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DISTRIBUTED SYSTEM FOR MONITORING AND FORECASTING OF WATER BODIES QUALITY

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Summary. The structure and principles of constructing a distributed monitoring and forecasting system for water bodies quality designed to forecast the state of water supply sources in the remote mode are considered. The database of water bodies of Ukraine for storing the received data, including the data from the non-government and international organizations, is implemented. The interaction between the distributed subsystems is carried out via the client-server architecture.

Key words: monitoring, distributed system, water body, water service.

Introduction

Sustainable development of water bodies of Ukraine and their adaptation to the changes of climate are possible within the condition of the systematic monitoring and estimation of quality of such objects. Creation of the monitoring systems of the state of water bodies and management of water services corresponds to the ecological aims of water resources control [1], it will allow to provide necessary water services, and also take optimal administrative decisions.

Efficiency of water bodies management and quality of providing water services largely depends on the presence and quality of information on the indicated objects state, as well as on the technological methods of treatment, project descriptions and sticking to the requirements of objects exploitation. Despite the fact that Ukraine keeps considerable reserves of water resources, mainly river sinks, which average annual volume is 4714 km^2, or 10,5 % of world river sinks, at present, in our country the question of water resources quality is acute [2]. Lately, many non-government and international ecological organizations accumulate information on the separate indexes of water quality, objects, rivers etc. The example of such practice is activity of Ukrainian Water Society WaterNet, that conducts systematic monitoring of drinking water quality, and also Ukrainian Ecological Public Organization "MAMA-86", that comes forward for accessible and safe drinking water and sanitation for all, and many other organizations. But the mechanism of exchanging and using information of similar organizations has not been implemented yet. The distributed structure of the offered system and the mechanism of co-operating with already existing databases can be used for forecasting the state of water bodies and laying the foundation for the development of the climate changes adaptation actions.

Structure and development principles of distributed system of monitoring and forecasting water bodies quality

A structure and principles of the distributed system of monitoring and forecasting water bodies quality, that will allow storing information and give operative access and possibility of further analysis of the sources of water supply are considered in the project. The offered system is designed for the automated collection, treatment, storage and visualization of control data and monitoring that can be used for creation of water bodies state forecasting. The structure of the system is presented on Fig. 1.

According to the offered structure, the indexes of quality of water bodies (WB) are sent to the data collection and processing subsystem (DCPS) and after the primary treatment – to the informative model of water bodies (WBIM).

WBIM is an aggregation of indexes that describes properties and state of WB, and also interaction with the outer world. The information collected this way is stored in the water bodies database (WB DB) and can be presented by the subsystem of visualization as charts, histograms, magazines of events etc. by the user request. The users of WB DB and visualization subsystems can be both separate citizens and research organizations, and also water services consumers (WS). Water services are the services, which are given for households, public institutes or for any economic activity [1]. According to Water Scope Directive of EU, WS consists of water sampling from surface or underground water, their accumulation, storage, treatment and separation; collecting and treatment of wastewater, which flows into superficial water. Water body database allows processing user's requests, keeping track and storing information about the provided services.

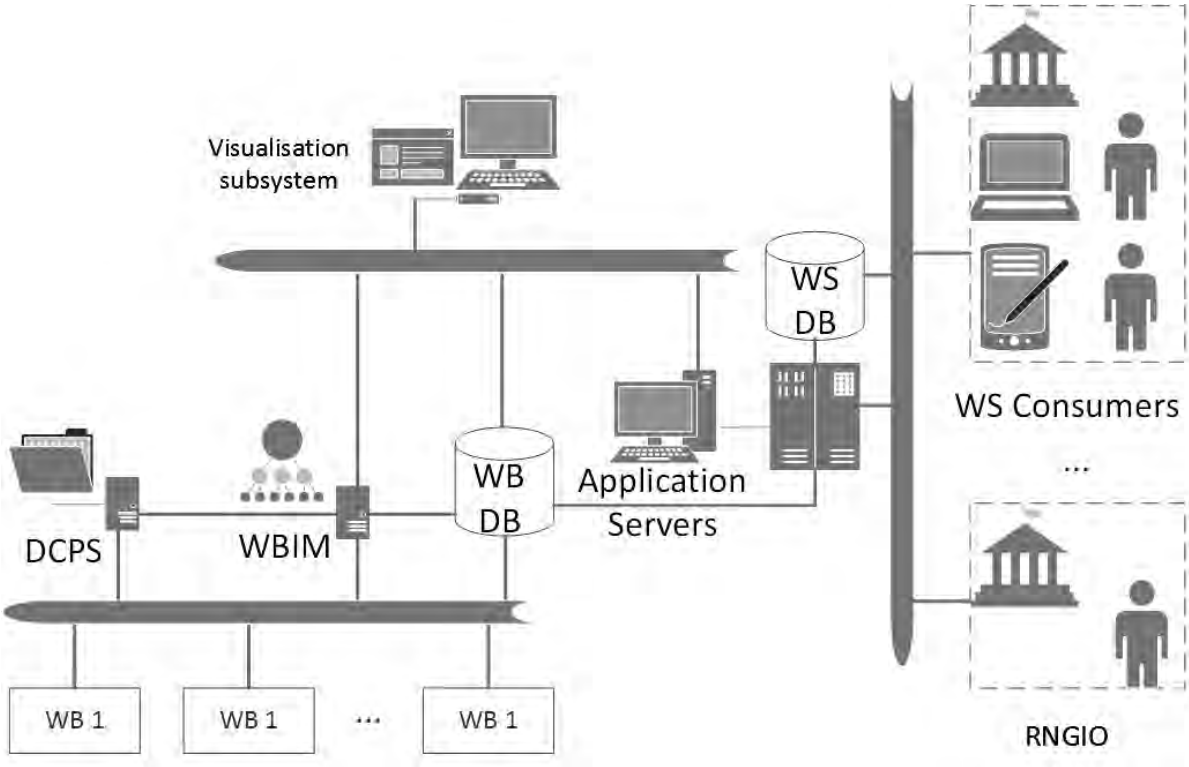

Fig. 1. Structure of monitoring and forecasting of water bodies quality:
WB – water body, DCPS – data collection and processing subsystem, WB IM – water body informative model, WB DB – water body database, WS consumers – water services consumers, WS DB – water services database, RNGIO – researching, non-government and international organizations

Developed databases are relational and consist of two types of tables. For example, in the base water bodies database WB DB these tables are presented: the table for storing water object quality indexes (Water Quality) and the table of Recommendations that contains a list of data about water object quality worsening and recommendations for normalization of the object's work. Each table as Water Quality has the key field – "DATE_TIME", which has the data in "DD.MM.YYYY HH:MM:SS" format. The rest of the table fields correspond to the water quality parameters to which the requirements are set [3]. The structure of the offered database is presented in Fig. 2.

The described database allows keeping the value of all indexes that is got at the certain moment of time. It should be noticed, that during the water analysis, estimation is executed on the basis of these indexes. However, data processing in accordance with the set quality indexes, envisages the work with large arrays of data that predetermines the necessity of using considerable computing powers. But not every laboratory is equipped with the powerful computing hardware with specially developed software. For now the solution of this problem can be considerably facilitated with using cloud services that help to execute necessary computing even without powerful computers in the laboratories.

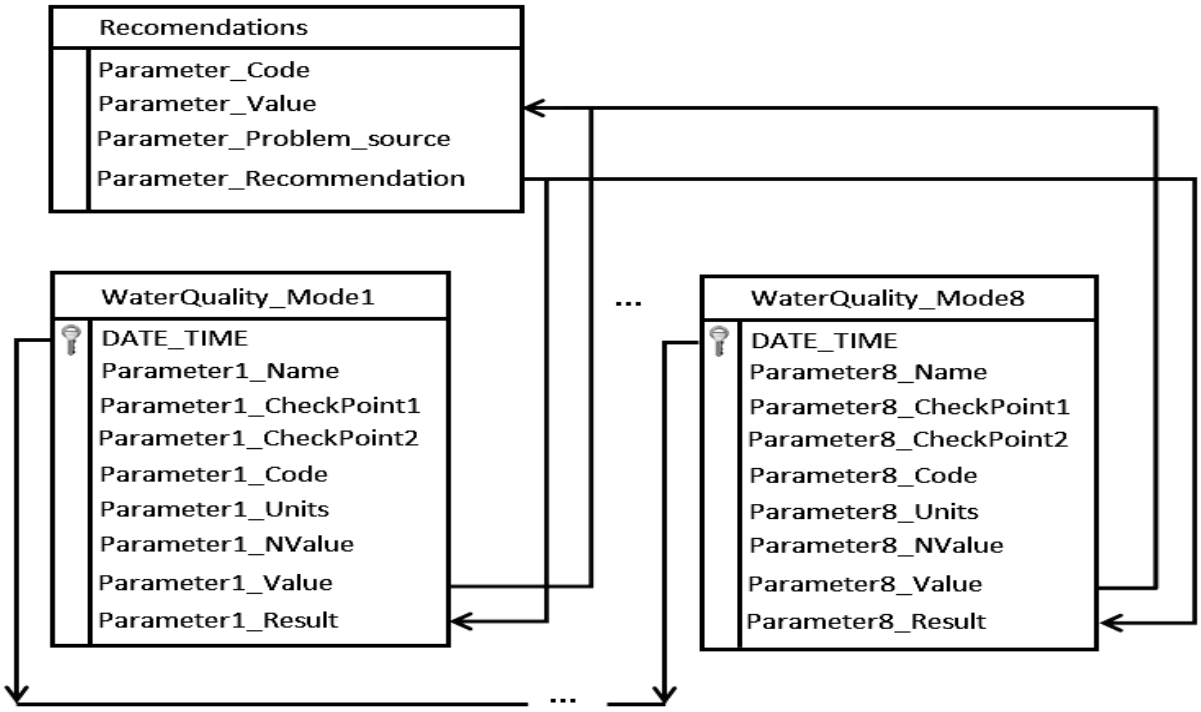

Fig. 2. Database structure

Cloud computing gives comfortable network access in "on demand" mode to collectively usable set of the adjusted calculable resources (for example, networks, servers, data storage, applications and/or services) which a user can operatively involve in the tasks and release to minimize the number of interaction with the service supplier or their own administrative efforts. This model is used to increase the availability of computing resources and gives an opportunity to execute calculations that need powerful technical resources in the remote mode. Market share of cloud services and platforms constantly grows due to the row of advantages for ordinary users and organizations. In recent years more companies are engaged in the development of information computing systems. They are oriented on further development exactly in the sphere of cloud services. It gives possibility to take the most optimal decision for the concrete aims of the end-user of cloud services.

The use of cloud services in water quality analysis system makes it possible to go separate ways: to use one of already existing cloud services or create the own model of cloud calculations. The conducted analysis of the terms, offered by the suppliers services of basic cloud services, showed, that the most common services are Dropbox, GoogleDrive, Mega, Bitcasa, Copy.com, OneDrive, and the cost of their use depends on the volume of the data, that is kept, and does not exceed 10 dollars per month for 1 terabyte. More detailed information on cost indexes and services provision is in [4].

During creation of the own model of cloud computing it is necessary to use cloud computing specialists. On the basis of the analysis data the authors of the work made a decision to organize their own computing environment. The results of the analysis in relation to the correspondence of the object quality to the indexes are added to the corresponding database section.

Results and Discussion

Superficial objects are examined as water bodies, which are considered to be separate and significant elements of surface-water, such as a lake, a storage pool, a brook, a river or a channel, a part of the brook, river or channel, transitional (intermediate) water or extent of coastal water [1, 2]. According to National lecture data about natural environment state in Ukraine the network of supervisions has covered over 170 rivers and storage pools and over 20 lakes [2, 5]. Besides, permanent control of waste water quality that comes to water bodies is carried out by communal and industrial enterprises which execute waste water cleaning. Governmental hydrometeorological service of Ukraine carries out watching hydrochemical state of water in 240 points on 151 water bodies. Data is collected with

periodical sampling 4-12 times a year for 46 indexes [5]. Data collecting and analysis of the state of such number of objects involves creation of the balanced hierarchical structure, that allows to quickly find necessary information. The research of processing methods and information analysis showed, that the main problems of such structure creating are the problems of data storing, the amount and value of the information which is being collected and organization of the interaction of the existing systems [5, 6].

Despite the high level of computer hardware development, it's hard for organizations to allocate the needed amount of memory for storing big amount of data, wherein the purchasing and supporting additional servers and relevant software is very expensive. That's the reason for using the so called cloud computing at the moment. Cloud computing is the model of supplying general and comfortable access on user demand via network for general amount of computing resources which can be operatively delivered and released with minimal costs and appeals to the provider.

The problem of organizing the interaction of already existing systems, which are financed by different international organizations and public institutions, which, in common, don't interact with each other, can be resolved by including distributed subsystem databases in the system of monitoring and forecasting water bodies' quality and their unification according to cloud computing type. By using parallel distributed computing, given tasks are divided between all the servers, which are located in data centers. By using uniform load distribution, the tasks are executed faster and more effectively with minimal costs. Cloud technologies development is very fast, it discovers new data protection methods, maintenance of uninterrupted power supply to prevent data loss.

The literature resources analysis showed that forecasting the complex object state now is maintained by using expert systems, custom neural networks and based on unclear methods. Neural networks give an opportunity to develop computing structures and model processes, associated with human thinking processes. Complexity of practical use of neural networks is connected with learned network adaptation to the features of management objects. Unclear methods give an opportunity to solve the tasks in conditions of ambiguity and take decisions according to the given precision. [5, 7], but they don't give single-valued and mathematically strict recommendations, which lead to subjectivity of decisions.

Using computer technologies, which are based on virtualization methods and cloud computing, using distributed servers and databases, parallel computing organization allows to process and analyze large amount of information, use water bodies quality forecasting in short and long-term perspective, and also create general information environment, which allows to integrate separate subsystems (which contain information about water bodies) in one generic system, which is used for further research and computing. Creation of such structures is able to ensure a higher level of integration of Ukraine into global network. Distributed computing organization scheme of the proposed system is presented in Fig. 3.

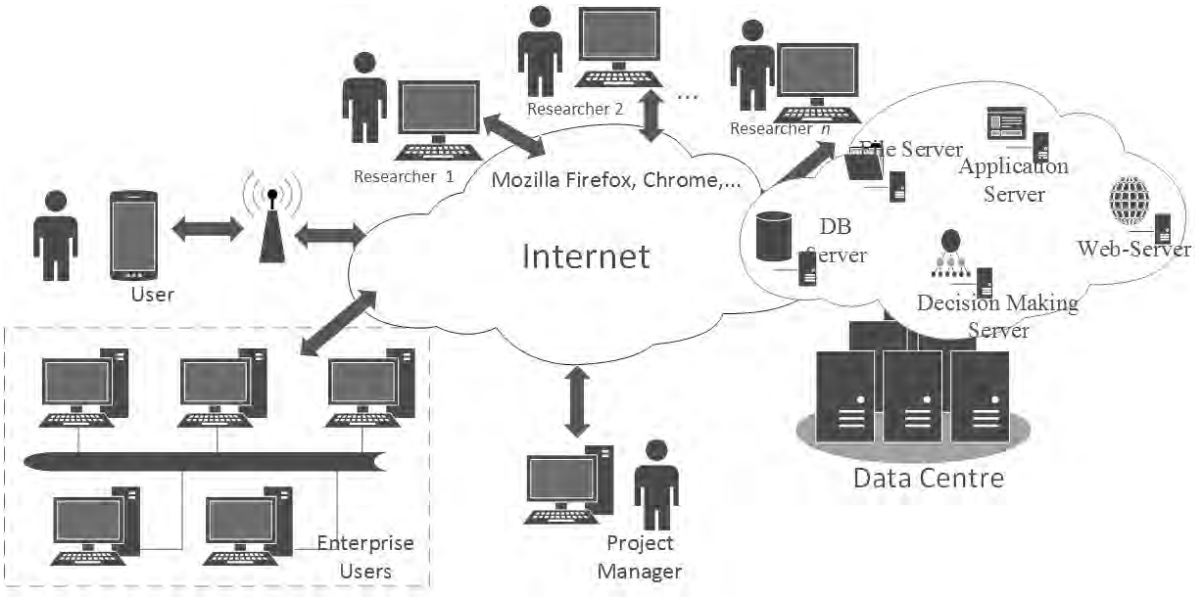

Fig. 3. Cloud architecture of water bodies quality monitoring and forecasting distributed system
Data Center – data processing center

According to the offered structure, the tasks are distributed between all servers, which are accommodated in the centers processing data (Data Centre). The necessary speed and efficiency of the tasks solution at minimum charges is achieved by parallel partition of loading. A part of calculations can be executed by servers of earlier created projects; the data, collected within the projects financed by other organizations, can be also used. Basic principle of development of such massive system is the obligatory use of the distributed servers of database subsystems and their unification according to the cloud computation systems. Such decision allows plugging any calculation programs in database, for example, forecasting of water bodies' quality, using the mechanism of in-built functions and having all computing programs on the database server's side. These built-in programs start working in case of happening appropriate conditions, for example, at the request of the user of water services etc.

Transmission of design results from distributed DBs in case of users' requests, who use any modern browsers (Mozilla Firefox, Chrome and others), is provided by the distributed application servers. The application servers are intended primarily, for rapid processing of huge amount of users, which can be more than thousand, and forming the necessary results as web pages. Such integration of distributed DB and application servers allows creating the distributed environment of design modes and computing tasks, which use data of different DB, regardless of their physical location.

Conclusions

A structure and principles of construction of the universal distributed system that allows executing the centralized storage and provides rapid access and further analysis of the sources of water-supply and their influence on the environment were considered.

The structure of relational database for storage and analysis of results of water quality measuring and is offered. It is shown that the use of database promotes the operation ability of processing the results of water quality analysis.

Implementation of the information-computing system is executed using service architecture that allows getting independence from technical equipment of separate laboratories and provides access to the database in multi-user mode. The results of processing the collected data allow determining the basic sources of pollution and forecasting their influence on the environment.

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