Overview of Bridge Health Monitoring

Peng Li, Jiachao Peng and Liuwei Huang

ABSTRACT

Bridge operation safety is a key to national security and people’s livelihood. The importance and the urgency of bridge health monitoring and damage detection are introduced here. In the past, the health monitoring of bridges often relied on experienced engineers. They rely on their rich experience to detect and repair bridges. This method is inefficient and has low universality. Engineers can only detect and maintain the bridge they are familiar with. With the increasing importance of safety, durability and normal use of large bridges, the research and evaluation system of bridge health monitoring has been developed and achieved a wide range of achievements in the 20th century. This paper introduces the composition of the bridge health monitoring system. It consists of sensor subsystem, data acquisition and transmission subsystem, data processing and control subsystem. The key problems in sensor subsystem: sensor location optimization, data transmission mode and data processing method are also introduced. At the end, varies issues in existing systems and directions on the near future are analyzed and summarized.

INTRODUCTION

The bridge is the main engineering structure of the road, and it is the throat of the highway traffic. Its technical status directly affects the highway unblocked, driving safety, economic and social benefits of road transportation. Today, the construction of highway bridges in China is an important condition to ensure the normal development of the national economy. The lack of necessary health
monitoring can cause the bridge function degradation and safety hazard. In the management and maintenance of bridges, the traditional method of artificial detection is hysteresis and inefficiency. This method will result in the increase of the cost of the bridge operation and the unreasonable allocation of resources, and it is far behind the development of the bridge. In order to ensure the normal operation of bridge structure and operation management of large bridge, the health monitoring of bridge is imperative.

Bridge health monitoring is an effective method to evaluate the main performance of the structure. It provides scientific basis and guidance for the maintenance and management decision of the bridge through nondestructive testing of the structure of the bridge, the damage location and degree of damage of the structure. Bridge health monitoring consists of sensor subsystem [1], data acquisition and transmission subsystem [2] and data processing and control subsystem [3].

1. The sensor subsystem is equal to development of monitoring program. It is the hardware system of the system. In the bridge health monitoring system, the sensor subsystem is the "eye" of the whole system. Through the sensor subsystem, the bridge health monitoring system can monitor the structure in real time and lay the foundation for the follow-up work. Its key problem is sensor location optimization: The maximum monitoring efficiency is achieved with the minimum number of sensors, which can reduce the burden of data transmission and data processing.

2. The data acquisition and transmission subsystem is responsible for processing the electrical, optical, acoustic, magnetic and other signals from the sensors into digital signals, and then transmits them to the central database after initial processing.

3. The data processing and control subsystem consists of data preprocessing module, safety early warning module, damage identification module and damage assessment module.

OVERSEAS AND DOMESTIC RESEARCH STATUS

The Sensor Subsystem

As one of the key problems of the design structure health monitoring system, sensor optimization layout [4] has a crucial influence on the validity of data collection. However the sensor subsystem itself is a paradox. On the one hand, in order to make a reasonable and scientific evaluation of the health of the structure, the subsystem needs to use as many sensors as possible to monitor more projects. On the other hand, in order to ensure the reliability and economy of the monitoring system, the subsystem requires that the monitoring equipment should not be used too much. In the already implemented bridge health monitoring system, some systems are too large, and the reliability of the system itself may not be guaranteed.
Some structural monitoring systems, by contrast, are too small to make scientific assessments of the health of the structure. Therefore, it is necessary to find the right balance between the two.

In general, the placement of sensors in the health monitoring system should meet the following two objectives: The measurement points of the installation sensor can best reflect the information of the spatial structure and the measurement information is sensitive to the change of the spatial structure state. Carne T G and Dohrmann C R of the Sandia National Laboratory in the United States stressed that the configuration of the sensor should make the test modality result in good visibility and robustness [5]. In most cases, the results of the modal test are processed by parameter identification method. Therefore, many literatures use the error of identification parameters to optimize the layout of the sensor. Its basic idea is to use the system parameter to identify the error unbiased estimate. When the Fisher information matrix gets the maximum value, the system parameter identification error is minimal. One of the most influential configurations is the effective independence method proposed by DC Kammer of The USA. Its basic idea is according to each candidate sensor location, use the contribution of linear independence of target modal components to sort sensor position, optimize the Fisher information matrix, and then optimization iteration method is used to get a set of sensor measuring point [6]. However, this method does not take into account the inhomogeneity of the structure mass distribution, which may result in the loss of information due to low energy of the selected sensor. In China, Dongchang Sun et al. proposed to distributed piezoelectric element method for vibration control of smart plates [7]. Yaxun Yang et al. proposed optimal placement of sensors for a bridge structure based on energy coefficient effective independence method [8].

The Data Acquisition and Transmission Subsystem

Signal sampling frequency, preprocessing of signals and data storage or sending strategies are some of the problems that need to be considered in the data acquisition subsystem. The selection of sampling frequency is a key problem in data acquisition. If the sampling frequency is too high, a single node will quickly generate a large number of sampling data to increase storage and communication overhead. At the same time, the system has higher synchronization requirements between nodes. If the sampling frequency is too low, the data collected cannot reflect the structural characteristics of the bridge. In the actual system, the frequency of signal sampling is determined according to the frequency range of the monitoring content of the bridge. For example, the static change of the bridge, such as deformation and inclination, has very low frequency characteristics, and the sampling frequency is usually less than 1Hz. The vibration frequency of the bridge is around 20Hz, which is more suitable for the sampling frequency of 50Hz.

Wireless sensor network (WSN) is a hotspot in the field of science and technology at home and abroad. Its nodes are characterized by low power
consumption, small volume and high intelligence. The application of wireless sensor technology to bridge health monitoring is beneficial to the miniaturization, low cost and intelligent development of the whole monitoring system. At present, the wireless sensor for the application of bridge health monitoring, mainly include: Sukun Kim et al. designed a WSN system based on TinyOS, and implement of the golden gate bridge structural health monitoring [9]. A WSN for structural health monitoring (SHM) is designed, implemented, deployed and tested on the 4200-foot main span and the south tower of the golden gate bridge. The vibration of the environment can be measured reliably at a lower cost without affecting the operation of the bridge. This system uses the advanced technology development of wireless communication, low-power microprocessor and microelectronic mechanical system sensor to monitor the short- and long-term performance of the structure. A complex set of instruction set computers microcontrollers are placed at the core of the unit in order to accommodate airborne calculation, measurement filtering and data query algorithms.

The Data Processing and Control Subsystem

The bridge health condition is monitored and evaluated by testing signals. It extracts all kinds of features from the data collected by sensors, and carries out parameter detection, monitors status and diagnosis damage of the structure. When the sensing system can provide a large amount of data on the structure performance, it needs to be effective and reliable to analyze and process the data in order to identify and locate the damage.

The proper selection and extraction of feature parameters often contain various classical and modern information processing methods and techniques. Wavelet technology and wavelet package analysis technique, Hilbert-Huang Transform, adaptive moving average technology etc. can be used to construct the input characteristics of damage identification. While the number of input characteristics of the building is large, if all features been directly as input vector of damage identification algorithms, this may be because of the redundancy of information lead to dimension disaster, which will reduce the efficiency and accuracy of damage identification algorithm. In this case, the principal component analysis can be used to reduce the input feature vector, and the main effect of the main component after reduction will be the input vector of the recognition algorithm.

CONCLUSIONS

This paper elaborates the method, background and current research application of bridge health monitoring. In terms of the current research level of bridge health monitoring and diagnosis, it still has the following problems:

1. At present, the evaluation of the healthy state of the bridge lacks effective and general indicators of damage quantification. And it is difficult to reflect the
influence of the damage of a local component on the working state of the whole bridge.

2. Location optimization of sensors is an important problem in the health monitoring and diagnosis of bridges, and it should be used to obtain as a lot of structural health information as possible with as few sensors as possible.

3. Development of special sensors for bridge structure monitoring is the key of bridge monitoring. The lack of precision and low efficiency in measuring devices is a difficult problem for bridge monitoring.

Research on bridge health monitoring relates to many disciplines about vibration theory, sensor technology, testing technology and system identification theory, signal processing, data communication, computer, random process and reliability etc. After years of active exploration, many achievements have been made. Its research is still in the basic exploration stage, and the vision has a larger gap distance of practical system, because the bridge structure is influenced by many uncertain factors and complex working environment, and lacks a comprehensive and in-depth understanding of the changes of the work characteristics of the bridge during its service life period. Development of bridge health monitoring needs a new theoretical breakthrough and modern science and technology, material, information technology and economic progress.

ACKNOWLEDGMENTS

This work is supported by the National Natural Science Foundation of China (Grant No. 51365012).

REFERENCES
