Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2022.28734

269 (2022) 303–312
September

Design of monitoring data visualization system of water resources based on J2EE architecture

Hairui Chen[a,*], Hechuang Wang[b]

[a]*Zhongyuan-Petersburg Aviation College, Zhongyuan University of Technology, Zhengzhou 450007, China,*
[b]*College of Information Engineering, North China University of Water Resources and Electric Power, Zhengzhou 450045, China*

Received 7 December 2021; Accepted 18 July 2022

ABSTRACT

In order to solve the problems of slow update speed and low definition of visualization results existing in traditional data visualization system, this research realizes the optimization design of visualization system from three aspects of hardware, database and software respectively under J2EE architecture. The wireless communication network and terminal acquisition device of the system are optimized respectively. On this basis, the database is built according to the type of water resources monitoring data, and the relevant data is imported into the database environment to provide data support for the operation of the software. Then, the 3D scene is constructed, and the location information of water resources monitoring points is imported into the created environment, and the real-time monitoring data is collected by hardware devices. By drawing visual images and generating image controls, the visualization of water resources monitoring data can be realized. The experiment shows that: compared with the traditional visualization system, the visualization update time of this system is reduced by about 0.69s, and the definition of the visualization results is effectively improved.

Keywords: Water resources monitoring; J2EE architecture; Monitoring data; Data visualization processing

1. Introduction

Water resource refers to the water source that can be used or is likely to be used, and it should have sufficient quantity and appropriate quality, and meet the specific needs of a place in a period of time. Water, which can be directly or indirectly used by human beings at present and in the near future, is an important part of the earth. With the development of science and technology, more and more water has been used by human beings, such as seawater desalination, artificial catalysis, Antarctic continental ice and so on. Due to the change of climate conditions, the spatial and temporal distribution of various water resources is uneven, and the amount of natural water resources is not equal to the available water. It is often used to build reservoirs and underground reservoirs to regulate and store water sources, or to recycle and treat industrial and domestic sewage to expand the utilization of water resources.

The total water storage in the earth is about 1,386 billion m^3, while the fresh water mainly used by human beings is about 35 billion m^3, accounting for only 2.53% of the total water storage in the world. A small part of them is distributed in lakes, rivers, soil and shallow groundwater below the surface, while most of them are stored in the form of snow, permanent snow and permafrost [1]. The average annual runoff of rivers in China is 271 billion m^3, ranking sixth in the world, and the spatial and temporal distribution is very uneven. In terms of spatial distribution, the water resources reserve in the Yangtze River Basin and its south area account for about 80% of the total water resources in China, while the water resources in the Yellow River,

* Corresponding author.

Huaihe River and Haihe river basins account for only 8% of the total water resources in China. The development of industry and agriculture has greatly affected the quality of water resources. Due to the impact of climate, China's available water resources also show an obvious downward trend.

In order to realize the protection of water resources on land, the monitoring method of water resources is put forward. The quantity and quality of surface water and groundwater change with time and space. This dynamic change is the result of the comprehensive action of various natural factors and human factors. Through the monitoring, we can know the dynamic changes of water quantity and water quality in time, and master their changing rules, so as to provide scientific basis for the development, utilization and protection of water resources. The quantity and quality monitoring of water resources is implemented through the dynamic monitoring network of water resources. In order to make the monitoring results more accurate, the existing hydrological stations, rainfall stations and meteorological stations are often included in the water resources dynamic monitoring network. The monitoring method of water quantity is simple and easy [2]. For surface water resources, water quantity can be determined by water level observation and flow measurement; for groundwater resources, water quantity can be monitored by the change of observation hole or spring flow. However, the data obtained in the actual monitoring process is difficult to directly reflect the current situation of water resources, so the data visualization method is proposed based on the water resources monitoring method. However, the data obtained in the actual monitoring process is difficult to directly reflect the current situation of water resources, so the data visualization method is proposed based on the water resources monitoring method.

Visualization is the theory, method and technology of using graphics and image processing technology to convert data into graphics or images to be displayed on the screen, and to carry out interactive processing. It involves many fields such as graphics, image processing, computer-aided design and so on. It has become a comprehensive technology to study a series of problems such as data representation, decision analysis and so on. Information visualization system can show people a new concept to realize data visualization and thinking visualization.

At present, the mature research results at home and abroad include data visualization system based on data warehouse, visualization system based on big data technology and visualization system based on Epicentre data model. However, the above-mentioned traditional data visualization system has obvious problems of insufficient definition in operation function, and the real-time switching between visualization data is not fast. From the perspective of system operation performance, the update speed and running speed of system visualization data need to be improved. In order to solve the above problems in the traditional system, this study applies J2EE architecture to it. J2EE architecture is a de facto industrial standard using Java technology to develop enterprise applications, which has the characteristics of high compatibility, portability and reusability. J2EE uses a distributed four-layer architecture, in which the client layer components usually run on the client, and other components run on the J2EE server or application server [3]. Through the application of J2EE architecture, the operation function and performance of water resources monitoring data visualization can be improved.

2. Design of visualization hardware system for water resources monitoring data

The design of water resources monitoring data visualization system is divided into two parts, one is water resources monitoring, and the other is monitoring data visualization. On this basis, the specific design and implementation are carried out from hardware, database and software. According to the composition structure of water resources data and the characteristics of network information release, the system adopts the four-layer distributed architecture of J2EE, as shown in Fig. 1.

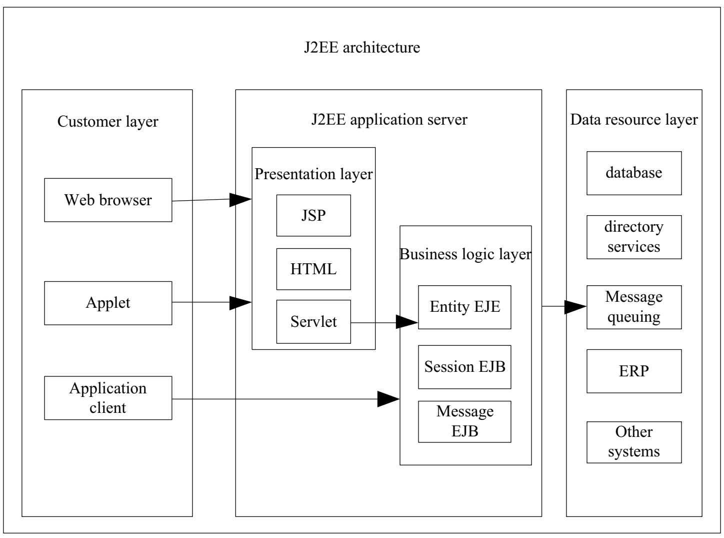

Fig. 1. Four-layer architecture of J2EE.

As can be seen from Fig. 1, the four logical structures of J2EE are data resource layer, business logic layer, presentation layer and client layer. Different service components in J2EE system are used to realize the functions of each layer, and different logical levels correspond to different running environments. The data resource layer component runs on the data server, the business logic layer runs on the application server, and the client layer runs on the terminal [4]. In the J2EE architecture, the core role of the customer layer is to complete the interaction task with the user and display the system information to the user. The presentation layer is the most flexible and rich in styles. In order to make the presentation layer of the system more beautiful and interactive, cascading style sheets and JavaScript language are often used to optimize the JSP or HTML interface of the presentation layer. The presentation layer also includes Bean classes for acquiring user input information. The related business Bean and its packaged service components support the presentation layer. EJB in the business logic layer is responsible for the realization of business requirements of enterprise level system in various fields. EJB receives requests from the customer layer, processes and analyzes the request data through a variety of encapsulated business Beans, and stores the business data in the data resource layer. The data resource layer is equivalent to the resource base of the whole system, including infrastructure, ERP system, database system, etc., which provides data reading and storage services for the business logic layer.

2.1. Design of terminal node

In the J2EE architecture environment, the terminal node of the system is set. Water resources monitoring terminal includes three parts: host, peripheral equipment and support system, mainly including water resources monitoring information processing module, data memory, positioning module, 3G/4G wireless communication transmission module and data communication interface [5]. The external equipment mainly includes wireless ad hoc network communication module, 433 M wireless communication antenna, 3G/4G wireless communication antenna, infrared video acquisition equipment and related sensor equipment. The supporting system is mainly power supply equipment, equipment support and equipment box. The monitoring equipment is the monitoring data collection equipment, which is one of the core equipment of the whole system. The key points of this part are composed of cameras, 3G video hard disk recorders and some closely related equipment. The core of the system is the camera, including lens, CCD, pan tilt, decoder, shield and bracket. The basic performance index setting of water resources monitoring data acquisition device is shown in Table 1.

The water resources acquisition equipment in Table 1 is mainly used to collect relevant data in the form of video or image. Similarly, it can set and install parameters of temperature, water level and other sensor equipment.

2.2. Design of data transmission network

433 MHz combined with 4G network is used to realize remote data acquisition of water resources parameters. Data acquisition is initiated by the remote server. The remote server sends data acquisition request to the 433 MHz master node with 4G communication module through the 4G network of the public operator, and then the 433 MHz master node sends data acquisition instructions to the sub node by polling. Finally, the 433 MHz sub node completes the data acquisition and sends back the collected data to the master node, and the master node completes the network management. After data collection of all sub nodes in the enclosure, the packet is sent back to the remote server through 4G network to complete the single data collection process.

The 433 MHz main nodes and sub nodes are distributed in a star shape. Considering the criticality of 433 MHz main nodes and the inconvenient maintenance of the actual terrain environment of water resources, the number of main nodes in a single 433 MHz network will be

Table 1
Performance setting of water resources data acquisition equipment

Parameter category	Parameter name	Parameter setting
Video	Video input	4 (or 8) channels of video input
	Video output	Two channel video output (RCA 1, BNC 1)
Audio frequency	Audio input	4 (or 8) channels of audio input
	Audio output	One-channel audio output
	Recording mode	Audio and video synchronization
Internal storage	2.5-inch SATA hard disk	
Interface	USB interface, serial port expansion interface	
Work environment	Working temperature	0.0°C–+55°C
	Working humidity	20%–85%
	Impact limit	Not more than 2,000 g (19, 600 m/S^2)
	Vibration limit	Not more than Smmp-p (5–22 Hz) 49 m/S^2 (5 g) (22–500 Hz)
	Enclosure protection	IP54 (GB4208-93)
	Power waste	Under normal working condition, the power consumption is less than 12 W, and the power consumption is less than 12 W in standby 0.5 W

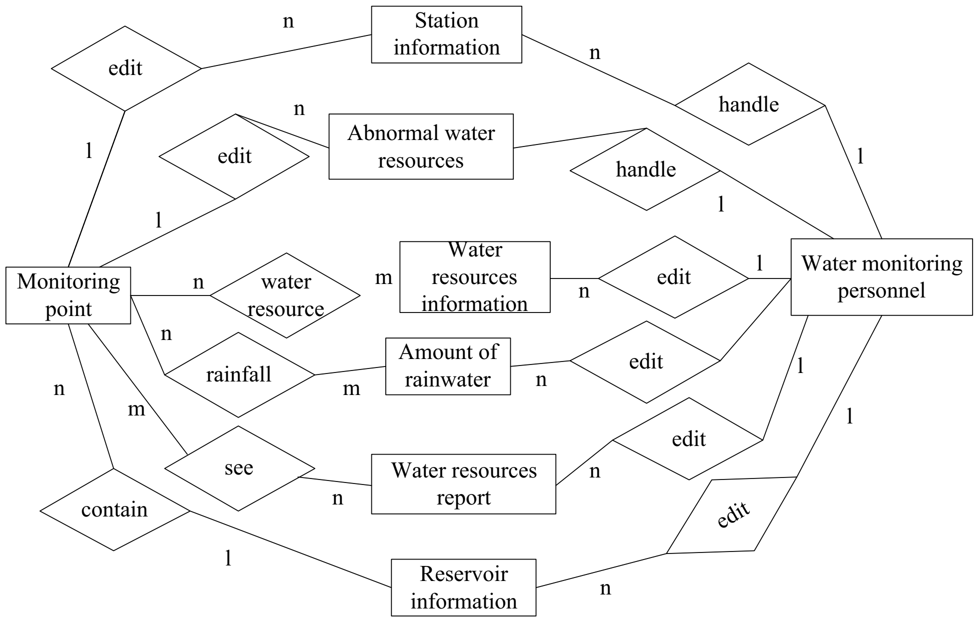

Fig. 2. E-R diagram of system database.

matched according to 10% of the total number of nodes in the network. When the remote cannot connect to the preset 433 MHz main node, the remote automatic connection equipment will use the master node for data collection, which can effectively prevent the failure of data collection of the whole network due to the failure of the master node in the case of a single master node [6].

In addition to the water resources monitoring terminal node and wireless communication data transmission network, the related data processing equipment, storage equipment and the hardware equipment of the monitoring center continue to use the hardware equipment of the traditional system.

3. Database design of monitoring data visualization system of water resources

A large amount of data information related to water resources is stored in the database, and the system design also needs to provide the functions of input, query and maintenance, statistics and so on. The data design should be based on the principle that users can easily, accurately and timely obtain the required information from the database [7]. Therefore, the design of system database follows the principles of normalization, paradigm theory and normalization of main and foreign keys. The water environment monitoring system adopts relational database for database management. Combined with the data content of water resources monitoring, the E-R structure is drawn, as shown in Fig. 2.

When E-R model is converted to physical model, entity is converted to corresponding table structure, identification attribute is converted to main code, other attributes are converted to table field, and then relationship is converted. The principle of relationship conversion should meet the conversion of three different relationship modes. The first is the one-to-one relationship, which requires the combination of two entities. The second is the one-to-n relationship, which is transformed into a foreign key constraint relationship, and the main code of the one-end identification attribute is used as the foreign key of the n-end table [8]. Finally, the m-to-n relationship is transformed to form a new table structure, and the identification attribute of entity 2 is transformed into the joint main code of the new structure, and is a foreign key constraint.

Combined with the logical relationship between the system data, the system data table is set, including the monitoring station data, real-time water and rain data, river water data, lake water data, daily water level data, gate dam/lake water data, etc. The data of the monitoring station is shown in Table 2.

Similarly, the water regime of the lake and reservoir can be obtained as shown in Table 3.

4. Software function design of monitoring data visualization system of water resources

Data visualization can be divided into four steps: source data cleaning, data storage, data selection and visualization drawing. Combined with the monitoring workflow of water resources, the basic realization process of system visualization function can be obtained, as shown in Fig. 3.

4.1. Construction of 3D water resources scene

The three-dimensional modeling process is mainly divided into three-dimensional data acquisition, three-dimensional data processing, three-dimensional modeling and other content. High resolution DEM, remote sensing images of different water levels, terrain vector feature layers and fine three-dimensional images of surface features

Table 2
Data sheet of monitoring station

Field name	Identifier	Type and length	Is there a null value	Unit
Station code	STCD	C(8)	Nothing	–
Flood reporting station code	STCDT	C(5)	Nothing	–
Station name	STNM	C(20)	Nothing	–
River name	RVNM	C(20)	–	–
Longitude	ESLO	N(7)	–	Degrees minutes seconds
Latitude	NTLA	N(6)	–	Degrees minutes seconds
Administrative code	ADCD	N(6)	Nothing	–
Datum elevation	BASE	N(6, 2)	–	–
Correction parameters	MDPR	N(4, 2)	–	–

Table 3
Water regime of lakes and reservoirs

Field name	Identifier	Type and length	Is there a null value	Primary key
Station code	STCD	C(8)	Nothing	Y
Mm/DD/yyyy	YMDHM	T	Nothing	Y
Water level in reservoir	ZI	N(7, 3)	–	–
Incoming flow, m^3/s	Ql	N(9, 3)	Nothing	–
Storage capacity, million m^3	V	N(9, 3)	Nothing	–
Characteristics of reservoir water	ZICHAR	C(1)	–	–
Reservoir water potential	ZITEND	C(1)	–	–
Flow measurement method	QMES	C(1)	–	–

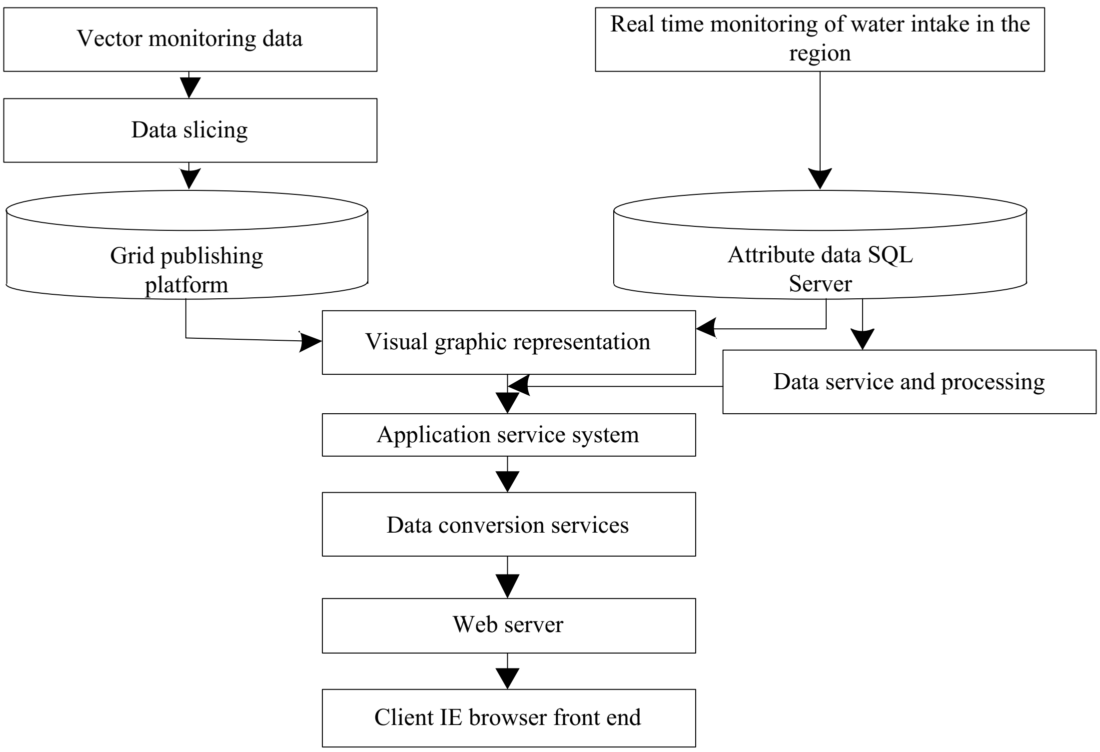

Fig. 3. Flow chart of visualization function of water resources detection data.

are obtained respectively. There are specific requirements for data format and size in building 3D scene, so it is necessary to process the relevant data. Data processing includes vector feature processing, terrain data processing, 3D model data processing and 3D model optimization processing. Among them, shape vector feature processing is that before importing vector feature layers into CityEngine, and feature layers need to be stored in the file geographic database to be recognized by CityEngine [9]. In order to ensure the consistency of the range and geographical coordinates of DEM and remote sensing image, the DEM and remote sensing image are clipped and space corrected, and then converted to TIF format. At the same time, the corresponding geographical coordinates and projection coordinates are given to the geographical element data, and stored in the file Geographic database. After the construction of 3D terrain model, elevation correction is needed to correct the wrong area. Finally, the digital terrain model is used to construct the 3D terrain, and the image data within the region is obtained. The 3D terrain model is generated through the image and DEM [10].

4.2. Positioning of water resources monitoring points

The monitoring points of water resources need to be marked in the constructed three-dimensional water resources scene. Assuming that the longitude and latitude coordinates of the monitoring points in the actual scene are $A(w_1, d_1)$ and $B(w_2, d_2)$ respectively, the longitude and latitude can be converted into radians. The specific conversion process can be expressed as follows:

$$s = 2 \times \arcsin\left(\sqrt{\sin^2\left(\frac{w_1 - w_2}{2}\right) + \cos w_1 \cos w_2 \times \sin^2\left(\frac{d_1 - d_2}{2}\right)}\right) \quad (1)$$

Then the distance between any two water resources monitoring points in the system can be calculated by Eq. (2).

$$d = s \times r \quad (2)$$

where r is the radius of the earth and d is the calculation result of the distance between two monitoring points [11]. Taking any monitoring point as an origin in the three-dimensional scene of water resources, the position of other monitoring points in the scene is obtained.

4.3. Collection and processing of water resources monitoring data

4.3.1. Collection of surface water level data

The water level sensor is mainly used to measure the buried depth of water level of surface hydrological long observation hole, which is mainly composed of pressure sensor, temperature sensor, single chip microcomputer, etc. Because the position of the sensor is fixed, the pressure change of the water column at the input position measured by the pressure sensor can be converted into the corresponding water level data by the matching telemetry substation [12]. The calculation of water level is based on Eq. (3).

$$H = L - h \quad (3)$$

where H is the buried depth of the water level; L is the line length of the sensor into the orifice; h is the buried depth of the probe. After the pressure sensor in the hole is placed under the water surface, a group of frequencies are generated by the pressure of water. These frequencies are transmitted to the substation through the high-strength cable, and the h value is obtained by the substation processing. Because the length of the line L in the hole is fixed, the substation can calculate H by using the above formula, so the telemetry substation can collect the groundwater level value.

4.3.2. Collection of groundwater flow data

The flow sensor can indicate the state of fluid through analog or switch output signal. In the system, the magnetic vortex flowmeter is generally selected for the measurement of pipeline flow, which is developed based on Faraday electromagnetic induction principle. A magnetic steel is placed at the bottom of the meter case to generate a strong magnetic field. The magnetic line of force passes through the pipe. When the medium flows through the strong magnetic field of the flowmeter, the cutting magnetic line of force induces a pulsating electromotive force. The electric signal is picked up by the electrode, and its frequency is proportional to the flow rate within a certain flow rate range [13]. The electrode is input with high-frequency oscillation signal, which is modulated by the flow signal. After modulation, the high-frequency signal enters the detector and single-chip microcomputer for calculation and processing, and the flow signal is accurately detected. The signal is converted into frequency signal by XY-II multi-function monitor and transmitted to the safety supervision system, and then extracted into the database of water resources monitoring system by the data extraction program of water resources monitoring system.

4.3.3. Monitoring data preprocessing

The real-time monitoring data are processed by using spatiotemporal interpolation method. Considering the correlation of the data in time and space, the known data in a certain time/space range are used to interpolate the data value of a certain point in time/space. The data points in the space are divided into several levels according to the relative distance, and the average distance $|h|$ and the corresponding average $\gamma(y)$ of the observation points in each level are calculated respectively. The experimental variogram can be obtained by connecting these average values [14]. The theoretical variogram of the data set is obtained by function fitting, and the least square method is used for fitting. The Gaussian model expression is set as:

$$\gamma(y) = C_0 + C_1 \times \left[1 - \exp\left(-\frac{y^2}{a^2}\right)\right] \quad (4)$$

where C_1 is the difference between C and C_0, representing part of the abutment value. According to the calculated range a of hydrological data, that is, the search radius of sampling point, the data set x_i around is determined, and the data value at sampling point x_0 is as follows:

$$Z(x_0) = Y^T W^{-1} B \quad (5)$$

where *W*, *Y* and *B* denote the matrix of $\gamma(y)$ and $Z(x_0)$ respectively. After Kriging interpolation, the water resources data will also have numerical value in the land area. In the process of visualization, it is necessary to cut the land area data, and high-precision sea land elevation data can be selected for processing. Through the spatio-temporal interpolation of water resources data, the spatial continuity of water resources data is realized, and the complete and smooth data of the specified sea area is obtained [15]. Using the method of time interpolation and Kriging interpolation, the data relationship on the time axis is considered, and the accuracy of the data is improved.

4.3.4. Calculation of water resources

According to the law of conservation of mass, the difference between the revenue and expenditure of water in any region of the biosphere in any period of time must be equal to the change of water storage in that region, which is called the principle of water balance. Water balance is the quantitative law of water resources cycle, the basic principle of studying the quantitative relationship between various water resources elements, and the basic criterion of water resources calculation. The water balance formula is as follows:

$$I - O = S_2 - S_1 = \Delta S \quad (6)$$

where *I* and *O* are the input water and output water of the region in a given time, and S_1 and S_2 represent the initial and final water storage of the region in a given time [16]. ΔS represents the change of water storage in a given time. When ΔS is equal to zero, it means that the storage capacity of the area remains unchanged in a given period of time. According to the water balance equation of small cycle in a watershed, it can be concluded that the three factors determining the regional water resources are precipitation, evaporation and runoff. Runoff usually refers to the dynamic water quantity of surface water such as rivers and lakes on land.

4.3.5. Water quality data

NI index and wastewater biodegradability index are respectively set as indicators for water quality data analysis and water resource quality judgment. The calculation formula of the two indicators can be expressed as follows:

$$\begin{cases} I_{\mathrm{NI}} = \dfrac{C_{\mathrm{NO_3^-}}}{S_{\mathrm{NO_3^-}}} + \dfrac{C_{\mathrm{NO_2^-}}}{S_{\mathrm{NO_2^-}}} \\ \mathrm{OI} = \dfrac{\mathrm{Ca^{2+}} + \mathrm{K^+} + \mathrm{SiO_2}}{\mathrm{Mg^{2+}} + \mathrm{SO_4^{2-}}} \end{cases} \quad (7)$$

NI index is the sum of nitrate and nitrite after standardization, OI index is the calculation rule based on the five indexes affecting the taste, and the ratio of BOD and COD is determined when the detection value of wastewater biodegradability is correct [17]. The dynamic updating of real-time monitoring data of water resources can be realized by integrating the results of data collection and spatiotemporal analysis.

4.4. Visualization of water resources monitoring data

4.4.1. Water level contour

Isolines are connected by points with equal values in a defined area. It uses graph to represent the size of number, which is a unity of number and shape. The isoline reflects the shape fluctuation or fluctuation of the described physical quantity in the vertical direction. Surfer can also be used to draw the isoline map in the system. The object-oriented technology and Surfer interface are used for embedded programming to quickly draw the graph and image. The isoline map realized by this method has the advantages of gentle and beautiful lines [18]. Firstly, the ActiveX object of Surfer is created dynamically by using the function of CreateObject, and the Surfer drawing document is generated by using the Surfer object. The calculation of groundwater isoline mainly includes two parts: generating isopoints and tracing isolines. Firstly, the number of all isolines in the grid is determined according to the maximum and minimum water level and the span of isolines, and a list of isoline water level values is defined. Then each grid is traversed, to get all the values of the contour that may pass through the grid according to the water level value of the four vertices.

Generally speaking, the water level changes dynamically with time. Through the analysis of the water level contour of the aquifer, especially the contour of the funnel area, the shape of the funnel can be clearly seen from the contour map, and the change trend of the funnel can be inferred.

4.4.2. Drawing real time curves and reports

Ajax as the core technology can draw real-time curves and reports. Only when the data on the server side is retrieved, the data will be displayed on the client side. By making use of the direct changes to the DOM tree, the page will not be refreshed. In this way, the page will not be refreshed, but the required data can be changed [19]. In SVG, this effect can also be achieved through script programming. SVG can interact with the database, retrieve the required data, and then render it by the parser. Real time and non-real time only depend on the refresh time interval of the client. If the data is retrieved only when the event is triggered, it is considered as non-real time ordinary data access. If the interval is short, it can be considered as near real-time state. During the whole process, SVG is responsible for displaying data and database is responsible for storing data. The server-side action and Ajax technology play an intermediate role. First, the client initiates the request and calls the get URL method. The parameter of the method is the requested server action. The requested action is executed, and the data is obtained by calling the corresponding DAO to operate the database. Then the server-side program will encapsulate the data in a certain format, which can be combined into SVG statements or XML formats [20]. When all the data is ready, it will be returned to the client, and the client will call the corresponding function to analyze and process. After data processing, the DOM tree can be changed to make the returned data a part of SVG document, thus changing the display of SVG page.

The data are selected to enter into the visual drawing module, and select the required standard. The intermediate data needed for visualization are generated according to the visualization algorithm, and then rendered and drawn. Through the operation and control of peripherals, the visual display and retrieval of water resources monitoring data are realized.

5. System test

In order to verify the feasibility of the monitoring data visualization system of water resources based on J2EE architecture, the following experiments are designed.

5.1. System operation environment

The development platform of the system is Apache+MySQL+PHP, with Windows XP as the operating system, Apache as the web server, MySQL as the background database, and PHP language as the program development language to realize the connection with the database and the control of the front-end browser; SuperMap IS of Beijing Chaotu company is used as the Internet platform. The architecture adopts B/S mode. Finally, Dreamweaver and Flash are used as development tools to make interface. On this basis, the designed monitoring data visualization system of water resources based on J2EE architecture is transformed into program code and imported into the experimental environment.

5.2. Preparation of system test data

In order to prepare sufficient test data for the system test, a certain area is selected as the experimental research environment, nine water resources monitoring points are set up in the research area, and the monitoring data of each monitoring point in the past week are collected, which can be used as the data support for the realization of water resources monitoring visualization function.

5.3. System test results

In order to form the experimental contrast, the traditional data visualization system based on Web and the data visualization system based on data warehouse are set as the two contrast systems. The same system development tools are used to get the main interface of the visualization system, and the same monitoring data are input into the system database, to get the visualization results through the operation of the data.

Firstly, the visual output of the system is obtained, as shown in Fig. 4.

Similarly, the visualization results of the other two systems can be obtained. The system test indicators are set as the update speed and output quality of the visualization function. The output quality is mainly obtained by the definition of the visualization image, and the update speed is mainly read out directly by calling the running program in the background of the system. The specific test results of the system running function are shown in Table 4.

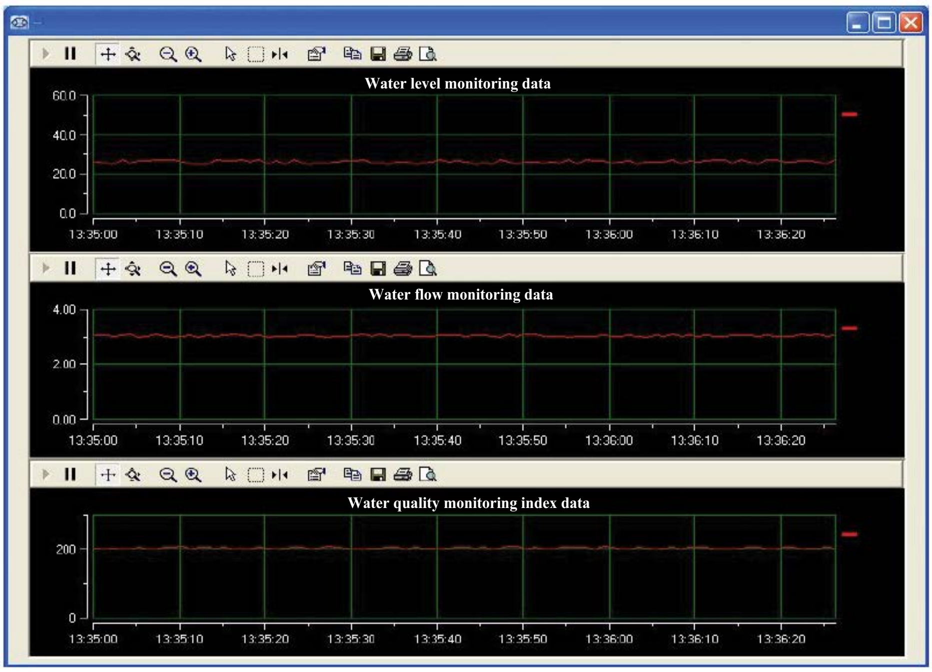

Fig. 4. Visualization results of water resources monitoring data.

Table 4
Comparison results of system operation function test

Experiment serial number	Data visualization system based on web		Data visualization system based on data warehouse		Water resources monitoring data visualization system based on J2EE architecture	
	Update time/s	Definition/dpi	Update time/s	Definition/dpi	Update time/s	Definition/dpi
1	0.89	720	0.54	960	0.25	1,080
2	0.91	720	0.56	960	0.14	1,080
3	0.87	720	0.37	720	0.33	960
4	0.88	720	0.49	720	0.23	960
5	0.94	720	0.56	960	0.19	1,080
6	0.86	720	0.62	720	0.11	960
7	0.91	720	0.66	960	0.17	960

According to the results of Table 4, the average update time and definition of the data visualization system based on Web are 0.89 s and 720 dpi, respectively. The average update time of the data visualization system based on data warehouse and the system in this paper are 0.54 s and 0.20 s, respectively, and the average definition of the two systems is 857.1 dpi and 1,011.4 dpi, respectively.

6. Conclusion

Because of the complexity of the dynamic monitoring data of groundwater resources, there are still many cases to be considered when using computer technology for three-dimensional display, and its accuracy also needs to be tested by more actual data. However, in the dynamic monitoring management of groundwater resources, the visualization system can express the "real" morphological characteristics of geographical space and the spatial relationship of various attribute elements more vividly. Combined with the information processing and spatial analysis function of J2EE architecture, it can make the dynamic monitoring information management of groundwater resources more intuitive and accurate, and open up a practical way for the scientific management of groundwater resources.

References

[1] F.L. del B. García, I.G. Ríos, Technology transfer: from the film industry to architecture, Enrique Castao Perea, 17 (2018) 105–118.
[2] D.E. Namiot, V.Y. Romanov, 3D visualization of architecture and metrics of the software, Scientific Visualization, 10 (2018) 123–139.
[3] S.M. Walzer, B. Hager, S. Toegel, V. Juras, D. Weinmann, B. Kubista, R. Windhager, S. Trattnig, Visualization of early collagen fiber architecture changes in human cartilage and developing osteophytes, Osteoarthritis Cartilage, 26 (2018) 456–457.
[4] C.D.D. Sohoulande, J. Martin, A. Szogi, K. Stone, Climate-driven prediction of land water storage anomalies: an outlook for water resources monitoring across the conterminous United States, J. Hydrol., 11 (2020) 125–133.
[5] A. Lal, B. Datta, Application of monitoring network design and feedback information for adaptive management of coastal groundwater resources, Int. J. Environ. Res. Public Health, 16 (2019) 4365, doi: 10.3390/ijerph16224365.
[6] G. Koubouris, Advances in prediction, monitoring and mitigation of climate change effects on water resources and good agricultural practices for crop adaptation to environmental stresses, J. Water Clim. Change, 9 (2018) 631–632.
[7] M.D. Behera, Use of satellite remote sensing as a monitoring tool for land and water resources development activities in an Indian tropical site, Environ. Monit. Assess.: An Int. J., 190 (2018) 40–51.
[8] M. Uprety, B.F. Ochoa-Tocachi, J.D. Paul, S. Regmi, W. Buytaert, Improving water resources management using participatory monitoring in a remote mountainous region of Nepal, J. Hydrol.: Reg. Stud., 23 (2019) 100–106.
[9] N.R. Finkler, J. Cocconi, T.A. Bortolin, L.A. Mendes, V.E. Schneider, Water quality monitoring in urban basins as support for water resources management: a case study from southern Brazil, Int. J. Environ. Impacts, 1 (2018) 298–311.
[10] C. Kohfahl, L. Molano-Leno, C. Guardiola, M. Manzano, F. Ruiz, N. Naranjo-Fernández, A. Rebollo, D. Martínez, A. Martínez, J. Heredia, E. Custodio, K. Vanderlinden, J. Horacio Higueras, V. Giráldez, Monitoring and current research of groundwater resources and recharge in the Doñana Natural area (SE Spain), Boletín Geológico y Minero, 130 (2020) 661–690.
[11] S.K. Gautam, T. Evangelos, S.K. Singh, J.K. Tripathi, A.K. Singh, Environmental monitoring of water resources with the use of PoS index: a case study from Subarnarekha River basin, India, Environ. Earth Sci., 77 (2018) 70, doi: 10.1007/s12665-018-7245-5.
[12] G. Chogovadze, G. Surguladze, N. Topuria, A. Gavardashvili, Ts. Namchevadze, Computer-aided design of the information ecosystem for monitoring of the black sea water resources, Bull. Georgian Acad. Sci., 12 (2018) 19–26.
[13] J. Ma, Water resources data acquisition and monitoring system based on internet of things, Desal. Water Treat., 122 (2018) 124–131.
[14] S. Arai, Control of mobile sensors for monitoring water resources with long time operation, J. Robotics Soc. Jpn., 36 (2018) 27–30.
[15] G. Koubouris, Advances in prediction, monitoring and mitigation of climate change effects on water resources and good agricultural practices for crop adaptation to environmental stresses, J. Water Clim. Change, 9 (2018) 631–632.
[16] B. Sabzipour, O. Asghari, A. Sarang, Evaluation and optimal redesigning of river water-quality monitoring networks (RWQMN) using geostatistics approach (case study: Karun, Iran), Sustainable Water Resour. Manage., 8 (2019) 439–455.
[17] T. Mitrović, D. Antanasijević, S. Lazović, A. Perić-Grujić, M. Ristić, Virtual water quality monitoring at inactive monitoring sites using Monte Carlo optimized artificial neural networks: a case study of Danube River (Serbia), Sci. Total Environ., 654 (2019) 1000–1009.
[18] M. de Souza Fraga, D.D. da Silva, A.A. Alden Elesbon, H. Alexandre Soares Guedes, Methodological proposal for the

allocation of water quality monitoring stations using strategic decision analysis, Environ. Monit. Assess., 191 (2019) 776.1–776.18, doi: 10.1007/s10661-019-7974-2.
[19] S. Padolski, T. Korchuganova, T. Wenaus, M. Grigorieva, A. Alexeev, M. Titov, A. Klimentov, Data visualization and representation in ATLAS BigPanDA monitoring, Scientific Visualization, 10 (2018) 69–76.
[20] C. Boddupalli, A. Sadhu, E. Rezazadeh Azar, S. Pattyson, Improved visualization of infrastructure monitoring data using building information modeling, Struct. Infrastruct. Eng., 23 (2019) 1247–1263.