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Research Article

The Design and Development of the Aquatic Resources and Water Environment Monitoring and Control System based on IOT

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Abstract: In order to achieve the status, distribution and variation of regional water environment and the aquatic resources in time and accurately, it is important for the water resources managers to predict the risk of accidents and generate the emergency plan, which is based on the technical route of the system function layer and data layer. The results show that the management system of the database management system, GIS and artificial neural network water quality forecast model can be expressed in real time and directly.

Keywords: Aquatic resources, artificial network model, Geographic Information System (GIS), water quality prediction, water resources management

INTRODUCTION

Water is a valuable natural resource. In our country, with the rapid development of industrial and agricultural production and social economy, population increases and the human activity influence intensifies, rivers and lakes water pollution problem is becoming more and more serious (Câmara *et al*., 1990), which has become a prominent problems facing the water environment in China. Water environment monitoring and early warning system is composed of automatic monitoring system, data acquisition system, data transmission system, information management system, early warning and forecasting system (Labadie and Sullivan, 1986). It can achieve real-time continuous and regular monitoring of water environment, automatic and continuous data, control the change characteristics of water quality, water quality and pollution load and trace pollution sources. Research on the application and development of the key technologies of the water environment automatic monitoring and early warning forecast system is carried on by many scholars.

Water environment automatic monitoring system has the characteristics of high cost, high maintenance cost, high monitoring parameters and monitoring representative, which can only be applied to some specific parameters, it is difficult to adapt to various environment and meet the requirements of different levels of testing (Hou *et al*., 2005). New methods, new equipment development, development, will be foreign mature technology and equipment to digest and absorb and can improve this situation. The research on the technology of water quality automatic analysis, more reliable and effective network technology, software platform and equipment development and application and the quality assurance of the system is a problem to be studied (Hu and Yu, 1997).

Water environment monitoring is an essential part of water resources protection and management and it is an important basic work. Through the monitoring of pollutants in the water environment and pollution factors, the reasons and the way of pollution are evaluated and the water pollution problems are identified and evaluated and the technical support is provided for the prevention and control of pollution (Zhang *et al*., 2002). In the field of water environment monitoring, the organic combination of routine monitoring and automatic monitoring should be adopted for different drainage and management needs. As early as the beginning of the seventies of the 20th century, the United States and other developed countries is the rivers, lakes and other surface water carried out hydrological and water quality of synchronous and continuous automatic monitoring of pollution sources and the water quality continuous monitoring; Japan to basin and the pollution source of two kinds of water quality automatic monitoring system (Johnson, 1986). The utility model is characterized in that only measured water quality parameters and measured hydrological parameters: European Rhine River water pollution early warning system and the Danube River Basin water pollution early warning system in the regional pollution control play an important role, reflecting the water environment monitoring technology of science, the level of modernization and the development direction. At the end of 1980s, our country began to introduce water environment monitoring system, the water environment monitoring system of real-time dynamic monitoring system has gradually been attached importance to the end of the 90 years, the water quality automatic monitoring station construction has been rapid development. At present, water quality monitoring system has been developed by manual sampling, manual titration and laboratory analysis, which is based on large instruments and automatic and intelligent monitoring technology (Maidment, 1996).

The core content of water environmental monitoring is to monitor and analyze the quality of water resources and its changing rules and to provide scientific basis for the development and utilization, management and protection of water resources. Organic pollution is the main problem of the current water pollution, the manual sampling and laboratory analysis is the main method to monitor the environmental pollution. It will cause the monitoring frequency is low, the sampling error is large and the monitoring data is not accurate. Therefore, the need to focus on the implementation of industrial pollution sources automatic monitoring of pollution sources. However, there is still a contradiction between the environmental protection management needs and environmental monitoring means in China. There are existing standards for monitoring analysis method or monitoring instrument is difficult to meet the requirements of routine monitoring (Câmara *et al*., 1990). Therefore, it is an important task to study the development and use of water environment monitoring instrument and the new method of water environment monitoring.

The application of online water environment monitoring system based on internet of things has greatly improved the effectively and real-time collecting of water environment monitoring system, It is an implementation of automatic online water environment monitoring network in the country.

In order to achieve the status, distribution and variation of regional water environment and the aquatic resources in time and accurately, it is important for the water resources managers to predict the risk of accidents and generate the emergency plan, which is based on the technical route of the system function layer and data layer. However, the technology of water environment monitoring and quickly moving analysis develops relatively late in china. Compared with Europe and the United States, the technology in our country is far behind them, which has been in the exploratory stage now. Therefore, taking the East Lake in Wuhan as an example, this research puts forwards the subject about study on online water environment monitoring system based on the monitoring and control system which is based on the distribution of the data acquisition and information management and the artificial network model (Câmara *et al*., 1987).

THE KEY PROBLEM INTRODUCTION

The water environment: Water environment information management system is an important means to realize the sustainable use of water resources. The research of water environment information management system has experienced the four stages of development which include the Relational Database Management System (RDBMS), Management Information System (MIS), Decision Support System (DSS) and the Geographic Information System (GIS). The system database model is developed from basic relational database model to the database model of spatial data storage and expression ability. The system functions is from simple data storage and query, to support office business process automation and provide decision support for the daily management of water resources and pollution accidents.

In this research, taking the East Lake in Wuhan as an example, the regional water environment information management system based on the latest GIS and DSS technology is studied to monitor and manage the complex water environment factors in the region, the state of water resources, distribution and variation of water resources in space and time scales. The potential accidents and emergency plan are predicted, which provide technical support for the unified scheduling and management of water resources.

East Lake is a shallow type lake which is located in Wuchang District, Wuhan City, Hubei Province. The water area of the East Lake is 34.59 km^2 and the total Lake volume is 86480 thousand cubic meters, which has a catchment area of 117 km^2. The East Lake is largest city lake in China, that is the national key scenic spots. The water in the East Lake are used in both fishery, regulation, climate regulation and many other aspects. Over the years, due to the extensive development and utilization of water resources in East Lake Source, the water environment quality in East Lake is worrying.

Basic technology and model: The Internet of Things makes the human life more intelligent, convenient and comfortable, which also stimulates the industrial production and environmental monitoring remote control and online real-time technology development. And it also promotes the realization of unmanned, remote on-line control and real-time online monitoring. The emergence and development of the Internet of things has given many industries a much broader development space and a new technology field.

Internet of Things (IOT) is emerged in recent years, interdisciplinary, the infinite field of a large concept of science and technology, at present the international for the Internet of things haven't a precise definition. The application of the Internet of things technology is very extensive. It is a new type of network technology which can be realized by the development of the Internet. As shown in Fig. 1, since the Internet of things can be achieved through two interactive mode between human,

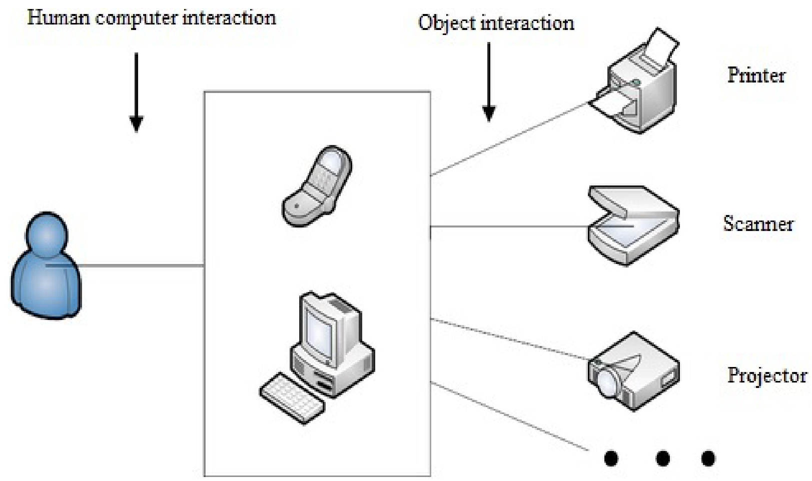

Fig. 1: Interactive mode and application of IOT

material, machine and the communication between them, the sensor technology, identification technology, based on the real-time monitoring of our daily life and all the realization of intelligent, automated, unmanned control becomes possible.

All in all, the Internet of things is a kind of information technology, such as the object and process of monitoring, connecting and interacting with each other in real time, collecting the information of acoustic, optical, thermal, electrical, mechanical, position and other physical characteristics.

THE OVERALL DESIGN OF THE SYSTEM

According to the system requirement analysis, the research object and the basic principle of the software engineering, the system structure is divided into two parts, the data layer and function layer.

The data layer is based on the elements of water resources and the relationship between water resources and water resources in the East Lake. The data layer is provided by SQLServer to provide a database management engine. And the data model is provided by Geodatabase and the spatial data model is provided by ArcSDE to store and manage the attribute data and spatial data.

Functional layer on the water resource management requirements and management processes are summarized, in order to expand the premise of the design of geographic information system of the various functional modules. Functional layer which uses ArcObjects secondary component development and implementation of spatial data management, real-time information query, water quality forecast, water resources management and early warning, decision support and advice document management subsystem, which spatial data management, monitoring and related document management query function direct access and modify the data layer; and analysis evaluation, early warning decision support and generate report form management and so on need through the access model, method base, calls and system closely integrated model or method and finally through the data access layer to obtain the required data is expected to complete function.

The selection of the monitoring network: In this research, the object of this research is based on the background of East Lake and it has a large scale of water area, which needs to adapt to the outdoor long-term collection work and complex and changeable climate environment. Therefore, this research designs a wireless network which must have the following characteristics: the network topology structure is wide and it is used to meet the needs of the work time, the number of nodes and the distance between the nodes and the collection point.

Table 1 lists four common types of Internet of things, they have their own characteristics. According to the characteristics and requirements of the design of water environment monitoring system, it can be seen that the ZigBee network type is more suitable for the construction of monitoring system network. The ZigBee network can work in three different frequency bands, the working time is long and low power consumption, which is more suitable for long time outdoor work environment, with the network topology structure can cover large area of the lake. And the cost is not high for the basic requirements of multi node. The remaining three kinds of network, in the study of the long and cost two aspects are difficult to meet the needs of the actual monitoring, more suitable for mobile phones, handheld computers, laptops and other mobile devices in urban life. Therefore, this research selects the ZigBee network as a wireless communication network for water environment monitoring.

The data layer design of the system: The design of geographic information database is to abstract the water resources and related objects in the East Lake as a

Table 1: Comparison of four common types of internet of things

Network types	Characteristics	Network standard	Transmission Distance/m	Work Time	Main Application
Zigbee Network	Short distance, low complexity, self-organization, low power consumption, low data rate, low cost	IEEE802.15.4 standard	10~100	6-24 months	Monitoring and controlling
Bluetooth Network	Low power consumption, small volume, Low cost	IEEE802.15.1 standard	10~30	Several weeks	Cable replacement
3G Network	Large amount of data transmission, long transmission distance in the range of city 3G network coverage	CDMA2000, WCDMA, TD-SCDMA, WiMAX	> = 1000	Several hours	A wide range of voice and data
Wi-Fi Network	High transmission speed, transmission distance High reliability	IEEE802.11 standard	75~122	Several hours	Web, email and image

spatial data model, which can be stored and expressed in the spatial database system. In this research, the following 5 steps are proposed to design the geographic information database, the system is needed to be transformed into the geographic information database:

- Getting data from the user perspective
  - Confirm the function module of data sources and the data flow
  - Grouping data into logical groupings
- Defining objects and relationships
  - Identification and description of the object
  - Identification and description of relationships between objects
  - Representing entities and relationships with UML diagrams
- Selecting the geographical expression
  - Confirm whether the elements are the space-elements
  - Analysis the impact for the data analysis caused by the elements of the shape selection
  - Selection of elements in different scales on the map
  - The text property of the confirmation element is significant on the screen or on the map's display mode
- Matching with the geographic information database model
  - Further analysis of the characteristics of spatial information, the right choice for the geographic information database model
- Organization of geographic information database structure
  - The judgment and definition to subcategories
  - Identification and geographic information data set
  - Defining geometric and topological relations

Through the above steps, the system of geographic information database design.

THE FUNCTION LAYER DESIGN OF THE SYSTEM

The division of landscape river and monitoring position selection: The selection of monitoring points in the overall and the macro must be able to reflect the water quality of the water environment and the region. The specific location of each section shall be able to reflect the pollution characteristics of the regional environment. According to the principle of layout, according to the landscape river in the center area of river channel length, average water depth, flow rate and from the south to the north, In the nine areas, the water quality monitoring points and water monitoring points are set up and the water quality monitoring points are set up in the central area of the East Lake and the water treatment facilities are connected with the recycled water treatment facilities. The water quality monitoring samples are collected at the distance of 0.3 m to 0.5 m.

The system will be the above landscape river and the monitoring point of spatial information through the system of spatial data management functions to capture storage, storage in the corresponding spatial elements of data. The spatial data collected at the same time, including the overall planning of the East Lake has been identified in the water channel, back water channel, water supply pipeline, drainage pipe, water pipe, reclaimed water pipe, channel connection pipe, water treatment facilities, etc.

The selection of the monitoring parameters: In order to monitor the water environment quality of the East Lake, the water quality of the water body, the water quality of the water source, the water supply and drainage mode and the functional requirements of different regions of the landscape water body, the water quality monitoring and control index and the sampling frequency are proposed.

Continuous monitoring parameters: pH, electrical conductivity, dissolved oxygen.

Daily monitoring parameters: Transparency, total nitrogen, ammonia nitrogen, nitrate, total phosphorus, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD).

Weekly monitoring parameters: Chlorophyll a and chloride.

The above information is established in the monitoring parameters table of the spatial database model in this system and the monitoring data is stored by establishing the relationship between the table and the quality of water relationship class.

Table 2: Alarm thresholds and response recommendations

Monitoring parameters	Alarm thresholds	Response recommendations
Dissolved oxygen concentration/ mg L^{-1}	<3.5	Aeration
Electrical conductivity/*μs* cm^{-1}	>800-1000	Changing the water source or improving the treatment effect
Chloride concentration/ mg L^{-1}	>55-80	Change the water supply
PH	>8.5 <6.5	Change water source
BOD/*mg* L^{-1}	>8-10	Changing the water source or improving the treatment effect
COD/*mg* L^{-1}	>25	
Total phosphorus concentration/*μg* L^{-1}	>35	Start the enhanced phosphorus removal device or the adsorbent material
Total nitrogen concentration/mg L^{-1}	>3	Improve the nitrification and denitrification capacity of the system water treatment facilities
Nitrate concentration/*mg* L^{-1}	>0.5-1.0	
Ammonia nitrogen concentration/*mg* L^{-1}	>1 (especially>8.5)	Improve the nitrification ability of the system water treatment facilities or change the water source

Integration of the water quality prediction model: The water quality prediction function of the system is integrated with the Artificial Neural Network (ANN) water quality prediction model. Artificial neural network is a nonlinear dynamic system, which is composed of a large number of neurons through a very rich and perfect connection. It is one of the most active research fields in the world. In this system, the artificial neural network model is used to study the most in-depth, the most widely used BP algorithm based on the multi-layer feed-forward network model.

In the three layers network, the output vector $X = (x_1, x_2, \ldots x_n)^T$ and the output vector of the hidden layer $Y = (y_1, y_2, \ldots y_m)^T$ and the output layer vector $O = (o_1, o_2, \ldots o_l)^T$. The weight matrix is represented by V, which is from the output layer to the hidden layer and $V = (V_1, V_2, \ldots, V_j, \ldots, V_m)$. Among the expression, the column vector V_j is the weight vector corresponding to the j neuron and W is the weight matrix from the hidden layer to the output layer and $W = (W_1, W_2, \ldots, W_k, \ldots, W_l)$ and the W_k means the weight vector corresponding to the k neuron and the calculation in every layer is listed as follows.

The output layer is as follows:

$$o_k = f(n_j), \quad k = 1,2,\cdots,l. \tag{1}$$

$$n_k = \sum w_{jk} y_j, \quad k = 1,2,\cdots,l. \tag{2}$$

The hidden layer is as follows:

$$y_j = f(n_j), \quad j = 1,2,\cdots,m. \tag{3}$$

$$n_k = \sum v_{ij} x_i, \quad k = 1,2,\cdots,m. \tag{4}$$

And the transmission function is the unipolarity Sigmoid function:

$$f(x) = \frac{1}{1+e^{-x}} \tag{5}$$

The system validates the model selection the water quality monitoring data in Germany seddin as the test data from 1992 to 2005., the input parameters of the model is aimed for the parameters of TN, Chl-a (chlorophyll a), NO_2-N, NO_3-N, TP, NH_4-N. And the model output parameters of the model are TN and Chl-a. The input output is trained to complete the prediction model. The data were input to the water quality prediction model in 1992 and 2004 and the water quality data was predicted by the trained model in 2005. Through the results of the model, the average error of TN is 10%, the average error of Chl-a is 12%. This results show that the accuracy is higher and it has certain application value.

Setting of early warning and decision: The water quality of the water system in the central area of the East Lake is required to reach and maintain the water quality requirements of the GB383822002 class III. With the special functional requirements of the water environment of the Olympic Park, the system is set up to meet the requirements of the water quality monitoring parameters of the alarm threshold and the data is shown in Table 2.

The system will be the above alert threshold and response to the proposed storage to the corresponding object table, with early warning and decision support function module to real-time monitoring of the park water environment and allows users to add and change the existing data and gradually improve the accuracy and scientific of the system's decision.

The system can be based on user needs of different data sets to the representation of the layer and the map file to zoom, drag, production of thematic maps, output and other functions. The system also has a highlight and a positioning tool, the map area of the selected elements will be highlighted and flashing display or the geometric center of the element as a map display center automatic positioning.

The system monitoring value query includes static query and dynamic display. The static query functions are selected from the map or object list box to choose the monitoring object, feedback the corresponding monitoring value and it also can be used for mapping and output. And the dynamic display function allows users to define the dynamic data frame, when the system automatically reads the database, the dynamic data frame in the map will be updated to show the latest monitoring and forecast values of the object.

The prediction function for the user selects the monitoring objects and parameters for water quality prediction and the prediction value with the existing monitoring values of drawing and output and the system can also be used to predict the real time display in the dynamic data box and predict the data as a warning.

By defining the degree of evaluation and correlation of the monitoring parameters in the East Lake, the real-time monitoring values of various water bodies are identified by using different colors, which can provide automatic and visual expression for the user to obtain the water quality assessment information. When monitoring or predicting the value of the data to achieve the defined early warning threshold, the system automatically sends out an alert and provides support to the user to provide measures to respond to different situations and to record the response measures of alert information and management.

Related document management functions as a large amount of water resources related laws, regulations, technical standards, standards, books and periodicals to provide quick document add, query and search functions, in the geographic database, the system designed to serve the document management functions of the relevant object classes and the relevant documents are classified into the geographic information database, to provide users with information to facilitate timely information.

CONCLUSION

This research takes the water environment system of Wuhan East Lake as the object, studies and designs the data layer and function layer of the regional water environment information management system based on IOT, integrated the database management system, geographic information system and artificial neural network. With the function of automatic alarm and decision support system, the system can realize the dynamic management of regional water related data and improve the automation degree of regional water environment management.

The system can expand the water quality prediction model, water quantity calculation model, evaluation model and decision support method based on the existing 6 functional modules, thus meeting the needs of users. The system only needs to input the corresponding area water environment condition the demand data, then can be applied in other similar water environment system.

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