A new dynamic regulation UIPO model of groundwater based on cloud computing and hydroinformatics

Wensheng Wang*, Huifeng Xue, Feng Zhang

School of automation, Northwestern Polytechnical University, Xi'an 710072, China

Received 3 March 2014, www.cmnt.lv

Abstract

In order to solve the problem of excessive mining of the coal resources in Yulin mine area caused enormous damage to groundwater and in turn threatening the regional sustainable development, proposed a new dynamic regulation UIPO model of groundwater, which combined hydroinformatics, cloud computing and multi-source data fusion algorithm, and the mine hydrogeological spatial database, the visualization of 3D geological model and groundwater dynamic evolution model are created. Simulation results show that the UIPO complete with these models and with groundwater - ecological environment - economy system model all connected data analysis for decision support system and with complete hydrogeological and spatial process method by means of big data, can simulate the temporal and spatial variations of groundwater resources, forecast future impact on Yulin mine area groundwater for sake of large-scale exploitation.

Keywords: hydroinformatics, cloud computing, groundwater, dynamic regulation, big data

1 Introduction

It is a very complex system engineering to dynamic regulation of groundwater resources [1], and integrated studies it involving cross between different disciplines. To effectively achieve the dynamic regulation of groundwater resources must first create the refinement of the dynamic control model. After 20 years in Yulin in the mining of groundwater resources monitoring period, the accumulated number of dollars in TB groundwater data assets and still maintain a geometric growth. These data include mining high-resolution remote sensing, InSAR, sensors and other monitoring underground mining "monitoring wells" information and "cadastral" information, including a diverse [2], heterogeneous, multi-scale spatial information. Faced with such a large scale, diversity and rapid proliferation of "big data", the model has not been available for large data deduction, making a simple mechanism based on the traditional assumption of certainty or aquatic ecosystem dynamics model approach has been limited.

So how to improve the "big data" management and service levels, to achieve its "crossover reuse" and "holographic visible" will be an important issue to realize mining groundwater resources dynamically regulated faces. Pressing need to design an application for large data natural sciences, social sciences and engineering disciplines fusion of dynamic regulation of cross-model integrated studies methods, to be able to effectively analyse "all data" relationship between groundwater mining "big data" and the ecological environment and socio-economic systems, so that show great value in use, can simulate mining temporal and spatial variation of groundwater resources, projections of future large-scale mining impact on groundwater, forming a technical methods and theoretical system and coupled ecological, socio-economic, groundwater "big data" decision support system dynamic regulation of groundwater resources.

This paper proposed and studied by means of information theory and method of water including cloud computing, networking, and big data analysis and other next-generation IT and the combination of three-dimensional GIS to solve the dynamic regulation of groundwater mining elm God unified model construction problems. Hydroinformatics methods have become a new trend in groundwater monitoring and numerical simulation of the ecological environment development. Foreign researchers have tried in the waters of rivers, groundwater, rainwater, water dynamics, water ecological environment to calculate [3], groundwater flow numerical simulation [4] variation of water environment [5], etc. into water information science, exploration of cross discipline between information technologies combined with the common water science. Now that the hydroinformatics is related to hydrological data management, analysis, water resources protection, investigation and assessment of water resources, it is very effective in hydrological models [6]. So, this article intends to use the hydroinformatics multidisciplinary and comprehensive features to create a dynamic regulatory model for groundwater resources in water-based informatics, combined with groundwater dynamics theory, create the basic framework for the evolution model of groundwater resources under conditions of coal mining activities associated with water cycle changes in the region, and then put forward have the versatility and

***Corresponding author** e-mail: wwsh2007@163.com

systematic UIPO (Unified-Input-Process-Output) conceptual model, it is a further foundation for the other models.

2 UIPO regulatory model based on hydroinformatics

This paper first carried on the dynamic monitoring method thorough analysis on groundwater hydrology spatial data, then the systematic research on the UIPO model, UIPO model framework, as shown in Figure 1, finally proposes the effective implementation method and experimental verification. The UIPO model mainly includes:

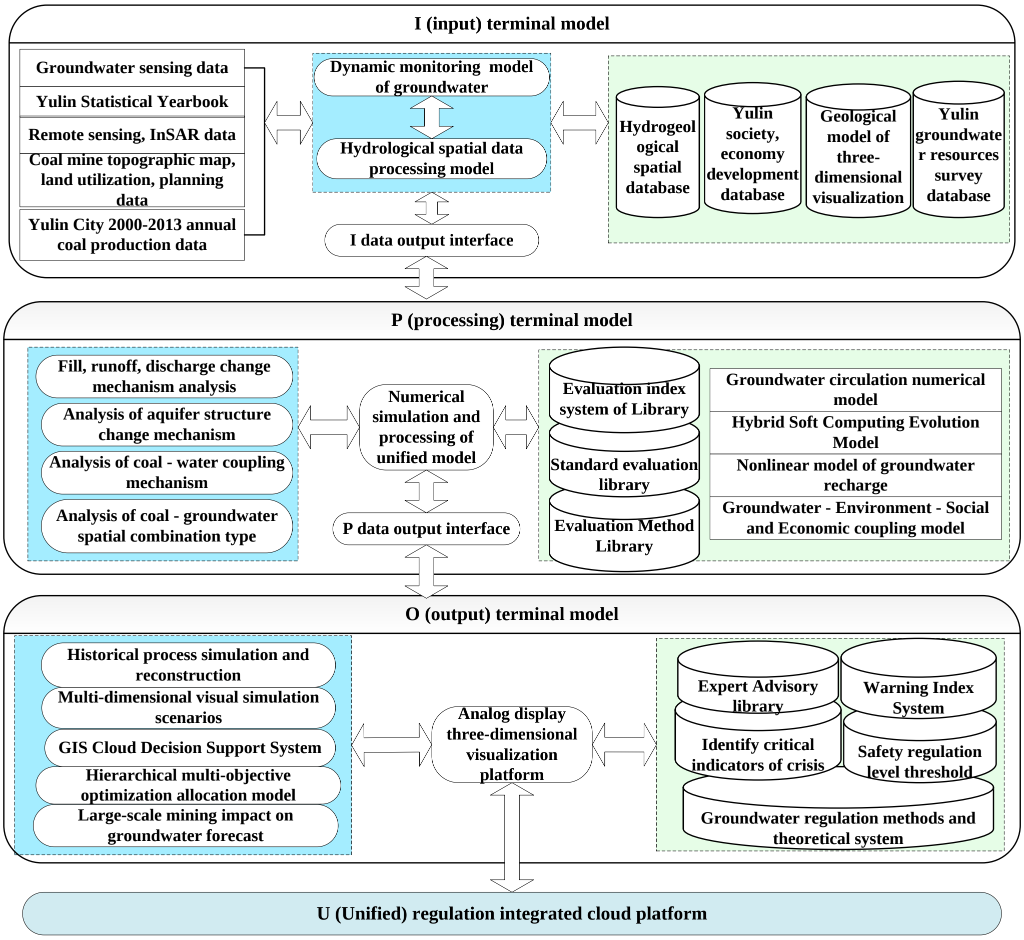

FIGURE 1 IPO model framework

2.1 CREATING OF A THREE-DIMENSIONAL GEOLOGICAL MODEL AND VISUALIZATION OF LARGE DATA PROCESSING HYDROLOGICAL MODEL SPACE

Effective realization of groundwater resources of refinement dynamic control problem was to obtain a large number of dynamic control data, In this paper, using of remote sensing, networking and a series of probing, testing techniques, to obtain the area aquifer hydrogeological parameters, create hydrogeological spatial database mining and visualization geological model, Build dynamic monitoring of groundwater resources and groundwater hydrology model space large data processing model, formation of I terminal model in UIPO. The main contents include:

1) The hydrological spatial data semantic modelling. Due to the diversity and heterogeneity of hydrological data sources a large space, research-based ontology semantic technology hydrological data for unified expression of a large space, to achieve an integrated processing, service publishing and storage technology for hydrologic data provide a large space data representation model.

2) Multi-source remote sensing data fusion model. Using of Yulin City TM images and MODIS images and Yulin 20 years of mining groundwater resources monitoring data and field data, based on pluralistic, multi-temporal, multi-scale, multi-source remote sensing image mining integration of heterogeneous data processing and evaluation techniques, The two information extraction and mining groundwater monitoring wells measured data from remote sensing

image analysis, generate the groundwater of multi-source remote sensing data fusion and monitoring model.

3) Dynamic monitoring model of groundwater. Groundwater resources in network research on perception, model structure, deployment framework, in order to realize the dynamic monitoring of groundwater resources, access to the aquifer hydrogeological parameter data fusion method, establishment of monitoring data based on D-S evidence theory.

4) A large space hydrological data processing methods. In order to meet the long-term dynamic monitoring of groundwater resources in the mining area, a hybrid cloud method of dynamic organization of information and structured, semi-structured and unstructured data storage model, Using NoSQL, MapReduce and machine learning techniques, structure support large data processing centre hydrological spatial data infrastructure, be able to multi-source, heterogeneous, lots of space for large hydrological data for dynamic organizations, the establishment of hydrogeological spatial database mining and visualization of geological models.

2.2 CREATING OF GROUNDWATER RESOURCES UNDER COAL MINING CONDITIONS ASSOCIATED WITH THE MINE WATER CYCLE CHANGES IN A DYNAMIC EVOLUTION MODEL

According to the key scientific problems of groundwater resource dynamic evolution system of mine hydrogeological characteristics, groundwater recharge, runoff and discharge characteristic, construct the index system, evaluation criteria and evaluation methods of evaluation, the formation of P terminal model in UIPO. The main research contents include:

1) Analysis of groundwater hydrodynamic field characteristics and evolutionary process. Using of historical data, related data model and I model output terminals nearly 20 years Yushen mining groundwater "recharge, runoff, discharge," the temporal variation, revealing the dynamic evolution of groundwater recharge. Dividing seams - a combination of the type of ground space, study the impact of coal mining impermeable layer stability, building evaluation index system, evaluation criteria and evaluation methods.

2) High Performance hybrid soft computing model. Study on groundwater dynamic process "recharge, runoff and discharge" model of temporal and spatial variation characteristics and mechanism, Create mining groundwater circulation numerical model and the dynamic evolution of high-performance mixed soft computing model to simulate groundwater mining cycle.

3) Groundwater recharges nonlinear model. Study on mining area containing variation of aquifer structure, groundwater recharge revealed qualitative and quantitative variation characteristics and formation evolution mechanism and time and space, a nonlinear model for mining area groundwater recharge aquifer structure change.

2.3 BUILD DYNAMIC CONTROL MODEL OF GROUNDWATER RESOURCES

Through the study of groundwater regulation methods and theoretical system, to build a unified regulation of groundwater comprehensive integration platform, achieve reasonable regulation of groundwater resources and the purpose of sustainable development and utilization. To form of O terminal model in the UIPO and U (Unified) control platform. The main research contents include:

1) Building of underground water resources regulation platform. Using of multi-disciplinary, multi-technology comprehensive integration and big data, cloud computing and other next-generation IT to create a "dynamic regulation of groundwater mining Yulin comprehensive integration cloud platform" (hereinafter referred to as U-control platform), realization of dynamic monitoring of groundwater and unified regulation. To create a unified mine three-dimensional groundwater flow model and mining groundwater flow - land subsidence coupling model on platform U-control, revealing the intrinsic link groundwater resources and water level changes between coal mining and land subsidence mechanism.

2) Groundwater regulation methods and theories. Based on the U control platform, using the P model output and the evaluation index system, evaluation criteria and evaluation method, constructs the groundwater of mining area ecological environment and social economy system is a complex coupling model of water resource optimal allocation model of multi-objective hierarchical; using GIS cloud data integration, statistical, spatial analysis, systems evaluation mining groundwater resources based on created three-dimensional visualization of the geological model and hydrological space large data processing model, building analysis based on all the data big data associated decision support systems. Affected by coal mining on water resources evaluation system, revealing the impact of coal mining on water resources and characteristics of the way to establish an expert advisory library. Based on the results of a variety of typical coal mining geological conditions were analysed to establish critical identity crisis groundwater mining index system, early warning indicators and safety regulation of groundwater level threshold.

3 Groundwater regulation of cloud computing architecture platform

In this paper, using of cloud computing solutions to build a data centre, including the design of a public and private cloud hybrid cloud groundwater cloud computing platform, as shown in Figure 2, Corresponding groundwater cloud storage can be divided into the corresponding public cloud storage and private cloud storage. Public cloud built on the Internet, and to learn building a private cloud within the Intranet, both through a bridge (Bridge) before they can communicate with each other, the daily works of the two are physically isolated.

3.1 PRIVATE CLOUD PLATFORM OF GROUNDWATER REGULATION

Private cloud combines the realization of cloud computing technology and methods to focus on building the Intranet; you can realize the integration and sharing of groundwater data. With the inner scale geographic, geologic map superposition, fusion, and further can be related to the ongoing construction of potentiality assessment of mineral resources, reserves by using survey data integration and sharing.

Groundwater regulation of private cloud within the LAN using server clusters, storage devices, networking equipment and other infrastructure, Using virtualization software background memory, memory, CPU division, loading a different operating system [7], in which the deployment of geological database, application server software platform. But we can also use an application-level virtualization technology, virtual application table level, so that users can seem like using a local machine using a remote operating system, applications, and so on. Groundwater regulation database is a large logical database, is more centralized, distributed database cluster, while the actual database stored in the background groundwater regulation of cloud storage, the formation of Earth Science Data Centre Data Warehouse based on groundwater regulation. Groundwater regulation database data centre computing centres through groundwater regulation of WebServices provide all kinds of groundwater regulation outward data services supported by the SOA Manager GIS server as a spatial data services and computing services, and constitutes a cluster of servers. Because Web Services returned to the user is the result of converting it later, it effectively hides the pluralistic, heterogeneous raw data, to the integration and sharing purposes.

3.2 PUBLIC CLOUD PLATFORMS OF GROUNDWATER REGULATION

Groundwater regulating public cloud is constructed in Internet, will be able to open basic geographic, geologic map publishing network support for SOA GIS server, released to the public resource called API. Groundwater can be achieved in the regulation of public cloud services and the Azure service resources, shared resources (such as Google, ESRI spatial services, etc.) Internet converge on the interaction of groundwater can provide cloud computing services in the public Internet, and background data services, computing services, etc. can be flexibly increased or decreased according to demand, but can also be integrated with other systems.

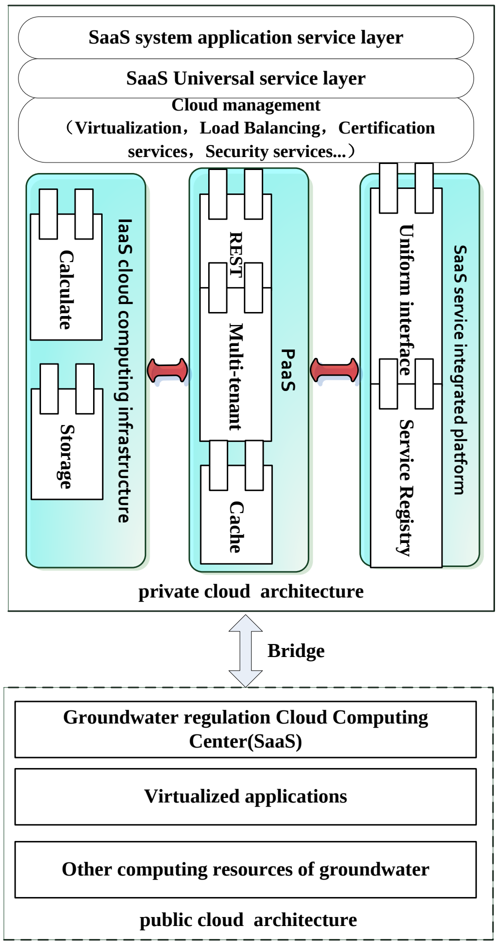

FIGURE 2 Load balancing test result

3.3 DESIGN AND IMPLEMENTATION OF VIRTUALIZED APPLICATIONS

In order for the existing hardware, software resources (genuine software can effectively solve the problem) were fully utilized, rational allocation of resources with virtualization technology, cloud computing applications using international recognized VMWare, Citrix, IBM and other virtualization products, building groundwater regulation of software and hardware resources virtualized application platform. Set one server into multiple virtual servers, we can also create a number on a single server or desktop level to achieve application-level virtualization application examples (the operating system can be Windows, Linux, Unix and other operating systems), managed by the virtual instance is ready to create a new instance of on-demand, upon request, and may also install supporting software. To meet people while online application, each person using different virtual instance, users can experience the benefits of virtualization vital brought. In a Windows operating system desktop virtual application instance, we can run ArcGIS, Oracle, Office and other software applications, and even the development of application software; Installing ArcGIS Server, Java EE applications on Linux and other operating systems. An example in ArcMap version management software in virtualized applications, install all virtual instances share a license manager [9], log a user license is available subtrahend one, until exhausted. Data and applications can be separated or stored centrally. Backup mechanism virtual instance is optional, virtual instance can be unified updates and upgrades, updates and upgrades can also be customized, but all users do not need, all done on the server side, the user can at any location simply by browsing connected to the server can be achieved as local as processing data. Multiple servers reasonable allocation of hardware resources, which will be a server as a central node server virtualization, virtualization management platform to establish, manage multiple situated LAN, WAN physical servers or virtual servers [8]; We can use virtual machines, virtual desktops run in two modes. Virtual machine model is not installed on the client virtual machine, but according to the user's application, automatically creates a virtual machine installed on the server according to various software applications, databases, software development and other virtual machine template for applicants and assign the appropriate hardware resources (disk space, memory, network card, bandwidth, etc.).

3.4 DESIGN AND IMPLEMENTATION OF GROUNDWATER REGULATION OF BIG DATA CLOUD STORAGE PLATFORM

Use of Yulin City TB level storage device (the future will use PB grade, EB level or ZB level) to build groundwater regulation cloud storage, and expandable distributed storage nodes as the provinces. Using IBM, HP and other multiple servers form data storage pool, cloud storage device is a large physical storage device through optical fibre connection; Data storage uses zoning, fast file method, data access optimization in the interview. Taking into account the future internal and external services also needs to be divided into public storage cloud storage cloud, private storage cloud. Which is the corresponding public storage cloud computing external public cloud services, public cloud analysis, and private cloud computing is on a private cloud inside the private network, private cloud analysis. The groundwater regulation of big data cloud storage platform is as shown in Figure 3.

Data stored in the data warehouse using the form geosciences organizations, and is divided into content database, file databases, relational databases and object types, geological maps, gravity data, geochemical data, isotope geology of the work, geological work arrangements, as preserve the original format mining belt, administrative divisions and other data in a file database, so easy future use. These data systems data checking, cleaning, conversion, and unified loaded into Oracle spatial database, spatial data using the Oracle Spatial option to achieve. Fast indexing by using spatial index, and the objects in the database are saved in different tables paces, and a table space unified stored in the cloud storage device. Data storage uses parallel file system (Parallel File System) or concurrent file system, distributed file system, data management is the table. A key feature relative to the general system is the stand-alone file can store the same block of a file stored in the group of nodes, while allowing access to a number of computing nodes concurrently, without confusion and error, each node can use the own local file system, the establishment of efficient synchronization between each other and co-processing capabilities.

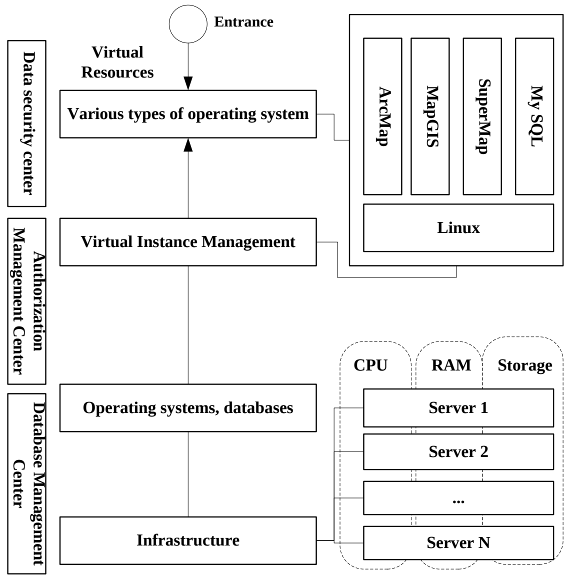

FIGURE 3 Groundwater regulation of big data cloud storage platform

3.5 MULTI-SOURCE DATA FUSION ALGORITHM FOR GROUNDWATER REGULATION BASED ON KALMAN FILTER

Mining groundwater regulation data involves the mineral resource potential assessment, field verification of mining rights, the extent of the work of geological data, geological work deploy data, geological maps and other data, the data is produced in different periods, data formats, and so have different spatial reference, the need for its data conversion, normalization processing operations. The original data on groundwater regulation database to keep a unified cloud storage device [10]. Combined with their standard-depth study of the actual construction of the library content of these heterogeneous databases, these heterogeneous data systematically cleaned to a unified coordinate system, unified administrative map, unified base map, unified geological bottom photo shows the basis for the conversion of spatial data. These databases are related to similar data dictionary table's entity name, domain, semantic standardization, to perform various special interactions, query analysis association.

Information fusion technology is proposed in the 1970s, which consists of a variety of information sources such as sensors, databases, knowledge bases and humanity itself to obtain the relevant information and filtering [12], correlation and integration, thus forming an expressed framework6 which is suitable to get information about decisions, explanation of the message to reach the target system, sensor management and system control. Information fusion is integrated multi-source information processing, with the nature of complexity. Signal processing and estimation theory indispensable for it's laid the theoretical foundation, which due to the high computational efficiency of the Kalman filter algorithm mature, etc., have been widely used.

Kalman filter based on minimum mean square error criterion for the best estimate, the basic idea is the use of state-space model of signal and noise, using the estimated value of the previous time and the current observation time updates on the status of the estimated variable, find the current the estimated value of the time [11, 13]. Assume that the discrete model for linear system:

$$x_k = F_k x_{k-1} + w_{k-1}, \quad (1)$$

$$z_k = H_k x_k + v_k, \quad (2)$$

where $v_k \sim N(0, R_k)$, $w_k \sim N(0, Q_k)$ are independent of each process, and $x_0 \sim N(x_0, P_0)$ independently in the initial state. Then for any loss function, the following Kalman filter equations:

The time update equations are given:

$$x_{t+1|t} = F_{t+1} x_{t|t}, \quad (3)$$

$$P_{t+1|t} = F_t P_{t|t} F_t^T + Q_{t+1}. \quad (4)$$

The measurement update equations are given:

$$K_{t+1} = P_{t+1|t} H_{t+1}^T (H_{t+1} P_{t+1|t} H_{t+1}^T + R_{t+1})^{-1}, \quad (5)$$

$$x_{t+1|t+1} = x_{t+1|t} + K_{t+1}(z_{k+1} - H_{k+1} x_{t+1|t+1}), \quad (6)$$

$$P_{t+1|t+1} = (1 - K_{t+1} H_{t+1}) P_{t+1|t}. \quad (7)$$

Kalman filter algorithm provides an effective way to filter out noise, is widely used to control, track, spacecraft orbit correction and other fields, has made many achievements. But the Kalman filter can only deal with the linear object, and the modernization of industrial production process the relationships among the variables are often very complex, using the linear model to reflect the relation between variables.

The Extended Kalman Filter (EKF) provides an online linearization method, namely the linearization of the nominal trajectory, and then uses Kalman filtering formula, which can solve the non-linear problem object to a certain extent. Set k time obtained system filtering system value is $x_{t-1|t-1}$ and $x_{t|t-1}$. The state equation is discrete systems in the vicinity of the $\widehat{x}_{t-1|t-1}$ by Taylor series expansion, the linear model of the top two can have the original nonlinear system [8], it is given

$$\begin{cases} x_t = F_t x_{t-1} + U_{t-1} + \Gamma_{t-1} W_{t-1} \\ z_t = H_t x_t + Y_t + V_t \end{cases}, \quad (8)$$

where

$$F_t = \frac{\partial f(x_{t-1}, t-1)}{\partial x_{t-1}} | x_{t-1} = x_{t-1|t-1},$$

$$H_t = \frac{\partial h(x_{t-1}, t-1)}{\partial x_t} | x_t = x_{t|t-1},$$

$$U_{t-1} = f(x_{t-1|t-1}, t-1) - \frac{\partial f(x_{t-1}, t-1)}{\partial x_{t-1}} | x_{t-1} = x_{t-1|t-1},$$

$$Y_t = h(x_{t|t-1}, t) - \frac{\partial h(x_{t-1}, t-1)}{\partial x_t} | x_t = x_{t|t-1}.$$

By Kalman filter, EKF, UKF and other methods as well as other information fusion technology for large data processing, you can filter out the noise and easier to obtain the corresponding relationships between variables to improve the accuracy of analytical results.

4 Experiment and analysis

In order to test Yulin city groundwater monitoring data standardization process, we simulate multiple concurrent processing requests, validate the multitasking parallel speedup ratio and load balancing effect. Software and hardware environment test system is as follows. Hardware: X86-64 architecture server specific CPU (8 an 8 nuclear, frequency 2.6GHz), DDR3 32GB memory, SCSI hard disk (1TB, 10000rpm), Gigabit ethernet. Software: CentOS 5.2, Python 2.5.4, PostgreSQL 9.

1) Concurrent performance speedup test. At the start of single processing node A and dual processing nodes A, B, simulation 200 concurrent processing request, test and record the operation of each node respectively 1, 2, 3, 4, 5, 6, 7, 8 parallel processing example is complete when all tasks required processing time, finally the corresponding calculation speedup.

2) Load balancing test. Start the two processing node, A, B, each instance running 4 parallel processing, were recorded 20, 50, 200 systems, 260 processing tasks, each task number A, B node.

According to the concurrent performance speedup test scheme, processing and recording processing time, rendering acceleration as shown in Figure 4.

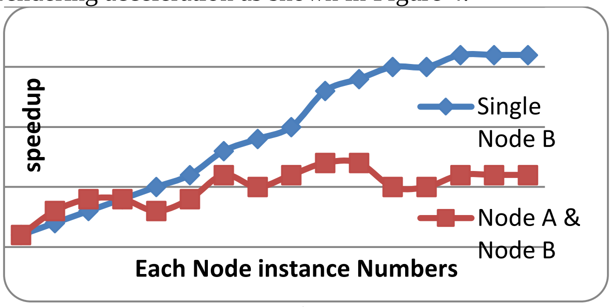

FIGURE 4 Concurrent performance speedup test result

From an overall perspective, both single node or double points, speedup ratio of parallel processing task instances with the growth in the number of approximate linear growth, with better performance of parallel processing system. With the parallel increase in the number of instances of processing tasks, accelerating gradually deviated from the theoretical speedup ratio, mainly due to an increase in instances of parallel processing with the internal system affect the communication time consuming and central control node and processing nodes for parallel processing speedup also gradually increased.

Testing according to the load balancing scheme, each node records the amount of processing to complete the task, the task of load balancing based on the drawing result of the number shown in Figure 5.

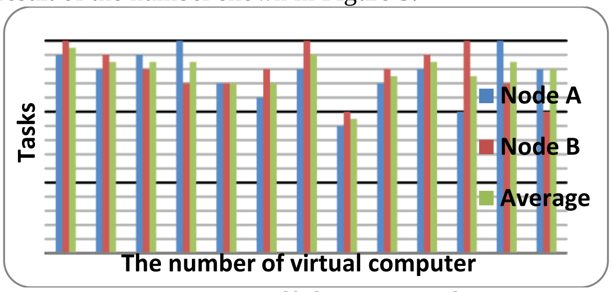

FIGURE 5 Load balancing test result

The test is repeated 15 times, the number of tasks handled similar to the average of each node, the total number of tasks as the load increases, the deviation gradually decreases, load balancing stability increase. Two node load quantity deviation, mainly because of the surplus is less than the number of instances of processing task concurrent processing, unable to realize the equalization processing, further processing resources or capability of instance share there are fluctuations and deviation.

5 Conclusions

This article has conducted the system research to the mine hydro geological spatial database and visualization of 3D geological modelling method, and created the data processing framework. From the perspective of water informatics starting to construct dynamic monitoring of groundwater resources groundwater model and a complete text of a large space method of data processing, thereby establishing groundwater regulation of technical methods and theoretical system of environmental, economic constraints, combined with groundwater regulation comprehensive integration platform implementation, and ultimately to create a unified UIPO models. In the model implementation, we have proposed a comprehensive cloud-based computing platform integration framework. Practice shows that this design is very suitable for implementing UIPO model.

Acknowledgments

This work is partially supported by Funding Project for Department of Education of Shaanxi Province of China (#14JK1864), Natural Science and Technology Project Plan in Yulin University of China (#14YK39), Thanks for the help.

References

[1] Quiroga, V M, Popescu, I, Solomatine D P, Bociort L 2013 Cloud and cluster computing in uncertainty analysis of integrated flood models *Journal of Hydroinformatics* **15**(1) 55-70
[2] Park Y, Hwa C K, Kang J H, Lee S W, Kшь J H 2014 Developing a flow control strategy to reduce nutrient load in a reclaimed multi-reservoir system using a 2D hydrodynamic and water quality model *Science of the Total Environment* 466-467(2014) 871-80
[3] Yu F, Lu W, Li P, Xin X, Li J 2012 Dynamic optimal control for groundwater optimization management with covariates *Journal of Hydroinformatics* **14**(2) 386-94
[4] Booth C J 1986 Strata-movement concepts and the hydrogeological impact of underground coal mining *Groundwater* **24**(4) 507-15
[5] McKinney D C, Cai X 2002 Linking GIS and water resources management models: an object-oriented method *Environment Modeling and Software* (17) 413-25
[6] Awan U K, Tischbein B, Martius C 2013 Combining hydrological modeling and GIS approaches to determine the spatial distribution of groundwater recharge in an arid irrigation scheme *Irrigation Science* **31**(4) 793-806
[7] Zhang F, Xue H-F 2013 Big data cleaning algorithms in cloud computing *International Journal of Online Engineering* **9**(3) 77-81
[8] Zhang F, Xue H-F 2012 Cloud manufacturing-based enterprise platform architecture and implementation *3rd International Conference on Digital Manufacturing and Automation* 190-191 60-3
[9] Younge A J, Laszewski G, Wang L, Lopez-Alarcon S, Carithers W 2010 Efficient resource management for Cloud computing environments *International Green Computing Conference* 357-64
[10] Menache I, Ozdaglar A, Shimkin N 2011 Socially optimal pricing of cloud computing resources *Proceedings of the 5th International ICST Conference on Performance Evaluation Methodologies and Tools* 16-25
[11] Kalman R E 1960 A new approach to linear filtering and prediction probles *Journal of basic engineering* 82 35-45
[12] Dhiman G, Marchetti G, Rosing T 2010 vGreen: A System for Energy-Efficient Management of Virtual Machines *Transaction on Design Automation of Electronic System* **16**(1) 1-27
[13] Ma S 2012 A review on cloud computing development *Journal of Networks* **7**(2) 305-10

Authors

Wen-sheng Wang, born on June 28, 1969, LiaoNing, China

Current position, grades: PhD in Northwestern Polytechnical University.
University studies: PhD in Systems Engineering from Northwestern Polytechnical University from 2008.
Scientific interest: hydroinformatics, cloud computing.

Hui-feng Xue, born on June 16, 1964, Shanxi Yuncheng, China

Current position, grades: professor in Northwestern Polytechnical University.
University studies: PhD degree in Water resource economics from Xi'an Polytechnic in 1995.
Scientific interest: the modelling of complex systems, simulation and performance evaluation, management, systems engineering, energy and environmental systems engineering, computer control, intelligent control, network control.

Feng Zhang, born on June 26, 1980, Shannxi Yulin, China

Current position, grades: PhD in Northwestern Polytechnical University.
University studies: MS degree in Computer science from Xidian University in 2009.
Scientific interest: cloud integrated manufacturing technology, the modelling of complex systems, the Internet of things applications.