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Method for Storage and Early Warning of Bridge Health Detection Data Based on Big Data

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Abstract: The rapid development of science and technology has promoted the leap in bridge engineering technology. The bridge construction technology is becoming more and more mature and mature. The bridges constructed by various new materials and new technologies are emerging endlessly, and the forms and functions of bridge structures are becoming increasingly complex. Over time, after the bridge is completed and opened to traffic, any bridge will become an old bridge. After long-term use, the bridge structure will inevitably cause various damage to the structure due to various reasons, thereby reducing the safety of the bridge and even affecting vehicles safe operation, endangering people's lives. How to carry out quality inspection and safety monitoring of bridge structures has become a hotspot in academic and engineering circles at home and abroad. In order to ensure the safety of bridges and to provide early warning of dangers, this paper specifically studies the method of bridge health detection data storage and early warning based on big data. This paper obtains an appropriate method by performing a multi-factor analysis of the bridge's many attribute data, the potential correlation collapse between each attribute, and the use of appropriate regression modeling. After the data correlation analysis is completed, select the characteristic index to generate a bridge service performance evaluation model, set the optimal numerical interval of the bridge attributes, and provide real-time warning when the bridge monitoring data shows abnormal values. It is hoped that the research in this paper can contribute to bridge safety and provide reliable data basis for future bridge safety development.

1. Introduction

As early as the beginning of the twentieth century, people have realized that bridge health detection technology has a very important role. It can provide technical support to ensure the safety of construction workers during the bridge construction stage, which will have a certain guiding significance for construction progress and engineering rectification. [1-2]. During the operation phase, the degree of fatigue, tilt, and displacement changes of the prayer beam can be monitored in real time, providing a reliable source of data for bridge safety assessment [3-4]. However, since the early detection methods for bridges used relatively backward forms such as visual inspection and manual calculation, the bridge health detection technology has been limited [5-6]. In the century, with the development of civil engineering technology, a large number of large bridges can be seen everywhere in daily life, and their role has become more and more important; in order to achieve large bridges for health testing, electronic technology must be relied on to form a powerful system monitoring network real-time monitoring of bridges in all directions [7-8].

The application of electronic technology to bridge health detection is different from traditional detection technology. It performs large-capacity bridge data collection and rapid data analysis. It uses computer software and image simulation software to intelligently evaluate bridges that are detected in real time. Condition detection and assessment are carried out for bridge construction guidance and bridge operation life estimation [9-10]. The structure of the bridge and the life cycle of people have similar laws. Although they are not as thoughtful and fleshy as humans, they also go through different periods; the initial safety risks of bridges that have been completed and operated are the lowest, and the health of the bridges is the best. There will be some small problems that require frequent health inspections, and maintenance, reinforcement and improvement for specific problems [11-12]. Preventing potential safety hazards cannot be resolved in a timely manner, causing serious bridge accidents, causing losses in economic property and personal safety; it is too late to be busy with bridge health testing at the stage of serious bridge damage, just like an infectious disease patients, the remaining time can only dying [13-14]. It can be seen that from the initial stage of the bridge construction to the ageing of the bridge, the entire process of bridge health testing has been a very important task. The smooth development of this work must rely on data collection and technology for bridge health testing. [15-16].

Jun Xu discovered that the Lingte Bridge was built by Siemens in 1936 and is currently the only three-hinged steel arch bridge in China. It has been declared a historic building by the local government. The bridge is located on the busiest road across Ningbo's city center and has carried more than 70 years of passengers. Taking into account the frequent ship collisions and other damage in recent years, and the safety of the bridge, the bridge owner conducts structural inspections every year. According to the latest inspections, the Lingqiao Bridge is suffering from many serious structural problems, including local deformation and deflection of arch ribs, cracks on decks, and severe corrosion of hangers. Therefore, at the end of 2014, the bridge management department overhauled the bridge. In order to maintain the traffic flow and the cultural function of the bridge, the overhaul project is different from the general maintenance project. The current overhaul mainly involves five parts of the structure: the hinge of the arched structure, the cantilever structure of the beam, the deck system, the hanger and the arched ribs. This article discusses the evolution of the hazards of the disease and related enhancements to address the disease [17]. In order to effectively evaluate the safety and reliability of bridges, Jun Li Wang established a comprehensive evaluation model based on AHP. Use this model to calculate the weight of the evaluation index, and the experts will give a score to each evaluation index according to the actual situation, to get the safety level of the bridge. Then, the model is applied to the engineering example of Huangjiaba Bridge. The results show that the bridge safety evaluation level is three, there are practical problems, and corresponding measures are proposed, which can provide scientific basis for bridge safety management [18]. In order to evaluate the safety and comfort of high-speed multi-line railway bridge trains, S. Cui needs to conduct simulation research on the coupled vibration of multi-line railway vehicles and bridges. In order to carry out this research, a three-dimensional spatial dynamic model of CRH3 cars and trailers was established using the multibody system dynamics software SIMPACK, and the SIMPACK substructure technology was used to assemble the train dynamics model using the established CRH3 motor and trailer models. The finite element software ANSYS was used to establish a bridge dynamic analysis model to calculate its natural characteristics. Then, according to the deformation compatibility conditions and force balance conditions between the train system and the bridge system, the displacement and force data transmission of the wheel-rail contact surface was performed. Based on the joint simulation of SIMPACK and ANSYS, the multi-line vehicle-bridge coupled vibration simulation was performed for the first time. At the same time, the dynamic index of bridge, comfort index and safety index of train were analyzed, and the general law and influence of coupled vibration on vibration were discussed [19]. Lv found that accurate and timely traffic flow information is critical to the successful deployment of intelligent transportation systems. In the past few years, traffic data has exploded, and we have truly entered the era of big data in transportation. The existing traffic flow prediction methods mainly use shallow traffic prediction models, and are still unsatisfactory for many practical applications. This situation inspired us to rethink the traffic flow prediction problem based on a deep architecture model with large traffic data. This paper proposes a new method of traffic flow prediction based on deep learning, which inherently considers the spatiotemporal correlation. Stacked autoencoder models are used to learn general traffic flow features and are trained in a greedy layered manner. To the best of our knowledge, this is the first time a deep architecture model has been applied using an autoencoder as a building block to represent traffic flow characteristics for prediction. In addition, experiments show that the proposed traffic flow prediction method has superior performance [20].

This paper analyzes that each bridge can have several spans, and spans consist of several beams. The spans and beams are the main components of the bridge. According to the division of the main components, the basic information management function of the bridge includes the management of the basic information of the bridge, the management of the basic information across, and the management of the basic information of the beam. In order to ensure the safety of the bridge, early warning of damage can be made.

2. Proposed Method

2.1. Causes of Bridge Damage

With the development of the country, China's traffic situation has been continuously improved. The total number of bridges and the total mileage are increasing. Highway bridges across the country reach tens of millions of meters. Many of these bridges have hidden safety hazards. For example, more than 10,000 dangerous bridges have been detected in highway bridges, accounting for 3.45% of the total. Of these, nearly 10,000 dangerous bridges belong to the fifth category of dangerous state bridges, some important components are severely damaged, the bearing capacity of the bridge is significantly reduced and it directly endangers bridge safety. "The reasons for the above are mainly the following eight aspects:

(1) The design load standard is low and the bearing capacity is insufficient. Most of the bridges built in the early years, especially those built in the 1960s and 1970s, had low design loads. Their carrying capacity is determined according to the load level used in the design. With the increase of traffic volume and the increase of load levels, the original bridges can no longer meet the needs of modern traffic, and some bridges have even suffered serious diseases.

(2) Inadequate capacity. Insufficient design of bridge deck width, linear standards of bridge plane and longitudinal profile are too low, and there is insufficient headroom to open and under the bridge.

(3) Structural damage caused by natural and human factors. For example, mudslides, ice floes, floods, freezing, strong winds, earthquakes, ship collisions, sunshine, etc., improper excavation of river channels, mine tunnels and karsts under bridge foundations, etc., cause local damage to bridge structures.

(4) Natural aging. There is an objective law that cannot be changed and ignored, that is, the

design life of early highway bridges is generally 50 years. However, as time goes by, the built bridges will continue to be damaged and aged, and their stiffness, ductility, bearing capacity and stability will continue decline.

(5) Extended service. It is mainly because of the earlier construction period, such as bridges built in the 1950s and 1960s. There are not many such bridges, and the design service life is only 30-50 years, but there are still some in use.

(6) Overloaded use. With the deepening of China's reform and opening up and the continuous improvement of the economic level, the use of bridges has greatly exceeded expectations. According to the expected design, their design load level is not low, but due to some special reasons, the bridge use load greatly exceeds the expected design load, which causes the bridge to be in a state of excessive heavy load for a long time, which accelerates the bridge damage.

(7) Innate shortcomings in design and construction. Some bridges are not very reasonable in design and structural structure treatment. Some bridges have certain technical defects due to the influence and limitation of construction quality, technology, and methods. With the increase of operating time, their diseases gradually show, develop, expand.

(8) Improper maintenance and reinforcement measures. Unfortunately, some bridge damage was caused by improper maintenance.

No matter what causes the damage to the bridge, the end result is that there are a large number of bridges with hidden dangers in operation. These bridges all require regular inspection or long-term monitoring, and other large bridges in use and bridges with relatively large traffic must be regularly inspected or long-term monitored as required. However, due to the immature bridge inspection and monitoring technology and the high cost hindering the in-depth development of bridge health monitoring, some bridges that should be monitored for a long time have not been monitored for a long time, and some bridges that require regular testing are obviously not frequent enough.

2.2. Deficiencies under Big Data

(1) Insufficient professional talents

With the continuous development of big data technology, the Internet environment and structure are more complicated, and the high integration of computer technology and network technology is required to improve the speed and quality of information data processing. In this context, the industry needs a large number of specialized, high-quality, innovative talents. But at present, there is a serious shortage of talents in related fields in China, and it takes a lot of time and resources to cultivate professional talents, which leads to a shortage of market talents. Therefore, in order to meet the demand for talents in the era of big data, relevant departments and colleges and universities need to increase personnel training, actively change the thinking model of talent training, focus on the comprehensive training of technical and management talents, and focus on strengthening professional education. At the same time, in the training of talents, colleges and universities should also focus on strengthening ideological education and cultivating students' spirit of hard work, innovation, and experimentation.

(2) Security defects

In the context of big data, whether it is work or study, people are more dependent on computers. More people use computers to store and transfer important documents, data, photos, and contracts. The office has basically become paperless, reducing resources. At the same time of waste and environmental pollution, work and study can be carried out more conveniently. Although computers provide people with many conveniences, they also provide a space for criminals to commit crimes. Some criminals use advanced computer technologies to attack users' computers in various ways, including phishing websites, Trojans, and viruses, to steal users. Account password and basic information, if users lack security awareness, they will suffer severe economic losses. Therefore, in order to better resist hacking attacks, users need to improve their security awareness and regularly disinfect their computers. China must also introduce corresponding protection laws to effectively maintain the normal order of the network.

(3) More false data

With the vigorous development of information technology, huge amounts of data are generated every day. Through big data analysis, it can provide important references for enterprise development and government decision-making. However, among a large amount of data, a lot of data is false information. If the data is discriminated one by one, it will not only consume a lot of resources, but also have no operability.

2.3. Main Methods of Bridge Health Monitoring

(1) Environmental vibration monitoring

The characteristics of the bridge during service life are repeatable and stable, such as the main frequency of the bridge vibration and the damping value. During the service of the bridge, all components should follow the design performance characteristics expected. By analyzing the time-history physical values, such as acceleration data, velocity data or displacement data, generated by the collected bridges under the effect of external excitation. Using the above data, the vibration frequency analysis method and modal parameter analysis method are generally used, based on the HHT vibration component identification method. The main frequency analysis method of vibration generally uses discrete Fourier transform to perform frequency spectrum transformation, convert time-domain data to frequency data, and use the peak characteristics of frequency-domain data to extract each peak. The peak corresponds to the main frequency of bridge vibration. The modal parameter analysis method analyzes the characteristic values unique to the structure. Each mode represents the natural vibration characteristics of the structure. The characteristic frequency, damping ratio, and modal shape of each mode are in the case of no damage to the structure. It is stable. By analyzing the changes of each mode and each mode, the health status of the bridge and its main components can be judged. The HHT vibration component recognition method is a method for processing non-stationary signal data. It consists of two parts. The first part is empirical mode decomposition and the second part is Hilbert spectrum analysis. Low-level stripping is automatically carried out layer by layer. It does not need to set analytical parameters. It can automatically strip according to the characteristics of the peak and wave bottom, especially for data processing of non-stationary signals. It has a good application for low-frequency drift terms. It can adaptively extract the frequency components in the signal.

(2) Deflection and displacement monitoring

Under different loads, the bridge will produce the corresponding deflection or displacement. The allowable deflection and displacement of the design can be calculated through the design data and structural model and prepared by the finite element method. Since the bridge deflection and displacement are the more direct manifestations of the bridge under load, the bridge's deflection and displacement under different loads can be used to quantitatively assess the bridge's health. However, the monitoring of deflection and displacement is often limited by the current equipment and the surrounding environment of the bridge, and it is difficult to directly measure or achieve the measurement accuracy required for evaluation. At present, there are four main types of measuring tools: displacement meters based on acceleration integration, laser displacement meters, and resistance type displacement meters based on vertical strain. The acceleration-integrated displacement meter uses acceleration for secondary integration. When measuring the dynamic deflection of small and medium bridges, it will be more severely disturbed by low-frequency signals, resulting in inaccurate or uncalculated detection results. It is rarely used in actual detection. But because it has certain application value, because the acceleration can also be used for the stiffness detection of the structure, if it can also be used to calculate the deflection, you can combine 2 functions in one. The related calculation methods and sensors are the hot areas of current research. The laser displacement meter is suitable for bridge deflection and displacement measurement where the platform can be built below, but it cannot be used for long-term measurement, because the platform at the bottom may be subject to temperature changes, and it cannot keep the platform absolutely motionless. There is a non-linear trend term, and lasers have high requirements on the measurement surface. For example, when measuring bridges in concrete structures, due to the unevenness of the concrete surface, certain errors will also be brought. Resistive displacement meters based on vertical strain have higher measurement accuracy and can measure the static deflection or displacement of the bridge, but they have higher requirements on the environment around the bridge, because they also need a fixed reference bracket, such as a high bridge clearance or there are river channels under the bridge, making it impossible to use a resistance displacement meter.

(3) Stress and strain monitoring

Stress is a direct expression of the bearing capacity of the bridge. In order to understand the stress distribution of the entire bridge and its main components, the strain can be directly measured according to the formula and converted into stress according to the formula to evaluate the bearing capacity of the bridge. Generally, the strain gage is installed on the surface of the main component of the monitoring bridge in the project. The installation process of the strain gage is tedious, and it needs to be polished, clear, glued, and welded. Bridge load tests need to install strain gauges at various measuring points, so strain detection and monitoring is one of the common methods of bridge health monitoring. Strain gauges are generally divided into two categories: differential resistance strain gauges, and string strain gauges. Strain gauges need to be connected to a dynamic strain acquisition instrument to collect dynamic strains. This is very important for studying the stress distribution of the bridge and its main components under the entire dynamic load. Business personnel can simulate the calculation results and actual detection in advance. The results are compared to assess the health of the bridge and its major components.

(4) Fatigue assessment

Fatigue assessment methods are usually very important for steel bridges. Fatigue failure of steel structures is the most important form of failure. The fatigue assessment process is generally very difficult, especially the fatigue assessment of materials is very complicated. At present, there are many factors that affect the fatigue strength of materials. It is difficult to give quantitative assessment methods for many factors so far. Therefore, it is difficult to accurately qualitative assess the materials in actual operation. The fatigue assessment of bridges and their main components needs to be built on a more reasonable structural system model, and fatigue reliability analysis needs to be performed from two perspectives, one is the fatigue reliability analysis of structural elements, and the other is the fatigue reliability of the two structural system. The fatigue reliability analysis of structural elements usually uses fatigue cumulative damage model, residual strength model, and fatigue life model for analysis. Fatigue reliability analysis of structural systems usually requires structural system model modeling, failure mode enumeration, calculation of the failure probability of a single failure mode, and finally comprehensive calculation of the failure probability of the entire structural system.

(5) Load transfer

When the bearing capacity of the bridge is reduced or reaches the design limit, the load often damages the bridge's transmission members, such as the joints of the plate beam. Once the joints are damaged, the load transmission capacity is gradually lost, and the hinge function fails. This in turn causes a stress on the veneer. Under the action of overloaded vehicles, it is easy to cause the main components of the bridge to crack or break. Therefore, it is necessary to be able to evaluate whether the bridge and its main components are intact, such as continuous monitoring and observation of the bridge, such as the evaluation and monitoring of the joint transmission performance of the plate beam structure. If the hinge joint is difficult to achieve the expected transmission effect, the opposite distribution of the deflections on both sides of the hinge joint has no correlation, and the reinforcement scheme should be implemented immediately.

(6) Material properties

In many cases, due to the use of materials, the actual performance of the bridge and its main components differs greatly from expected. The main reason may be the inaccuracy of the performance parameters of the materials or the existence of information errors, and the stability of the materials has deteriorated over time. Material degradation mostly occurs in bridges of concrete structures. In extremely adverse environments, large differences may occur. The measurement method of concrete materials is relatively simple. The rebound material can be used to measure the quality of concrete materials. Under normal circumstances, due to manufacturing, man-made factors and other factors, steel bridges may have local quality unevenness, which will become the weak point of the steel structure, and the weak point will become the first and most vulnerable place. Due to the convenient construction of the slab beam structure, Shanghai used a large number of hollow slab beams in the bridge construction in the 1980s and 1990s. The slab beam is prefabricated in advance by the factory, which can greatly reduce the problem of uneven quality of the cast-in-situ slab beams at the construction site, but there are some prestressed hollow slab beams that may have cracks before leaving the factory. The generation of cracks may be a material problem, and it may be caused by other issues that cannot be fully managed.

2.4. Main Contents of Bridge Health Inspection

According to the goal of bridge structure inspection, bridge inspection can also be divided into local inspection and overall inspection. The overall detection method is to evaluate the overall condition of the bridge structure by measuring the overall frequency of the bridge structure, such as the vibration frequency, deformation, and shape of the structure; the local detection method is to use non-destructive testing technology. Figure 1 is a diagram of the entire bridge health monitoring system.

Local inspection mainly includes two methods, namely, empirical visual inspection and non-destructive inspection technology. Early non-destructive testing technologies mainly include penetration tests, magnetic experiments, eddy current instruments, and ultrasonic tests. Since the beginning of the new century, non-destructive testing technology has made great progress, and fiber optics, optical interference, holography, infrared detection, natural potential detection, shock echo detection, radio imaging, gamma or X-ray detection, neutron radiography, and scattering have appeared. Pulse radar and other technologies. Local damage detection is mainly the detection of cracks, stresses, and deterioration.

The overall detection is mainly the detection of bridge deflection, displacement, vibration frequency and acceleration. Bridge deflection is the vertical displacement of the center of the bridge cross-section perpendicular to the axis of the bridge. After the bridge is put into operation, the deflection changes due to changes in temperature and humidity, natural aging of the bridge and loading of heavy objects. The magnitude of the deflection can reflect the overall stiffness of the bridge structure and is an important basis for evaluating the safety of the bridge. The healthy bridge deflection change range is within the safe range, and when the deflection changes caused by a certain excitation source, the deflection value can be restored after the excitation source is cancelled.

For example, under the condition that the objective conditions remain unchanged, if the deflection value of the bridge is 1v under no load, and the deflection becomes 2v after adding a certain load, then the deflection value of a healthy bridge should fall to 1v after the load is removed. Bridge deflection is a key parameter that reflects the overall health of the bridge. You can evaluate whether the stiffness of the bridge structure meets safety requirements by measuring static and dynamic deflections. Therefore, deflection can reflect the overall health of the bridge and is an important indicator for evaluating bridge health.

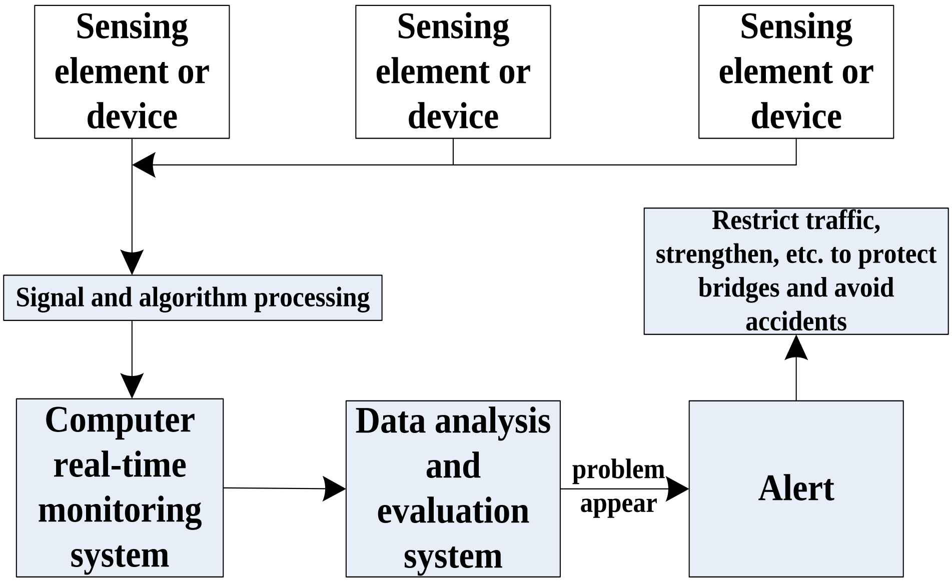

Figure 1. Bridge health monitoring system diagram

2.5. Bridge Health Big Data Distributed Processing Method

By analyzing the current application status and existing problems of big data in bridge engineering, a method for distributed processing of big data for bridge health is proposed to overcome the shortcomings of bridge health monitoring systems in a traditional centralized environment. The distributed processing method for bridge health big data should have sufficient scalability and flexible configuration. The expansion can improve the processing capacity of bridge health big data. The method for distributed processing of bridge health big data includes the storage capacity of bridge health big data. The ability to analyze and calculate big data on bridge health.

As shown in Figure 2, the distributed processing of bridge health big data consists of the smallest processing units. The minimum processing unit consists of a control management section, a file management group, and a computing group. The file management group consists of multiple file management nodes, and the computing group consists of multiple computing nodes. The control node is responsible for receiving bridge health big data, allocating physical storage space for bridge health big data, encoding bridge health big data, registering bridge health big data, accepting calculation results files for bridge health big data, bridge health big data. The allocation of the physical storage space of the calculation result file, the encoding of the calculation result file of the bridge health big data, the registration of the calculation result file of the bridge health big data, and the management of the basic information of each node. Each file management node is responsible for the management of bridge health big data, the management of bridge health big data calculation result files, and the management of basic information of file management nodes. Each computing node is responsible for querying the bridge health big data to be calculated tasks, reading bridge health big data, computing bridge health big data, submitting bridge health big data calculation result files, and managing the basic information of computing nodes. According to the business volume of the bridge health big data, the processing capacity of the bridge health big data with the smallest processing unit can be dynamically adjusted through the number of configuration file nodes and the format of the computing nodes, and the entire bridge can be dynamically adjusted by adding or removing the minimum processing unit processing power of healthy big data.

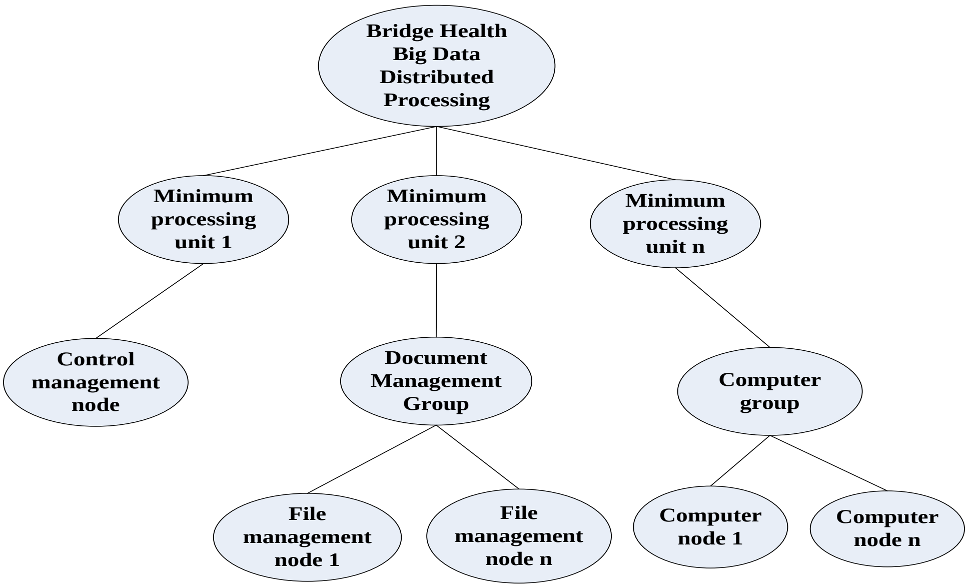

Figure 2. Bridge health big data distributed processing composition

3. Experiments

3.1. Test Object

Bridge health test data is an important reference for bridge safety management. Each bridge can consist of several spans, and spans consist of several beams. The spans and beams are the main components of the bridge. According to the division of the main components, the basic information management function of the bridge includes the management of the basic information of the bridge, the management of the basic information across, and the management of the basic information of the beam. The functional requirements of the management of bridge basic information are that bridge safety managers can add, modify, query, and delete their basic information through the management of bridge basic information. The basic information of the bridge needs to include the bridge's safety management unit and the structure of the bridge. Type, name of the bridge, bridge identification number, physical coordinates of the bridge, rating grade of the bridge, total number of spans contained in the bridge, design level of the bridge load, time of completion of bridge construction, and total load capacity of the bridge. Storage and analysis of bridge health inspection data is performed through big data to ensure bridge safety.

3.2. Design and Implementation of Experiments

Multi-factor analysis of the bridge's many attribute data, mining the implicit correlation between each attribute, and then using regression model fitting calculation to obtain the fitting method. After the data correlation analysis is completed, the characteristic indicators are selected to build a bridge service performance evaluation model, and a reasonable numerical interval of the bridge attributes is set, and real-time warning is given when abnormal values appear in the bridge monitoring data.

(1) Determine the correlation between bridge attributes.

First of all, the data is preliminary analyzed, and some descriptive parameters such as the mean and variance of numerical data are analyzed, and then graphical display is performed to initially understand the law of the data.

(2) Establishing a regression model of associated attributes.

This part mainly uses regression methods to fit the data, and compares the fit of multiple methods. When performing data regression analysis, it is necessary to consider the "overfitting" and "underfitting" of the regression. "In regression" underfitting ", we need to adjust parameters and other methods to improve the degree of fit. At the same time, we need to conduct in-depth analysis of the data to find the most suitable method for regression fitting of the data.

(3) Establish service performance evaluation model and early warning model. The first is the evaluation of service performance. In the analysis of the data, it is necessary to consider the use time of the bridge. The load capacity of the bridge to various temperatures and pressures is the strongest in the early stage of construction, but the bridge will be damaged after long-term use. The deflection regression model of multi-factor analysis can also be combined to verify whether the deflection data conforms to the regression model. If there is a large deviation, it indicates that the bridge is abnormal.

4. Discussion

4.1. Yellow Warning Threshold for Natural Frequency

Analyze the characteristics of the bridge's natural vibration frequency affected by temperature changes, take the monitoring value of the temperature sensor T2 at the top of the box girder in the main span as the representative temperature value, select two days with a large difference in average temperature throughout the day as samples, and analyze the frequency affected by temperature. They were April 1 (average temperature throughout the day at 16 ° C) and June 1 (average temperature throughout the day at 23 ° C). The statistical analysis of the whole-day average value of the frequency of vertical bending at each step. The temperature change of the first-order frequency throughout the day is shown in Figure 3. It can be seen from the figure that the first-order frequency is affected by the natural environment and fluctuates within a small range. .

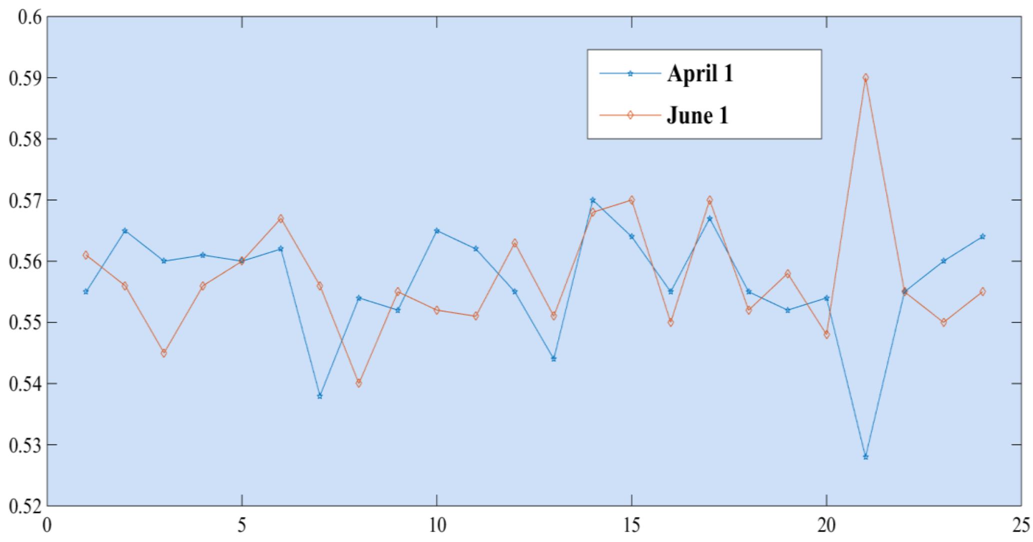

Figure 3. First-order frequency

4.2. Yellow Warning Threshold for Natural Frequency

According to Fig. 4, the day-to-day natural frequency fluctuation range of the bridge under normal operating conditions is ±4% of the average value, and ±4% of the average value is selected as the upper and lower limits of the natural frequency monitoring and early warning threshold. Vibration frequency yellow warning threshold is shown. Bridge health assessment methods often compare actual tests with design values to determine the bridge's health. This brings another problem, that is, the performance status of the bridge during service depends not only on the bridge's design standards and design ideas, but also on the materials used in the bridge construction and the construction quality. Therefore, the design value is used as the threshold for the judgment. In the process of actual use, it brings a lot of confusion to the actual work of the bridge safety manager. The criteria for health assessment and the starting conditions for early warning become an indeterminable problem, as shown in Table 1. It is difficult to judge the use of design values to bring about practical application effects.

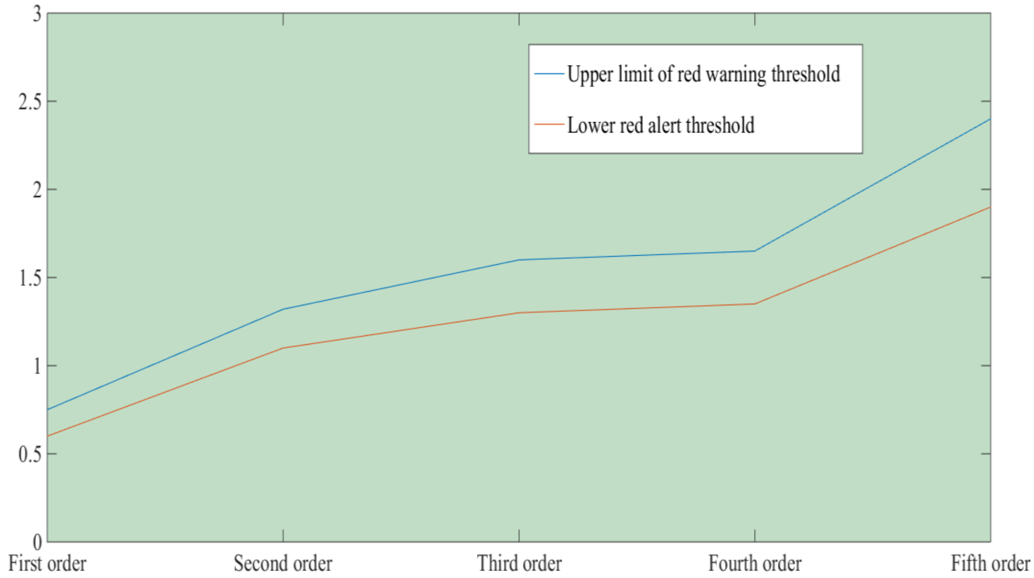

Figure 4. Red warning threshold for natural frequency

Table 1. Standard for bridge natural frequency evaluation

Evaluation standard value	Rating scale
⩾1.10	First level
[1.0,1.1)	Secondary
[0.9.1.0)	Third grade
[0.75,0.9)	Fourth grade
<0.75	Fifth grade

4.3. Data Preprocessing

Of the bridge health monitoring data, data that obviously does not meet the statistical law of the overall monitoring data or that the sensor monitoring data exceeds the sensor range is considered abnormal data, which usually exceeds the bridge sensor monitoring range and appears as outliers. The graph shows a rising or falling step by step, beyond the sensor monitoring range, and then suddenly returns to normal. In this monitoring system, there are many abnormal values in the strain monitoring project. As shown in Figure 5, there is abnormal data in the temperature measurement of the strain measurement point. The existence of such data not only makes the early warning system trigger by mistake, but also has a very disturbing effect on later damage identification and safety assessment. Therefore, it is necessary to identify and replace such data reasonably.

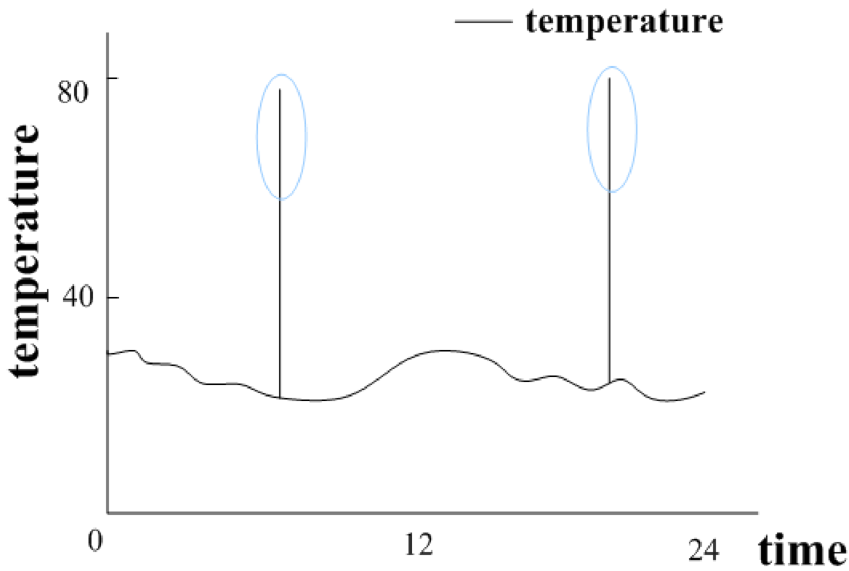

Figure 5. Strain measuring point temperature abnormal value

4.4. Strain Test Results

As can be seen from the test span strain test results in Figure 6, under the action of the test bridge, the measured strains are less than the calculated strains, and the strain check coefficient is between 0.115 and 0.95. The maximum strain check coefficient is 0.95. The requirements of the strain check coefficient in the "Measures for Highway Bridge Bearing Capacity Testing and Evaluation" are not greater than 1, but the check coefficient is large and the safety reserve is low.

Kang's judgment is divided into two states, they are the monitoring threshold initialization state and the monitoring stage. The initial state of the monitoring threshold is generated based on the healthy fingerprint, and the current healthy fingerprint is set as the threshold for health evaluation. The monitoring phase is based on a 10% difference between the current health fingerprint and the threshold, that is, a certain frequency in the current health fingerprint is less than 90% of the corresponding threshold. Be alert. In order to prevent repeated warnings, the monitoring threshold is initialized again. After initialization through the monitoring threshold, it enters the monitoring stage again. As shown in Table 2, the bridge's health fingerprint and its health status judgment threshold, the threshold value is 90% of the corresponding main frequency value. When any of the main frequencies in the current measurement is less than the evaluation threshold, the bridge is considered to be major health abnormalities.

Table 2. Threshold table for judging the health fingerprint of a bridge

Frequency order	Frequency (Hz)	Judging threshold (Hz)
1	5	4.5
2	9	7.5
3	12	11

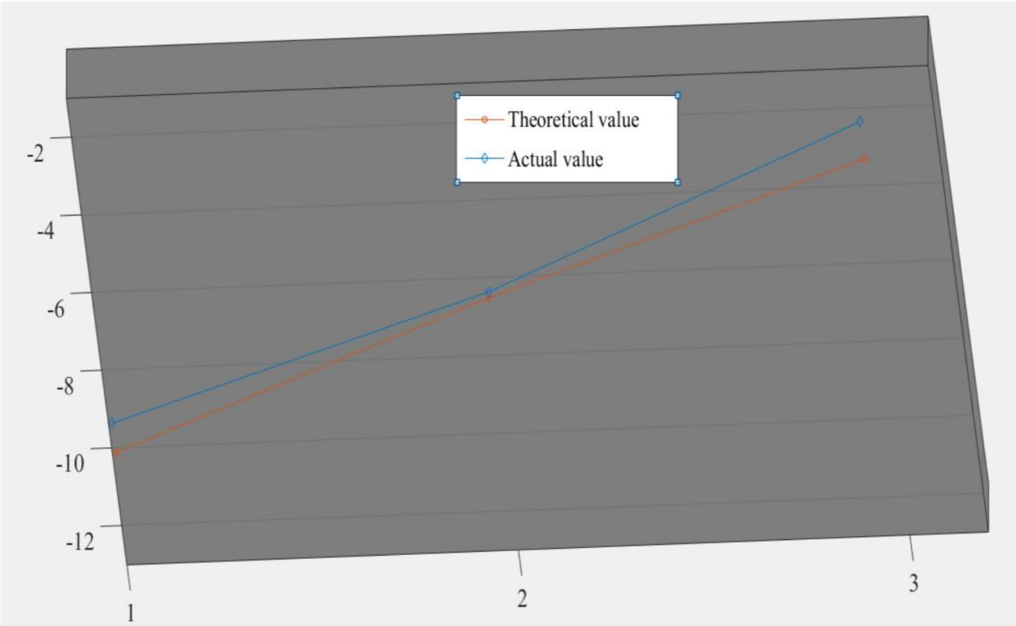

Figure 6. Comparison between the measured curve and the theoretical curve of the eccentric load deflection measurement point in the static load test

5. Conclusion

China is a large bridge country. The occurrence of bridge accidents has caused major national economic losses, and it has also seriously threatened people's lives and property. In recent years, the bridge health inspection has been highly valued by the state, and it has also given great support to the research and implementation of bridge data acquisition systems and technologies. Because the bridge health condition detection requires a continuous and long-term real-time monitoring, it is difficult to predict the time and space of the occurrence of the strain problem, and it is random in time and space. Therefore, the research on the bridge health inspection data collection system and its technology has important practical significance; in the bridge health inspection work, comprehensively affect the bridge geometry, structural section stress, cable force, prestress, load, structural strength, etc. Data collection from all aspects of measurement, real-time grasp of the bridge operation status, requires us to continuously accumulate experience starting from a single measurement of a single measurement, starting from the bridge verification work.

This article is mainly from the perspective of bridge health detection, according to the types of bridge, internal structure, environmental factors, etc., the sensors used for bridge detection are selected, and the factors that affect the bridge's strain are introduced accordingly. Then, a regression method is used to calculate the fitting method. Based on this, bridge data is collected and related technologies are specifically designed and tested. Finally, the obtained technology is applied to the bridge inspection site. After the data correlation analysis is completed, the characteristic indicators are selected to build a bridge service performance evaluation model, and a reasonable numerical interval of the bridge attributes is set, and real-time warning is given when abnormal values appear in the bridge monitoring data.

It is hoped that the research in this paper can make the bridge structure safety monitoring system more complete, cheaper, and richer in function. The research and application analysis of the structure safety monitoring system is also more important as a research topic. According to the actual situation in China, for different types of long-span bridges, establish a bridge structure safety monitoring and early warning system, evaluate the current health status of the bridge through appropriate bridge health status assessment methods, and formulate appropriate maintenance strategies, which can not only greatly improve the bridge's current operating status is undoubtedly of great significance for ensuring the safety and durability of large bridges, extending the service life of bridge structures, ensuring the smoothness of transportation arteries, and promoting economic prosperity and development.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] C. Sun, Y. Zhang. Research on Automatic Early Warning Method for Rail Flaw Based on Intelligent Identification and Periodic Detection. Tiedao Xuebao/Journal of the China Railway Society, 2018, 40(11):140-146. DOI: 10.3969/j.issn.1001-8360.2018.11.020

[2] Thomas Le Guenan, Farid Smai, Annick Loschetter. Accounting for end-user preferences in earthquake early warning systems. Bulletin of Earthquake Engineering, 2016, 14(1):297-319. DOI: 10.1007/s10518-015-9802-6

[3] Sheikh K. Ghafoor, Ryan Marshall, Faisal Hossain. LiquidEarth - river. Acm Sigcas Computers & Society, 2015, 45(2):42-42.

[4] Preeti Verma, Soma Sarkar, Singh Poonam. Devising a method towards development of early warning tool for detection of malaria outbreak. Indian Journal of Medical Research, 2018, 146(5):612-621.

[5] Jian Li, Baoqiang Yan, Mingjiang Zhang. Long-Range Raman Distributed Fiber Temperature Sensor with Early Warning Model for Fire Detection and Prevention. IEEE Sensors Journal, 2019, PP(99):1-1. DOI: 10.1109/jsen.2019.2895735

[6] C.-C. Ma, T.-B. Li, H. Zhang. An evaluation and early warning method for rockburst based on EMS microseismic source parameters. Rock & Soil Mechanics, 2018, 39(2):765-774.

[7] Shuli Fan, Liang Ren, Hongnan Li. Real-Time Monitoring and Early Warning Method Utilizing FBG Sensors in the Retrofitting Process of Structures. International Journal of Distributed Sensor Networks, 2015, 2015(11):1-9. DOI: 10.1155/2015/359549

[8] Yixuan Yuan, Dengwang Li, Max Q.-H. Meng. Automatic Polyp Detection via a Novel Unified Bottom-Up and Top-Down Saliency Approach. IEEE Journal of Biomedical & Health Informatics, 2017, PP(99):1-1.

[9] Yifan Yu, Student Member, IEEE. Delta-Connected Cascaded H-Bridge Multilevel Converters for Large-Scale Photovoltaic Grid Integration. IEEE Transactions on Power Electronics, 2016, PP(99):1-1.

[10] Mohamed G. ElBanan, Ahmed M. Amer, Pascal O. Zinn. Imaging Genomics of Glioblastoma: State of the Art Bridge Between Genomics and Neuroradiology. Neuroimaging Clinics of North America, 2015, 25(1):141-153.

[11] Sébastien Schmerber, O. Deguine, M. Marx. Safety and effectiveness of the Bonebridge transcutaneous active direct-drive bone-conduction hearing implant at 1-year device use:. Archiv für Klinische und Experimentelle Ohren- Nasen- und Kehlkopfheilkunde, 2016, 274(4):1-17. DOI: 10.1007/s00405-016-4228-6
[12] C.-Y. Xia, N. Zhang, H. Xia. Dynamic analysis of a train-bridge system under vessel collision and running safety evaluation of its high-speed train. Zhendong Yu Chongji/journal of Vibration & Shock, 2015, 34(6):155-161.
[13] Xiao-xiao Lai, Hua Lin, Yi-ni Luo. [Summary and analysis of safety warning on clinical application of anti-cold Chinese patent medicine preparations]. Zhongguo Zhong Yao Za Zhi, 2015, 40(8):1594-1600.
[14] Guangrui Tang. Analysis and Study on Safety Warning Distance of Human Body Near The Transmission Lines. IOP Conference Series Materials Science and Engineering, 2018, 392(6):062182.
[15] Sabrina S. Adler, Ian E. Mclaughlin, Seth E. Mermin. You Want a Warning with That? Sugar-Sweetened Beverages, Safety Warnings, and the Constitution. Food & Drug Law Journal, 2016, 71(3):482-518.
[16] Jessica K. Pepper, Margaret J.M. Cress, Doris G. Gammon. Battery Safety Information and Warnings on E-cigarette Packages and Online. Tobacco Regulatory Science, 2018, 4(1):605-613.
[17] Jun Xu, Kaiyuan Lv, Cheng Ma. Rehabilitation of old three-hinged steel arch bridges - A case study of Ling Bridge. Stahlbau, 2016, 85(8):543-551.
[18] Jun Li Wang. Application of Analytic Hierarchy Process in Bridge Safety Comprehensive Evaluation. Applied Mechanics & Materials, 2015, 744-746(4574):744-748.
[19] S. Cui, P. Liu, Y. Cao. Simulation Study on Multiline Vehicle-Bridge Coupled Vibration. Journal of Southwest Jiaotong University, 2017, 52(5):835-843.
[20] Lv, Yisheng, Duan, Yanjie, Kang, Wenwen. Traffic Flow Prediction With Big Data: A Deep Learning Approach. IEEE Transactions on Intelligent Transportation Systems, 2015, 16(2):865-873.