

Using ArcGIS Engine to provide medical decision makers accurate data

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Abstract

This contribution shows the usage of ArcGIS Engine for computer based spatial decision support in the field of water quality. For a developed Spatial Decision Support System (SDSS), more than 2,000 wells were digitized in the area of the upper Ouémé catchment in Benin (West Africa) and included in a comprehensive geo-database. Latter contains multi temporal water quality data, digital photographs, addresses in case of an emergency, etc. This paper shows the preliminary development results of this SDSS, which provides the users developed Graphical User Interfaces and therefore the opportunity to (i) select specific wells out of the geoDB based on a chosen location, (ii) to visualize the data in a developed map panel (based on JAVA and ArcGIS Engine) and finally (iii) to save the selection in a vector file. The presented SDSS as well as other systems are developed within the interdisciplinary research project IMPETUS (www.impetus.uni-koeln.de).

Introduction

Spatial Decision Support Systems (SDSS) contain functionalities of Geographical Information Systems (GIS) and Remote Sensing (RS). Additionally, they have interfaces available to access and run scientific models, and they use expert knowledge as well as logical decision trees to generate their results (Keenan, 2006, Malczewski, 2006, Laudien and Bareth, 2007). These SDSSs can be used as comprehensive computer based decision support tools for numerous problems in environmental research and management.

The work described in this paper is carried out within the interdisciplinary research project IMPETUS (An integrated approach to the efficient management of scarce water resources in West Africa) (Speth *et al.*, 2005). One major task in the third project phase (2006-2009) is the development, implementation and application of such SDSSs for water resource management in two selected catchments in Benin and Morocco (both West Africa). The SDSSs of IMPETUS are implemented in a Java/XML based software framework (Enders *et al.*, 2007) by using ArcGIS Engine and other libraries. One problem cluster of IMPETUS, which is defined as a meta-problem which requires a multi-disciplinary analysis in order to allow drawing conclusions with respect to possible future developments (Speth *et al.*, 2005), provides information about the situation of drinking water supply and -quality in the communes belonging to the upper Ouémé catchment. Inadequate access to safe drinking water supply is one of the most pressing issues in the rural upper Ouémé basin in central Benin. Wells, both modern and traditional, account for 90% of all water sources in the region and thus provide the most commonly utilised form of disposable water supply. In contrast, boreholes equipped with closed pump systems, which deliver bacteriological harmless water, make up only 6% of the registered water sources (Mazou *et al.* 2008). Inadequate water hygiene and a lack of basic sanitation cause a risk of infection with waterborne diseases for consumers of contaminated water. To provide the stakeholders in Benin information in a user friendly way, a SDSS named SIQeau ("Système d'Information Qualité de l'eau") was developed in terms of a computer based interactive system. By using SIQeau the user has several options: (i) Inform him/herself about all aspects of drinking water quality and factors that may cause hazardous situations; (ii) observe the situation of drinking water supply and the results of bacteriological, viral and chemical water analysis in a certain village or area; (iii) use the database as a monitoring tool; (iv) inform him/herself about options for action to ameliorate the situation of drinking water in a certain area; and (v) get information about first aid steps and contact data of responsible persons in case of an epidemic of water-borne infectious diseases.

SIQeau is based on an IMPETUS dataset containing GPS-data, photos, descriptions of the surroundings and information about the construction all drinking water supplies of the area of investigation between the cities Parakou, Djougou and Bassila. In 2001 data of almost 1,300 water sources have been registered. Since the situation of water supply changed continuously due to drying-out of old wells and construction of new wells and pumps, the database has been updated during field campaigns in 2005 and 2008. Actually information of almost 1,900 water sources have been included in the database of water sources. In SIQeau these data have been combined with data collected by the national services in charge of water to cover a zone of seven communes (Bassila, Copargo, Djougou, Dali, Parakou, Ouaké and Tchaourou) in the centre of Benin as complete as possible. Finally information about a total of 3,748 water supplies are stored in SIQeau (as of May 2009). Whereas the data from the national services in charge of water are particularly limited to the geographical coordinates, the historical aspects and the modes of hydrant of each water point, those collected by IMPETUS project insert the results of the water analysis.

To address the frequency and pattern of viral, bacteriological and chemical contamination, samples from drinking water sources in the upper Ouémé catchment were taken during the dry and wet season. These water samples were analysed for the presence of adenoviruses as indicator for viral/faecal contamination and rotaviruses as important pathogen in developing countries of severe diarrhoea especially in small children. *Escherichia coli* and *Salmonella enterica* were isolated as important bacterial indicators for faecal contamination of drinking water and in order to estimate the risk of infection for water consumers. Chemical parameters like Nitrate, Nitrite, Phosphate and Ammonium have also been analysed. In order to assess risk factors for contamination of drinking water, latrines were geo-referenced and included in the database of drinking water sources additionally.

Material and Methods

The object oriented programming language Java was used to develop the SDSS. By using Java, the source code is translated into byte code and then executed in a special environment, the so called Java Runtime Environment (JRE). The major part of the JRE is the Java Virtual Machine (Java-VM) which interprets and executes the byte code. By the existence of a Java-VM, the major advantage of programming with Java consists in the fact that all developments run on different computers and different operating systems. Therefore, software which is developed with Java is nearly platform independent (Herter and Koos, 2006).

To fulfil the given requests of guaranteeing GIS- and RS-functionalities within the SDSS SIQeau, the ESRI® developer library ArcGIS Engine 9.2 was used to complete the Java source code. With ArcGIS Engine the software developer gets the opportunity to implement spatial analysis functions. The full version of ArcGIS Engine which is accessible by C++, VB.NET, C#, or Java comes with several different extensions which can be integrated based on the user needs. In detail these are: *Spatial extension*, *3D extension*, *Geodatabase Update extension*, *Network extension*, *Data Interoperability*, *Schematics Maplex* and *Tracking* (Minami, 2000).

The SDSS is developed by using the programming environment Eclipse SDK which contains the Eclipse platform (Eclipse 3.2), tools for Java programming and the environment to develop Eclipse plug-ins. In addition to that, Subclipse is used to backup the source code. Subclipse is an Eclipse plug-in that gives the opportunity to connect to a Subversion Repository (SVN). Subversion is a source code repository, which allows several software developers to work on the same project independently without causing backup or versioning errors. To execute SIQeau on the client computer, the JRE and the ArcGIS Engine Runtime Environment need to be installed.

The (geo-) data (e. g. rasters, vectors, and alphanumeric data) of SIQeau are stored in an ArcGIS file-based geo-database. Compared to previous geo-databases available with ArcGIS, such as the personal geo-database (ArcGIS Version 9.1), these file-based geo-databases are platform-independent and

compressible when used in a read-only context, e. g. when deploying an SDSS to the user who does not write any data to the geo-database. Furthermore, they show a much higher performance when large amounts of data are involved, and these databases are almost not inherent in size limit (the limit is that of the file-system itself). These geo-databases interact directly with the operating system's file-system. This results in the absent size limit. The large performance boost with large geo-databases results from the poor performance MS Access-based personal geo-databases have once a certain size is reached (ESRI, 2008). SIQeau is based on the collected water supply data (see also chapter Introduction). Data of more than 3,700 wells are stored in a point feature class which includes numerous attributes like type of the well, depth, position, etc. In addition to that geo-referenced photos show the user how the well looks in reality. Besides the wells feature class, bacteriological, viral and chemical water analysis data is stored wells specific.

Results

Figure 1 shows the IMPETUS Client in terms of a screenshot. Besides others, it also contains the SDSS SIQeau. Screenshot 1a illustrates the start screen of this Spatial Decision Support System containing the title, a short description and other brief information. By clicking on the Go-button, SIQeau connects itself to the wells geo-database and provides the user the opportunity to (i) select a spatial distribution in terms of an administrative area, (ii) choose certain parameters out of the database, and (iii) adjust certain parameters based on his/her requirements (see fig.1b and 1c). The selection as well as the adjustment is done by developed SIQeau processors which are part of the IMPETUS framework (Enders *et al.*, 2007).

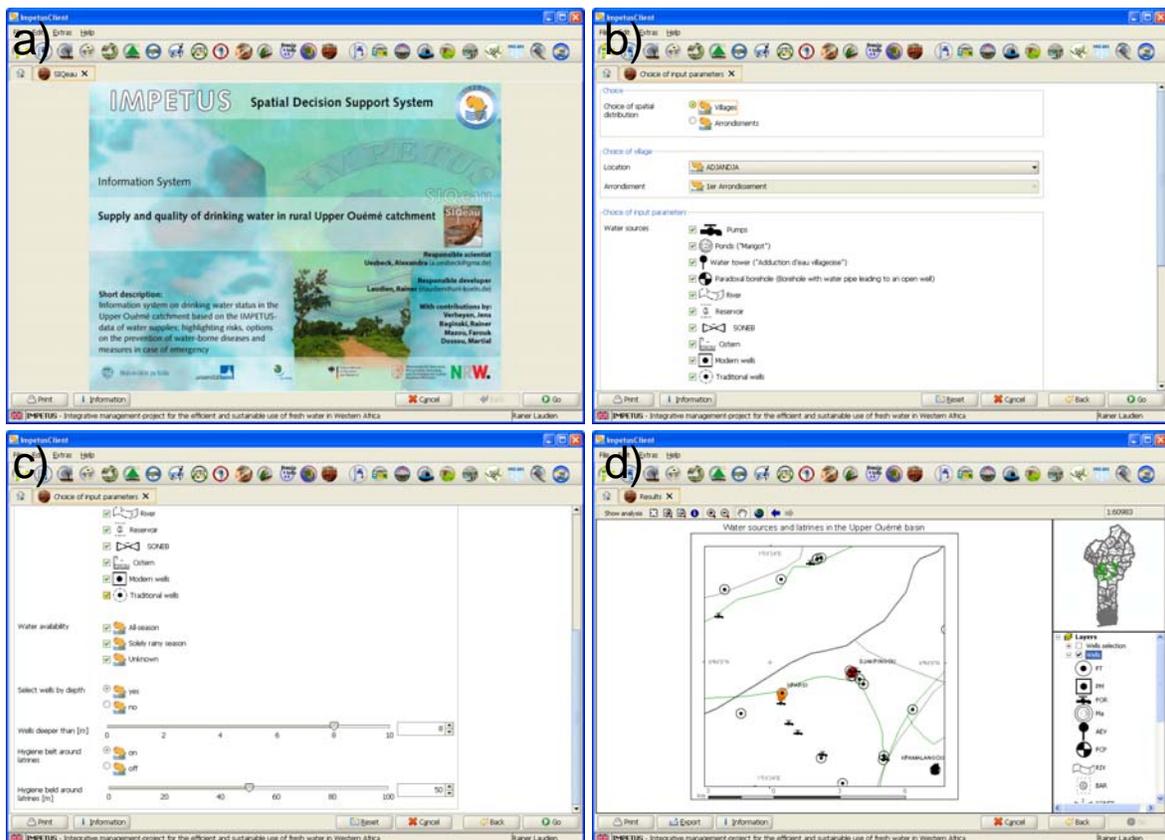


Figure 1: The preliminary results of SIQeau: a) Startscreen, b) upper area of parameter panel, c) lower area of parameter panel, d) result panel.

The processed result of this procedure is shown in screenshot 1d: an implemented self developed ArcGISMapPanel, containing a major map bean, an overview map bean, a toolbar, and a toc bean, displays the result. In this case, it shows the selection based on the given user settings. Within this ArcGISMapPanel, the type of the water supply is classified and shown as individual symbols.

Hence, SIQeau provides fast and well processed data out of the comprehensive database of drinking water supplies based on the user's needs and demands. SIQeau uses a selected location as an input for the query. By following this approach, SIQeau only displays the location based SQL-result and therefore shows a high-performance by clipping that data out of the comprehensive geo-database. Fig. 1d also shows the implemented GIS tools, which guarantee the user to visualise the attribute data of the selected water supplies.

Besides the common GIS tools like *Info*, *Zoom in and out*, *Full extent*, etc., a SIQeau specific tool was developed and implemented which provides the user multi-temporal water quality analysis data from a selected well. This functionality is hidden behind the toggle button *Show analysis* (fig 1d and 2). By enabling this button and by clicking at one water supply symbol, SIQeau executes a one to many database relationship processor which provides all the implemented analysis data of that specific well. The result of this procedure is visualised within an information panel showing the analysis data and all its parameters (see fig. 2).

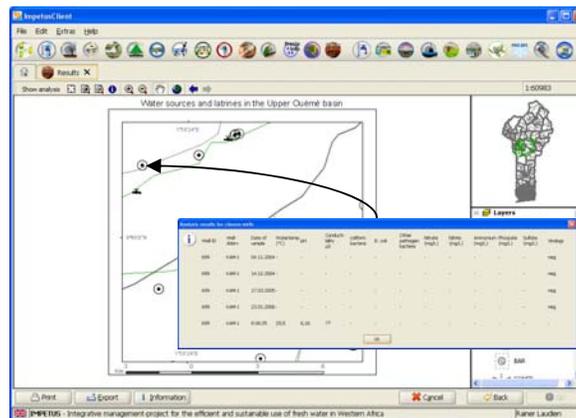


Figure 2: The developed analysis tool showing one to many database relationships.

Besides the quick visualisation of the data and the implemented GIS functionality, export functionality is also integrated which provides the user the opportunity to save his/her location based selection in a shape file (see Export button on the lower left corner of the screenshots).

Conclusion

The usage of Java and ArcGIS Engine as well as the followed development approach show major advantages in terms of handling and visualising large amount of spatial data. By the implementation of SQL-processors, visualisation functionalities, and specific GIS tools, the user is able to navigate through the comprehensive geo-database, select and visualise user defined data, and export these database subsets in terms of shape files.

Medical and communal decision makers in Benin did show a significant interest on SIQeau, particularly with regard to biological contamination issues of drinking water. Since the decentralisation in 2002, the Republic of Benin is subdivided into 12 Departments which are on their part subdivided into 77 communes in total. The commune constitutes the autonomous administrative unit and it is responsible for planning and local development. The management of water infrastructure is gradually transferred to the communes

without having a data base on the drinking water. The conducted presentations and talks with potential SIQeau users approved that the chosen development approach represents the topic sufficiently. In addition to that, the training and education meetings illustrated application fields (e.g. science, national administration, or public body), in which SIQeau could be used to support management and risk strategies. In general, the conducted sessions demonstrated that SDSSs in general provide additional helpful tools for decision making processes.

Information about the availability of drinking water sources and water quality in specific regions *of the analysed* can be used to decrease the lack of drinking water according the need of intervention. Moreover, SIQeau may provide important information to improve water quality in this area without general water supply.

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