OPERATIONAL FLOOD FORECASTING AS A WEB-SERVICE

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KEYWORDS

BPEL language, flood monitoring in forecasting, modeling and simulation of ecological and technological objects.

ABSTRACT

The paper presents flood forecasting and simulation system applied to a river flood analysis and risk prediction. An advanced river flood monitoring, modelling and forecasting approach is introduced. It extends the traditional approach based on modelling of river physical processes by integration of different types of models and technologies such as input data clustering and filtering, digital maps of a relief and river terrain, data crowdsourcing, heterogeneous data processing, hydrological models for time scale modelling water flows and geo-simulation, inundation visualization and duly warning on flooding. The service-focused architecture of system of monitoring and anticipatory forecasting of floods and weak connectivity of program modules peculiar to it allows to convert developed system to a format of the "cloudy" application implemented as service. The paper presents the implementation using BPEL language implements the business process work hydrological model, and describes how to use the BPEL can be realized by using CASE representations continuous and independent operation of several different hydrological models and automatically provide the user with the results of an optimal model for the present time. Developed service-focused architecture can be used for other infrastructure projects. Group of authors focuses on program-mathematical and algorithmic support of research projects.

1. INTRODUCTION

Flooding is one of natural disasters that often cause significant economic losses, human and social tragedies. Floods may be caused by different reasons, such as snow and ice melting in rivers in the spring causing freshet; heavy raining in the nearby areas, and wind-generated waves in the areas along the coast and river estuaries. Therefore, flood forecasting and its effective control is always a huge challenge for governments and local authorities.

A system of flood monitoring and forecasting allows to determine the estimated area of a spill in advance and thus significantly increase the safety and reduce the economic damage caused by the floods. Forecasts of river flow may be developed in the short term, over periods of a few hours or a few days, in the medium term, for several weeks, and in the long term, up to nine months [8]. An efficient flood alarm system based on a short-term flow forecasting may significantly improve public safety, mitigate social damages and reduce economic losses associated with floods.

Recent advances in spatial modeling of floods, modern geo-information systems and remote sensing of the Earth opens up new promising areas of flood control due to significant improvements in the quality of the simulation result. Experience in creating system of short-term flood forecast in previous stages of the project showed the difficulties associated with the interconnection of heterogeneous software. Previously used hydrological model demands Microsoft Windows to run.

The main task of the authors was using developed earlier but poorly applicable solutions for the flood tasks, and offer advanced software solution based on open source code, which allowed different achievements and integrate them into a single software complex. The broader goal was develop a policy framework that can be applied in other infrastructure projects and alleviate their implementation.

Other components of the system run on Unix-like systems. Moreover, modules of the system are geographically distributed. Previously developed software prototype used set of different protocols and technologies to ensure interoperability of modules. This reduces the flexibility of the system and hampered its development.

The architecture of software prototype was drastically reorganized in this stage of the Project. Now it is based on Service Oriented Architecture (SOA).

This paper provides approach based on the use of language Business Process Execution Language (BPEL) for scenarios of river flood modeling and forecasting

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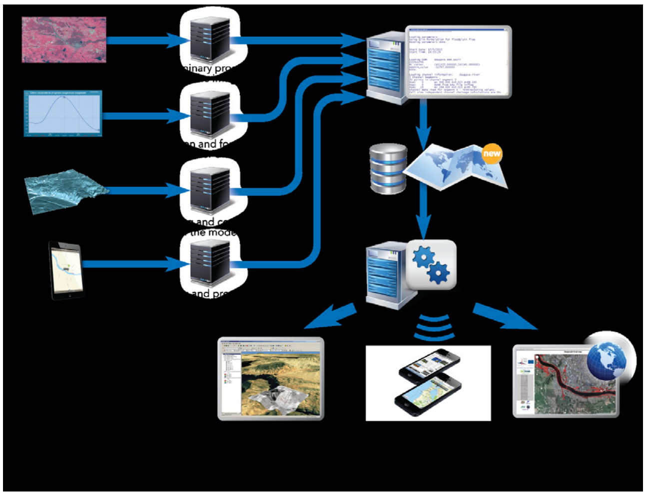
system operation.

2. ADVANCED APPROACH

In the paper, the traditional flood model-based forecasting approach based on river physical processes modelling is enhanced by integrating different models and technologies for improving flood risk output prediction such as input data clustering and filtering; digital maps of a relief and river terrain; data crowd sourcing; forecasting models; different hydrological models for time scale modelling water flows; computer simulation for the river behaviour modelling; visualisation tools; geographic information systems (GIS); and techniques for flooding scenario generation and comparison.

Taking into account the floodplain width and the speed of flooding processes, satellite and aerospace monitoring allows to regularly examine large areas and provide high efficiency information on the research object. Additionally, to get a holistic view of the current situation, remote sensing is supplemented by data obtained from ground-based monitoring devices.



Figures 1. Short-term forecasting based integration of space and ground-based data.

Clustering of dynamic historical data allows to identify typical dynamic flooding patterns in the real-life situations which occurred in the past and might be expected in the future.

A symbolic regression-based forecasting model is integrated into short-term forecasting of the river flow discharge and monitoring in a specific real-life situation [8]. Here, the main challenges are a small number of input factors and a small set of flow measurements. For developing a symbolic regression-based forecasting model, genetic programming within HeuristicLab is used. A trend-adjusted exponential smoothing is applied to predict the water levels in the river.

Hydrological models are advanced by realistic physical models that are derived from topological maps and represent geo information of the river and its neighbouring areas.

Data crowdsourcing is used for calibration of a hydrological model based on comparison of the actual situation with forecasted. Additionally, regression-based metamodels using river simulation results allow to perform sensitivity analysis of input factors influencing the river water levels and inundation areas, and to improve understanding of the model behaviour and interpretation of the flood forecasts.

GIS and technology present the most powerful tools emerged in the hydrological field, which allow for the collection and analysis of environmental data as well as provide a platform for integration of space and ground-based data for flood monitoring and modelling. Observed data support the creation of information through modelling, and the information evolves into knowledge through visualisation and analysis of digital elevation pictures and finally supports analysis of flooded geographic areas.

Finally, automatic generation and analysis of flooding scenarios will allow to analyse dynamics of the river floods and to evaluate their potential effects in the near future to support preventive actions to mitigate impacts of floods.

The analysis showed that the processes that characterize the flooding accompanied by active interactions of active and artificial objects. Let us introduce the concept of natural and technological objects (CNTO). The next section will discuss about description of the model natural and technological objects

3. TESTING OF THE MODEL

Testing of the model was developed for a short-term flooding forecast for the Daugava River near the city of Daugavpils in Latvia, in spring 2013 when unexpected intensive flooding was observed, exceeding the previous highest water level in spring 2010 - 7,7 m. The main reasons for spring floods in Daugavpils are considered as river ice jams arising from ice melting and rapid rise in the river water level.

A digital elevation model of the research area was obtained by means of airborne laser scanning performed by a specialised company with a horizontal resolution of 5 meters and a vertical resolution of 0.25 meter. To define hydrological characteristics of the river required for modelling water flows of the river channel network, a simplified model of the river channel on the selected section of the river was built. The width data of the river channel were determined based on the archival optical range space image for the period of low water levels in the river.

The flood forecast horizon is defined by a period up to 12 hours, with 1-hour interval. There is only one hydrological station on the selected section of the

Daugava River which can provide hydrological data on water levels, heights of waves, a flow direction, etc. To get operational data on the water levels in the river on-line web service has been created (Fig. 2).

Ikstundas maks. ūdens līmenis Daugavpilī (cm)	
Datums un laiks	Ūdens līmenis Daugavpilī
16.04.2013 08:00 - 09:00	490
16.04.2013 09:00 - 10:00	479
16.04.2013 10:00 - 11:00	478
16.04.2013 11:00 - 12:00	461
16.04.2013 12:00 - 13:00	462
16.04.2013 13:00 - 14:00	547
16.04.2013 14:00 - 15:00	572

Fig. 2. Operational data from a hydrological station.

Absolute heights of the river bottom channel were calculated using a digital elevation model

To predict the river water levels for the upcoming period of 12 hours on a daily base, a trend-adjusted exponential smoothing model is applied to observed water hourly level time series. By application of a symbolic regression method, a model for converting the water level into the water flow discharge in m^3/s was created.

To determine the functional dependency between the water flow discharge in the river and its water level within the forecasting horizon, several modelling scenarios such as linear, nonlinear regression models and a symbolic regression were experimentally tested [3]. Finally, a symbolic regression-based method implemented in HeuristicLab optimisation framework [1] has been selected. In order to train the model, historical data on water level forecasts for the previous intensive flooding period in March-April 2010 were used. A web service for recalculation of the river water level into the water flow discharge was created providing hourly receipt of the water discharge in the river. In fact, forecasts of the water levels are transformed into forecasts for the water discharge values. The forecasting accuracy of the river water flow discharge was within 95 % confidence interval.

4. STRUCTURE OF FLOODS FORECASTING SYSTEM

The architecture of software prototype was drastically reorganized in this stage of the Project. Now it is based on Service Oriented Architecture (SOA).

Several functions of software prototype were transformed into web-services: hydrological data collection, modeling, results storing and converting, publishing on geoportal. SOA demands the standardized interfaces and protocols to be used. To archive the coordinated work an Enterprise Service Bus is commonly used. It is a middleware that have ability to convert different data formats to SOAP standard. Technical specification of each web-service is stored in WSDL-file (Web Services Description Language). Thus, now we have the catalogue of web-services, ready to be invoked and able to exchange SOAP messages.

Data exchange standards do not define the application logic. There are several standards describing the logic of web services execution.

XLANG (XML-based language) developed by Microsoft, was initially designed to describe successive, parallel and multi-variant working flows for BizTalk Server. The main purpose of XLANG consists in defining the business processes and in the organization of the messages exchange among the Web-services. This language has tools for processing extreme situations and supports long-term transactions.

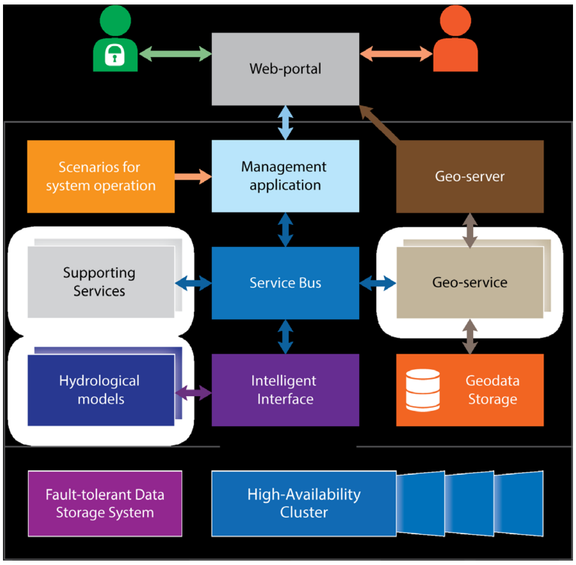
BPML (Business Process Modeling Language) is a language designed to describe the business processes on the basis of XML. Its specification is developed by the Business Process Management Initiative organization. It enables planning of the tasks and contains functions for data long-term storing. The data exchange among the participants is realized in XML format, using roles and definitions of the partners, similarly to BPEL constructions. BPML supports a recursive composition, intended to form integrated processes from components, and provides both long-term and short-term transactions.

In May 2003 Microsoft, IBM, Siebel, BEA Systems and SAP have developed together a version of the specification of BPEL4WS language. This specification, called BPEL, enables the modeling of the behaviour of the Web-services in the interaction of the business processes.

The service-focused architecture of system of monitoring and anticipatory floods forecasting and weak connectivity of program modules peculiar to it allow to transfer developed system to a format of the "cloudy" application implemented as service (Software as a Service, SaaS), by means of virtualization process of hardware resources. To cloud computing essential increase of flexibility of hardware-software implementation is a consequence of transition. In particular, the modules implemented algorithms of monitoring, forecasting and decision-making support, can be distributed considerably territorially and structurally, that is, to be carried out at the computing capacities which are not only in the different cities and the countries, but also belonging to the different organizations. Thus synthesized system of monitoring from the point of view of the end user will function as a local solution unit.

Efficiency of the analysis of a situation and taking measures to manage a situation often depends on speed of access to information that is available in the monitoring system. Despite the general trend towards the establishment of mobile clients of various industrial systems, many existing and widely known systems in the world implement a monitoring system "tied" to the situational center user interface.

The uniting of Web-services with Business Process Execution Language for Web Services increases the efficiency of the applications integration (Fig. 4.).



Figures 4. Structure of the system access to the results of flood monitoring and proactive modeling through Geo-portal.

5. ENTERPRISE SERVICE BUS AND SCENARIOS FOR SYSTEM OPERATION

Since we have chosen the general structure of the web portal, it is necessary to define a metric on which selected development tools for the proposed scheme of representation and processing of data will be working.
Software development tools need to be open source, because part of the system users are scientists or government organizations, and they often do not have the opportunity to purchase a system based on expensive software products focused on business. Development tools must be based on the standards for obtaining and processing information for easy integration with other software environments. In addition, it is desirable that the development tools do not require depth knowledge of programming and provide the ability to use of subject matter experts who do not have expertise in programming in an easy and understandable way. They should be able to visualize the process of writing the script, based on the CASE-diagrams.

These conditions determined the choice of software development tools. To develop web services Java language and development environment NetBeans IDE was used. NetBeans IDE is free, open source, and has a worldwide community of users and developers.

Enterprise Service Bus (ESB) which is a model of the software architecture used for the development and implementation of communication between mutually interacting software applications in a service-oriented architecture (SOA). As the Enterprise Service Bus was chosen OpenESB, It used to be owned by Sun Microsystems, but after Oracle and Sun Microsystems merged, the OpenESB Community was created to maintain, improve, promote and support OpenESB. OpenESB is the easiest and the most efficient ESB tool for building Integration and SOA applications. OpenESB offers a complete set of tools to design, develop, test and deploy integration applications and Service Oriented Applications. Relying on JBI (Java Business Integration), OpenESB proposes a unique development process that promotes migration to real service oriented development and organization.

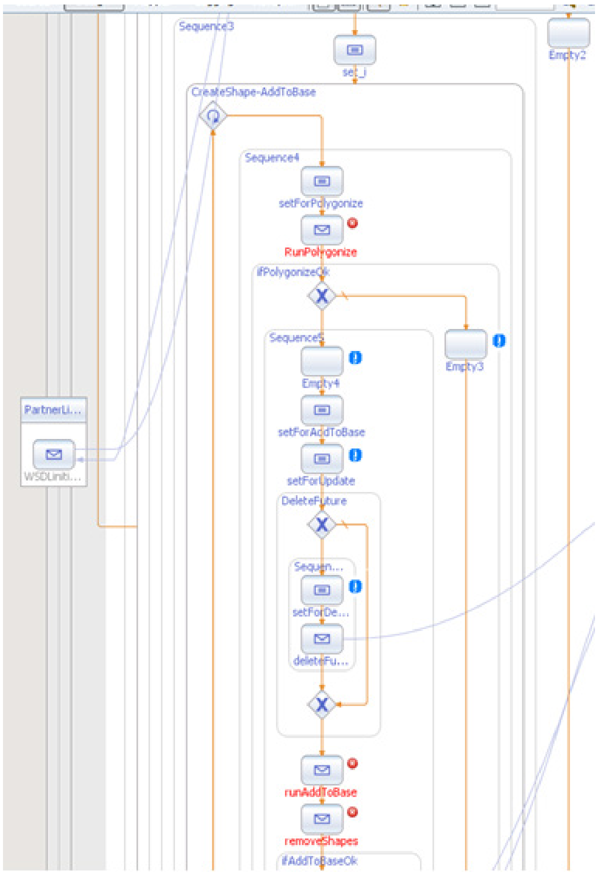
Business Process Execution Language (BPEL), short for Web Services Business Process Execution Language (WS-BPEL) was selected as a Language for Scenarios. It is an OASIS [10] standard executable language for specifying actions within business processes with web services. Processes in BPEL export and import information by using web service interfaces exclusively.

6. EXPERIMENTAL ENVIRONMENT

On the basis considered in the preceding section development tools, software was developed. Software implemented to obtain data for hydrological model for geo-services and used LISFLOOD model for which it is necessary to provide the input of a number of parameters, by which it becomes possible to predict the flood.

A LISFLOOD hydrological model is developed to simulate water flows in the riverbed of Daugava and within the channel network by integrating the digital map of the relief of the specified area and obtained hydrological characteristics of the river. To increase an accuracy of flood forecasts, 3D elevation model data with low vertical resolution that does not exceed 1 meter is used. Consequently, based on the water flow discharge data and a digital elevation model, LISFLOOD-based hydrological model is built which allow forecasting inundation territories along the river basin.

The figure (Fig. 5.) presents a part of business process for the hydrological model. As can be seen, the software implements the standard side-by-circuit characteristic of CASE tools. Furthermore, developed scheme is not only for illustrative purposes, but also includes executable program code, which is connected in an easy and understandable way to the web service. This executable code may run on remote servers, and monitors the correct operation of dependent web services and processes. Proposed architecture allows you to use and other hydrological models floods, which may have a different data source, use specialized software and can be installed on remote servers. In this case for the specialist in the domain will not have any value, where the server, and how the data will be processed, as it has to deal with a set of web services with predetermined parameters. This means that experts can concentrate on the design data and simulation modeling.



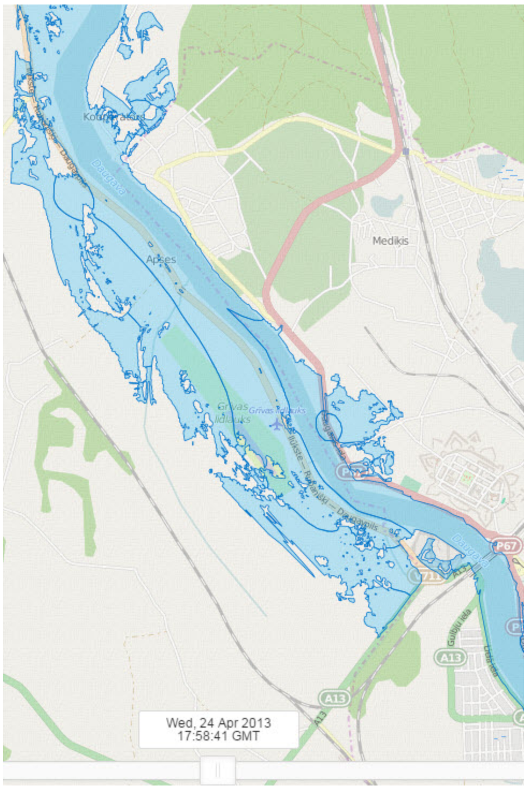
Figures .5. Business process implements the acquisition and processing of data for use in geo server.

It should be noted that the hydrological model is quite complex, has many options to customize and big set of output data that have to be processed for presentation on the web portal.

That's what has been written the business process, which at the entrance receives data from hydrological stations having information on water consumption, and output the results operation of a model, after conversion to the geo- server for later display on the web portal.

It should be noted that the designed system after installation does not require any interference in their work that is operating in automatic mode. That is automatically requests data from hydrological stations processes them and sends the results to the database server. This operation is done once an hour, this means that the user of web service has updated forecast floods every hour with the newly received data.

However, this model gives the best results floods only for certain parameters such as the initial stage of flooding. Some other models provide good results for the other steps of flooding or other year time periods.



Figures .6. The contours of the flood.

This implies another advantage of this architecture, which is the ability to run multiple independent business processes using the system bus. As a result, we have a number of independent processes, some of which will implement a continuous and correct operation of the various models of flooding.

The final step is a business process that uses the one hand data on flooding in real time, on the other hand compares them with different prognostic floods models, and has the ability to provide the user with the best (according to the selected criteria) short-term (24 hours) forecast of situation in the zone of possible flooding. The next step of research will be to create a business process to automate the work of filling the store geospatial data and their further use in the geo server, depending on user requests.
Developed software system is an example of the successful use of the enterprise service bus provides using BPEL language in flood forecasting problems.

7. CONCLUSIONS

The review of the state-of-the-art in river flood flow forecasting and simulation allows defining the most efficient models and tools for water flow forecasting and river simulation. These models and technologies provide input data clustering and filtering, using of digital maps of a relief and river terrain, data crowdsourcing, different hydrological models for time scale modelling water flows and geo-simulation, visualization of the modelling results as well as duly warning and personal notification on the flood status. The architecture of software prototype now based on Service Oriented Architecture (SOA). Approach based on the use of Business Process Execution Language (BPEL) for scenarios of system operation of river flood modeling and forecasting demonstrated its applicability and efficiency of use in floods forecasting applications. Implemented approach using previously obtained diverse solutions to meet the challenges of flooding, and offer advanced software solutions based on open source code that allowed various achievements integrated into a single software package.

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