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СОДРЖИНА
CONTENT

CLOUD COMPUTING APPLICATION FOR WATER RESOURCES MODELING AND OPTIMIZATION

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Abstract: Modeling and optimization of water resources is complex multidisciplinary collaborative task suitable for development of a cloud computing application. The presented application for water resources modeling and optimization is built on three latest advancements in computer science and technology: Cloud Computing, Service Oriented Architecture and web Geographic Information Systems. The cloud computing application have three tiers: (1) database tier capable of storing all relevant data and information (including geospatial information) (2) middle tier that support multiple data sources and provide platform for building specialized web services and (3) web services tier. The web service tier contains three web services (1) for geospatial data management, (2) for water resources modeling and (3) water resources optimization. The cloud computing application for water resource modeling and optimization advantages over previous solutions are: accessible from everywhere, available all the time, scalable, interoperable, distributed and ultimate collaboration platform. The application web address is www.delipetrov.com/his/.

Keywords: Cloud computing, GIS, modeling, optimization, water resources.

8 Introduction

Water is one of the most valuable human resources. Population growth, higher livings standards, industry, power production, food production are the main factors for continuous increase of water demand. These factors together with climate change put additional pressure on water managers demanding efficient and optimal distribution of water resources between all users and functions. New tools and methods are needed for development of integrated water management systems. These water management systems will include stakeholders, users and functions into one integrated platform addressing technical, economical, social and ecological aspects.

Water managers nowadays use sophisticated decision support systems for integrated water management. Core component of these systems is water resources modeling and optimization. Water resources modeling and optimization is usually performed by computer models of the real world. In the last decade advances in ICT (Information and Communication Technologies) significantly improved water resources modeling and optimization leading to improved management of engineering, economic, social, ecological, hydrological and institutional aspects of complex multifunctional water systems. These contribute to improved design, implementation, management and knowledge of the water systems.

Existing water modeling systems are usually available as stand-alone applications, frequently relying on GIS (Geographic Information Systems) that provide the framework for management and integration of all geo-spatial data [1]. Recent advances demonstrate transition to web-based applications, using similar GIS frameworks [2]. There are successful examples of open source water modelling solutions [3], while other solutions are combination of open source and commercial software components, creating web services for distributed and interoperable hydro information system [4].

The main objective in the presented research is to create cloud computing application for water resources modelling and optimization that is internet based and only a web browser is required to use it. The cloud application is conceived to contain all necessary data and information concerning water resources and to provide a platform for development of specialized web services. Additional application objectives are: (1) available from everywhere, (2) accessible all the time, (3) flexible for adding additional web services and components, (4) interoperable, (5) designed to operate in distributed computer environment, (6) based on open source software and (7) can be simultaneously used by multiple users that are geographically dispersed, therefore enabling web-based collaborative environment.

The presented cloud computing application for water resources modeling and optimization satisfies all previously specified objectives. This application is one of the most feasible solutions for future development of integrated water modeling systems where all data, services and processing are carried out on one common platform enabling integrated management of the physical system in question that addresses various economic, social, ecological and other objectives. The cloud application presented here have three web services:

1. Web service for geospatial data management.
2. Web service for water resources modeling.
3. Web service for water resources optimization.

The cloud application is developed using several programming languages (JavaScript, AJAX, PhP), additional applications (GeoServer, PostgreSQL, PosgGIS), libraries (OpenLayers), geospatial standards protocols (WMS, WFS, WFS-T) and others additional components. All components and software packages used in the application development are open source. The system design and components allow easy upgrade, interoperability, distribution and scalability.

The cloud application for water resources modeling is designed to work in private cloud architecture e.g. its compliance isn’t tested on any current cloud provider. Main idea in cloud computing is to use the service without knowing (or caring) about the infrastructure being what this application does.

9 Main concept and technologies

The three main concepts and technologies for the development of cloud application for water resources modelling and optimization are: (1) Cloud Computing, (2) Service Oriented Architecture (SOA), (3) web GIS.

Cloud computing is the latest ICT trend. The core concept of cloud computing is “only a web browser is needed” while everything else is in the cloud. Data, models and software reside in the cloud and are available “on demand” anytime and everywhere. Only internet connection and browser is needed to use the system. This concept is analogous to the electricity grid where we just plug in our devices and use them without understanding the infrastructure behind. Cloud computing [5] also creates new possibilities and advantages for companies and users. This is demonstrated by the fact that the largest IT companies like Apple, Google, Facebook, Microsoft, and Amazon are heavily investing in their cloud computing facilities.

Service Oriented Architecture (SOA) [6] defines a group of rules for design, development, integration and implementation of information systems. The key idea behind SOA is how to integrate and connect various information system components. SOA define components interfaces and communications protocols using messages in XML (eXtensible Markup Language) format. SOA enables previously developed components and applications, various programming languages and different platforms to be joined into one integral solution.

Third and crucial concept used in this application is web GIS. GIS provides integration framework for modelling in any domain with geospatial information (water, climate, population, etc.). Almost all water resources information's are geospatial in nature. Latest standards and tools of Web GIS allow development of fully distributed web applications, making the Internet as the new medium for using these systems [7]. The presented cloud application is successful demonstration of the latest web GIS technologies and standards.

10 Architecture of the cloud application

The cloud application architecture is based on SOA and presented on Figure 1. The arrows in this figure represent communication between the different web services, as they have been introduced earlier. The three different web services, together with the technologies and components used for their implementation are explained in the following sections.

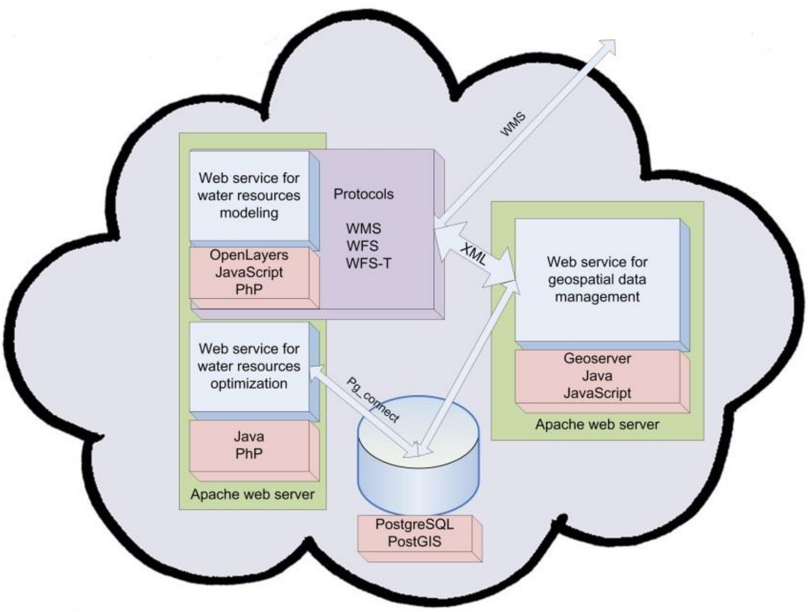

Figure 1 Architecture of the cloud application for water resources modeling and optimization

3.1 Web service for geospatial data management

The web service for geospatial data management is composed of two main components: web application GeoServer and relational database HMak created in PostgreSQL and PostGIS. The relational database HMak stores relevant water resources related data (river network, canals, towns, cities, irrigation fields, etc.) as well as data for the web service for water resources modeling and the web service for water resources optimization.

GeoServer is a middle component that can connect to mutiple data sources and provide data to other components using Open Geospatial Consortium (OGC) standard protocols (WMS, WFS, WFS-T). GeoServer abstracts data sources and provides data access platform for various web services. In the current implementation, the web service for water resources modelling is connected to GeoServer using WFS-T protocol. WFS-T protocol is based of XML messages and operate asynchronous or “on demand”.

3.2 Web service for water resources modeling

The web service for water resources modeling is created using OpenLayers library and prototype code of the programing languages JavaScript, AJAX and PhP. The web service geospatial capabilities are enabled by OpenLayers library that support OGC standards (WMS, WFS, WFS-T, etc.). The web service gives possibility to draw, edit, delete or modify vector geospatial data online. In the current implementation, the web service is connected over WMS to Google map servers and Open map servers and uses these layers as background maps. The web service through WFS-T connects to the GeoServer and indirectly with the HMak database. HMak database stores six geospatial vector layers: rivers, canals, users, reservoirs, inflow and agricultural areas. For each layer attribute tables are defined and stored, together with the geospatial data, same as in GIS. The web service provides a toolbar for operations with geospatial objects from the six vector layers and creating the water resources model shown on figure 2. Moreover, the web service provides the interface to enter attributes data to the objects. When a geospatial objects is selected, JavaScript code is activated that reads attributes data from HMak and fills the data under the tab “Attribute Info”. Users can change this data and store it back to HMak. In the current demonstrator implementation attribute data is still relatively simple but the possibilities for extending every object with additional information are possible.

An example model representation using the web service was developed, by entering rivers, canals, reservoir, users, and agriculture areas, as shown on figure 2. Together with the geospatial data, sample attribute data was provided for every object.

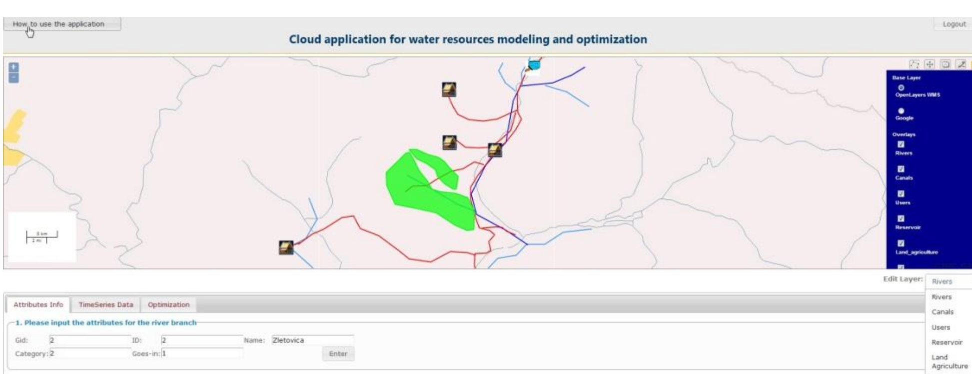

Figure 2 River basin model created with the service for WRM

3.3 Web service for water resources optimization

The web service for water resources optimization is composed of the prototype Dynamic Programming (DP) application developed in Java and the appropriate web interface. This application is based on the dynamic programming algorithm provided in [8] for calculating optimal reservoir operation that simultaneously satisfies the objectives for flood control, downstream water demand and recreation on the lake reservoir. The application works with 5 input tables: reservoir inflow, total demand, upper flood limit, lower recreation limit and reservoir discretization shown in table 1. Timestep is denoted with TS in table 1. The weight factors in tables Demand, Flood and Recreation describe the relative importance of satisfying the three objectives.

Table 2 Input tables of the web service for water resources optimization

Inflow	Demand	Flood	Recreation	Reservoir Discretization
Integer:TS Double: Inflow	Integer:TS Double: Demand	Integer:TS Double:Flood Double:Weight	Integer:TS Double:Recreation Double:Weight	Double:Discretization

The web service has web interface for entering data, performing basic data quality checks and uploading of the data into HMak database. The execution starts the dynamic programming (DP) algorithm, which uses the uploaded data and provides the results on a separate web page. Application result is optimal reservoir operation in terms of reservoir releases.

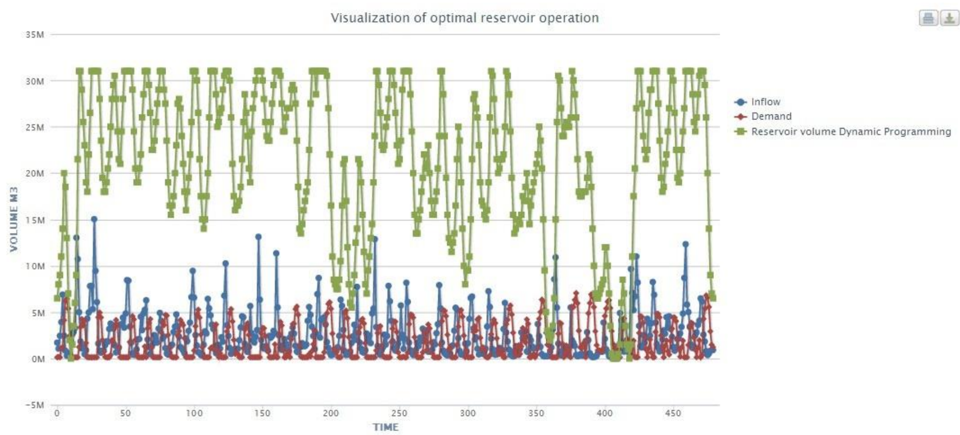

Figure 3 Visualization of optimal reservoir operation

This service is started by selecting a reservoir object from the main working window. The execution of the application loads the data from HMak, runs the DP algorithm and provides the results. Such results are shown on figure 3 where reservoir inflow, total demand and optimal reservoir operation curve are plotted together. The idea of including this service is not to present state of the art optimization algorithm or hard mathematical background which can be found in [8], but instead to demonstrate that cloud computing platform can facilitate different programming languages and components.

4. Discussion

The development of the application demonstrates the possibilities of ICT for creation of integrated cloud solution for water resources modelling and optimization. The main goal of using only web browser for operating the application is accomplished. The presented cloud application is web based, accessible and available all the time and from everywhere. The current implementation of the system is on one physical server with one relational database HMak, one GeoServer instance, and two apache web servers on which three services are working. The system components and technologies provide seamless scalability, interoperability and can work in distributed environment. GeoServer can connect to several distributed relational database and other types of data sources. The source code of the cloud application can connect to more instances of GeoServer, which can be distributed on many physical servers. This demonstrates the power of the presented solution to work in heterogeneous server environments and the opportunity to adjust hardware and software resources based on the workload. The cloud application SOA increases the flexibility to add additional web services or upgrading the existing ones. The service for optimizing water resources demonstrates how different applications (using different programing languages) can be connected to the existing services and integrated into cloud application.

The current cloud application is open to everyone, and anyone with internet connection can use the web services. Geographically dispersed users using only a web browser can jointly model the water system, draw rivers, enter attributes, run optimization and view results. This is the ultimate collaborative environment that provides same interface, data and users working windows. Each user action is processed by the cloud application and presented immediately in the web service where all other users can see it. Example for this is if one user is entering (drawing) rivers other can enter canals and with each refresh of the web browser can actually monitor the overall progress and jointly develop the water model. All services, data and modes are accessible to users at every time and everywhere. Additionally, future cloud application development can create different working environments for different user categories, such as decision makers, water managers and the general public. These working environments would be based on different services, capabilities and data access. Important advantage of the presented solution is that all services will be based on one common platform.

There are several possibilities for upgrading and improvement of the existing services. The service for water resources modelling can be upgraded with adding new layers and creation of quality attributes tables. The most important part is development of a computational framework that will create an intelligent system, connect different objects and define dependencies between them. Example for this is when a river enters a reservoir the river discharge to be added to the reservoir storage and update the reservoir level. These extensions can lead to the development of a full-fledged water resources modelling system as a cloud application. The service for water resources optimization can be improved by including additional algorithms based on other optimization techniques (reinforcement learning, stochastic dynamic programming etc.) or by improving the existing one with adding additional input information.

5. Conclusion

The shifting of desktop applications, information, and processing power to the cloud has started. Future applications, software and services will be increasingly cloud oriented. The developed cloud application for water resources modelling and optimization is a pioneer in future integrated water management application. The software components and the web services presented in the article demonstrate that there are software and technologies to develop a robust and complex cloud application. Important to notice is that cloud application is build using open source system components and prototype code. Advantages of the presented application are its availability, accessibility, flexibility, scalability, interoperability included in the design and software components. Further development of the application can also include various water related data, population growth, urbanization, climate variations, etc., as they are needed for analysing and solving particular water resources management problems. The platform for development of such applications is already created and future applications will be additional services or modules of the existing cloud application.

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