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A Bridge Monitoring System on Web-GIS Linking with UFID and BMS

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ABSTRACT

Nowadays, the importance of safety monitoring for facilities is increasing. Therefore, the introduction of ubiquitous technology to replace the existing manually-operated methods is required. In this study, a web-based GIS system that provides monitoring information of bridges in real-time for the application of a bridge management system through the use of ubiquitous technology is constructed. Particular attention is given to the effective interconnection of bridge monitoring information and bridge management system and, through a ubiquitous environment, how to connect this with the UFID and the GIS-based bridge management system (BMS) operated by the Ministry of Construction and Transportation. In addition, data expression methods are also suggested that state the detailed locations and attributes of structures in bridge management by using GIS.

Keywords : ubiquitous monitoring, bridge management system, UFID, web GIS

요 약

시설물의 노후화에 따라 시설물의 안전한 사용을 위한 모니터링의 중요성이 증가하고 있다. 기존의 인력에 의한 수동 계측에 의존한 방법을 대체할 모니터링 방법으로 유비쿼터스 관련 기술의 도입이 요청되고 있다. 본 연구에서는 유비쿼터스 기술을 이용한 교량관리 시스템의 실용화를 위해 필요한 교량의 모니터링 정보를 실시간으로 제공하는 웹기반의 교량관리 GIS 시스템을 구성하였다. 특히, 교량 모니터링 정보와 교량관리 시스템과의 효율적인 연동을 위해 국가공간프레임인 UFID와 현재 건설교통

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부에서 운용예정인 GIS 기반 교량관리시스템(BMS)과의 연계방안을 연구하였다. 또한 GIS를 활용하여 교량관리를 수행함에 있어서 필수적인 구조물의 세부위치와 속성을 표현하는 데이터 표현 방식에 대하여 함께 제안하였다.

주요어 : 유비쿼터스 모니터링, 교량관리시스템, 고유식별자, 웹기반 지리정보시스템

1. Introduction

Recently, the increasing frequency of construction-related accidents makes us consider the importance of an effective monitoring technology and the management of facility safety. Existing methods, however, mainly rely on manual measurement that require a massive number of work force and entail huge costs, resulting in inefficiency. In that sense, there is an urgent need for the development of a safe and cost-effective facility monitoring system.

Ubiquitous computing is a technology that allows one to watch, track, and optimize conditions, shifts, and locations of facilities by integrating sensors in a wireless network[1]. If we integrate facility monitoring in a wireless ubiquitous network and real-time measuring technologies, it would be possible for us to not only monitor a lot of facilities from a single control tower but also to reduce unnecessary costs and lessen the number of the work force. In addition, by combining those technologies with GIS (Geographic Information System) and LBS (Location Based Services), we envision possible applications in facility safe management area such as SMS (Short Massaging Service), electronic warning posts, and route-channel closing[2].

In this study, a U-bridge management prototype system and a web-based bridge management GIS, to apply ubiquitous technology to the application of bridge management systems, are constructed. Along with this, attention is given to the effective interconnection of bridge monitoring information and bridge management systems and how, through a ubiquitous environment, to connect with the UFID authorized by Korea and the GIS-based bridge management system (BMS) operated by the Ministry of Construction and Transportation. In addition, data expression methods that give detailed locations and attributes of structures in bridge management by using GIS are also suggested.

2. Bridge Monitoring Technology, BMS and UFID

2.1 Bridge Monitoring Technology

Under most current monitoring systems, only sensors and loggers are established on-site, while programs for analysis, monitoring, diagnosis and interpretation are all located in remote offices since temperature and humidity could badly affect on-site systems like computers and also because maintaining these systems onsite could cost a great deal in terms of time and manpower. Sensors, widely used for bridges in Korea, include stress meters, accelerometers, thermometers, strain gauges, Inclinometers, seismometers, wind indicators, settlement sensors, humidity meters, extensometers, and load cells. The data from these various kinds of sensors are backed up by modem once a day or at intervals of several days[3].

This kind of measuring system has two problems. First, it cannot accomplish real-time measurements. Currently, most of the BMS depend on visual verification methods and, even when using devices, back-up of data is usually only possible once a day; therefore, it is almost impossible to cope with emergencies or dangerous situations. Second, the data transmission also contains problems. Most data are transmitted through a cable network regardless of measurements at constant intervals or at random intervals; most problems of operation come not from the sensors but from reliance on this cable network, and improvements like the use of a wireless network are therefore urgently needed.

2.2 Technology Trend of UFID

UFID (Unique Feature IDentifier), currently under construction under the Ministry of Construction and Transportation in Korea, is used as a common key to manage, search, and apply topography and, thanks to its ability to judge locations, is the only electronic identifier distributed to the entire nation's topography[4]. UFID is commonly used as a reference to topography for different organizations and is also a basis of the LBS. A systematic UFID application and its management and system are therefore indispensable for the management of national land in the near future.

The features of UFID are shown in Table 1

Table 1. Features of UFID

Features	Contents
Diversity of information management	Containing item, location, administrative sector, map sheet and by managing organization in the Id., to output information as necessary
Interoperability of information	By using UFID as a primary key to the database of each organization, it provides a basis for integrating DBs that are managed separately
Systematic management of national geographic information	By distributing UFID to those who supply references on basic national geographic information for the integration of information, it supports a framework to systematically manage information
Consistency and efficiency of information	Maintains consistency of information by preventing repetition of input among independently-managed DBs, yielding cost-reduction
Practicability of information	From the introduction of UFID and ubiquitous systems, expect the application to all sectors related to location information such as resources, disaster prevention, logistics, and LBS related industries

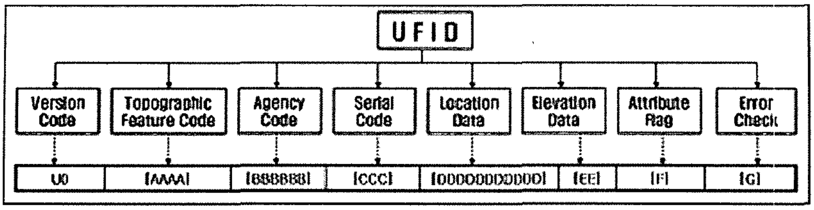

Figure 1. Structure of UFID

Table 2. Items and Main Contents of UFID

Items	Main contents	Length
Version code	code to identify UFID, versions of UFID	two digits
Topographic feature	System made by the National Geographical Information Institute, used in the Map version 2.0	four digits
Agency code	Organization to manage topography	six digits
Serial Code	Serial No. of the same topography within a region (having the same location information)	three digits
Location data	1" x 1" Unit Lattice Identifier, ex: 36425173829 is located on latitude 3642'51" , longitude 12738' 29"	eleven digits
Elevation data	In the case of buildings, the ground and underground expressed as 01-90 and 91-99, respectively. Others that get additional document at attribute information are given attribute flags In the case of roads, expressed as 01, 02 by the numbers of layers of overpasses, and 91, 92 in the case of tunnels or underground roads	two digits
Attribute Flag	Where one particular attribute is found in the same topography, it is used to refer to other attribute DBs	one digit
Error Check	Code to identify transmission errors of ID	one digit

and Figure. 1 is a composite of UFID. Eight fields are shown in Table 2.

3. UFID Application in U-bridge Monitoring System

3.1 UFID in a Ubiquitous Environment

Near future, all information of items in the national territory can be managed in a ubiquitous environment, and, in the course of this, location information is the most basic and important information. In some cases, there might be a great deal of uncertain information for locations. To apply a ubiquitous environment efficiently, this kind of basic location information management system is needed and should be necessarily considered in the facility monitoring under this environment. In this study, a measure to connect UFID to the location management system of ubiquitous-based facility monitoring--based on bridge monitoring--is studied.

1) The Expression of Location Information

The current standard of location information accepted by UFID is the expression of a representative location of a unit target. The precision required under a ubiquitous environment, however, is higher. A RFID or USN (Ubiquitous Sensor Network) is located on the unit structure or on all the inside elements of the target. Particularly in the case of the facility monitoring process, location information from the unit measurement sensor is very important in the behavior analysis of the bridge and the process requires coordinate information in cm units. Therefore, an additional standard for location information that expresses each part of the bridge is needed.

2) The Expression of Detailed Attributes

Like the location standard, UFID itself has a limitation in the ubiquity of bridge facility monitoring in the expressing of detailed attributes. Although the classification of the facility itself and the managing organizations are expressed, UFID needs a much more detailed approach. In particular, the bridge is comprised of various materials while road facilities are above deck. Different sensors are set to monitor these things. The DB structure and code that expresses the detailed attributes should be designed from this.

3) Linkage to the Telecommunications Environment

Various wired and wireless telecommunications play a great role in the ubiquitous environment, where telecommunications modules united with sensors will transmit information that sensors receive or USN, for local area-telecommunication among sensors, and will need to be constructed[5]. In the progress of a ubiquitous system, each ubiquitous device in the facility will get identification numbers based on telecommunications protocol in the short term; all facilities will be given telecommunications addresses like TCP/IP, telephone numbers or identifiers, in the long-term. The most proper identifier for this is IPv6, which could be an important means to transmit the status information of facilities, including location information, to users or systems and will be necessary for meeting the situation requirements, as well.

3.2 Connection UFID to BMS

1) BMS DB Table Analysis for the Connection with UFID

The DB table is analyzed for the connection of UFID and BMS. The analysis is classified into location information, materials attributes, quantitative information, maintenance information and management information items. This is a fundamental process for connecting UFID with detailed locations or materials attributes of bridges, as shown in Table 3.

Table 3. BMS Detail Input Item

Classifications	Detail input item	Related item				
		Location Inf.	Materials attributes	Quantit-ative Inf.	Mainten-ance Inf.	Mgnt. Inf.
Common materials	4 items, incl. bridge No.					O
Basic materials	21 items, incl. usage	O	O	O		O
Bridge specifications	8 items, incl. lines	O		O		
General specifications	31 items, incl. date of start of work	O	O	O	O	O
Cross materials	3 items, incl. cross kinds and states					O
Structural materials (Superstructure)	21 items, incl. span-length	O	O	O		
Structural materials (Substructure)	17 items, incl. site No	O	O	O		
Inspection materials	38 items, incl. inspection date	O				O
Load Bearing Capacity evaluation	11 items, incl. evaluation date		O	O		
Repair Records	13 items, incl. preparation date	O		O	O	O

2) Location Expression in BMS

As mentioned above, the location expression of sensors or materials of a bridge cannot be fully satisfied using the existing UFID only, which leads to a new method to express exact locations of sensors and materials.

By analyzing the currently-used input items of BMS, the item related to the location on the bridge is drawn out. The contents are shown below.

○ Bridge Length : Calculates the length between bridge spans of the abutment of the bridge along with the center of the bridge and then rounds this number off down to two decimal places in m units

○ Bridge Width : Defines bridge width as the right angular width to the bridge axle from the superstructure

○ Bridge Height : Defines bridge height as the longest perpendicular-direction length from the deck to the ground surface

○ Water depth : In the case of bridges over a river or the sea, the maximum water depth of the bridge is calculates.

Water depth here means at the time of inspection.

- ○ Number of Spans : Defines the number of spans as the space between one bridge pier and its neighboring bridge pier. The total number of spans are input.
- ○ Maximum Span Length : Calculates the maximum span length. Span length means between the supports of spans but for the convenience of calculation in the case of a single bridge, between the platform of the bottom, and in the case of a continuous bridge, between the platform and the center of the bridge, or the length between the center of the bridge.
- ○ Span Length : Inputs the span length in charge
- ○ Column No. : Inputs the number of columns into the data of the substructure. Column No. starts with 1 in order and is entered in three digit-natural numbers.

3.3 Measures to Connect BMS and UFID

The existing BMS and UFID separately manage the same bridge with different systems and identifiers. In this situation, the integration of these identifiers makes the information of different systems shared with each other. For this, the linkage of BMS and UFID is as the following.

1) The relation table (or field) with UFID is added to the bridge management system DB and the basic geographical information management system of the UFID server. E.g., "Bridge No. 0000 = UFID XXX"

2) The common 'Bridge No.' item of the BMS DB detail input items is replaced by UFID.

Figure 2 shows the linkage between the BMS and the UFID server.

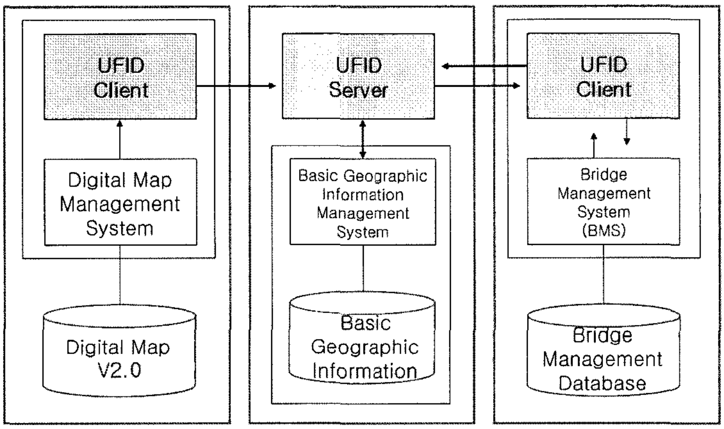

Figure 2. Linkage between BMS and UFID Server

4. Construction of a Web-based GIS Bridge Monitoring System

4.1 Design and Build-up of a Web GIS System for Real-Time Monitoring

1) Location Expression in BMS

The GIS is mainly categorized into a device DB and an attribute DB. The device DB is divided into a vector DB and a raster DB, while the attribute DB is made up of a static attribute DB and a real-time attribute DB. In this study, the Web GIS was built for bridges on the Han River in the Seoul Metropolitan area and a vector numerical map of 1:25,000 and LANDSAT raster satellite pictures were used for the device DB. Further, for the attribute DB, a static attribute DB of seven bridges, governed by the Seoul Construction Safety Office, and a real-time attribute DB through the real-time bridge monitoring of the Mapo Bridge were constructed.

The constructed web GIS provides results through a real-time bridge health analysis of the ubiquitous environment by wired and wireless Internet, so users can get static and dynamic attribute information about the bridge.

The web GIS developed in this study is used for static and real-time information sharing for bridges on the Han River. Therefore, along with the device DB above, the device DB of the bridge is made as a polygon and a static attribute DB and real-time attribute DB were constructed.

2) Attribute DB Design According to the Introduction of UFID

The attribute DB used for the construction of the web GIS for bridge management builds the bridge information that the Seoul Construction Safety Office provides with a static DB. In addition, the real-time DB has been constructed so as to divide the measured results from sensors in a bridge into a real-time-based table of information as well as graphed information[6].

The construction of GIS data occurs by applying ArcGIS S/W and, in the case of bridge construction, basic attribute information with polygonal characteristics is created. Table 5 shows the attribute DB contents, which are created when building basic model information.

Figure 3 shows the information of the Mapo and Hannam Bridges, provided by the Construction Safety Office homepage, which is built by an attribute DB in this study.

In the web GIS monitoring model system of this study, the static attribute DB is constructed based on the information of bridges on the Han River. Table 6 is the definition of the static attribute DB items and data

Table 5. Creation attribute DB when building bridge model DB (polygon)

Field	FID	Shape	Bounday_ID	AREA	UFID
Type	Num	Text	Num	Num	Text

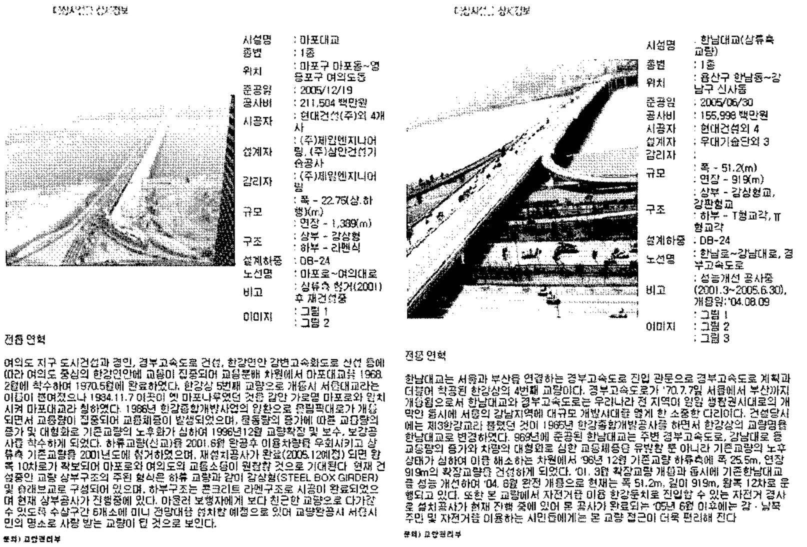

Figure 3. Bridge attribute DB (Mapo Bridge (left), Hannam Bridge (right))

Table 6. Static attribute DB and data type of bridge

Field	UFID	Name of facility	Type	Location	Date of construction finish		Construction cost
Type	Text	Text	Text	Text	Date		Num
Builder	Designer	Administrator	Scale	Structure	Design load	Name of line	Pic
Text	Text	Text	Text	Text	Text	Text	Image

Table 7. Real-time attribute DB Items and Data Type of bridge

Field	UFID	Name of facility	Sensor kinds code	Sensor ID	Setting location No.	Signal update period	Input unit code	Input day/ month	Input time	Input value	Sensor management data code
Type	Text	Text	Text	Text	Text	Num	Text	Date	Time	Num	Text

types of bridges developed in this study.

Table 7 shows the definition of the real-time attribute DB items and data type received from sensors of a bridge such as accelerometers, thermometers, strain gauges and wind indicators.

4.2 Web GIS Construction

1) Web Service

In this study, ArcIMS is used for constructing web-GIS. Service should be constructed on a web server to show the information and analysis results of GIS. ArcIMS transforms the

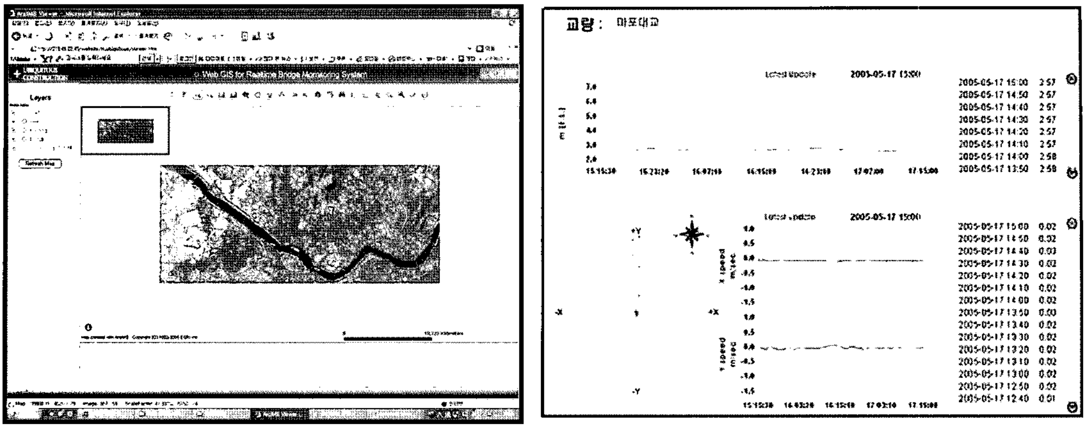

Figure 4. The result screen performed real-time monitoring (wind indicator)

constructed GIS map into image-information and provides this to users on the web. Such a transformation processes high-capacity GIS data quickly. When requested by users of a client for the display of GIS DB and analysis, it transmits the analyzed results to the web in response. That is, the realization of a one-only response per one request reduces the burden on the server and enhances processing speed.

In this study, ArcMap forms a map; therefore, service is created by ImageServerArcMap1 as the virtual server.

2) Real-Time U-bridge Monitoring Web GIS

The developed real-time bridge monitoring web GIS is made by the HTML Viewer, making it possible to amend it easily.

This model test was made to perform real-time monitoring and 22 GIS functions through the web GIS site. In this model, along with some basic functions of GIS such as Expand, Reduce, Select and Index Map, various GIS tools like a DB search through Query and a Buffer Zone through a space search are brought about. Through real-time monitoring, the data from sensors could be updated with web GIS together in real-time.

The most important purpose of this study, the real-time monitoring function, is expressed as an symbol (Figure 4) that shows a real-time attribute DB (text/graph) which is received from bridge measurement sensors. As shown in the Figure, through real-time monitoring, by giving information about displacement, acceleration, wind indication and temperature changes to the server via a CDMA wireless telecommunications network, the real-time-based information is expressed by way of an attribute table and graphed results.

5. Conclusion

The purpose of this study was to collect and analyze data from sensors, inspect the status of facilities in real-time and develop a system to cope with emergencies. In this study, a web GIS system was developed in order to integrate and manage many facilities through a single integrated system rather than to develop a system that monitors a single facility only.

The effective connection between bridge monitoring information and bridge management system and, in a ubiquitous environment, how to connect Korea's certified UFID and GIS-based bridge management system, operated currently by the Ministry of Construction and Transportation, is studied. Additionally, in GIS-applied bridge management, data expression methods to express detailed locations and attributes of structures are suggested.

The purpose behind this was to make an initial web model that, along with the original functions of GIS, manages structures which build and reflect the dynamic attribute database. For the purpose, wireless packet telecommunication was adopted for real-time information acquisition.

The current web GIS could express materials-based results and accomplish simple space analysis. However, a semantic web GIS, which analyzes and processes information based on knowledge, should be created. Therefore, the technology that is needed to bring about a semantic web GIS requires more study.

In closing, the demand for adding USN to the existing bridge monitoring is fast increasing. Based on GIS, the study for expressing and analyzing real-time measured information, location information and attribute information is also surely required.

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