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A Study on the Construction of an Urban Disaster Prevention System based on WSN/GIS

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ABSTRACT

In these days, Disaster Management Systems have still put emphasis on its recovery more than the prevention of disaster events. However, the countermeasure of restoration has limitations to prevent the caused loss because the disasters often happen and are massive. Therefore, we propose a disaster prevention system for supporting the safe urban. In this paper, we try to construct a real-time monitoring system to prevent disaster events using new technologies such as Wireless Sensor Networks (WSN) and Geographic Information System (GIS). As a prototype to simulate the fire disasters on real-time, we construct gas sensors and temperature sensors. Our system consists of a WSN system to collect data of the gas and temperature sensors and to monitor the situation information. Our contribution is to provide a prototype application to prevent the disasters from the fire by constructing a WSN system with gas and temperature sensors.

Keywords: WSN, GIS, Disaster Information Monitoring, Disaster Prevention Systems, Urban Safety

1. INTRODUCTION

In recent, damages from artificial disasters as well as natural disasters have been increased because of the change of climate such as global warming and complex society. The disasters are able to cause the loss of the human's life and property by the car accidents, crash, flooding, and fire [1]. Thus, scientific analysis and management methods are required to prevent the disasters as viewpoints of prevention before the disasters happen.

Many countries have tried to research systems for the reduction of the disasters [2-4]. In case of America, FEMA (Federal Emergency Management Agency) is trying to diminish the dangers. They effectively manage 50 states via 10 intendances [5]. In case of Japan, the central organization called as the Cabinet manages whole disasters, and detail management is controlled by the local government [6]. In cases of developed countries, they have been more interested in preventing the disasters through scientific analysis methods [7,8].

However, the disaster management systems of Korea focus on the disaster countermeasure and recovery services rather than the danger prevention services with analysis and prediction. Therefore, we must change disaster recovery management systems into disaster prevention management systems with scientific analysis like other advanced countries. With this mind, the disaster management systems must be constructed with various sensors and location information to

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exactly and rapidly manage prevention, countermeasure, and recovery steps [9].

The automated monitoring systems are required to measure data related with disasters such as gas, rainfall, and smoke because manual data collection by human can cause distortion or inaccurate information. Also, integrated databases for the management of disasters must be constructed to prevent and reduce the damages [10].

In this paper, we propose a construction of a disaster prevention system including an integrated database connected with WSN. The system consists of the WSN for gatherings raw data on the real-time environment and the GIS for providing the urban location information. The proposed WSN system is the real-time monitoring system for keeping the safe urban on the mobile environment. Also, we implement a prototype in order to monitor the environment information on the GIS map using gas sensors and temperature sensors.

The contents of this paper are organized as follows. In section 2, we describe related works mobile computing environments and WSN construction. Next, we present the design of an urban disaster prevention system with WSN and GIS. In section 4, we implement a prototype system and display the results of sensing data on the GIS map. Finally, we summarize our paper and describe the future works.

2. RELATED WORKS

2.1 Mobile GIS and Mobile Computing Environments

Mobile GIS refers to the use of geographic data in mobile devices like PDA (Personal Digital Assistants), Tablet PC, mobile phone, and so on. The main components for Mobile GIS are GPS (Global Positioning System), mobile device, and Mobile Computing Environments [11]. The Mobile GIS can be used in various domains such as Telematics, Delivery Service, Security, and information services like environment monitoring systems, fire management systems, and health care services [1,2,4,5].

Mobile Computing Environments can offer network services to users on a moving situation. In other words, you can work with portable computers and digital wireless communication with portable peripheral devices without cutting the connection off [12]. In these days, the processing capability, storage capacity, and the environment of data communication from advanced technology of portable computing units have been largely improved for a short time. Especially, Tablet PC and notebook computers have smaller size and more powerful functions, and can provide the wireless internet services in every place as the progress of the 4-Generation mobile communication such as WiBro and W-CDMA.

2.2 Sensor Devices and Network Construction

The WSN is defined as the technology for detecting and managing environment information such as temperature, humidity, pollution, crack, and smoke with attached electronic tag on real-time in any place where we need [13].

The fives different kinds of core technologies such as sensors, processors, communication, interfaces, and security are required to implement a WSN. The Sensors, processors, and communication need for cognizing the environment information, and the interfaces and the security need for the natural communication with human.

Fig. 1 shows a star topology in the architecture of general sensor networks. The PAN Coordinator on the center manages sensor nodes around the PAN Coordinator. Each sensor node sensing the events around them transmits the collected information into the central coordinator node. The Sensor nodes around PAN Coordinator can only communicate each other through the PAN Coordinator.

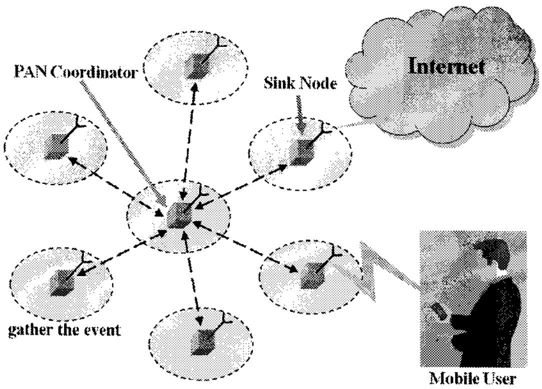

Fig. 1. Architecture of General Sensor Networks.

In sensor networks, a role of each node is as followings. The sensor nodes gather the information from sensor fields and transmit the information to sink nodes. Then sink nodes transmit the information to the gateway. The gateway can be constructed as the type of the star topology with only sink nodes and manages the topology. At this time, the gateway takes a role as a PAN Coordinator. The gateway can send the data transmitted by each sink node to the Application Server, and user can monitor the data gathered from each sensor field on a client personal computer. In the sensor field, if the distance from one sensor field to another sensor field is over maximum, the sensor node can transmit the data into another sink node via the multi-hop routing. Fig. 2 shows the multi-hop routing sensor network.

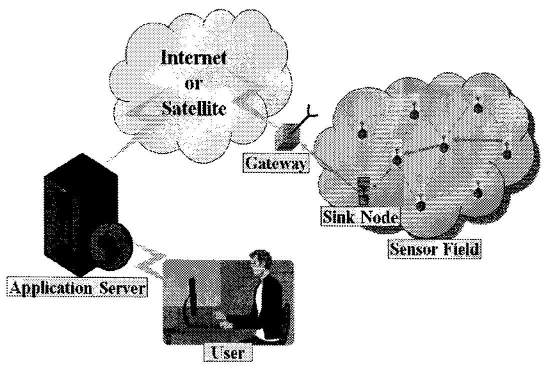

Fig. 2. Architecture of Multi-hop Sensor Network.

In general, the WSN is usually used as a monitoring system. Cha [6] developed a remote monitoring system for wind turbine using wind sensors in UNIX environment. It can perform various monitoring work and control tasks in wind-turbine applications. Lee [8] proposed a context data monitoring system for gathering and analyzing context data based on the WSN. It can sense more user-environment information than existing monitoring technologies based on the wire-communication technology. Kim [14] proposed a system of water supply facilities to monitor the facilities and treatment information of value-room and flowmeter-room installed to supply water based on WSN and PDA. It provides safe installation management via CDMA (Code Division Multiple Access) network which transfers data to remote servers to monitor the system situation from remote distance. However, users can not manage effectively the sensors because these systems [6,8,14] do not provide geographic information of sensors. It is important that not only sensing and monitoring the environment information but also managing the installed devices effectively. However, most researchers have paid no attention to manage the equipments of sensors.

3. DESIGN OF URBAN DISASTER PREVENTION SYSTEM

In this section, we design a monitoring system which can gather the information by using gas and temperature sensors to escape fire accident which can happen around our lives and store the data to databases on real-time.

Our entire system consists of three tiers, which are client applications, WSN field, and databases to gather historic data of the disaster data as shown Fig. 3. In sensor network, each sensor node transmits the collected data to sink nodes through ZigBee protocol, and gateway transmits the data to the RS-232C Communication Module in client

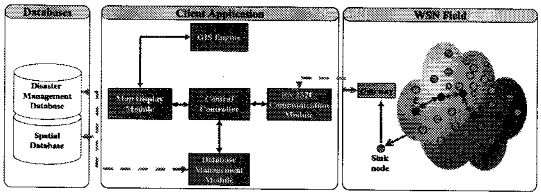

Fig. 3. Architecture of Entire System.

applications. The Central Controller of the client applications processes the collected data.. Main components of our system are described in detail like followings.

Databases. The Disaster Management Database store manages disaster history information of the risk factor gathered in sensor fields. The Spatial Database stored geometric information to show the map on the client side.

GIS Engine. This module extracts digital map information from the Spatial Database and display geographic information through the Map Display Module.

Map Display Module. This module can display the geographic information and the position of sensors stored in the Disaster Management Database and the spatial databases through the GIS Engine. Users can search the location information of installed sensors on the map viewer.

Central Controller. This module controls the whole processes executed on the user applications. In other words, this module manages the priority order and the schedule of each module.

Database Management Module. This module takes a role to connect the spatial database and the disaster management database to related modules. This module extracts geometric information from databases to execute the operation such as moving, reducing, and magnifying digital map. This working is executed by transmitting GIS Engine through the Central Controller. Also, if a user sends a query, this module extracts the disaster history information from the Communication Module or the Disaster History Databases and transmits the results to the users.

RS-232C Communication Module. This module parses the data from the Sensor Field and checks the critical values and parsed data. When the data was over the critical value, this module displays alarm signal to the Client Applications and transmit the history information to the Database Management Module via Central Controller.

4. IMPLEMENTATION OF URBAN DISASTER PREVENTION SYSTEM

The prototype system is divided into two parts, one is hardware part and the other is software part. The software part is developed in Visual Studio .NET 2005 environment. The Disaster History Database and the GeoSpatial Database Server is constructed in MS-SQL Server 2003 environment. The sensor networks of the hardware part is implemented by using the Nano-Q+ developed in Electronics and Telecommunications Research Institute (ETRI), the Nano-24 Development Kit of Octacomm, and the CYGWIN for cross-compile environment.

4.1 Implementation of Sensor Network

Table 1 shows the information of nodes in con-

Table 1. Node Information of Sensor Networks

	Sink Node	Gas Sensor Node	Temperature Sensor Node
Application Node ID	0000	0001	0002
Node Type	SINK	SENSOR	SENSOR
PAN Coordinator	True	False	False
Permit_ID_Start	0001	-	-
Permit_ID_End	0009(0255)	-	-
Application Name	mySink	gasSensor	tempSensor

structing the sensor networks. Setting Permit_ID_Start to '0001' and setting Permit_ID_End to '0009' are that sink nodes manage just node-id from '0001' to 0009 values on sensor networks.

Sink Node. Sink node received data from sensor nodes and transmit the data to PC of users via RS-232C interface serial communication.

Gas Sensor Node. Gas sensor nodes transmit the data extracted from the gas sensor into sink node. The gas sensors located on the Nano-24 Sensor Board can be usually used in leakage alarm systems of inflammable gas such as LNG and LPG.

Temperature Sensor Node. The temperature sensor node transmits the data extracted from the temperature sensor to the sink node like Gas Sensor Node. Temperature sensor in Nano-24 can measure the range of the temperature -30℃ through +100℃.

4.2 User Application

We applied results of previous research to GIS Engine and Map Display Module [15]. Thus, this paper focuses on the method of connection between GIS and sensor.

RS-232C Communication Module. The RS-232C Communication Module sets up the port to communicate with sink nodes and parses the data from sensor networks. Then, the data is displayed on screen of users. Also, after the module checks whether the data goes over the critical value or not, it sends the alarm signal to the central controller. We set up the critical value for the sink node of gas to 100, and set up the critical value of temperature to between -20℃ and +40℃. The battery of sensor nodes usually keeps up between 2.3V and 3, and we set the critical value of battery to 2.3V. When the critical value is under the defined value, the alarm signal is sent to a user.

Central Controller. The Central Controller manages the whole processes which are running in the user application. If the RS-232C communication module receives a message is that the sensor value is over the critical value, calls the database management module, connect the database, and store the data to the disaster history database.

Database Management Module. This module tries to connect the disaster history database through wireless internet. We describe the important three tables in databases.

① TempSensor Table

Database management module stores the data received from each sensor on real-time as the TempSensor structure of the table 2. Because the received data is too much amount for storing all of them, we use the trigger for maintaining the last 40 number of data.

② SensorLog Table

The SensorLog table of the table 3 needs to store the log information when each sensor has a trouble. When the battery value of sensor remains less than critical value, or the data of sensor is over the critical value, the Database Management Module automatically store the log as the structure of this table.

Table 2. Architecture of TempSensor Table

Column name	Type	Description
SensID	Integer	Identification of sensor node (Primary Key)
SensType	Integer	Type of sensor • 0 : Not a sensor node • 1 : Gas sensor • 2 : Temperature sensor • 3~10 : Reserved
SensValue	Integer	Sensed data. Value must be one of 0~1024
SensPower	Integer	Remained battery value of sensor

Table 3. Architecture of SensorLog Table

Column name	Type	Description
LogID	Integer	Identification of Log Data (Primary Key)
SensID	Integer	Identification of Sensor Node (Foreign Key)
SensType	Integer	Type of Sensor (same as TempSensor table)
SensValue	Integer	Sensed Data
CondInfo	Varchar(30)	Information of Abnormal Condition
LogDate	datetime	Date of Received Data

Table 4. Architecture of SensorInfoFormat Table

Column name	Type	Description
X	Integer	Value of current point X-Coordinate -20
Y	Integer	Value of current point Y-Coordinate -20
nX	Integer	Value of current point X-Coordinate +20
nY	Integer	Value of current point Y-Coordinate +20
SensID	Integer	Identification of sensor node (Foreign Key)
SensType	Integer	Type of sensor (same as TempSensor table)

③ SensorInfoFormat Table

As the structure of table 4, this table needs to store the location information and the data extracted from each sensor. The stored data is processed when a user event such as moving or clicking the cursor on the sensor icon happens in the geographic map. X, Y, nX, and nY is the location information, which is stored as the 40×40 area of a point to easily handle the location rather than processing a point.

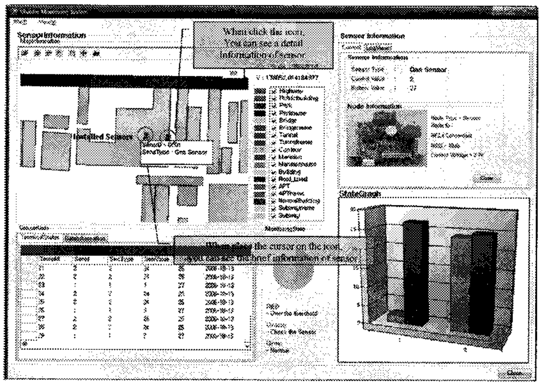

Fig. 4. A Screen Shot of a Prototype System.

4.3 Implementation result

Fig. 4 shows a screen shot for the execution of map, sensor, and log data on real-time. A user constructs the sensor networks and registers the location of the sensors using the sensor registration interface. When the registration is finished, the icon of each sensor is registered. The user can monitor the real-time information of each sensor. If data is over the critical value, the log data will be automatically stored in the disaster history database. System manager can confirm the log information of the system as shown in Fig. 4.

The developed system can automatically gather the data of the disaster factor, and a manager can easily monitor the gathered data on real-time. Also, the system provides visualized information for the efficient management of each installed sensor. To visualize the information, the system shows geographic information at the 3D bar type of graph. The log data shows a result of sensed gas and temperature information.

To use the result of this research, we can gather the high quality of the disaster data by using wind velocity, CO_2, or water level, and other sensors which can be factors of disaster prevention system. However, we can not provide the functions such as spatial analysis, because of focusing on gathering the information of each sensor. Because the sensed data from each sensor node is raw data, the work measuring correct calibration must be processed.

5. CONCLUSIONS

In this paper, we designed and implemented a prototype of disaster prevention systems for keeping the safe urban using WSN devices and GIS technologies. It is difficult to apply to all sensors of the disaster factors. Therefore, we chose the gas sensor and temperature sensor because of the disasters caused by the gas explosion and fire happened in urban. Also, we implement a prototype and verify the proposed system and confirm the possibility of the system.

It is important that the system can gather the information on real-time and can offer the location information of disaster events such as fire or gas explosion. In this point of view, it is sure that the construction of disaster prevention systems with GIS is a basic and important factor.

Our next research is going to research about how to manage sensing errors in complex and poor environment.

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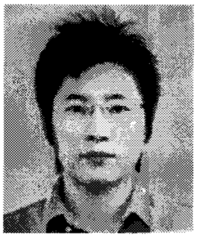

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