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A Test Operation and Development of User–Based Health Monitoring System for Cable-Supported Bridges

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ABSTRACT

Thanks to the remarkable development of measurement instruments, various kinds of bridge health monitoring systems (BHMS) are in operation. Those systems are designed for the requirements for the structural characteristics of the bridges where the systems are operated. Most of the current systems have a serious problem that it is difficult to replace or upgrade a part of the whole system. In order to resolve the problem, we propose a user-based health monitoring system (UBHMS) in this study. This new system UBHMS is able to detect replacements or new equipments automatically so that there is no need to modify the operating software. UBHMS provides a single platform in which multiple monitoring systems can be integrated. An example of the UBHMS developed for a cable supported bridge is shown in this paper.

1. INTRODUCTION

Recently, measurement devices and monitoring systems that have been installed in bridges have been typically operated depending on a characteristic that differs among bridges. Additionally, it is difficult for the user or bridge manager to add new items. Accordingly, if measurement devices must be added or device information needs

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to be modified, it is difficult for a user to perform work by themselves. In this study, for the purpose of solving these problems, middleware was developed from which measurement data can be generated automatically when sensors or data loggers are expanded. In the case of this middleware, it is possible to freely expand sensors (electric resistance type, current type, voltage type, electrolytic type, fiber optic type) and data loggers (CR1000, Fiber optic logger, Netpod, NI-cRIO, GeoSig, etc.). Additionally, it is possible to add automatically in the inner program when devices are expanded. This paper presents the test operation of a new system for a cable-stayed bridge, the User-Based Health Monitoring System (UBHMS).

2. CHARACTERISTICS OF THE UBHMS

When replacing or expanding different types of sensors and data loggers, the User-Based Health Monitoring System (UBHMS) has the advantage of not requiring any modification of the existing program, featuring automatic linking with measurement data. Modifying existing bridge instrumentation software requires the support of software developers. In contrast, this monitoring system can be modified using only a program without need for a software developer. Therefore, bridge administrators can add or remove sensors and data loggers through a simple setup. The added and deleted sensors or data loggers can be immediately linked to the bridge measurement program. In addition, when building the system by introducing an open database structure, it is introduced into the system setup method through the user's settings. Table 1 shows the characteristics of UBHMS.

Table 1 Characteristics of UBHMS

Item	Existing Monitoring System	User-Based Health Monitoring System
Time Required for Development	▪ Need for program modification when adding sensors and loggers ▪ Time required is over a week	▪ Immediately possible by user
Maintenance Cost	▪ Need for development cost when adding sensors and loggers	▪ Minimal additional development cost
Data Acquisition	▪ Data loss occurs as the program is developed	▪ Minimal data loss

When performing measurement data analysis, the user can directly specify the filter settings for each sensor. The Fast Fourier Transform (FFT) analysis is increased to 2^{14} samples from the existing value of 2^{10}. The FFT analysis is utilized to extract natural frequencies of the bridge and mode shape, as well as to estimate cable tension. This improvement of the number of samples provides the ability to more precisely perform an FFT analysis. The statistical processing of dynamic data is carried out every 10 minutes by the UBHMS. The resulting processed statistical data are stored in the database. Here, the statistical method calculates the maximum, minimum, average, median, kurtosis, skewness, and standard deviation.

Fig. 1 shows the main screen of the UBHMS. There is the function of sensors list views, views of the real-time sensor data, event views, and report display. This program allows users to freely edit the views form. The export can include a variety of data as a text file or Excel file. It has the advantage that it can be linked to separate analysis programs for purposes such as dynamic analysis.

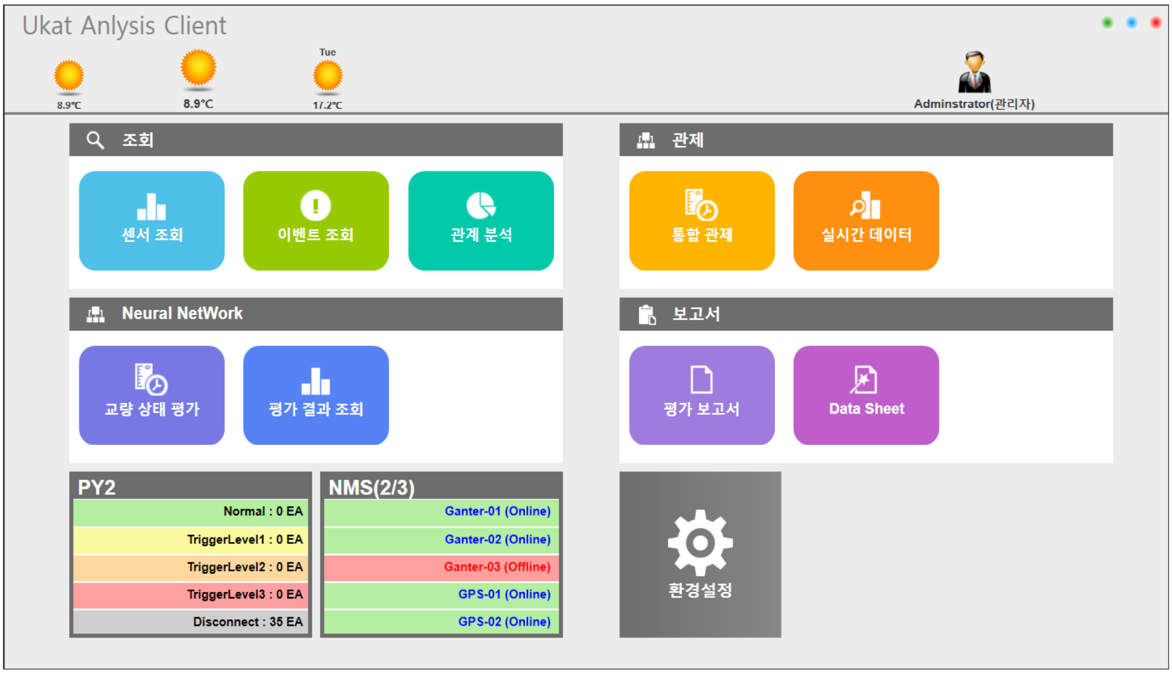

Fig. 1 Main screen of the UBHMS

There is a feature that displays photos and drawings of the selected sensor in the sensors views list. It is displayed on a separate screen, as shown in Fig. 2, when each picture is clicked.

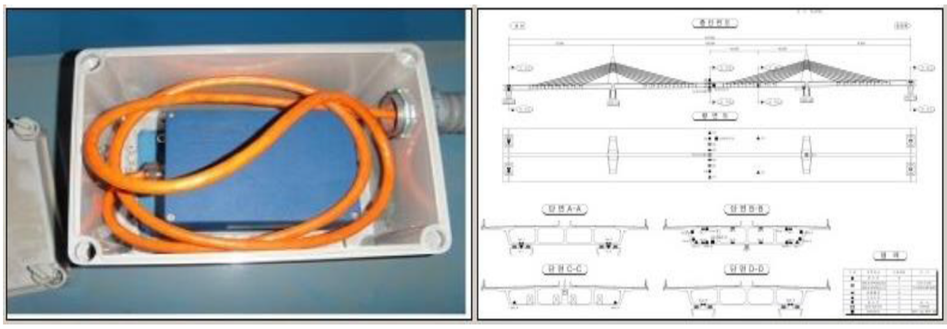
Fig. 2 Check of the sensor picture and plan for the bridge

Fig. 3 is a data view screen of the sensor to be selected by the user. It can view a graph of the data for a user's specified period of time. In the case of an accelerometer, it can be found at the natural frequency extraction results. The inquiry data are available as an Excel file format data sheet. Extra storage is shown in the lower part of Fig. 3.

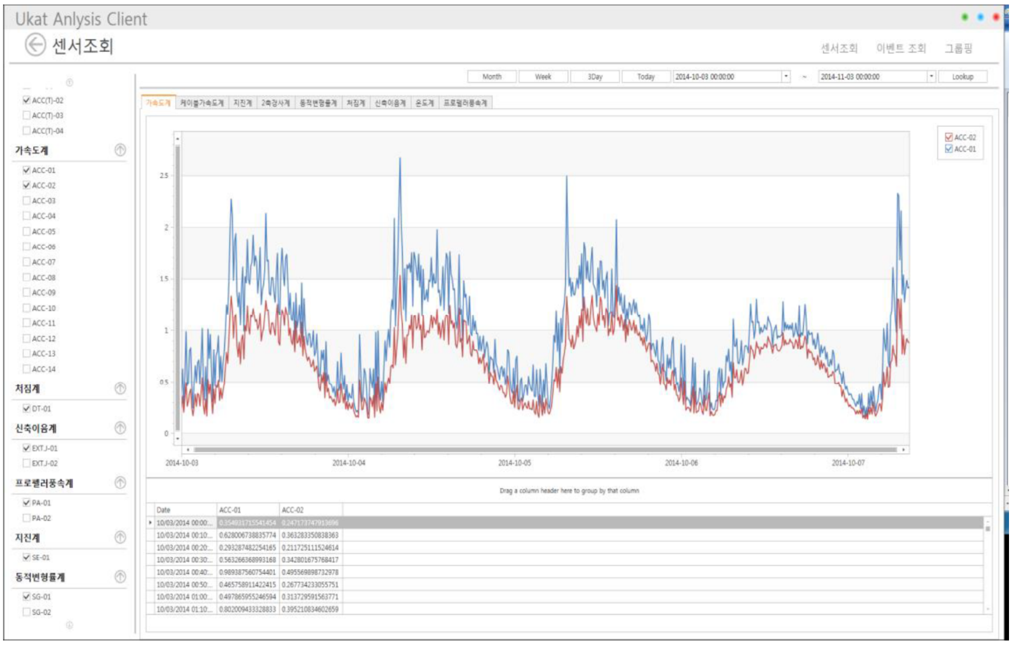

Fig. 3 Data view screen of accelerometers

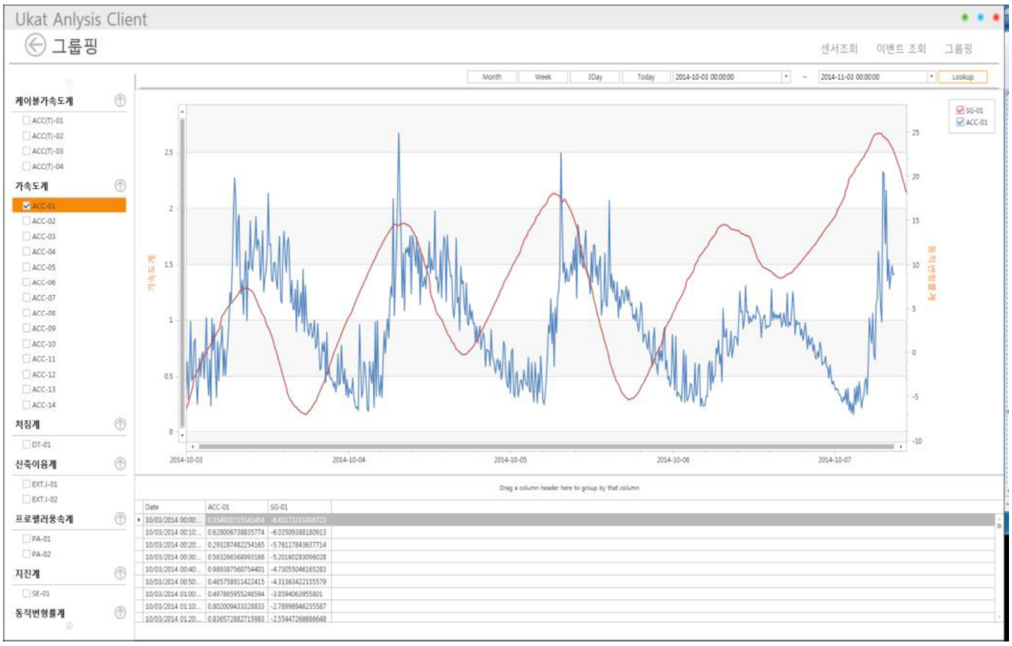

Fig. 4 Simultaneous view of multiple sensors

The management program allows users to add or delete direct measurement sensors and data acquisition devices. Replacement or expansion of data collection devices and sensors at the bridge are frequent occurrences, and the manager of the separate programs can set these directly without modifying the source code. Figs. 5 and 6 show the function of adding the sensor and data acquisition devices.

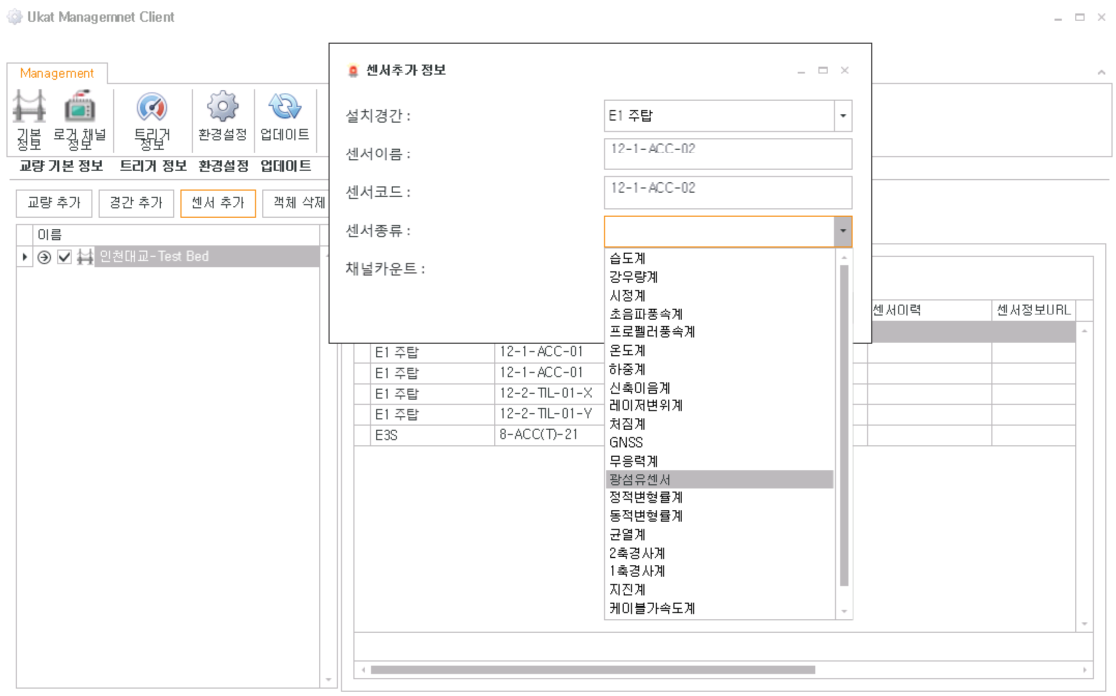

Fig. 5 Adding sensor functionality

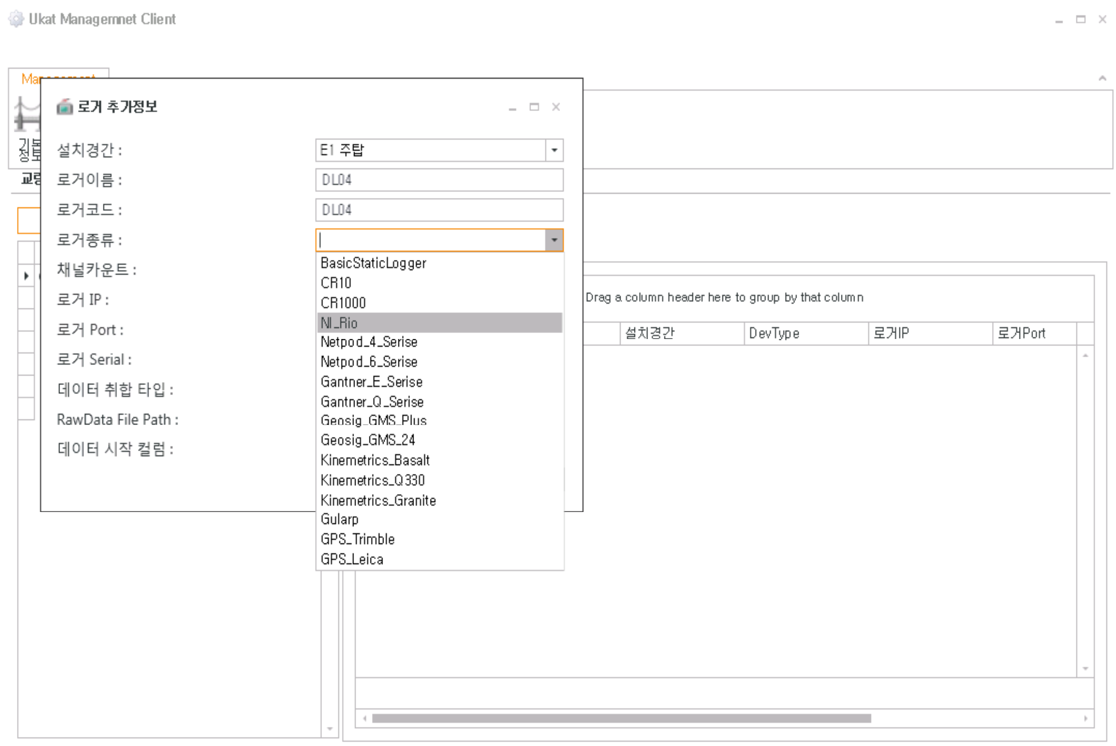

Fig. 6 Adding data acquisition device functionality

3. THE TEST OPERATION OF UBHMS FOR CABLE-SUPPORTED BRIDGE

To test the operation of UBHMS, measured data from an operating bridge were linked to UBHMS, and 3 types of data loggers (fiber optic data logger, seismic data logger, and electrical data logger) were added. The system was subsequently tested for normal data acquisition.

Fig. 7 System configuration

A fiber optic tension meter, a strain meter, and a thermometer were connected to the fiber optic data logger. A seismometer was connected to the seismic data logger, and foil-type strain gauges were connected to the electrical data logger.

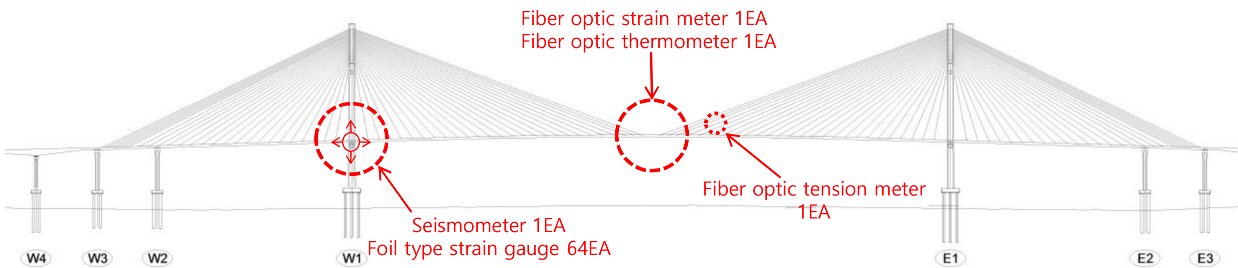

Fig. 8 Location of sensor installation

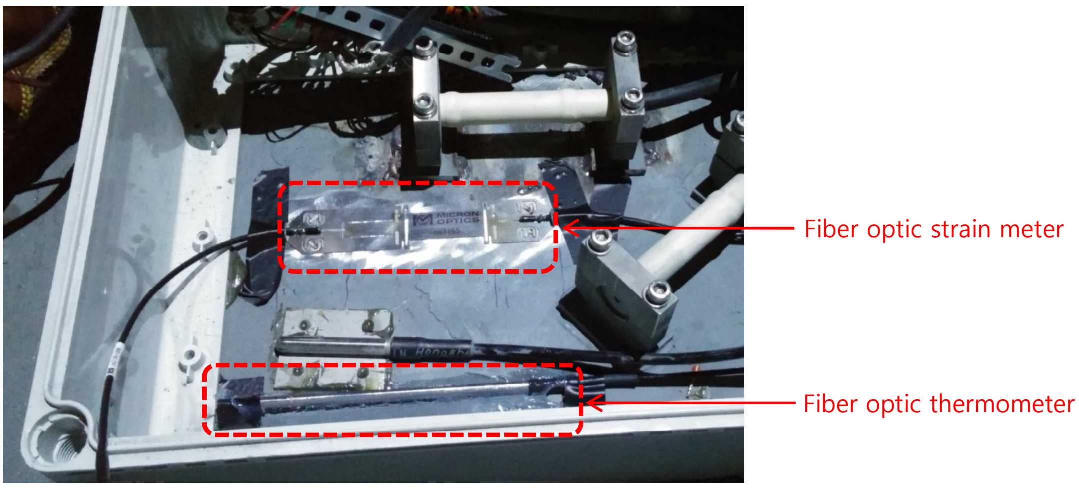

Fig. 9 Installation picture of fiber optic sensors

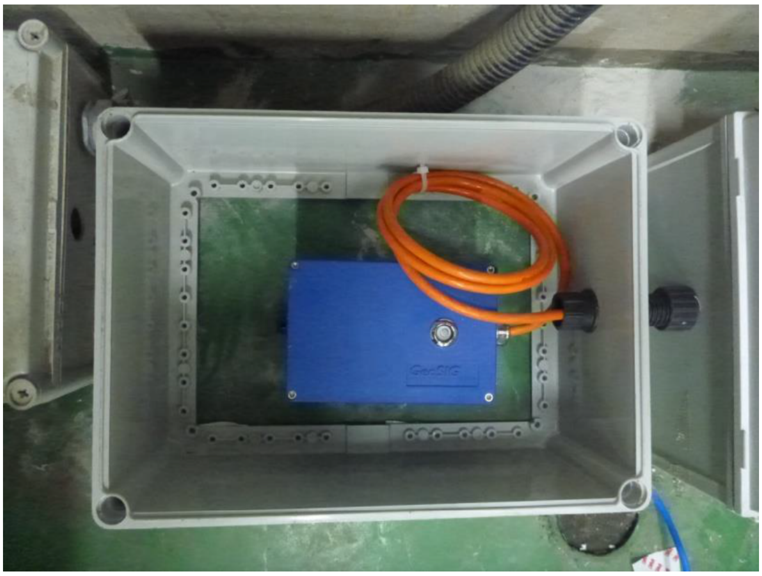

Fig. 10 Installation picture of the seismometer

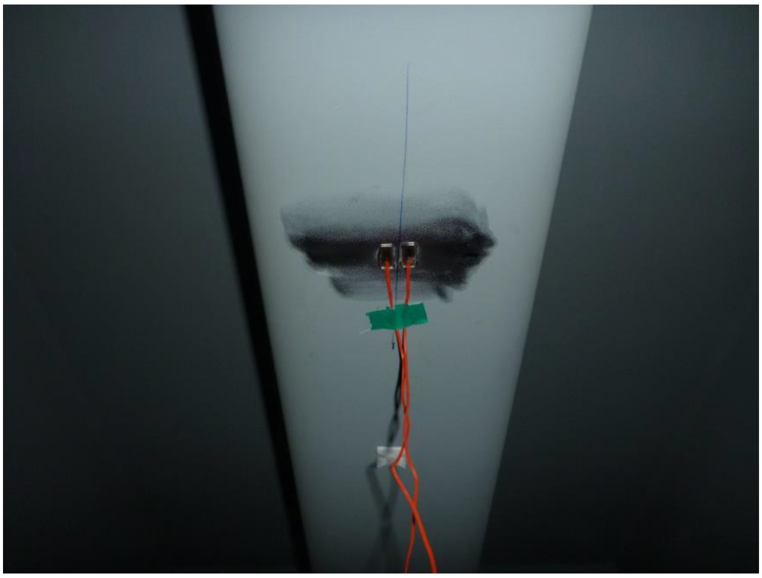

Fig. 11 Installation picture of foil-type strain gauges

A network configuration for collecting signals from each sensor is shown in Fig. 12.

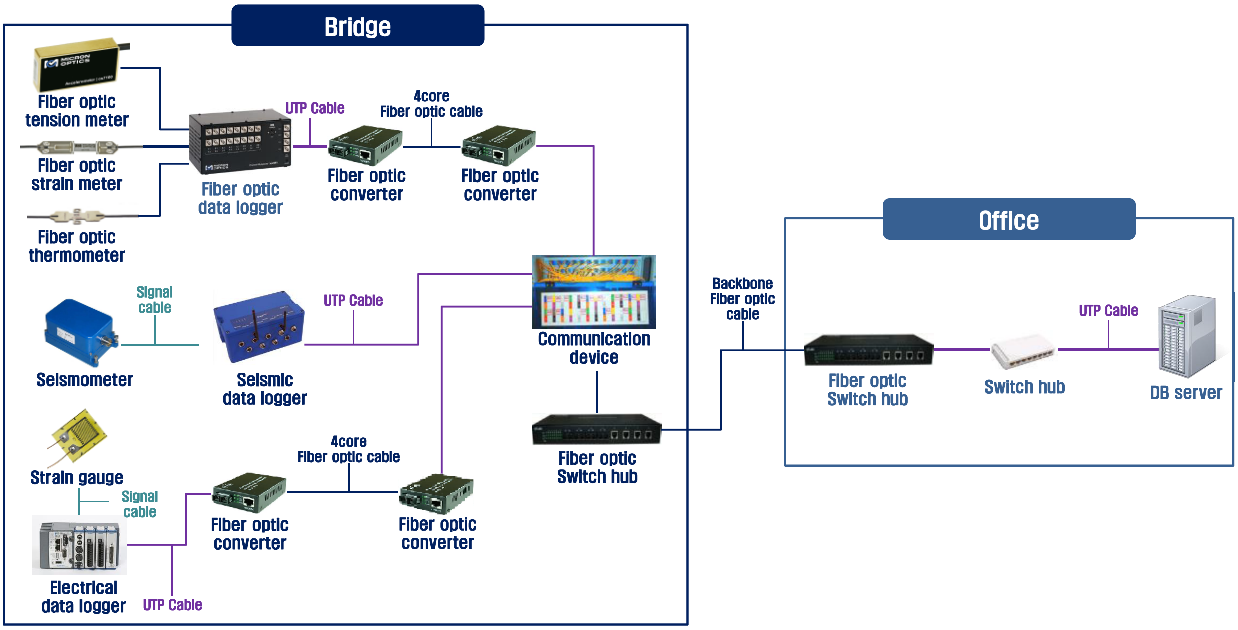

Fig. 12 The network configuration

For the purpose of linking measured data in an operation bridge to a new server of the UBHMS, two previously-installed data loggers in the E1 pylon of the cable-stayed bridge and a previously-installed data logger in the W1 pylon were linked to the UBHMS server. It was confirmed that additional program installation or modification would not be required for expansion of the data logger. Fig. 13 shows connecting states of the data loggers. As seen in the 'State' component of Fig. 13, all data loggers are normal connecting state in that states marked with 'Online'.

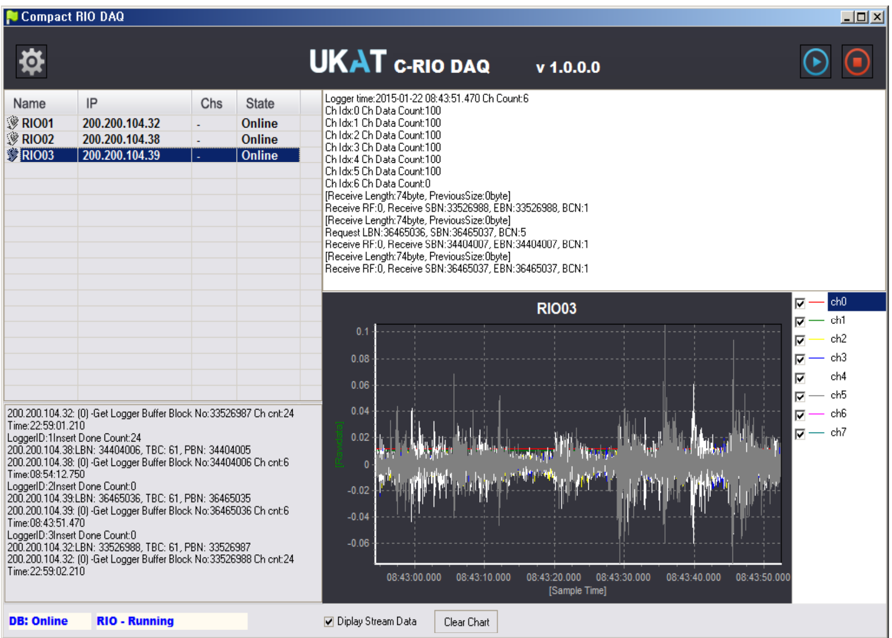

Fig. 13 Verification of existing measurement data connection

The statistical signal processing program was operated normally, as shown in Fig. 14. Raw data were saved in the database normally, as shown in Fig. 15.

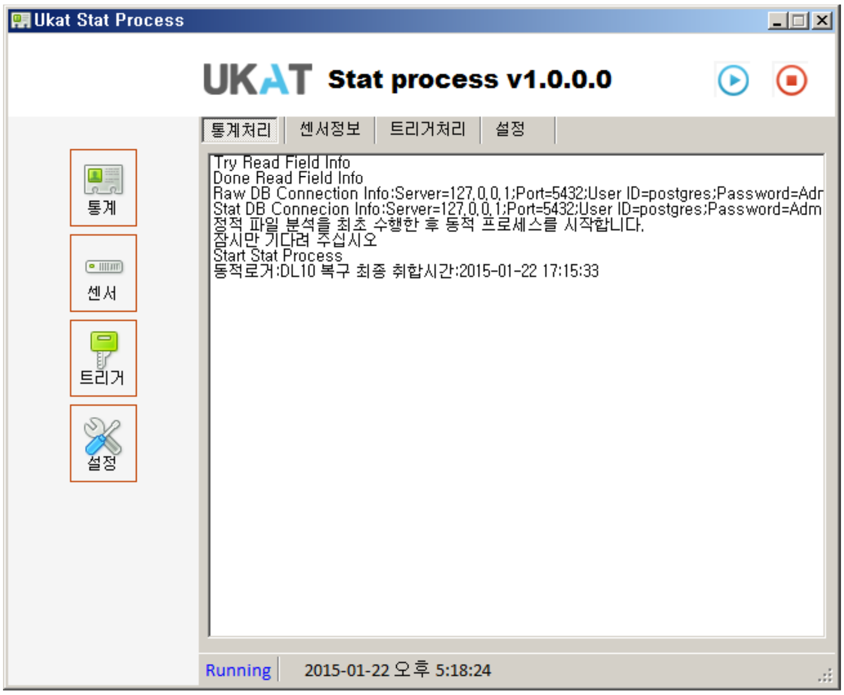

Fig. 14 The statistical signal processing program

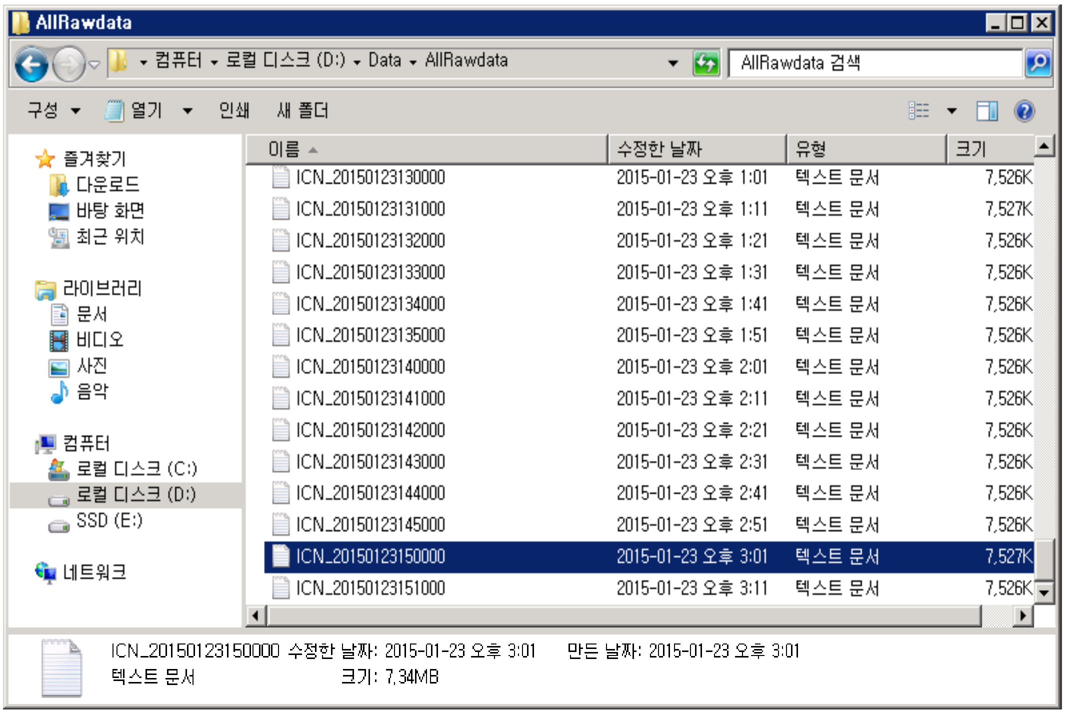

Fig. 15 Verification of saving in the database

Normal real-time data display of the newly-installed sensors (Fig. 16), statistical data display (Fig. 17), and the check, modification, and editing functions (Fig. 18) were verified.

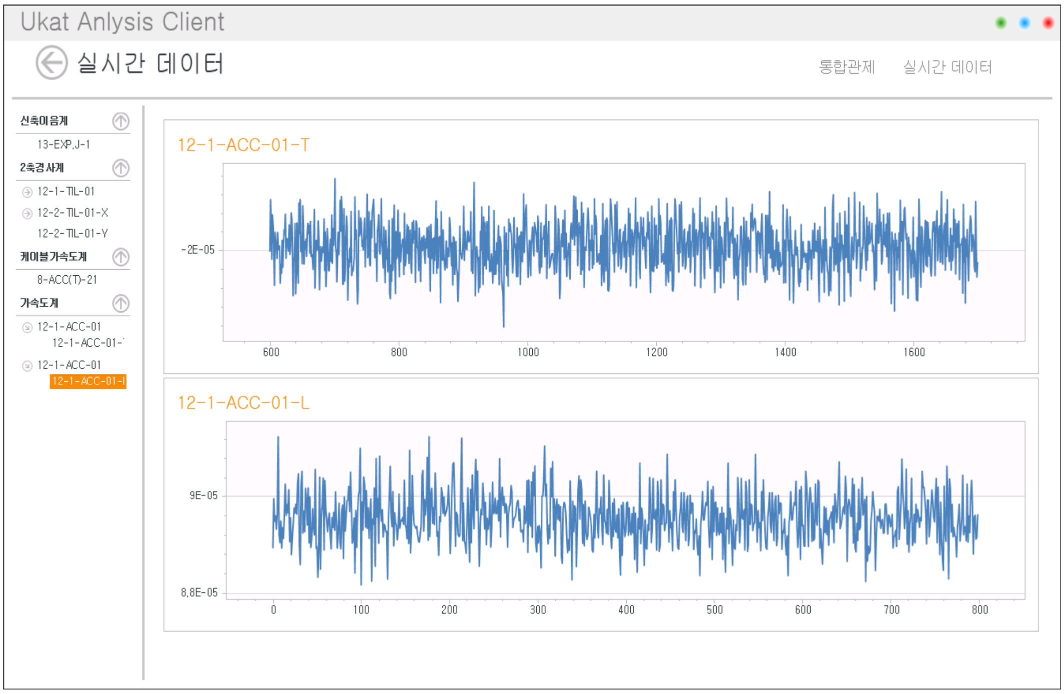

Fig. 16 Display of real-time data

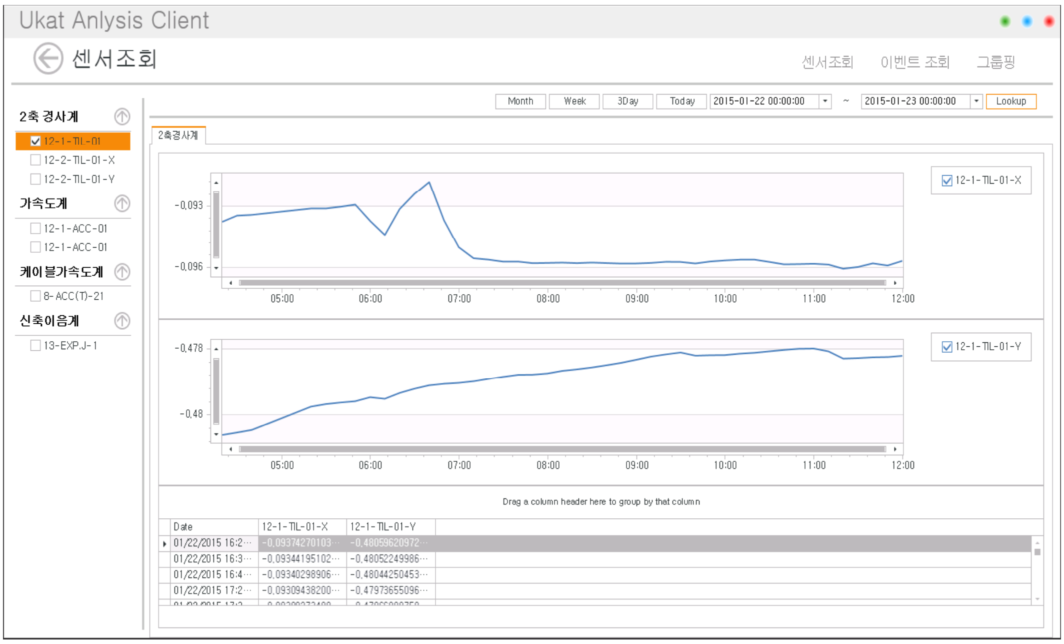

Fig. 17 Display of statistical data

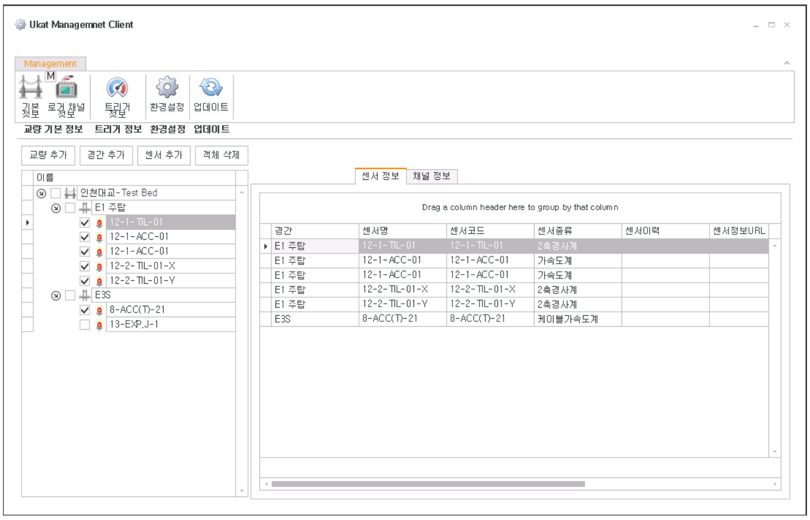

Fig. 18 Check, modification and editing functions of the sensor and channel information

3. CONCLUSIONS

Current bridge health monitoring systems have a serious problem that it is difficult to replace or upgrade a component of the whole system. In order to resolve this problem, we have proposed a user-based health monitoring system (UBHMS) in this study. This new UBHMS system is able to detect replacements or new equipment. UBHMS provides a single platform into which multiple monitoring systems can be integrated.

As a result of the test operation of UBHMS for a cable-supported bridge, it is possible to link measured data in an operation bridge and receive data from extra installed sensors so that there is no need to modify the operating software. Also, the statistical signal processing program was operated without any problem, and raw data were saved in the database according to normal procedures. Therefore, it would be expected that existing developer-based measurement system environments, which cannot be modified with information related to measurement sensors and data loggers, would be upgraded to this user-based measurement system environment that features compatibility and scalability. Difficulties inherent in measurement system control would be reduced because there is no need to modify any software when sensors and data loggers are added.

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