results of turnout structure in cross-high-speed railway

5 Conclusions

In this paper, the computer image processing technology is used to monitor the damage of high-speed railway turnout structure, the topological distribution of the high-speed railway turnout structure damage is analyzed, and combined with the image processing method, the high-speed railway turnout structural damage monitoring is carried out. This paper presents a damage identification method for high-speed railway turnout structure based on machine learning. The computer vision image analysis method is used to detect the damage of high-speed railway turnout structure. The feature matching and formwork registration are carried out in the block area of high-speed railway turnout structure image, and the depth learning of damage monitoring of high-speed railway turnout structure is carried out considering the significance of corner point. The dividing line and contour of the damage part of high-speed railway turnout structure are extracted, and the damage identification of high-speed railway turnout structure is realized according to the result of feature matching. The results show that the accuracy of this method for damage monitoring of high-speed railway turnout

structure is high, and the identification rate of high-speed railway turnout structure is better than that of high-speed railway turnout structure.

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