Dynamic Evaluation Technology of Bridge Based on Multi-source Heterogeneous Data Fusion

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Abstract. Based on the multi-source and heterogeneous characteristics of massive state sensing data of bridges, this paper establishes a multi-source heterogeneous bridge state sensing data feature extraction and analysis method. A dynamic evaluation model of bridge technology based on multi-source heterogeneous data fusion is proposed. For the first time, the relationship between multi-source perceptual data and bridge infrastructure technology is established, the knowledge graph of bridge infrastructure technology is constructed, and the relationship between various state-aware data and bridge technology is explicitly expressed by the map. This collaborative association is used to dynamically evaluate and predict bridge technology.

1. Introduction

According to the evaluation standard of bridge technical condition in our country [1], highway maintenance and management unit should carry on the regular inspection (the general bridge regular detection frequency is 1 year), and carry on the score and the appraisal grade according to the test result. And the expressway maintenance and management unit will also accumulate a lot of data in the actual operation process, including daily inspection, regular inspection, special inspection, special inspection, structural monitoring, environmental monitoring, maintenance and maintenance data (called multi-source heterogeneous data), these data have not been used at present. On the other hand, the current evaluation standard of highway and
bridge technical condition is evaluated by combining stratified comprehensive evaluation with single index control. However, this standard does not take into account the influence of the environment, traffic load, and maintenance effect on bridge technical conditions. Therefore, the maintenance management unit urgently hopes to carry on the comprehensive dynamic evaluation of the bridge technical condition according to the multi-source heterogeneous data (also known as multi-modal data), in order to obtain the technical condition evaluation result of the short time interval (such as daily or weekly), to provide the guarantee for the bridge operation safety, and then to provide some theoretical support for the maintenance management unit to make an accurate and fast decision.

Recently, Limin Sun et al. pointed out that there is an urgent need for data fusion analysis for bridge structure monitoring Structural Health Monitoring (SHM), and deep learning, integrated learning provides a new algorithm for the extraction of structural state-sensitive features. Anomaly identification, correlation analysis, transfer learning, and other methods can provide support for bridge SHM damage identification. Xiaobin Zhu proposed a new algorithm for bridge health monitoring information clustering based on big data theory, analyzed the operation efficiency of the new algorithm, and then experimented with the bridge monitoring data. The results of clustering under different working conditions were obtained by data clustering analysis, which showed that the clustering results changed with the change of health status. Based on the improved clustering network algorithm and the influence line method of the finite element model, Naixuan Ma and others calculated the relationship between load and bridge response, and based on the data of structural safety monitoring system of Jinan No.2 Yellow River Highway Bridge, the clustering model was trained. The data mining model of bridge health monitoring is established. Pu Ren et al. proposed a platform framework for bridge health monitoring systems based on big data to monitor and evaluate the service performance of bridges in real time. Jinxiang Hou and others based on big data analysis of bridge structure health state evaluation architecture BSHE-Hadoop, solve the large-scale data storage problem, in the bridge structure damage state identification, the depth belief network as the bridge structure damage identification algorithm. Xiaojiang Luo studied the correlation of bridge health monitoring data, such as temperature and strain, strain at different measuring points and under different working conditions; studied the feature extraction methods of bridge health monitoring data, such as feature extraction method based on temperature and strain correlation, energy feature extraction method and dimensionality reduction feature extraction method. Tiancheng Liu constructed a mapping between the model and the entity, which represents the change of some concerning quantities, to achieve the effect of the model as the entity and the entity as the model. Wenrui Sun used the improved fuzzy Kohonen clustering algorithm and the benchmark finite element model of the structure to determine the theoretical threshold of identifying abnormal data. This method can accurately identify the abnormal data generated in bridge health monitoring. Based on the data mining technology and the current situation of the bridge monitoring system, Peng Zhang put forward the ability to use data mining technology to deal with large data sets to analyze bridge monitoring data. A variety of data mining models are established, which are cluster model, abnormal monitoring of bridge data and reduction of data. Siyang Qin introduced the time series analysis method into the analysis of bridge monitoring data, and put forward the application of the data processing method (ARIMA model) based on time series analysis in monitoring data analysis.

Through the above literature review, the existing researchers mainly focus on bridge structure monitoring, while the existing research is mainly to solve the problems of bridge damage identification, abnormal state identification, early warning threshold acquisition, data prediction, monitoring parameter correlation analysis, abnormal data identification and so on. At present, there is no relevant research on data fusion based on a routine inspection, regular inspection, and regular inspection to evaluate the technical status of bridges. Therefore, based on the mining and analysis of existing multi-source heterogeneous monitoring data, it is very important to establish a dynamic evaluation mechanism and model of bridge technology for multi-source heterogeneous data fusion.

2. Extraction and Feature Analysis of Perceptual Data for Multi-source Heterogeneous Bridge

Bridge infrastructure technology status sensing data has the characteristics of cross-platform, heterogeneous, and massive. There are many different display forms and data interfaces such as HTML, XML, JSON, database. Under the traction of the cognitive bridge infrastructure technology status task, the relationship of multi-source heterogeneous bridge perception data is analyzed, and the extraction and feature analysis
method of complex bridge infrastructure technology status data is established. This paper studies the unified description of complex technical data and establishes the fusion mechanism of multi-source heterogeneous data.

Considering the factors such as bridge detection data, monitoring data, environmental facility monitoring data, traffic flow data, maintenance and maintenance data and other aspects of bridge infrastructure technical condition perception data type, modal, environmental interference and data characteristics generation mechanism, statistical theory, graph theory, and function method are used to analyze the correlation characteristics between data and the internal relationship between data and state and to establish the relationship description between monitoring data and bridge technical state. Aiming at the characteristics of bridge infrastructure monitoring complex multi-source heterogeneous big data, such as longitudinal multi-scale, transverse multi-modal, structural unstructured coexistence, high noise, and high dimension. Based on the characteristics of tensor multi-linear mapping, the high-dimensional tensor data relationship analysis model and the high-dimensional tensor data unified description model are established. It is difficult to separate the information space from the noise space and to uniformly represent and reconstruct the multi-source heterogeneous data; Combined with the depth network, the characteristics and laws of the depth learning network autonomous learning based on tensor reflect the technical status of the bridge and form the technology of characterizing the technical status of the bridge infrastructure. Based on deep learning and knowledge transfer small data analysis method to explore the law of abnormal condition data, from the aspects of information volume, relationship and feature set representation ability between features, the knowledge graph of bridge infrastructure technical condition is established, and the model and algorithm are verified based on Monte Carlo method. Multi-source heterogeneous sensing data analysis planning diagram, as shown in Figure 1.

![Diagram](image)

3. **Construction of Knowledge Graph of Technical Condition of Bridge Facilities**

This paper studies the logical structure of the knowledge graph of bridge infrastructure technology and the technical structure and knowledge updating system of the knowledge graph of technical status. This paper studies the methods of knowledge extraction, knowledge fusion, knowledge representation, knowledge calculation, and knowledge evaluation of bridge infrastructure technology, and studies the construction of...
knowledge graph ontology database and the learning technology of the entity layer. This paper explores the independent reasoning rules of bridge infrastructure technology, such as entity, attribute, semantic relation, and so on, and constructs the knowledge graph of bridge infrastructure technology.

Research the logical structure of knowledge graph of bridge infrastructure, such as bridge and bridge track detection data, bridge track monitoring data, environmental facility monitoring data, traffic flow data, maintenance and maintenance data, and the technical structure and knowledge updating system of bridge infrastructure technical status knowledge base. This paper studies the methods of knowledge extraction, knowledge fusion, knowledge representation, knowledge calculation, and knowledge evaluation of bridge infrastructure technology, and studies the construction of knowledge base and learning technology of entity layer. Explore the bridge infrastructure technology status entity, attributes, semantic relations, and other levels of knowledge autonomous reasoning rules. The application platform of the knowledge base is studied to realize knowledge management and autonomous reasoning and updating. In view of the above research contents, this part mainly adopts the following research ideas:

The joint learning method of bridge infrastructure technical condition entity identification and relation extraction is established to form the knowledge expression of technical condition relation networks and from bridge infrastructure and other state entities and their relations. Build bridge infrastructure technology knowledge base ontology model layer. The mapping process (feature extraction) of bridge infrastructure technology from massive perceptual data to knowledge base is established through a deep learning networks, and the consistency description of semantic knowledge representation between the knowledge base and actual bridge infrastructure technology is realized. Considering the technical status, attributes, and semantic conflicts of bridge infrastructure, a deep fusion method of bridge infrastructure technology and its semantic knowledge is established based on deep neural network. The depth learning is used to realize the entity alignment of bridge infrastructure technology, and the entity link is realized based on tensor decomposition algorithm, and then the knowledge graph of bridge infrastructure technology is formed and stored in the graph database. Based on the distance scoring model, the knowledge graph is embedded, the link prediction of the map is completed, and the expert experience is combined to realize the update of the technical knowledge graph of bridge infrastructure. The plan is shown in Figure 2.

![Diagram](image)

**Figure 2.** Graph of bridge technical status

### 4. Construction of Dynamic Evaluation Model of Technical Condition of Bridge Facilities

This paper constructs and analyzes the correlation characteristics between massive perceptual data and bridge infrastructure technology, and establishes the dynamic mapping relationship between bridge infrastructure
technology data space and massive perceptual information space. The formation mechanism of bridge infrastructure technology is analyzed: studies the characterization model of bridge infrastructure technology status, and constructs the dynamic evaluation model of bridge infrastructure technology status.

Based on the basic information of bridge, the construction quality information during construction period, combined with daily inspection, regular inspection, special inspection, structure monitoring, environmental monitoring, and operation monitoring, and supported by the standard specification, expert knowledge, and class structure big data, combined with machine learning, This paper studies the dynamic evaluation method of bridge technical condition based on the fusion of multi-source detection information in whole life period.

The specific research scheme is as follows: first, according to the data accumulated by the experts according to the operation process, referring to the relevant specifications, with a short time interval (for example, every day or every week, Specific intervals can be adjusted), the current bridge or bridge overall evaluation, give a comprehensive score. The features of all kinds of data extracted from research content 1, including bridge type, bridge structure parameters, etc., are used as input of the deep neural network, expert scoring is used as output label of a deep neural network, and a large amount of data is used for neural network training. The trained neural network model can dynamically evaluate the bridge technical condition.

Expert scoring is subjective, and the results of different experts may be different. In order to make the scoring results more objective, multiple experts can be invited to score, and then calculate the final score according to certain rules. For example, direct average, weighted average, remove the highest score, and the lowest score re-average rules. In order to evaluate the accuracy of the neural network model, some input data were randomly selected as the test set and did not participate in the training process. The output score is compared with the corresponding expert score. The accuracy of the neural network model can be quantitatively evaluated to a certain extent.

5. Prediction of Technical Status of Multi-source and Heterogeneous Data Cooperative Bridge Facility

After the establishment of the dynamic evaluation model in the previous step, the dynamic evaluation results form temporal data, which may have a certain periodicity, and is related to the factors such as holidays, fixed inspection time and so on, and also to the evolution process of bridge infrastructure. Based on these existing data and models, it is proposed to predict the technical status of bridge infrastructure in the future.

This paper studies the artificial intelligence learning method of bridge infrastructure technology status cognition based on the knowledge graph, predicts the bridge infrastructure technology status, studies the cooperative strategy and model of multi-source heterogeneous data information, and establishes an incremental online learning network based on multi-source heterogeneous data information collaboration to realize the prediction of bridge infrastructure technology status.

The attention mechanism based on knowledge graph realizes the understanding, knowledge extraction, expression, and fusion of bridge infrastructure scenarios. The deep feature expression of heterogeneous data is studied by a multi-modal depth network. By describing the new objects in the scene and the relative relationship between the new objects and the existing objects, an online deep learning network based on features is constructed to realize the transformation of machine learning and understanding from the data layer to the semantic layer.

On the basis of the knowledge graph of bridge infrastructure technology, the powerful temporal memory and extensible input and output dimension characteristics of Path-RNN network (or LSTM network, etc.) are applied to establish the relationship reasoning model between the technical condition and characteristic law of bridge infrastructure based on Path-RNN model, and the learning strategy is established by gradient descent method. By introducing attribute recognition rules and knowledge depth expression, a deep understanding and interpretation model of technical state based on knowledge graph is established and based on deep learning and expert experience, the evolution trend of the technical condition is explored. The technical condition prediction of bridge infrastructure based on multi-source heterogeneous data is realized. As is shown in the following Figure 3.
6. Summary

In this paper, the key technology of dynamic assessment of bridge technology based on multi-source heterogeneous data fusion is studied, which focuses on the active detection of micro-variable anomalies in the early stage of a bridge, the dynamic assessment of bridge infrastructure technology, and the operation management of human-computer-environment integration. Based on the multi-modal and heterogeneous characteristics of massive state-aware data, the state-aware data analysis and processing method and the dynamic evaluation model of bridge technology are established from the point of view of data fusion analysis. This model overcomes the limitation of traditional bridge technology assessment considering single detection data. For the first time, starting with the analysis of the relationship between multi-source perceptual data and bridge infrastructure technology, the knowledge graph of bridge technology is constructed. The correlation between various state monitoring data and bridge technology is explicitly expressed. A dynamic evaluation mechanism and model of bridge technology for multi-source heterogeneous data fusion is constructed in this paper. The model is more reasonable than the evaluation method in the JTG/T H21-2011 and can provide a reference for the revision of the specification. Furthermore, it can guarantee the operation safety of highway and bridge facilities in China, and to a certain extent, it can promote the maintenance and management of bridge facilities to standardized, standardized, and scientific development.

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References:

[1] Ministry of Transport of the People's Republic of China. (2011) Standard for Assessment of Technical Condition of JTG / T H21-2011.

[2] Sun, L., Shang, L., Xia, Y. (2019) Present situation and Prospect of Bridge structure Health Monitoring under the background of big data Chinese Journal of Highway, 32(11):1-20.

[3] Zhu, X., Zhou, Y.X, Yang, J.X Yun Ma. Clustering Analysis of Bridge Monitoring Information based on
big data. (2015) Highway Traffic Technology (Applied Technology Edition), 11(04):167-169.

[4] Ma, N.X., Xu, C.C., Sun, W.R. (2019) Data Mining Model of Health Monitoring system based on improved clustering algorithm. Shan dong Traffic Technology, (03):24-28.

[5] Ren, P., Ding, Y., Li, Y.D., Liu, G. (2019) Storage and early warning methods of Bridge Health Monitoring data based on big data. Science, Technology and Engineering, 19(12):266-270.

[6] Hou, J.X. Assessment of bridge structure health status based on big data analysis. (2018) Chongqing University.

[7] Luo, X.J. Big data association analysis and mechanism research of bridge health monitoring. (2018) South China University of Technology.

[8] Liu, T.C., Cheng, Q., Liu, G. Qiu Xin Zhang. (2019) Research on Information Fusion Technology of structural Health Monitoring of Pingtang Bridge based on BIM platform. Highway, 64(09):18-22.

[9] Sun, W.R. (2014) The Establishment of Data Mining Model for Bridge Health Monitoring Based on Fuzzy kohonen Clustering Algorithm. Harbin University of Technology.

[10] Zhang, P. (2007) Data Mining of Bridge Monitoring Based on Neural Network. Chongqing University.

[11] Qin, S.Y. (2015) A Study on Monitoring Data Analysis of Small and Medium Bridge Based on Time Series Technology. Jiaotong University of Chongqing.