SPIDER - An Open GIS application use case for irrigation water management

Juan Manuel Moreno-Rivera*, Anna Osann*, Alfonso Calera*, Javier Sánchez*
*Group of Earth Observation and GIS (IDR), Universidad de Castilla-La Mancha, E-02071 Albacete, Spain
E-mail: JuanManuel.Moreno@uclm.es

ABSTRACT

PLEIADeS (Participatory multi-Level EO-assisted tools for Irrigation water management and Agricultural Decision-Support) is a research and technological development project co-funded by the European Commission's Sixth Framework Program. It addresses the efficient and sustainable use of water for food production in water-scarce environments. It aims to improve the performance of irrigation schemes through a range of measures. It revolves around the open GIS online spatial analysis and visualization system SPIDER, which is being used and evaluated in various scenarios with actual users.

This **S**ystem of **P**articipatory **I**nformation, **D**ecision support and **E**xpert knowledge for irrigation **R**iver basin water management (SPIDER) is based on three pillars: First, the potential of Earth Observation (EO) technologies for irrigation advisory and water management from farm to river-basin scale. Second, SPIDER explores further the concept not only of GIS, but of Participatory GIS (PGIS) and offers the main core functionalities of a GIS based on Web technologies (Web 2.0) applied to the irrigation water management domain. Third, these tools are applied in synergy with advanced participatory methodology to achieve a maximum of active participation and transparence in irrigation water management and governance. To support specific domain functions, specific tools are defined that offer users the opportunity to explore data from different sources, comparing them with similar data in the same zone and time or even similar data from other zones or dates. It offers in a dynamic interactive graphics interface the temporal evolution of crops based on images or linked tables, zonal statistics linked to the GIS and combination of all the SPIDER data with other data from OGC standards services from other servers or institutions. This is done by using Open GIS technologies available like viewers (Flamingo) and libraries (GDAL/OGR), as well as charts (Open Flash Chart) for exploiting information in a visual and easily understandable way, combining the AJAX family technologies in the web client.

As a modular software, other models data can be integrated to its data repository easily and implementing a module for those models to be integrated directly in SPIDER is straightforward. SPIDER serves also as a valuable tool in research and academic teaching, in order to introduce students in a very practical way to an implemented tool for crop monitoring, checking field data, and studying crop evolution, water efficiency and EO technologies concepts.

This paper will introduce the audience in what SPIDER is and how it works. We explain SPIDER, introduce its main ideas and the users who can benefit from it. Then we show some more detail about SPIDER design and its technology. We also explain the interaction with OGC standards in more detailed. Then software used to calculate zonal statistics (OVeRSATS, a desktop Overlaying software based in GDAL/OGR) will be introduced, explaining its benefits compared with other software. Application use cases from a range of different countries around the Mediterranean and in the Americas will be shown to illustrate each point.

1. Introduction

SPIDER has evolved from the on-line Space-Assisted Irrigation Advisory Service (e-SAIAS®) prototype developed in the project DEMETER (DEMETER 2005). Based on the potential of EO technologies applied to the typical functions of Irrigation Advisory Service (IAS) (A. Calera et al. 2005) the DEMETER prototype is a tool that builds on the water-saving potential of traditional IAS and extends their capacity vastly by means of new Technologies such as EO, GIS and Information and Communication Technologies (ICT). E-SAIAS offers a user-driven toolkit for monitoring the evolution of crops and water use in large areas. It is based in a client-server architecture where the IAS technicians load the data into the server (from Data Providers or Stations) and the users, IAS Technicians or farmers directly, can access the information and make decisions based on the analysis and information provided by the system by means of charts, maps, data tables and reports.

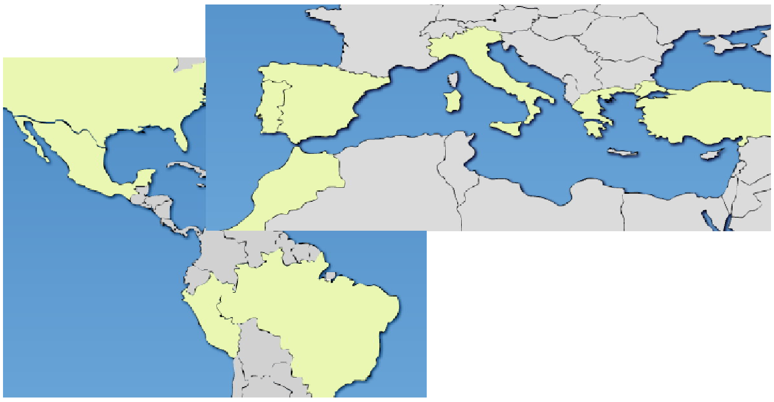

Figure 1. PLEIADeS pilot zones countries

PLEIADeS (PLEIADeS 2007) goes beyond in order to develop a multi-language and multi-spatial reference systems toolkit for supporting all the requirements from the wide variety of PLEIADeS project groups (see Figure 1). Those groups are from different countries, with different problems and spatial reference systems, different satellite resources, different user hierarchy, etc. In that environment it is necessary to offer a toolkit that allows technicians, farmers and managers in all levels interchange information and data about crop and water efficiency. Therefore a system for supporting different spatial reference systems for distributed data from different groups is necessary. The project PLEIADeS focuses on the Water Management level as the most important one, offering a toolkit to evaluate many different social, economical and environmental parameters for supporting decision about water management.

Other projects have also developed toolkits providing decision support models for water management. Hidrogest (P. Mateus et al. 2005) is an irrigation projects management tool that integrates different models for different purposes with an ARCGIS plug-in for visualisation. GISAREG (P.S. Fortes et al. 2004) is a GIS-based application to support implementation of improved farm irrigation management in the Aral Sea basin. WEBISAREG (R. Branco et al. 2005) has moved to the Web-based technologies offering a distributed interface through the web to use the model defined in GISAREG but without visualisation or typical GIS functions. GeoDOVE (G. Hobona, 2005) is Web-based software that offers an interface to show and query data from a GIS throw the web with the basic GIS functionality.

2. SPIDER concept

SPIDER is a Web-based GIS (S. Dragicevic, 2004) that doesn't need to install any software in the client PCs. The SPIDER concept is based on the new Web 2.0 concept, where the web itself has become the platform and a participatory component has appeared (T. O'Reilly, 2005) increasing widely the potential of web applications. Dynamic webs based in Asynchronous JavaScript And XML (AJAX) is a new approach to develop web applications (J. J. Garrett, 2005) and it has given developers the opportunity of implementing complex but easy to use interfaces for almost all possible domains.

SPIDER has been developed based on those new technologies as a centralized data server where different users can upload different kind of layers (vector, raster, alphanumerical, etc) and work together with them in a participatory and collaborative environment, as a support for the academic and research groups, as well as for the different stakeholder levels implicated on the water management issue. One of the basic pillars of this software is the use of EO technologies to cover large areas with a few images, and supporting different resolution satellites provides a high potential toolkit for the different levels of water management (river basin, governmental and irrigation level stakeholders). As demonstrated in DEMETER, the temporal evolution of crops obtained by EO data is the key Decision Support System (DSS) toolkit for irrigation water management, especially at farm and irrigation scheme level

Figure 2 SPIDER interactive chart

The temporal evolution is visualized in interactive charts that also allow accumulation along the time axis. This kind of layers consist of a dynamic mosaic of images with a spatial and a temporal component, covering different areas on different dates, making available the temporal raster-based analysis of data. The data is analyzed through interactive time-series charts that allow the users to define a range of dates and to accumulate the point values along time. Probably one of the most innovative toolkit is this new version of interactive time evolution charts. Those charts allow accumulating values in the chart dynamically from one point to another by dragging the mouse over the chart (see Figure 2) and comparing different temporal evolutions from different points from the map being possible to compare different crop types or the same crop in different regions (e.g. the two arid regions from Mexico and Morocco share climate characteristics and compare the results in each pilot area with the other). The grid size for the calculation is defined by the user in the interface and the result is the average value of all the pixels in the grid. This way the error due to EO sensor resolution is reduced and each image has its corresponding point in chart.

The architecture of SPIDER (see next section) has allowed to develop two web clients for SPIDER. One for administrative purpose with multi-window interface that offers to an advanced user the possibility of displaying multiple maps, multiple charts or tables. It has also the administrative interface that allows the administrator to define new groups and users, and to decide which layers can be accessed by which groups and/or users. The other version of the client interface (see Figure 3) is a more attractive interface for a advanced exploitation of information, providing a very easy-to-use toolkit to a generic user without any need of high-level knowledge about SPIDER technology, combining the interactive charts information with maps, tables and the creation of reports to help users in the process of making decisions. SPIDER has got some GIS-Dominant toolkits to implement Spatial On-Line Analytical Processing (SOLAP; S. Rivest et al. 2005) functionality, enabling more dynamic interaction with users when analyzing data.

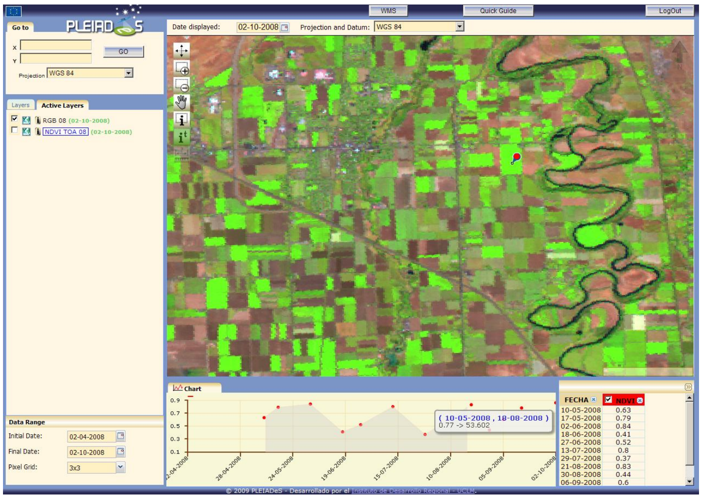

Figure 3. Spider Default Viewer

The two most important ways SPIDER helps users can be resumed as: 1) in the river basin level, the system offers a wide land coverage visualization and data exploiting tool for monitoring historical changes based on the land cover use maps and EO data, as well as for planning water distribution plans for following campaigns; 2) in the irrigation level as a real-time process, farmers can follow the evolution of their different crops knowing in each moment the amount of water it needs and detecting problems in irrigation systems, crop diseases, etc. The system is operational in three configurations, as a local server (for example in Peru, Mexico, Portugal or Morocco), as a global system (through http://www.pleiades.es users can access Global SPIDER with data from the 10 pilot areas) and as a "portable server", implemented on a standalone PC for demonstration mode for use anywhere.

3. SPIDER Design

The users interact with the system through a web interface. This user interface is the first level of the tree-tier architecture, the presentation tier, and connects with the Service Interface, the logic tier, to obtain data from server. The presentation tier has been developed using a combination of HTML, JavaScript and Flash languages to implement the dynamic web-clients. The server side has been implemented using PHP and C++ languages, PHP for implementing services and C++ for the heavy process to improve performance. The Database (DB) forms the third layer of the architecture. The architecture of the system is a typical 3-Tier design as shown in Figure 4.

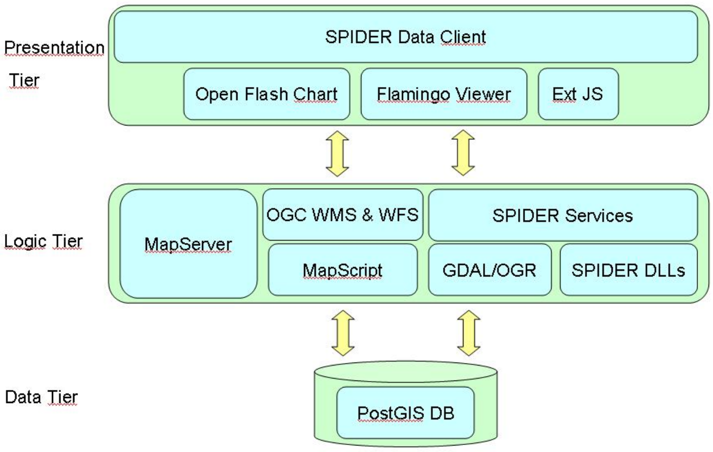

Figure 4. SPIDER Architecture

This is the most commonly used architecture for those kinds of Web-Based applications and is the ideal solution for such a system like SPIDER. Basically each module in the server side has an equivalent on the client side that accesses the logic tier interface throw web services. SPIDER, as a system based on web services, can evolve dynamically by defining different interfaces for each device available in each pilot area, adapting to local requirements, as can be done, for example, with mobile devices. This modular structure also makes the system more adaptable to future technology evolution, being able to change the client without having to change the server, or changing a SPIDER module without having to change the whole SPIDER server side or the database.

As shown in figure 4, the Open GIS software is the core supporting technologies in each tier of the SPIDER design. This is due to the Open GIS technologies potential and how this family of software offers different solutions for real problems in research and enterprise environments and a continuous support thanks to Open GIS community. Bellow are introduce how each Open GIS technology interacts with the system:

1. Presentation Tie: The web interface of SPIDER has got an attractive looking thanks to Ext JS support as well as Flamingo, which is a very user-friendly map viewer based on flash. Then Open Flash Chart supports the char and multi-chart temporal evolution and its aggregation in client side, given one of the most interesting toolkits from SPIDER for analyzing data.
2. Logic Tier: The core technology of this tier is MapServer and its API for PHP and the Web Map Service (WMS) wrapper functionality very usefull for implementing OGC standards support and other personalized functionalities. Then GDAL/OGR offer SPIDER the driver to manage different spatial data sources (raster and vector).
3. Data Tier: here PostGIS is the layer itself and is accessed through the data interface in SPIDER for querying data and alphanumerical data.

As mentioned before SPIDER moves towards OGC standards (OGC Consortium) compliance and as a WMS client you can integrate the information in SPIDER with the one offered by public or private Institutions throw the WMS. Those services are widely used in the network as Web Feature Service (WFS) or Web Coverage Service (WCS) and others like Web Processing Service (WPS) have just started being used. So, the use of those standards allow the system incorporating information available on the web, increasing the data the user can access throw the system. This path towards distributed data through OGC standards is supported by the increasing number of data servers available due to some institutional initiatives like the INSPIRE European Commission Directive (INSPIRE, 2007). More than that, due to the SPIDER dynamical map files generation, it is prepared to work as a WMS and WFS server with very little effort with the MapServer support. Due to this, SPIDER, apart from using OGC standards, gives a pass towards defining architecture for supporting INSPIRE philosophy, offering a core Web-GIS software that can work as a Spatial Data Infrastructure (SDI) (Global Spatial Data Infrastructure, 2004).

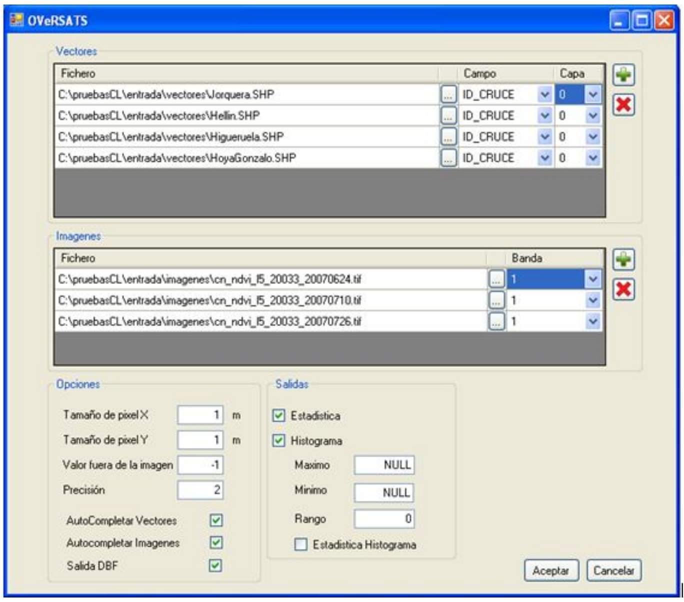

Figure 5. OVeRSATS screen shot

4. OVeRSATS

The **O**verlay **Ve**ctor-**R**aster for **S**patial **A**ggregation: **T**abulate areas and **S**tatistics (OVeRSATS) is GPL licensed software developed in C based on GDAL/OGR and SPIDER also includes a server-side alpha version of this algorithm. It was born from the needs of solving the typical GIS commercial software lacks that we were suffering in our research group and is part of the software family available to provide data input for SPIDER. Comparing it with other software as ARCMAP or ERDAS it gets a similar precision with a better performance thanks to the configurable parameters of its algorithm. It also offers a complete list of statistics that other software didn't offered and a batch mode that allows user configuring different raster and/or vector layers to be used during operations. Its algorithm is based on two bases, 1) the correlation between the true area of a polygon and the one represented by the image, and 2) virtual pixels which size can be configured by user and test lines used to detect which portions of pixels from the raster layer are inside the polygon. It doesn't count pixels directly, neither virtual ones, we consider portion of virtual pixels which improve accuracy.

5. Summary and conclusions

The SPIDER version 1.0 Beta is an attractive and dynamic application of Web-GIS software that the project groups has already started using, and that is ideal to control and manage wide regions of land taking decisions about water management based in the knowledge this DSS offers, combining all the data providers, SPIDER and others, into one toolkit without having to install any additional software apart from the web browser and giving a lot of visual and easy to understand information, just with a few clicks of the mouse. Technicians can check field data with satellite information and making field work more robust expending little time and covering huge land coverage earning time and efforts. The centralize data offers managers, technicians and farmers the fastest way to access and distribute information in all levels, which is being demanded by public administrations as a way of supporting management transparency, without duplicating data and having available always the last version of data when updated by data providers without requiring any action from other users. Apart from having a great potential as DSS and PGIS, it is also very important its potential to introduce students into the EO and GIS world, being a powerful toolkit for learning as well as researching.

6. Acknowledgments

PLEIADeS is being co-financed by the Sixth Framework Programme of the European Community (Priority 6: Sustainable Development, Global Change and Ecosystems, Contract GOCE 037095).

7. References

Branco, R.P., Teodoro, P.R. & Pereira, L.S., 2005. WEBISAREG - Web Based Decision System Support for Irrigation Management. In *EFITA-WCCA*. Vila Real, Portugal.

Calera, A. et al., 2005. Irrigation management from space: Towards user-friendly products. *Irrigation and Drainage Systems*, 19(3), 337-353.

Dragicevic, S., 2004. The potential of Web-based GIS. *Journal of Geographical Systems*, 6(2), 79-81.

DEMETER, 2005. DEMETER. Available at: http://demeter-ec.net/ [Accessed May 11th, 2009].

Fortes, P., Platonov, A. & Pereira, L., 2005. GISAREG--A GIS based irrigation scheduling simulation model to support improved water use. *Agricultural Water Management*, 77(1-3), 159-179.

Garrett, J.J., 2005. AJAX: a new approach to web applications. Available at: http://www.adaptivepath.com/ideas/essays/archives/000385.php [Accessed May 25th, 2009].

Hobona, G., Fairbairn, D. & James, P., 2005. AN RDBMS-SUPPORTED, WEB-BASED, 3D GIS, VISUALISATION AND ANALYSIS TOOL. In *IEEE ICC*. Seoul, Korea.

Mateus, P., Correia, L. & Pereira, L.S., 2007. HIDROGEST, a GIS framework for integration of decision support tools for improved water use and participatory management in pressurized on-demand irrigation systems. *Water saving in Mediterranean agriculture and future research needs*, 1(56), 303-317.

OGC Consortium, OpenGIS® Standards and Specifications | OGC®. Available at: http://www.opengeospatial.org/standards [Accessed May 25th, 2009].

O'Reilly, T., 2005. What Is Web 2.0 | O'Reilly Media. *What Is Web 2.0: Design Patterns and Business Models for the Next Generation of Software*. Available at: http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html [Accessed April 28th, 2009].

PLEIADeS , 2007. Available at: http://www.pleiades.es/ [Accessed May 11th, 2009].

Rambaldi, G. et al., 2004. Participatory GIS. Available at: http://www.iapad.org/participatory_gis.htm [Accessed May 25th, 2009].

Rivest, S. et al., 2005. SOLAP technology: Merging business intelligence with geospatial technology for interactive spatio-temporal exploration and analysis of data. *ISPRS Journal of Photogrammetry and Remote Sensing*, 60(1), 17-33.