Hydrol. Earth Syst. Sci. Discuss., 4, 1879–1891, 2007
www.hydrol-earth-syst-sci-discuss.net/4/1879/2007/

Hydrology and Earth System Sciences Discussions

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Web services for distributed and interoperable hydro-information systems

J. Horak, A. Orlik, and J. Stromsky

Institute of Geoinformatics, VSB-Technical University of Ostrava,17.listopadu15, Ostrava-Poruba, 70833, Czech Republic

Received: 11 June 2007 – Accepted: 15 June 2007 – Published: 26 June 2007

Correspondence to: A. Orlik (antonin.orlik.hgf@vsb.cz)

Abstract

Web services support the integration and interoperability of Web-based applications and enable machine-to-machine interaction. The concepts of web services and open distributed architecture were applied to the development of T-DSS, the prototype customised for web based hydro-information systems. T-DSS provides mapping services, database related services and access to remote components, with special emphasis placed on output flexibility (e.g. multilingualism), where SOAP web services are mainly used for communication. The remote components are represented above all by distant data and mapping services (e.g. eteorological predictions), modelling and analytical systems (currently HEC-HMS, Modflow and additional utilities), which support decision making in water management.

1 Introduction

Integrated water management requires an integrated view of water related issues and a way of management reflecting the complexity of the water system. The objective is supported by the integrated approach to components of the hydrological cycle as well as complex utilisation of a wide range of different information services. Very often information services act to solve only a particular part of information support within a distinct application sphere and its respective part of hydrological system. Among different approaches to integration of these individual services the utilisation of web services should play a dominant role due to its ability to preserve the development of individual specialised systems, and glue them to the powerful distribution system, where each subsystem can fully deploy the services of other subsystems and end users are not annoyed by solving individual tasks in different systems, and different requirements for input data and providers. Such issues are sensitive mainly in cross-border localities where different sources, services and approaches complicate demanding integrated management.

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2 Architecture of distributed information system

The architecture of the system determines the logic of the system and its extensibility, scalability and interoperability. Two approaches to the distributed system deployment can be distinguished: local system oriented to integration of individual systems (SW, data, etc.) situated in a local network and global system where Internet plays the role of main communication media.

The local system can directly access data and other sources shared locally between different parts of distributed information. Particular parts of a distributed system can be interconnected more tightly, establishing powerful and effective solutions.

Seamless interaction among modelling systems, the integration and combination of their functions in order to improve final results, are the main features of Open Modelling Interface (OpenMI, http://www.openmi.org), the output of the European project HarmonIT (Gijsbers, 2004). OpenMI should solve or improve the quality of many difficult issues concerning model communication (i.e. spatial and temporal scale differences, system feedback, unit differences, variable marking etc.). OpenMI represents an important step towards standardization of the model linking on the local level. The interface currently supports primarily C# programming language and also Java language. Though OpenMI creates an independent multi-platform environment above modelling systems, it is suitable particularly for more tightly connected systems. OpenMI does not possess sufficient independence for implementation in heterogeneous systems in global networks (e.g. it is impossible to connect wrappers prepared in C# and Java languages).

Another example of a local system solution is described in (Donchyts, 2007). The architecture of the RODOS DSS is N-tier and Plug-in based, with an Object Relational Mapping solution for system data management and GIS subsystem. The model wrapper should be implemented as a plug-in and utilises IModel class for model management. Unfortunately the class and its role are not fully documented.

On the contrary, global system enable us to take advantage of independent high-end services, developed and operated by individual organisations. In such systems, web services represent one of the best solutions for integration and communication.

3 T-DSS

The concepts of web services and open distributed architecture were fully applied for the development of T-DSS, the prototype customised for a web based hydro-information system. T-DSS is a modular web application system running in an Internet environment using Open Sources technologies. The T-DSS is developed within the framework of the TANDEM project, but the original idea of such web based distributed systems arose in the TRANSCAT project (EVK1-CT2002-00124) (Horak and Owsinski, 2004). T-DSS represents a distributed and a platform-independent system. Originally standalone systems in the category of decision application, modelling servers, data warehouses and relevant information services were integrated with GIS in the unified system where web services were mainly applied for communication. T-DSS consists of following basic server-side components (Fig. 3). T-DSS Server, Database management system with Data Abstraction Layer (DAL), Web Services Application Interface (WS-API) and remote Modelling and Data Processing services. T-DSS represents a server system implementing a required business logic using ArteGIS Server system. The ArteGIS Server system extends University Minnesota MapServer capabilities and enables a dynamic generation of the client application including its behaviour. The system offers all basic map composition elements, the linkage of remote components, modelling and processing services and utilisation of Web Map Services. Using the method of geo-data visualization, labelling or attribute selection is able to reflect the national lingual and cultural environment, because the client application is dynamically created according to the user who is currently logged in, his access rights, selected language and current time (system checks if requested data is up to date). T-DSS incorporates a framework for building web based applications (ArteGIS Web). It allows developers to build a requested application quickly using specialized web components. The database management system is a fundamental component intended to carry out the management of all system data and data warehousing. PostgreSQL is implemented in a position of DBMS, and a PostGIS extension is used for the storing of spatial data in a database. This way of spatial data storing provides wide usage possibilities by other systems. The system also allows for connection to other spatial databases to use additional spatial data. User and group management at the database level ensures privileged access to stored data as well as to T-DSS.

The web client is an application written as DHTML using JavaScript, interpretable by common web browsers. The client provides spatial data visualization and common functions for manipulation of interactive digital maps. More advanced features include document attached info, utilisation of WMS, info panels and access to modelling and decision applications (see Figs. 1 and 4).

4 A connection to hydrological and hydrogeological models

Analysis of numerical modelling systems for water management was provided within the framework of the TANDEM project (Tylcer et al., 2004). The requirements of end-users in this project indicated an interest in systems which are freely available. Interfaces to selected systems have been developed to provide an integrated system with the capability to utilize numerical modelling for the solution of various water management tasks. The distributed information system utilizes four kinds of services – services that receive models' input data from remote servers (numerical models, observed values), services as wrappers for modelling software (HEC-HMS, ModFlow, additional utilities), and service for data sharing and services for data visualization (map layers, images, graphs). The first service receives input data and passes it to an integrated database with appropriate metadata. The model wrappers are able to read the necessary input data from the database and update the model input files. Models are calculated in the correct order (results from one model can be used as input for another model) and the results are stored in integrated database. The management and iterative processing both are supported by model parameters as well as space and time extent specifications, which are similar to the JAMS spatial, temporal and model contexts (Kralisch and Krause, 2006). The Visualization service allows the user to obtain a result for a selected place and time in a suitable format (map layers can be visualized by map server).

Figure 2 shows a simplified scheme of basic components needed for modelling in the T-DSS system. On the left side there are remote sources of input data necessary for models. Input data is stored in an integrated database, and model wrappers are called automatically at given times or upon the user's request. Data sharing enables reading and storing the models' data. Other services support data imagery, geographical data transformation etc.

4.1 Interface to HEC-HMS

One of the main outputs of a hydrological model is a predicted water flow for selected profiles at a river. For this purpose the HEC-HMS 1-D hydrological model (http://www.hec.usace.army.mil/software/hec-hms/hechms-hechms.html) was integrated into the system. The HEC-HMS program is designed for the Windows operating system but the core system of T-DSS server operates on the Linux system. The web services help to overcome the differences and provide remote control that can allow data exchange and model launching. The interface is a wrapper over the HEC-HMS hydrological rainfall-runoff model that allows Web Service binding. The input data is derived mainly from precipitation predictions. Predicted precipitations may be obtained from various sources – e.g. the ALADIN/LACE model is recommended for a short-term prediction, the GFS model (http://www.wetterzentrale.de/) for a medium-term prediction. The web client enables management of input and visualisation (Fig. 3).

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4.2 Interface to ModFlow 2000

Interface to ModFlow 2000 (MODular three-dimensional finite-difference ground-water FLOW model) (http://water.usgs.gov/nrp/gwsoftware/modflow2000/modflow2000.html) is intended to modify and compute a hydrogeological model. The wrapper is written in PERL language as a Web service for Linux OS. The service allows changing the model's input data, computing the model as well as processing the resulting data to a form suitable for visualization. The resulting georeferenced raster file and vector isolines of underground water levels are visualized through the University Minnesota Map Server in the map client (Fig. 4). The interface can also provide a calculation of baseflow contribution for rainfall-runoff modelling.

4.3 Interface to additional utilities

Various additional utilities and systems, such as GRASS GIS, may be wrapped as Web Services and used in the frame of T-DSS. GRASS (Geographic Resources Analysis Support System) (http://grass.itc.it/) is a raster/vector GIS and image processing system, which contains over 350 programs and tools to render maps and images; manipulate raster, vector, and sites data; process multi- spectral image data; and create, manage, and store spatial data (Neteler and Mitasova, 2002). In this way, an interpolation service was designed for mDSS (Mulino Decision Support System) http://siti.feem.it/mulino/). The service receives XY points with values, delimiting polygons and processing parameters, returns requested statistical information of a selected area or returns a raster file with interpolated values.

5 Conclusions

Web based distributed information systems offer open and platform independent architecture. Such systems represent a promising solution for integration of heterogeneous services and an effective way to create complex systems from partial, independent systems. A prototype of T-DSS provides an example of how to implement these ideas. The system combines various services, data sources and also provides special support for international regions. The decision-making is supported by numerical modelling tools; web based wrappers have been developed for HEC-HMS, ModFlow 2000 and GRASS GIS. The system provides services of numerical modelling for various tasks in water management. Solution of the interfaces to such systems is not only a task for software engineering (model wrapper, distant management, result presentation) but above all the efective solution requires:

- a conceptual solution, model development and calibration,
- input data flow,
- data storing,
- definition of processes for deployment these models and
- their integration to the uniform information system.

Model selection and calibration is a demanding expert's task. Created models must still be under expert control. Deployment of the system has to be organised according to the restriction related to source data, models and services; and under control (or with tight cooperation) of authorities responsible for providing monitoring, predicting and warning tasks.

Acknowledgements. The project is supported by the Grant Agency of the Czech Republic ("Application of Geoinformation Technologies for Improvement of Rainfall-Runoff Relationships", GA 205/06/1037). Data and related services are provided by the courtesy of Czech Hydrometeorological Institute.

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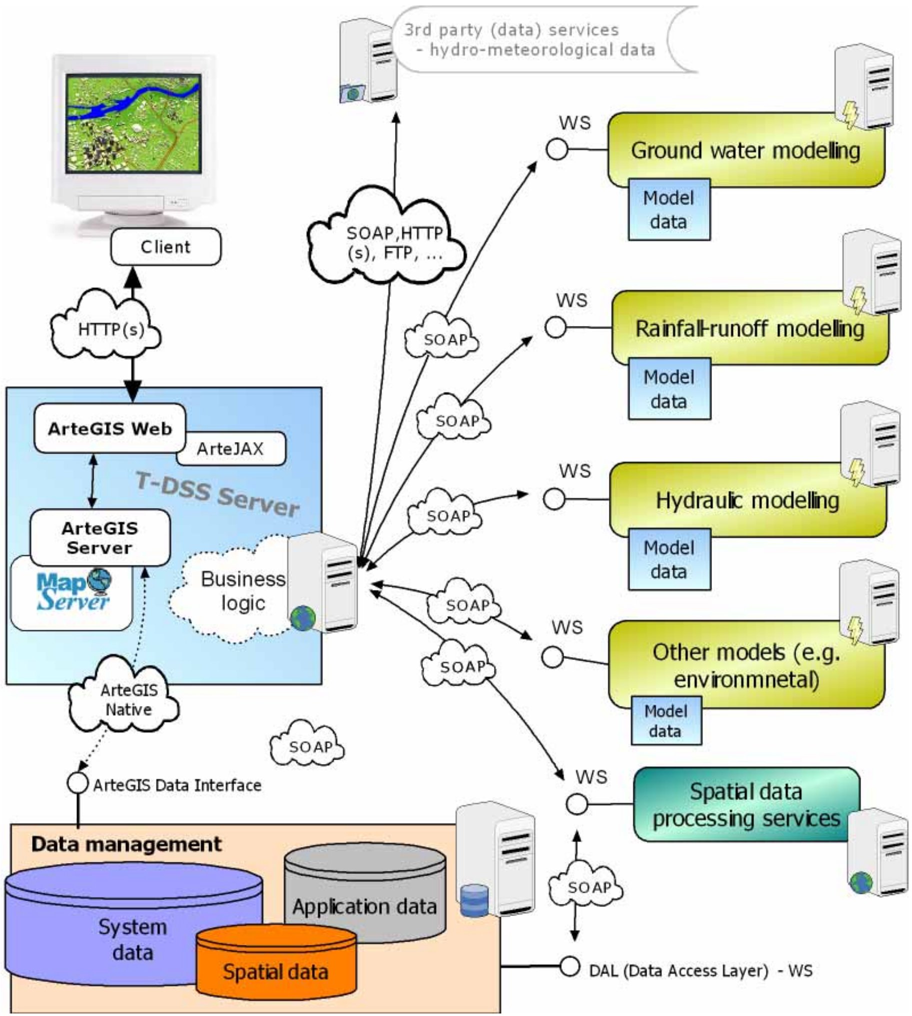

Fig. 1. T-DSS architecture.

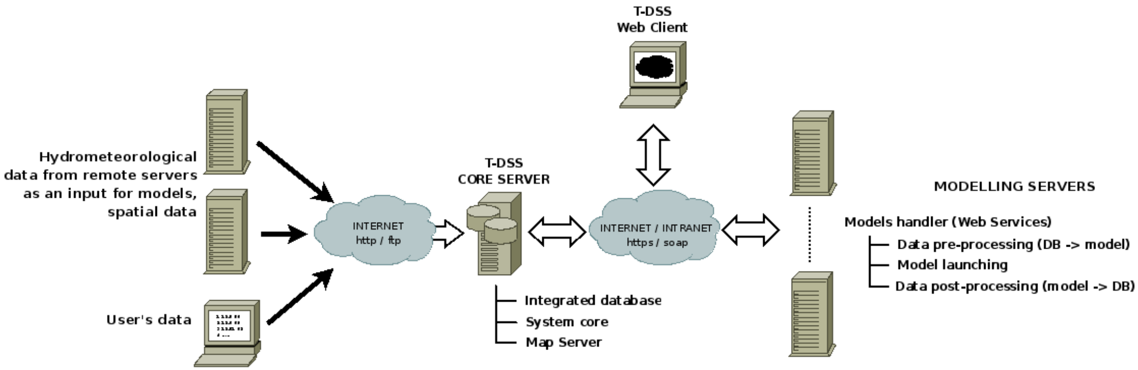

Fig. 2. Communication between core system and surrounding subsystems.

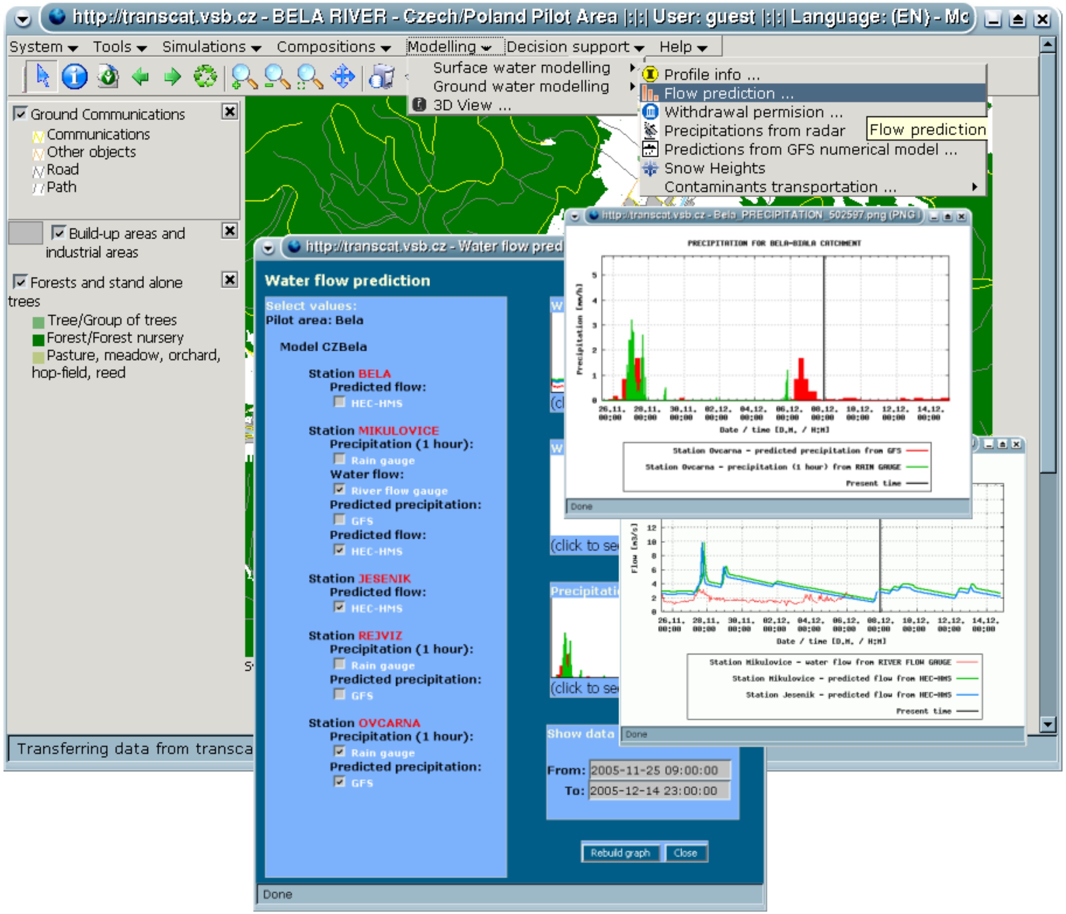

Fig. 3. Web client in the frame of project TRANSCAT. Flow predictions from menu "Modelling".

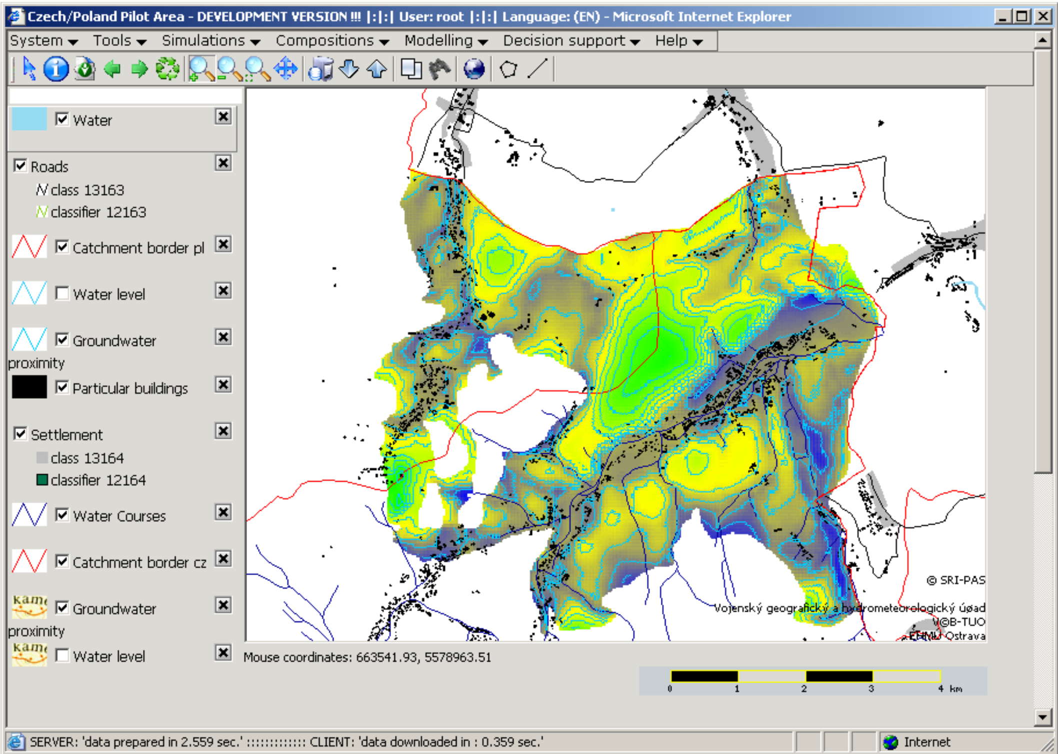

Fig. 4. Groundwater level (both isolines and raster) as a result of ModFlow model presented by web client.