Research on Health Monitoring and Intelligent Operation and Maintenance of Bridge Structures

Bohan Gao

School of Civil and Transportation Engineering, Beijing University of Civil Engineering and Architecture, Beijing, China

202102020316@stu.bucea.edu.cn

Abstract. In recent years, with the continuous evidence of traffic volume, the problem of overloading caused by vehicles has become increasingly serious. At the same time, there are many safety risks in existing Bridges due to insufficient original design, construction defects, improper operation and maintenance. Therefore, it is necessary to carry out health monitoring on the existing bridge structure. This paper mainly studies the health monitoring and intelligent operation and maintenance method of bridge structure and its application. The health monitoring system of small and medium-sized bridge structure and large bridge structure are analyzed respectively. The results show that in the health monitoring system, the small and medium-sized Bridges need the characteristics of low power consumption, low power, reliable and easy to replace. However, large Bridges are more focused on technology integration and real-time comprehensive monitoring. At the same time, both kinds of health monitoring are developing towards lightweight. In addition, this paper also studies the bridge intelligent operation and maintenance scheme based on BIM. The results show that BIM can achieve full coverage and full time real-time monitoring. Health monitoring and operation and maintenance are developing towards more accurate data and more efficient work.

Keywords: Health Monitoring, bridge structure, intelligent operation and maintenance.

1. Introduction

In recent decades in China, the construction of Bridges and various innovations have emerged endlessly, constantly refreshing the mileage figures of Bridges. However, all kinds of Bridges bring great pressure and challenge to the later management and maintenance. For example, the Point Pleasant suspension bridge in the United States adopts the tempered steel eye rod as the suspension cable, and the middle part of the suspension cable and the upper string of the stiffened beam are integrated. When the net section of the eye bar was cracked at its hole and expanded due to corrosion fatigue and stress corrosion, the maintenance staff could not check it because of the nonchalance, and the suspension cable was suddenly disconnected on December 15, 1967. As a building structure that has been exposed to the natural environment for a long time, the bridge needs to be monitored for health and maintained regularly.

The main starting point of bridge structural health monitoring is still the monitoring and evaluation of the structure. In recent years, with the development of advanced sensing and Internet of things technology, online grasp of structural response characteristics, identification of possible structural damage forms, and disclosure of structural collapse and failure mechanism have gradually become a hot spot in monitoring operation and maintenance.

This paper first introduces the health monitoring design of small and medium-sized Bridges and then systematically analyzes the health monitoring system of large Bridges. Then, the intelligent operation and maintenance scheme of bridge based on BIM is studied. This paper can provide effective reference for bridge structure health monitoring and intelligent operation and maintenance.

2. Design of Bridge Structural Health Monitoring

2.1. Health Monitoring Design of Small and Medium Span Bridges

2.1.1 Introduction to monitoring equipment design

First of all, because the investment of small and medium-sized Bridges and the funds that can be invoked by operation and maintenance are limited, too large and too complex equipment can not be used in monitoring equipment. And small and medium-sized Bridges have low requirements for their own carrying capacity, so the measurement accuracy of the equipment can be compromised to a certain extent, and there is no need to blindly pursue extremely accurate data. Under the condition of meeting the needs of overall data analysis, low power sensors with appropriate accuracy and lower cost are selected as well as data acquisition and transmission equipment. In addition, the equipment should also have a certain degree of reliability and stability in different harsh environments. The equipment can be used for continuous and uninterrupted data collection and provide accurate and lasting stability measurement in harsh environments such as dust density, high humidity, high temperature and low temperature changes and high corrosive environment. The indicators of temperature drift, time drift and electromagnetic interference avoidance ability of the sensor should meet the technical requirements. The service life of the sensor is generally not long, according to the design life of most Bridges, it needs to be replaced within the continuous monitoring time, so the choice of equipment should be easy to replace and replace the equipment [1].

2.1.2 Hardware acquisition and software system

In view of the low energy consumption monitoring needs of small and medium-sized Bridges, it is necessary to study the hardware equipment for data collection, which must be an integrated terminal for data collection, data processing and data transmission. The acquisition system has a small built-in industrial computer to realize centralized data acquisition, pre-processing and remote transmission. The equipment should have the characteristics of low power consumption and fast transmission speed, strong anti-interference ability, and can be expanded more flexibly. The software is the top building of the bridge monitoring system, responsible for various data analysis, security audit, equipment manager and other operations. The quality of the monitoring software determines the direct availability and ease of use of the system, which is the key to the entire system. Based on economy and feasibility, it is suggested that some small and medium-sized Bridges do not set up monitoring stations, and directly connect to the cluster monitoring software platform to achieve unified maintenance and management [2].

2.1.3 Power supply system

Under the premise of economy, stability and safety, when there is a power supply point near the bridge itself, and the distance from the bridge deck is not more than 500 meters, the power supply point can be directly used to supply power to the system. When the power supply point is too far away from the bridge floor and the measuring system, the economic advantages and disadvantages of laying cables and constructing solar energy, micro wind power generators and other facilities that must maintain stable power supply can be considered. The stable power supply is the first condition to ensure the stable operation of the equipment. [1]

2.2. Long-Span Bridge Health Monitoring System

2.2.1 Composition of large bridge health monitoring system

The design of large bridge health monitoring system is a comprehensive system integrating information technology, electronic technology and computing technology, mechanical technology, structural mechanics analysis technology, sensor technology, automation technology and so on. It is of great help to the safe operation and accurate management and maintenance of large Bridges [3].

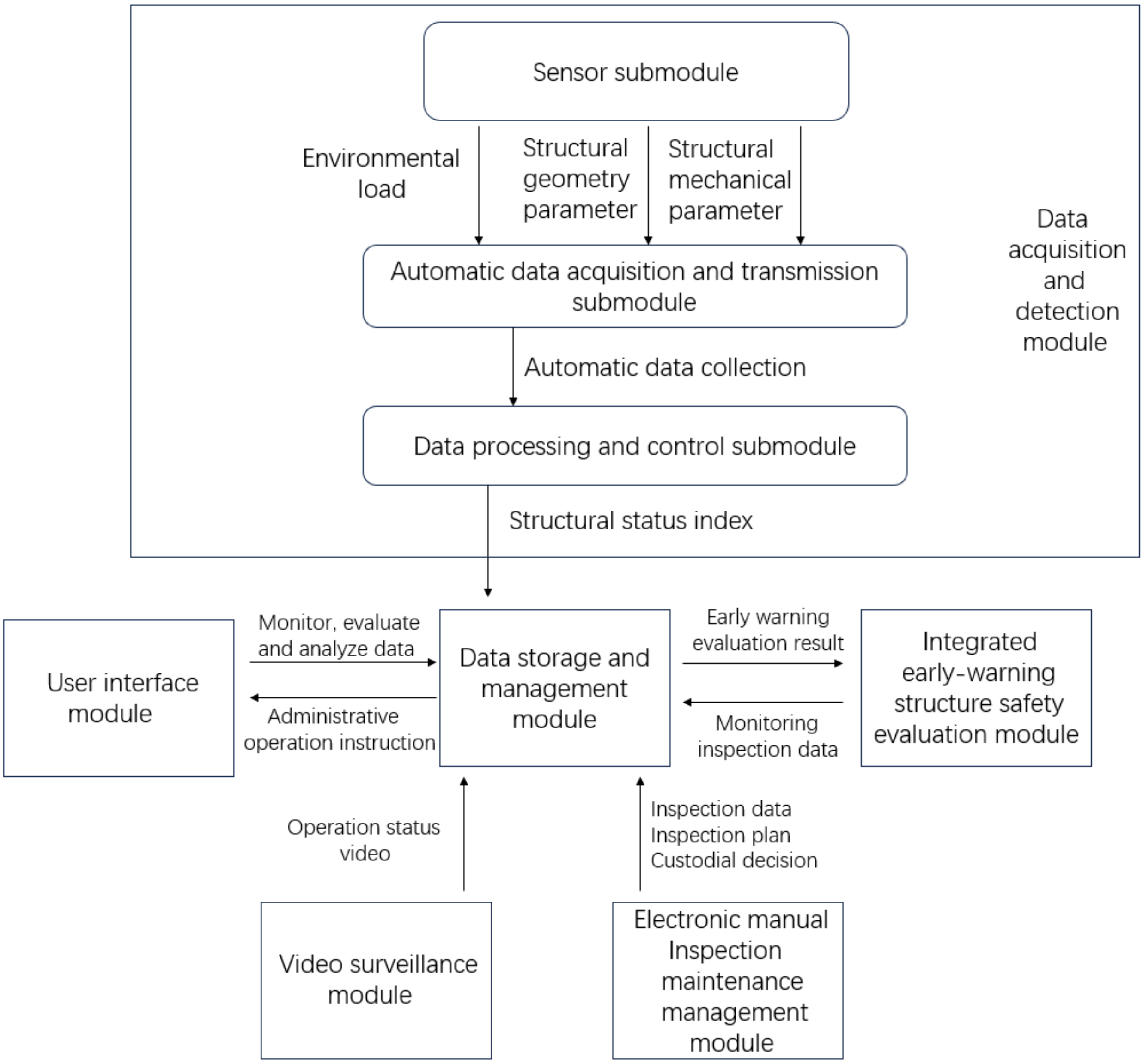

Fig. 1 System composition [4]

The monitoring content mainly includes the following aspects: (1) Environmental monitoring, real-time understanding of the bridge during the work of the wind direction, wind speed, surrounding temperature, humidity of each time period of the specific situation. (2) Operational load monitoring, traffic flow through the bridge, vehicle type, speed and other traffic load information monitoring. (3) Bridge characteristics monitoring, Real-time and complete monitoring of the temperature effect, static influence line and influence coefficient of the bridge, as well as the vibration mode, mode frequency, mode mass participation coefficient and mode damping ratio of the bridge. (4) the response monitoring of the bridge to obtain the dynamic performance of the bridge, and then analyze and judge whether there will be harm to the bridge, and provide a strong basis for the evaluation of wind resistance and earthquake resistance. Monitor the structural state stress, deformation, fatigue and other information during the operation of the bridge, and grasp the actual stress and operating conditions of the bridge in real time. (5) Real-time monitoring and recording of natural disasters of the bridge, as well as all man-made disasters. Combined with the structural characteristics of the large bridge itself and the requirements of the bridge health monitoring system, the whole system is designed to consist of six functional modules: automatic health data collection and monitoring, data storage and management, user interface, electronic manual inspection and maintenance management, comprehensive early warning and structural safety assessment, and video monitoring, as shown in **Fig. 1** [3, 4].

2.2.2 Lightweight health monitoring system for long-span bridges

According to the needs of bridge operation and maintenance, combined with the requirements of bridge operation early warning and structural safety assessment, the lightweight bridge health monitoring system adopts a centralized and unified distributed architecture. It is composed of cloud platform/monitoring center and on-site monitoring station, and the cloud platform and monitoring center exist together. Specifically, as one of the important components of the system, the field monitoring station includes the sensor module and the data acquisition and transmission module. The sensor module obtains the relevant data information in real time through various kinds of sensors installed in different positions of the bridge, such as temperature, vibration, displacement and other parameters. These sensors can detect the small changes of the bridge structure with high precision, and the collected data is processed and sent through the data acquisition and transmission module. On the other hand, in the cloud platform/monitoring center, there are several key modules to process and manage the massive data from the field monitoring station. Among them, the data processing and management module is responsible for storing, sorting and classifying the original data received; The data analysis and security early warning evaluation module uses advanced algorithms to conduct in-depth analysis of historical and real-time data, and provides accurate and reliable security early warning information based on preset thresholds or rules. In addition, the system integration user interface interaction module is also a very important link. It provides users with a friendly and intuitive operation interface, so that users can view and understand the current operating status of the bridge and the trend chart of various indicators at any time. At the same time, it also supports the remote operation function, so that the staff can flexibly adjust the system Settings or perform necessary maintenance tasks. In short, the lightweight bridge health monitoring system is complemented by the on-site monitoring station and the cloud platform/monitoring center, which realizes the comprehensive and real-time tracking and evaluation of the structural health status of the bridge under the condition of normal operation, and can quickly respond to abnormal situations and provide effective solutions. This will undoubtedly bring more convenient, efficient, scientific and reliable means of work for large bridge builders, maintainers and relevant management agencies [5, 6].

3. BIM Based Bridge Intelligent Operation and Maintenance Scheme

With BIM technology as the core, make full use of advanced technologies such as the Internet of Things, the Internet and big data to build an intelligent bridge management system. The specific structure is shown in **Fig. 2** [7].

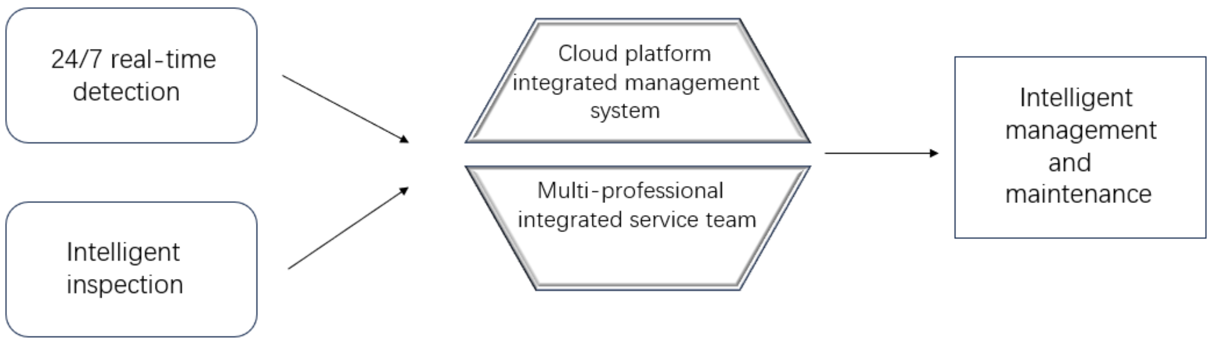

Fig. 2 Specific structure [7]

By installing sensors at key locations, real-time monitoring of the bridge can be achieved around the clock while the monitoring data is transmitted and stored in the BIM model in real time. At the same time, intelligent devices such as inspection vehicles, drones and inspection robots are combined to obtain data of areas that cannot be covered by manual inspection. This can not only comprehensively understand the operation status information of the bridge, but also solve the problems of poor accessibility, low safety and high cost existing in traditional manual inspection. Finally, big data technology is used to analyze and calculate the massive data obtained from long-term monitoring, and scientifically evaluate the "service" status of the bridge, so as to provide intelligent services for management and disease remediation [8].

(1) By setting intelligent inspection equipment such as sensors and drones at key parts of the bridge, the operation status parameters and disease information of the bridge are collected online, and are immediately uploaded to the bridge maintenance management platform to complete a comprehensive physical examination. At the same time, when the disease is found, the corresponding remediation measures are automatically associated to solve the problem in a targeted manner. The emerging diseases can be formed by remote expert consultation, and imported into the disease database for reference. In addition, BIM technology can intuitively display the position and state of the disease, and simulate and predict its development trend, so as to provide basis and help for prevention and remediation [8, 9].

(2) By setting sensors at key parts such as supports, the pure load-bearing bridge becomes capable of sensing and thinking, and 24-hour online monitoring of its stress and deformation [9]. At the same time, patrol drones and other equipment are used to carry out intelligent inspection to improve the quality. The "online monitoring" system and the "intelligent inspection" equipment together constitute the bridge nervous system, which transmits the perceived data to the operation and maintenance management service platform in real time, and completes the real-time collection of the "body indicators" [10]. In this way, a series of problems such as low degree of automation and poor implementation effect in the previous data collection are solved, and basic data is also provided for the "service" state of the bridge [11, 12].

(3) Make full use of big data technology, analyze and calculate the long-term monitoring/inspection test data, and then complete the scientific evaluation of the "service" state of the bridge, and transform the empirical operation and maintenance into the intelligent and fine management supported by data. Through the long-term detection of "physical indicators", the level and accuracy of operation and maintenance management are greatly improved, and the left and right maintenance and reinforcement are transformed from a single momentary mode to a long-term care "service mode" to ensure the safe and efficient operation of "service" of the bridge [12].

4. Conclusion

This paper mainly studies the health monitoring methods and intelligent operation and maintenance systems of small and medium-sized Bridges and large Bridges. The main conclusions are as follows:

(1) The monitoring equipment of small and medium-sized Bridges should choose the sensor with low cost, low power consumption, reliability and stability. It is necessary to meet the needs of data analysis and adapt to harsh environments. In addition, equipment should be easy to replace and replace. These include terminals with integrated data acquisition, processing and transmission functions. Monitoring software quality determines system availability and ease of use. At the same time, it is recommended to connect small and medium-sized Bridges to a unified monitoring software platform for management. The power supply system should consider economy, stability and safety.

(2) The large bridge health monitoring system integrates a variety of technologies, which can monitor the environment, operating load, bridge characteristics and response in real time, and provide functions such as structural safety assessment and disaster monitoring. The lightweight bridge health monitoring system can complement each other through on-site monitoring stations and cloud platform/monitoring center to achieve comprehensive and real-time tracking and evaluation of the bridge's structural health status, and can quickly respond to abnormal situations and provide effective solutions.

(3) Using BIM technology combined with advanced technologies such as the Internet of Things, the Internet and big data, an intelligent bridge management system can be built. Realize all-weather

real-time monitoring and acquisition of bridge operation status information, and use big data analysis and calculation to evaluate the "service" status of the bridge. The application of bridge intelligent inspection equipment and big data technology has realized the online collection of bridge operation status parameters and disease information, the correlation of renovation measures and the prediction of development trend, and has improved the level of operation and maintenance management and safety.

(4) For some urban Bridges or small and medium-sized span Bridges, the high price monitoring system is difficult to apply because of the low cost. Therefore, it is a direction worth exploring to study the low-cost health monitoring system suitable for such Bridges. The health monitoring of the bridge needs to ensure that the system can stabilize the output, and the monitoring method and layout should reflect and output the operating condition of the bridge more comprehensively. Therefore, more scientific and reasonable research on sensor layout is needed to obtain more accurate bridge monitoring parameters. And the establishment of structural performance state evaluation model is worthy of further discussion.

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