HydrIS: An Open Source GIS Decision Support System for Groundwater Management (Morocco)

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Abstract  A regional groundwater management system has been elaborated, integrating Relational Database Management System (RDBMS) and various web services. It consists of web geospatial application so-called HydrIS (Hydrogeological Information System) based on Open Source components and technologies, leading to a feasible and low-cost solution. Therefore, HydrIS permits delivery of data from a number of heterogeneous sources to standards supported by the Open Geospatial Consortium (OGC). The protocols used for exchanging data are also derived from OGC standards, i.e., WMS (Web Mapping Service), WFS (Web Feature Service), and WCS (Web Coverage Service). Finally, a geoportal was developed, which consists of client-applications that communicate with different Web Services (WMS, WCS, and WFS) through HTTP-requests.

A prototype for web-based GIS application was designed using the deegree Framework to provide systematic interfaces and functions. This system was developed to demonstrate the value of making hydrogeological data more widely accessible through client/server architecture. This experience and knowledge already gained in this project will be a source for technology transfer and policy decisions. Otherwise, this will enable user groups to improve the management of their groundwater resources and contribute to enhanced decision support capabilities.

Keywords  Open Geospatial Consortium (OGC); deegree framework; database management; hydrogeology

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Introduction

Morocco is a semiarid country, with a significant increase in population. Combined to a sustained economic growth, enormous pressure is generated on the country scarce in water resources. Therefore, the management of water resources takes priority[1].

Fundamental research in engineering geology and hydrogeology cannot be performed adequately without appropriate management[2]. There is an increasing need for government agencies to work together to provide improved access, distribution, and viewing of data holdings. Advances in web-based mapping and data standards are progressively making this more possible.

Many Moroccan government agencies collect, analyze, and report on groundwater. However, only a restricted number of technicians and managers can access the data. On one hand, there are a lot of spatial hydrogeological data stored in different formats, and the data providers cannot find appropriate ways to redistribute them. On the other hand, the data users who need spatial hydrogeological data cannot fully use it,
while recollecting Hydrogeological data is labor intensive and cost expensive, causing redundant data construction\[^3\].

To solve these problems, the Open Geospatial Consortium (OGC) has introduced standards by publishing the specifications for GIS services. OGC has variety of contributors from different areas such as government agencies, private industry, and universities aimed at growing interoperability for technologies involving spatial information and location. Its mission is to promote the development and use of advanced open system standards and techniques in the area of geoprocessing and related information technologies delivering spatial interface specifications that are openly available for global use.

The WebGIS server was implemented with the deegree framework. Deegree is a Java framework offering the main components to build spatial data infrastructure\[^4\]. Its entire architecture is developed using the standards of the OGC. The software is protected by the Lesser General Public License GNU and founded by the GIS and Remote Sensing unit of the Department of Geography, University of Bonn\[^5\].

This paper is organized as follows. Section 1 presents an overview of the development of relational database to support the storage of groundwater data. In Section 2, we detail the proposed architecture of HydrIS (Hydrogeological Information System) application. This is followed by a short discussion about future development in Section 3. In Section 4, we present a short conclusion.

1 Database design

For the hydrogeological database, the Open Source (OS) software PostgreSQL was selected as Relational Database Management System (RDBMS). PostgreSQL is an object-relational DBMS, which provides data definition, data manipulation, and data control feature needed to manage large volumes of data\[^6\].

The focus of the database model is to represent groundwater system. As much of groundwater data is gathered from wells, it is important to establish classes for representing wells and borehole data. For representing wells and associated boreholes and how they relate with specific aquifers, the framework includes the Aquifer, Wells, StratLog, PumpingTest, GeoLine and GeoArea classes, and the HydroGeoUnit table.

Aquifer class is a polygon containing information class representing aquifer boundaries and zones within them, such as an outcrop or downdip area, which are commonly presented in aquifer maps\[^5\]. A well is an artificial excavation, for the purposes of withdrawing or monitoring subsurface water. This class contains further descriptive data for a single well (type, depth, and land surface elevation). The StartILog table is used to store information that describes the succession of aquifer layers penetrated by wells\[^6\]. Data containing the descriptive attributes (i.e., texture, age, and fabric composition) are in the HydroGeoUnit table. Information about hydrogeological tests is stored in the table PumpingTest (information related to quantitative tests made in a well). GeoLine is a line feature class representing faults. The geological area is represented by GeoArea class\[^7\].

Relationships established in the database model represent the logical connectivity between these features and are implemented in a relational database by using primary and foreign keys. In relationships, the primary key of one table is linked with its equivalent, known as the foreign key, in a second table. The overall structure of the relationships in this RDBMS is illustrated in Fig. 1.

2 Web application system

The WebGIS server was implemented with the deegree framework. As an application server, it provides Web Services for groundwater potentiality information, geology, topography, and hydrology.

The Open Source WMS of the University of Bonn, which is compliant with the standards of the OGC, allows maps to be constructed and viewed (JPG, PNG, and SVG), selected features to be queried via the Web Feature Server (WFS) and raster data to be accessed via a Web Coverage Server (WCS) (Fig. 2). For flexible data access, the deegree WMS does not implement specific classes for accessing data but offers access to data source as LOCALWFS or LOCALWCS. One WFS or WCS can be registered as a data source to the WMS. This does not necessarily mean that an
actual Web Service has to be accessed but that data source acts like WFS or WCS\cite{4}. Deegree WFS will talk to the PostgreSQL database server through Java Database Connectivity (JDBC), perform the transaction, and send the response to the client in HTML format (Fig. 3).

The last is the geoportal that consists of client applications that communicate with the different Web Services (WMS, WCS, and WFS) through HTTP-requests. The geoportal was realized by using the Java Struts-Framework, which is based on Java Server Pages (JSP) and Java running in a Jakarta-Tomcat Servlet Container\cite{7}.

The map viewer supports all necessary functions of a GIS map viewer, such as changing the visible extent of the map, map navigation, spatial query, map legend, saving map context, and performing an identify operation on the selected map layer. After identifying a map feature, a dialog shows some attributes of the selected feature on the map (ID, Type, XY, …), and the user can explore a PostgreSQL database developed in this project (Figs. 4 and Fig. 5). For Hydrogeologi-
cal point data, the user is able to select single points and is offered a link to download the detailed set of hydrogeological data such as general information about boreholes, stratigraphic logs, and some hydrogeological parameters (transmissivity and permeability).

![Fig. 3 Connection between WFS and PostgreSQL database using JDBC technology](image)

3 Future development

The system can provide a platform for developing Spatial Data Infrastructures (SDI) through collective participation and also serve as a means for standardizing data collection.

We plan to implement Web Catalogue Services (CSW) and Web Processing Services (WPS). They should be implemented according to the OGC specification.

The OpenGIS Web Catalogue Services will support the ability to publish and search the collections of descriptive information (metadata) for data, services, and related information objects. Metadata in catalogues represent resource characteristics that can be queried and presented for evaluation and further processed by both humans and software. Catalogue services are required to support the discovery of registered information resources within a collaborating community.

The WPS will give the possibility to integrate some Hydrogeological model (i.e., ModFlow, ...). WPS can describe any calculation including all of its inputs and outputs and trigger its execution as a Web Service.
4 Conclusion

In this project, a WebGIS application entitled “Hydrogeological Information System (HydrIS)” was implemented by using an open source development environment. This work is divided into three major parts. First, a RDM was established by using PostgreSQL database that allows display of spatial data as well as queries on relational data and spatial data via the Internet. The second step was the implementation of different Web Services (WMS, WFS and WCS) and the elaboration of geoportal in order to make hydrogeological data more widely accessible through client/server architecture. The last step was to communicate PostgreSQL with different services by using Java Database Connectivity (JDBC).

By integrating OSS package deegree and PostgreSQL, the prototype system enables users to access spatial Hydrogeological information that comes from different data servers via a standard Web browser and promote groundwater data sharing and interoperable capability.

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