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Design and Implementation of Monitoring and Early Warning System for Urban Roads Waterlogging

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Abstract. Waterlogging happens almost in every rainstorm in city roads and the concave type of overpasses in Beijing. It causes to serious effect for the security of people's daily travel. For resolving this kind of problem, this paper designed a monitoring network by water level sensors and other technologies of internet of things, and developed a monitoring and early warning system for detecting the real-time information of waterlogging conditions in urban roads. This system can capture the real time information of waterlogging depth, make a fast query statistics for certain road or area, and also provide the short message service for the public. It is very convenient for the managers working in department of flood control and command center to collect the real-time information of waterlogging status around urban roads. This is helpful for the local government to perform the correspondingly emergency plan and issue waterlogging information for the public, so as to reduce the impact on the security of people's travel caused by the suddenly bad weather.

Keywords: urban roads waterlogging, monitoring and early warning system, design and implementation, sensors

1 Introduction

The speed of city construction has become more and more quickly with the rapid development of urbanization in recent years. As side consequences, the disaster of regional flood in urban areas has increased significantly, and some other weaknesses in city planning, construction and management have been also emerged at the same time [1]. A large number of concave type of overpasses and tunnels have been constructed to alleviate traffic pressure and to ensure travel unimpeded in some mega-cities such as Beijing and Shanghai[2-4]. A big challenge should be faced by the people working in the department of city flood control because some sudden extreme rainfall weather happens now and then in recent years. For example, the 7 roads were in traffic disruption, the 27 bridges were covered with water, and the traffic was resumed until 6 hours later during the severe natural disaster happened at July, 21, 2012 in Beijing. The main reason for this phenomenon is due to the unreasonable planning of the city drainage system, additionally, there was no systematic monitoring

for the status of the road waterlogging which caused the delay of the early warning and forecasting because of no real time monitoring and transmission of the data with real time water condition[5-6].

For resolving the above mentioned problems, this paper designed a road waterlogging monitoring network covering the whole Beijing urban areas by means of sensor technology and wireless transmission technology. Based on this network, a road waterlogging monitoring and early warning system was developed. The system can provide real-time information for managers performing decision-making strategy, and offer technical support for the organization of municipal drainage management. This system can be also used to release water monitoring information to the public through the micro-blog and other rapidly updated media, so as to guide the public travel. The monitoring method, system design and implementation were discussed in this paper.

2 Methods

As shown in Fig. 1, sensors were installed near the concave type of overpass or low-lying courtyard road where often suffer from waterlogging. Sensors in the whole study areas constitute a waterlogging monitoring network. The mobile GMS/GPRS communication network was used to transmit water information to the monitoring center at certain preset intervals. The road waterlogging monitoring system was developed through the information collected by sensors. The waterlogging locations are displayed in this system. It can be used to query the real-time water information and make an early warning for urban flood. This monitoring system software is installed on the WEB server, which can provide service of real time water information to the public. The workers in department of flood control only needs a computer with internet access to operate the software, realizing the real-time query of road waterlogging, water retention, reminding of early warning, water site inquiries with exceed the standard water, and 12 hours of water values etc..

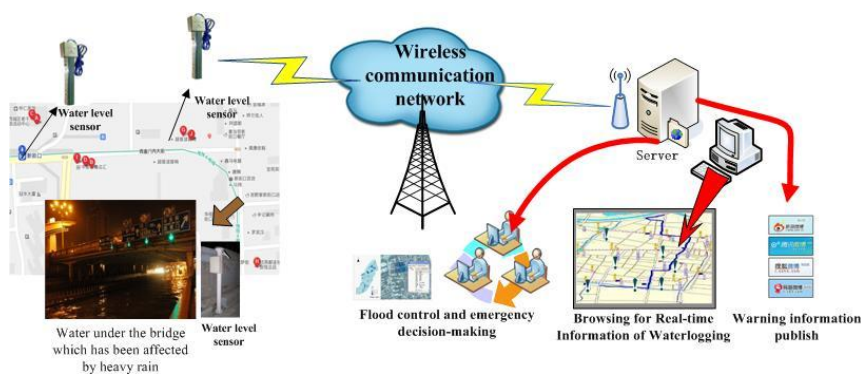


Fig. 1. Schematic diagram of monitoring method for urban roads waterlogging

3 System Design

2.1 System Architecture

This system includes two parts, that is, road waterlogging monitoring stations and monitoring center, as shown in Fig.2.

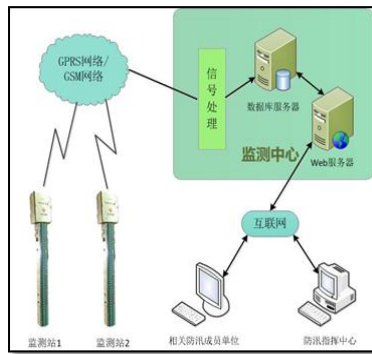


Fig. 2. The system structure diagram

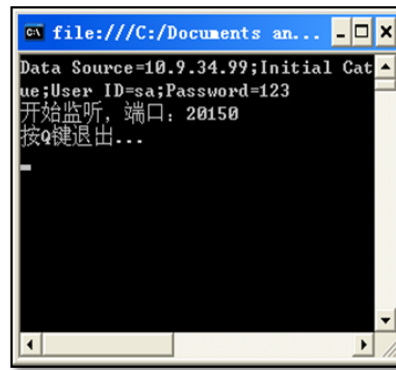


Fig. 3. Data receiving Service

Road waterlogging monitoring station is consists of electronic gauge and wireless terminal, which are responsible for data acquisition and data transmission of real time road waterlogging. Electronic gauge and wireless client machine are the important components of road waterlogging monitoring station. Electronic gauge is used to collect data of water level. It is equipped with advanced microprocessor chips for digital water level controller, and built-in communication circuit of sensor. It has the characteristics of high reliability and anti-interference performance with measurement accuracy of 1cm. The wireless client machine: it is used to data transmission. It is a whole new generation of intelligent telemetry terminal through assembling RTU, GPRS/GSM communication module, protection module and the charge controller. It can directly access the 5-10W solar panels or other accords with the power supply voltage requirements.

Monitoring center is responsible for data reception, data processing and data display[7]. It is consists of hardware such as the database server, web server and software such as data receiving software and application software. As shown in Fig.3, the data receiving terminal is responsible for receiving, decoding, checking and storing of the receipted road waterlogging data transmitted by the monitoring network.

2.2 Core Functions

This system is an integrated flood control synthetic application system for digital urban which assembles electronic map, real-time water monitoring, early warning analysis. As shown in Fig.4, the core functions of this system can be divided into 3

major parts, also known as a subsystem. They are water information receiving module, water monitoring and early warning module, and a warning short message service module, each module has its own corresponding function.

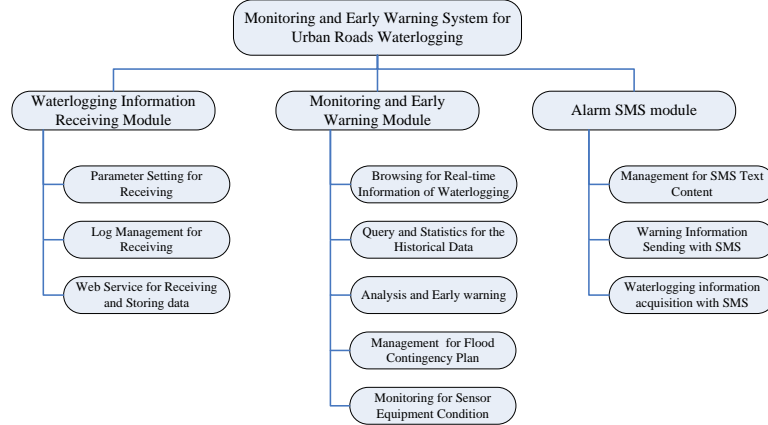


Fig. 4. The core functions of monitoring and early warning system for urban roads waterlogging

2.3 Road Waterlogging Alert Levels

There are four alert levels designed in this system. They are blue, yellow, orange and red alert in an ascending order level. The alert level in a single monitoring station is determined by the waterlogging time and water depth. The alert standard for different warning levels is shown in table 1.

Table 1. The alert level of real-time monitoring data for urban roads waterlogging (single monitoring site)

The Depth \ Duration	5 cm -	10 cm -	15 cm -	>= 20cm
	10cm(Ex)	15cm(Ex)	20cm(Ex)	
0-15 min(In)	Yellow alert	Orange alert	Red alert	Red alert
15-30 min(In)	Yellow alert	Orange alert	Red alert	Red alert
30-60 min(In)	Blue alert	Yellow alert	Orange alert	Red alert
> 60 min	Blue alert	Blue alert	Yellow alert	Red alert

The synthetic alert in the whole urban region is based on the comprehensive analysis of all the monitoring sites. The alert standard is shown in table 2.

Table 2. The alert Level of real-time monitoring data for urban roads waterlogging (taking all the monitoring sites into account)

The Comprehensive Alert Level	The Specific Standards
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Blue Alert	More than 50% of all monitoring sites have issued blue alert; or more than 30% of all monitoring sites have issued yellow alert; or more than 20% of all monitoring sites have issued orange alert and over.
Yellow Alert	More than 80% of all monitoring sites have issued blue alert; or more than 50% of all monitoring sites have issued yellow alert; or more than 30% of all monitoring sites have issued orange alert and over.
Orange Alert	All monitoring sites have issued blue alert; or more than 80% of all monitoring sites have issued yellow alert; or more than 50% of all monitoring sites have issued orange alert and over.
Red Alert	All monitoring sites have issued yellow alert; or more than 80% of all monitoring sites have issued orange alert; or more than 50% of all monitoring sites have issued red alert.

Water retention alert only relates to the early warning in an individual site. The alert level is issued based on the water level decline rate. The alert standard is shown in table 3.

Table 3. The alert Level of water retention in urban roads

Withdrawal Rates (unit: cm / hour)	2.0(In) - 5.0	2.0(In) - 3.0	1.0(In) - 2.0	< 1.0
Alert Level	Blue alert	Yellow Alert	Orange Alert	Red Alert

4 System implementation

City Road Waterlogging Monitoring and warning system is designed as a browser / server (B / S) software system architecture. Flex framework and C# were used as the programming language, and SQL Server 2008 as the database server. ArcSDE is adopted to store the spatial data, and ArcServer is employed to provide the map service. The interface is shown below, as shown in Fig.5.



Fig. 5. The Interface of Monitoring and Early Warning System for Urban Roads Waterlogging.

5 Conclusions

With the rapid development of social economy in urban region, the disaster of waterlogging or lost caused by sudden rainstorm or other bad weather might become more and more serious. It makes the managers in department of flood control and command center to collect the correct and real time information of waterlogging much more convenient that the establishment of the monitoring and early warning system [8-9]. This system built by means of sensors not only provide reliable information for the local government to perform some decision-making in flood control and command, but make the working be more of efficiency and the decision-making policy be more of scientificness, so as to guarantee the security of people's daily travel much more better.

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