WATERMARK
From Modules to Application

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Abstract
WATERMARK is a multi-disciplinary research initiative at the Austrian Research Centers which aims at developing intelligent knowledge-based services and solutions in order to support the implementation of the EU Water Framework Directive (WFD). One of the basic requirements for realizing the requested integrated water management approach is to develop advanced information and data management tools and applications. WATERMARK combines the research expertise of experts in water management, information technologies and environmental planning in order to develop innovative methodologies for comprehensive information management in the field of water resources management. Main objective of the WATERMARK project is to produce additional value out of the environmental data which will become available in the course of WFD implementation. This is done by integrating several data sources and modules into one coherent application. A couple of data sources easily available in house was chosen together with a handful of use cases. An architecture was defined, that allows to glue together all the data sources to one system allowing to work on the use cases. Some of these use cases were implemented together with all necessary access to the underlying data sources. Future development of WATERMARK is directed towards full ORCHESTRA (Open Architecture and Spatial Data Infrastructure for Risk Management) architecture compliance, integration of additional ORCHESTRA services, real-time access to sensor networks, and implementing further environmental management modules.

1. Introduction
The WATERMARK initiative at the Austrian Research Centres in Seibersdorf combines the expertise of several disciplines. Experts in water management, environmental planning and information technologies are working together to develop innovative methodologies for comprehensive information management supporting the implementation of the EU Water Framework Directive (WFD).

Main objective of the WATERMARK project is to produce additional value out of the environmental data which will become available in the course of WFD implementation, e.g. by supporting the decision making process in companies and public authorities, providing impact and risk assessment tools and performing scenario analyses. Consequently, the WATERMARK application is a precursor of a completely new class of applications that will be able to tap into data currently available only to hydrologists, (if at all), possibly merge this data with knowledge from other domains, and present the end results in a way most suitable to support the decision making process of experts from other domains and the interested public. WATERMARK related research activities focus on the following tasks and services:
- Information & knowledge management and modelling
- Development of web-based services, using OGC and ISO standards
- Information-Visualization
- Risk analysis and decision support

The main technical challenge originates from additional WATERMARK business requirements:

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- Centralised development, maintenance and support
- Support for emerging GIS standards (OGC/ISO 191xx)
- Easily deployable at the end-user site
- Intuitive and easy to use, preferably not requiring any end-user training
- Easily extensible with new application modules to meet new user requirements
- Support integration of new data sources

2. **EU Water framework directive**

   In order to fully understand the WATERMARK project, it is important to understand the consequences the WFD (European Commission 2000) implementation will have with respect to availability and usability of the water related information. The aim of the WFD is to ensure that all European waters, including groundwater, inland surface waters, transitional waters and coastal waters are protected according to a common standard. WFD has two key components:
   - a system of management of the natural water environment based on natural river basin districts instead of administrative and political regions; and
   - coordinated "programs of measures" with the ultimate objective of preventing any deterioration in the existing status of waters and achieving at least "good status" of all European waters by 2015.

   According to Marent (2005) the formal transposition of the WFD into national law has been achieved by the member states and the "competent authorities" responsible for the implementation and reporting have been identified during 2004 (Art. 3). In addition, approx. 195 European River Basins where identified and an economic and environmental analysis (Art. 4) has been performed.

   Future WFD implementation steps foresee establishing monitoring networks and development of river basin management plans. For this purpose, IT infrastructure that allows unified reporting of the river basin indicators on the European level needs to be developed, with a distant goal of eventually achieving the full interoperability of all the WFD-relevant data and services.

3. **Interoperability of the WFD data and services**

   One of the major requirements of the WFD is to make information more accessible and interoperable by all data users. With WFD agenda moving from organisational to technical questions, the focus of research is turning towards ensuring interoperability of water related data and services in heterogeneous networks.

   As a first step in this process, several national and international activities have been started to develop tools to streamline the reporting. Typically these systems harmonize, collect and prepare data for reporting:
   - At the EU level different EU organizations and member states have agreed on the establishment of a comprehensive and shared European data and information management system for water, called WISE. The intention of WISE is to provide modern technology for streamlining the reporting process, gathering more useful and relevant information and making the exchange process as efficient as possible (European Commission 2005).
   - At the national level, different member states are developing their own platforms, such as the Austrian Water Information System WISA which will be fully operating by 2007 (Nemetz 2005).
   - Even more platforms are being developed at the river basin level, such as the Geographic Information System for the Danube River Basin (DRB GIS) that will allow uploading the harmonized geo-data sets and facilitate the “upstream” reporting required by the WFD for the DRB (Hadrbolec 2005).
All the above mentioned systems define themselves as portals to upload the WFD related reports. Moving from “simple” upstream reporting systems currently in development towards full interoperability and publicly available data and services requires novel IT architecture capable of easily integrating variety of legacy systems and data formats.

WFD Common Implementation Strategy partially addresses these problems, in particular through the working group Geographical Information System (GIS) whose work goes far beyond the implementation of just the geographical elements of the WFD (European Commission 2003). Specification elements of the current GIS Guidance document are listed in Vogt (2002). However, the incompatibility of data sources remains a major issue.

4. The WATERMARK architecture

The selection of the implemented architecture was mainly driven by the business requirements mentioned in the introduction. In particular, the requirements for easily deployable and centrally maintained application naturally translated into the design of a web application. Additional requirements from a set of use cases (see below) that were identified in the course of the project mainly influenced the design of the user interface and backend components.

4.1 The user interface (client side of the application component)

WATERMARK business requirements have put severe limitations on the user interface of the WATERMARK client application. First, the requirement for "easy deployment on any client device" immediately disqualified all platform-dependent solution, limiting the viable technology choices to clients written in java, one of the interpreted languages and simple web-browser based solutions.

In addition, we interpreted the "easy deployment and maintenance" as "no user-side installation", which further limited the viable technology choices to "java web start" and web browser based clients. In the end, the java web start was also disqualified due to the fact that java may not be installed everywhere, and that the network configuration may not allow its deployment.

Based on these demands a web browser based interface was chosen. The thin client requirement didn't allow any applet based solutions so an AJAX-based component – map builder – was integrated to display map based data. This allows a certain degree of interactive work like choosing appropriate panes of the map, getting information about certain features (see the indicators use case), marking spots on the map (for the well-use case).

4.2 Server side

On the server side, several major components are visible to the client (see also):
- The application component, which is responsible for the user interface and the flow of control itself.
- WMS and WFS servers, that supply the client with map based data.
4.2.1 The application component

This component is the “glue” between all other parts of WATERMARK. It binds all components into an application, controls the user interface and allows the users to navigate through the application. The navigation is supported by several “wizards” that help the user to solve his problem. Due to the fact, that the user interface is a browser based UI the application is a web application. Its internal architecture is derived from a MVC architecture and is implemented using STRUTS.

4.2.2 WMS/WFS-Server

Depending on the format and availability of the map based material, one of the two map server – GEOSERVER (http://docs.codehaus.org/display/GEOS/Home), or MAPSERVER (http://mapserver.gis.umn.edu/) – is used to publish the data. They are also responsible to publish some static data like background maps. GEOSERVER is chosen wherever static material has to be published, esp. where one of the integrated data sources (see below) is involved. Map data that is derived from simulations (see below) is published via the map server as automation of the publishing process turned out to be much easier using this product.
4.2.3 The simulation manager and the model calculation

Some use cases need data derived from groundwater models. Running a typical simulation needs some 10 seconds up to several minutes depending on the problem, the spatial and temporal resolution and some more parameters. Therefore, calculating the results of a simulation synchronous with the web server requests was not feasible. We developed an additional service that is responsible for running the simulations in background.

The models were not developed in house. Instead, standard components were taken, namely GRASS GIS, MODFLOW and MODPATH. To some extent these modelling components have special demands to the environment they are running in disallowing their execution on one single machine. So it is the responsibility of the simulation manager to control and chain the execution on several different machines, to supply the parameters needed to run the model and to gather the results. Format conversion and other pre- and post processing is also done by the simulation manager. As ORCHESTRA proposals for the interface design were not available at that time, the simulation manager has a proprietary interface. We are considering transforming this to an ORCHESTRA compatible "simulation management service" in future.

4.2.4 Data source integration

It was early decided to use existing standards within WATERMARK. One emerging standard for the integration of geo referencing data is the OGC-WFS standard which we decided to use. One implementation of an WFS-server is given by the GEOSERVER implementation which is based on the GEOTOOLS library. GEOTOOLS allows – by the means of its plugin concept – an easy integration of new data sources, an ability also inherited by GEOSERVER. This framework was used as a base to integrate our own data sources.

4.2.4.1 SEMIKAT integration

One of the systems to be integrated into WATERMARK was the existing SEMIKAT database. SEMIKAT is a repository of data allowing to store data organized in a manifold of ways and to calculate several scenarios. SEMIKAT is already equipped with a powerful data import mechanism which allows importing many different formats like all MS-OFFICE, all JDBC and all ODBC accessible data bases. For the integration into WATERMARK SEMIKAT was enhanced with the ability to store geometry data together with other feature data. With this precondition it was possible to establish SEMIKAT as a data source for the GEOSERVER for all geo-referenced data stored in SEMIKAT. This opens up the WATERMARK access to a broad variety of imported or derived data.

4.2.4.2 UWEDAT Integration

UWEDAT is a system to manage temporal orientated data (time series). As there is no adequate way to map time series to OGC features, only selected times can be queried (the latest value in time, a value XXX minutes (hours, days, ...) before now, fixed times) can be queried. With this compromise UWEDAT is also available as a data source for the WATERMARK project. With this feature, WATERMARK has access to a wide pool of data gathered from long term measurement campaigns.
5. The WATERMARK use cases

Several use cases were developed for the purpose to drive and test the development of an application using the user-friendly WATERMARK technology. Those use cases that were really implemented are explained in the following.

5.1 Influence of wells on ground water level

One use case deals with placing new wells into an area. One can place a new well and simulate the influence of this well on the ground water level. Parameters are the location of the new well and its capacity. Other parameters control the temporal resolution of the model which allows giving some data about the ground water variation in time. Besides calculating models the user can also manage its models allowing the calculation of several variations and recall model results later. These use cases use MODFLOW to calculate the simulation.

![Fig. 3: Simulating the influence of new wells on the groundwater body](image)

5.2 Transport of pollutant entry to the groundwater body

It is possible to simulate the transport of a pollutant inserted into the groundwater body. Parameters are beside the location and the time of the entry the nature and abundance of the pollutant. Also taken into account are the meteorological conditions at the time of the incident. This use case uses MODFLOW together with MODPATH to calculate the simulation.
5.3 Water quality indicators

To allow a fast yet comprehensive assessment of water quality a system of indicators was developed. These indicators are organized in a hierarchical manner allowing a fast overview as well as detailed access to underlying base data. This indicator system can be reached through the user interface.

Fig. 5: Example of an indicator for water quality in a well. It shows the concentration of elements related to the allowed limits.

5.4 Future development:

Our work at developing the WATERMARK shows that developing the easy to deploy and use applications relevant for WFD is indeed feasible. However, a number of open issues remains to be solved:

- Currently (2006) available implementations of OGC software still lack stability and several features that enhance their usability as GIS components. For instance, Geoserver does not support automated publishing of data, and the specifications do not even foresee map details hiding depending on map scaling.
- In addition, OGC technology does not cover all aspects of communication needed for writing WATERMARK-like applications. In particular, some kind of extended WFS protocol allowing to
exchange non-geo referenced data would allow standardizing the communication between WATERMARK service components.
- The exchange of time series based measurement data is neither supported by geotools nor by Mapserver.
- Although a certain level of interoperability of the related components was achieved, certain aspects (like the inclusion of the model calculation) remain proprietary.

Some of the above mentioned issues are caused by immaturity of the currently available OGC technology implementations. Others are inherent to ISO 191xx standard, and may only be solved through further development of the standard itself. This kind of work is far beyond the scope of the WATERMARK project, but the lessons learned during the project have been incorporated in ORCHESTRA IP (http://www.eu-orchestra.org). ORCHESTRA architecture integrates the following aspects of the problem within a single concept:
- an organizational view that considers a cross-boundary information flow, i.e. across regional, national and organizational boundaries
- a process view that considers the life cycle of the information involved including the fact that information (source) systems will change over time
- a data view that integrates both geo-data, tabular and textual data, thematic documents and metadata
- a functional view that considers what generic and specific functions (services) are required on which level as well as their signatures and access methods across networks.

Main characteristics of these views are highlighted in Usländer (2005). Once developed, ORCHESTRA architecture shall be usable for variety of tasks in any environmental domain, and may form the IT basis for the second generation of the WFD services. It will also allow re-implementing the WATERMARK services using only the open standard-compliant interfaces.

Bibliography