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Development of bridge diagnosis system by using sensor network

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Abstract

This paper focuses on maintaining a bridge 's safety by developing a daily management system. And the purpose of this study is the development of the health monitoring system. It supports the maintenance by using sensor network and Independent Component Analysis (ICA) when there are some troubles in a bridge. The result of this study brings out the vibration behavior of the overall structure in a bridge. This vibration is caused by the external force such as wind pressure, and running vehicle. The character frequency was extracted from the analysis result using ICA and Spectral Analysis.The actual sensor network system has been developed and the performance was demonstrated.

1 INTRODUCTION

The demolishment and rebuilding method had been used in the large-scale building such as a bridge, a road, a harbor and an educational facility etc. in the past. But it has changed to method of preventive maintenance to operate recently a long life in the existing large-scale building. Therefore, the necessity reducing the financial burden and the construction waste has increased. Specially, the bridges have passed 50 years in serviceable life that rapidly increase between 2020 and 2030. Therefore the technological development is demanded strongly that it measures various phenomena such as deterioration and corrosion in quantitative and handy.

But the past diagnostic technology was hammering test, visual check, and section test by a concrete core in the structure. They are conducted about once every five years. Therefore, they can 't test and measure for the health diagnosis in daily. When trouble is detected, the past prevention was conducted by the symptomatic therapy. Therefore, the preventive maintenance and repair that are based on health determination can 't be worked out effetely.

For example, the health data of a bridge can 't be collect in daily by estimation method of bridge pier scouring using shock and vibration method.

However, this paper focuses on maintaining a concrete bridge 's safety by developing a daily management system using sensor network.It includes the technology of a signal processing, a structure analysis, and the weight estimation of the running vehicle in a bridge. And, the vibration information of an entire bridge is measured through a small displacement and vibration caused by the external force such as impact, wind pressure and running vehicle in a bridge. And then, the diagnosis technology is developed to understand the phenomenon like deterioration and corrosion of a bridge through the measurement result in certain and effective. The bridge diagnosis technology can measure vibration behavior of a bridge simply. It aims for obtaining valuable knowledge on the basis of the data from the measurement result about common and regular maintenance of concrete structure. Also, measurement technology, structural interpretation and signal processing have developed remarkably in recent. And, accuracy and the reliability of the structure di-

agnosis technology have risen more than the past by major price decline of sensor and computer. It can measure the vibration by a variety of ways and treat large quantities of data collectively. Therefore, process rationalization becomes possible because the realistic situation can be understood exquisitely using the diagnosis technology of a high precision degree, large quantities and low cost.

2 DIAGNOSIS METHOD

2.1 Independent Component Analysis

ICA is a computational and statistical technique for revealing unidentified factors that underlie sets of random measurements, variables, or signals. ICA can separate independent signal from mixed input signal.

Therefore, it is applied in various fields such as blind signal separation, feature measurement and character recognition etc. [1], [2] . There are many algorithms proposed. FastICA algorithm was used in this research.

$$x = (x_1, \ldots, x_m)^t \tag{1}$$

$$s = (s_1, \ldots, s_n)^t \tag{2}$$

$$x = As(A : m \times n) \tag{3}$$

Here, x is the observation signal matrix, s is the independent variable and A ismixing the matrix in Eq. (1) (3). ICA can estimate the independent variable s and the mixing matrix A from the observation signal matrix x.

2.2 Bridge Diagnosis

Bridge diagnosis technology includes the technology of sensor network, signal processing, structure analysis, and detection of a running vehicle. And it measures the vibration information of an entire bridge in real-time through the small displacement and the vibration caused by the external force such as the wind pressure, the running vehicle 's vibration, and the flow velocity pressure of a river in a bridge. Therefore, it can evaluate health condition and conduct a comprehensive deliberation on repair and reinforcement work based on the measurement data. Fig.1 shows the outline of bridge diagnosis technology. The purpose for development of bridge diagnosis technology is to achieve the maximum effect in the minimum investment through understanding of the exiting public facility 's health and the present asset value in systematical.

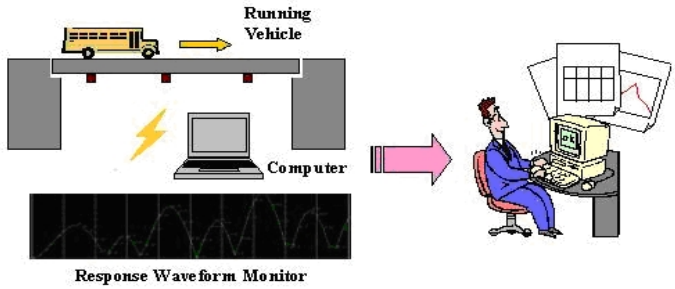

Fig. 1: The outline of bridge diagnosis system

3 WIRELESS SENSOR NETWORK

Wireless sensor network (WSN) is a wireless network consisting of spatially distributed sensing modules to cooperatively monitor or collect various physical data such as temperature, vibration, pressure and etc in the real world.The collected data would be transmitted to data recorder. Compared to the conventional method, bridge diagnosis system by using WSN provide high performance at a lower cost.

Referring to the past research of monitoring system with WSN technology, we would be able to design this sensor system for evaluating the health level of bridge mainly by the vibration data in real time,to some extent. But, in our system,thetre are some hard problems. In addition to how to control the electricity consume and make an appropriate routing protocol,plural vibrations data is required for time synchronization of each nodes in sampling to analyze structual vibrations correctly. The data with no time-synchronization

Fig. 2: The full view of the Seiran Bridge

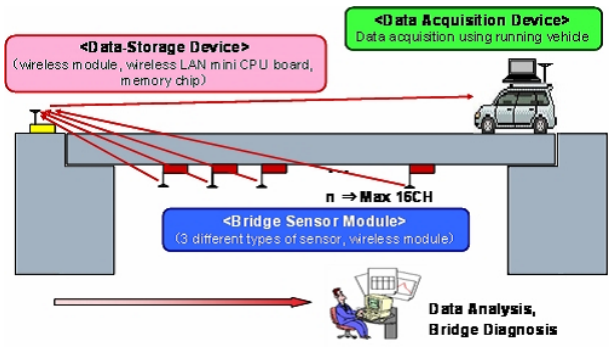

Fig. 3: Bridge Diagnosis System

has no value for our system.

4 FIELD EXPERIMENT

4.1 The outline of field experiment

This field experiment was conducted in 2007. The experiment object is the Seiran Bridge at Kokura, Kitakyushu city in Japan. It attempts the detection of character frequency from the disturbance vibration caused running vehicle in the road bridge.

Fig.2 shows the full view of Seiran Bridge. The field experiment is colleted to vibration information caused by running vehicle using accelerometer and velocimeter. In this field experiment, the accelerometer and the velocimeter are used as follows. The accelerometer is used KXM52-1050 of Kionix,Inc. The vibration caused by the running vehicle is measured about ten times. Moreover, the running situation of the vehicle was recorded with video camera.

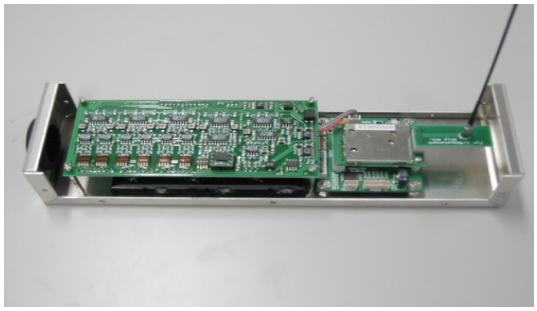

Fig. 4: Wireless Module

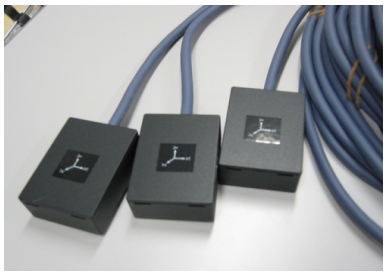

Fig. 5: Acceleration Sensor Module

The bridge diagnosis system are composed of some bridge sensor modules, a data storage device and a data acquisition device. The bridge sensor module are shown at Fig.4 & Fig.5. The steps of bridge diagnosis are follows,

1. The vibration of the bridge is measured by the Bridge Sensor Module.
2. The measured data is transmitted wirelessly.
3. The data are preserved in the Data-Storage Device.
4. The preserved data are collected in the data acquisition Device using running vehicle.

Finally, the bridge is diagnosed by analyzing the collected data. In the diagnosis about superstructure, first the judgment that there is some defect or not is done by using ICA. Next if there is some abnormal, the position is decided by using AR model -ing and the transfer function 's change.

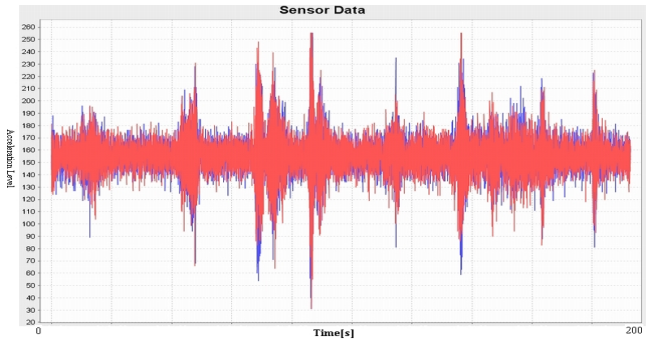

Fig. 6: Vibration Data

4.2 Result of field experiment

We put the acceleration sensors on the pier and put the acceleration & distortion sensors on the crosstie of the bridge for collecting the vibration data when the car crossing the bridge and transmit the collected data to data recorder in this experiment. And also we made a monitoring program for checking whether the data were transmitted to the recorder or not. Here is a part of our collected data shown as figure 6. In this experiment, collecting the vibration data & confirming the radio communication are the primary purpose. As the result shown, the sensor modules were working well in the experiment.

5 FUTURE WORK

As we described in the section 3, for making an accurate signal analysis we required all the vibrations data measured in synchronization time from the whole sensors. We confirmed the sensor modules could be work for measured vibration data in this experiment. In next experiment, We hope they could work in same time and we could make a detailed data analysis.

6 CONCLUSION

This paper unfolded the vibration behavior of a bridge when there are heavyweight impact, wind pressure, running vehicle, deterioration, and corrosion. We have successfully done the experiment that putting sensor modules on the bridge and measuring the vibration data based on the purpose of building a bridge health monitoring system with wireless sensor network technology. In future, we will try to improve the sensor module and make a desirable health monitoring system at a low cost.

Acknowledgements

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