Development of distributed geographic information catalog services, oriented toward the web and based on open standards: Effective steps toward a National Geographic Information Infrastructure
TIC-2000-1568-C01, 02,03

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Abstract

This work describes a three-year collaborative project to create the technology underpinnings of a Spain National Spatial Data Infrastructure, its objectives, the work currently in progress and the strategy defined for transferring results to the entities which will collaborate with it. This project began at the end of year 2.000 and it is being developed by researches from three Spanish Universities (Polytechnic University of Madrid, University Jaume I and University of Zaragoza). The main objectives of this project include the demonstration of the benefits for geographic data providers and customers in having access to services created around the concept of a national SDI. This will be done by creating the basic technology for a set of services specified using OpenGIS Consortium standards as starting point. These services will be tested during 2.002 in a pilot project which includes three nodes (one in each University) offering the basic functionality. This functionality will be developed around a geographic catalog. During this pilot project, efforts for capturing metadata and geographic data will be focused, contrasted and tested by the providers of a restricted set of users (providers and customers) who has the task of testing the initial prototypes and operational versions trying to identify problems and malfunctions and to find new functionality to be incorporated. It is very important to create a set of metadata enough for testing search services with valid results. This pilot project will be used, as well, as a tool to convince public entities about the technological, social and economical viability of a national SDI.

Keywords: OpenGIS, CORBA, Java, Catalogs, Catalog Services, Metadata, Geographic Information, GIS, Internet, Map Servers, Interoperability, Distributed Objects, National Geographic Information Infrastructure, Open Standards, Data Bases, Data discovery/recovery, Natural language

1 Project objectives

The main objective of this project is to leverage recently developed geographic information processing standards and technologies, as well as developments in web services and related fields within the wider Internet community, to create and demonstrate the viability of software components which can contribute to a nascent Spatial (Geographic) Data Infrastructure in Spain. Key among these components is a spatial data catalog service, which allows data providers –

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traditionally from the private sector—to both organize and publish their spatial data holdings. This goal of helping "unlock Public Sector Information" coincides with the title of a recently published E.U. Green Paper (DG-INFSOC), and thus with the desires of the EU. Organization of data holdings under the SDI concept helps data providers reduce duplicated data creation and processing, while controlled publication of key reference data allows them to better serve users, from partner organizations (i.e. Ministry to Ministry) to the general public, as well as give a boost to the economy[1]. Currently individual institutions implement taylor-made information systems which may serve their internal needs, but certainly have not be designed with network-based data sharing and maintenance in mind. Recent SDI standards, both technical and political (rules and guidelines for best practice), allow for both internal optimization and external interoperability of these information systems. This project exercises (implements) several of the technical standards underpinning the SDI concept, and is producing demonstrations which can serve (and have served) politicians in Spain who are contemplating the construction of a Spatial Data Infrastructure in Spain, following those already created in the USA, Australia and several European nations such as Netherlands, UK and Finland. In the process, a long list of collaborators, from the students and researchers at the 3 collaborating universities, to government officials and private companies are gaining valuable pratctical competence in the new technologies (and policy decisions) involved in making SDI a reality.

In this project the following concrete subobjectives have been proposed and are being implemented:

- Subobjective 1: **Technology Watch** activities, following the progress of standards activies in several related fields, especially with regard to the 3 main technology components of an SDI: metadata creation and maintenance; catalog services; and web map services. The fact that members of the research team are intimately involved in many of these standardization efforts allows for early and priveledged access to draft documents, providing an advantage over the general public which would normally only learn of interesting developments *a posteriori*. This allows the research group to work proactively.

- Subobjective 2: **Implement components** for metadata creation and publication, using on-line catalog services.
    - To maximize interoperability the metadata model proposed by ISO/TC211 (Technical Committee on Geographic Information), also adopted as version 4.0 of the OpenGIS Abstract Specification volume 11, is being supported. This model has been the result of a fusion of metadata models from the USA (Federal Geographic Data Committee), Europe (CEN) and Australasia (ANZLIC) as well as the digital library community (Dublin Core group).
    - Creation of Catalog Services also follows accepted international standards of these two organiszations, specifically version 4.0 or greater of the OpenGIS Catalog Interface Implementation Specification.
    - As additional value to the project, natural language interaction and reasoning techniques are being applied to the catalog searching and retrieval components.

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[1] Economic gains due to SDI-like data sharing initiatives have been demonstrated by government agencies in nations such as the USA, Netherlands and UK.

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- Subobjective 3: **Creation of web services** to deliver geographic information, especially web map servers.
    - Several implementations of the OpenGIS Web Map Server Interface Specification v1.0 or greater will be undertaken, to demonstrate how multiple servers running on heterogenous platforms can peacefully coexist and collaborate to provide the user a seamless view of multiple overlayed datasets to his/her web browser. The WMS interfaces assure that data views (bitmaps) are delivered upon demand, and connection via OGC Catalog services greatly improves the ability to first identify what is available on-line to be retrieved and viewed.
- Subobjective 4: **Pilot project** demonstrating viability of standards-based SDI components.
    - The client and server components developed by the research group are to be tested in a network pilot setting, utilizing University of Zaragoza as a principal node. There most all isssue of hardware/software compatibility, configuration and testing will take place, whereas the universities Politécnica of Madrid and Jaume I of Castellón will be secondary testing nodes within the prototype SDI.
    - The research group aims to exploit the pilot testing to become a reference at national and European level, as experts in designing and implementing open solutions for building and sustaining SDIs.
    - Because public and private sector "buy-in" (collaboration) is essential, the research group will strive to involve a healthy subset of these organizations and will attempt to obtain and make publicly available as much relevant reference data as is possible.

- Subobjective 5: **Product definition** to assist institutions and businesses in adopting SDI technology.
    - The project will identify suitable products to be plugged into the SDI framework. This indentification process may be done in an objective manner using as a guide the international standards which have been adopted wholly or partially by each product.
    - Three types of organization can benefit from this categorization of products:
        1. Spatial data providers (ex. national mapping agency) who need to catalog and publish data;
        2. Institutions wishing to establish local or regional nodes for the interchange of spatial data;
        3. Third party collborators or brokers who would facilitate data retrieval.

    - Identification of possible e-Commerce solutions to assist with the sales/payment for data acquired.

- Subobjective 6: **Promotion and dissemination**.
    - Dissemination of project results and general publication of best practice information is a key part of helping establish a SDI. This includes participation at relevant conferences and seminars, creation of a project web portal with news items and hyperlinks to important information, and targeted visits to potential collaborator institutions.
    - Aside from the (anonymous) web portal, the research group also strives to create an umbrella identity for itself, as a consortium of reference within Spain, dedicated to the development and uptake of SDI technology.

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- Subobjective 7: **Coordination of subprojects**.
  - o This is a global subobjective which seeks to coordinate the three subprojects and to eliminate, where possible, duplication of effort and to assure the project meets its stated goals.

The work to achieve the previously mentioned objectives is structured into nine activities according to the following time table:

Activity	First year	Second year	Third year
1. Project coordination and management	‖‖‖‖‖‖‖‖‖	‖‖‖‖‖‖‖‖‖	‖‖‖‖‖‖‖‖‖
2. Metadata support and improve	‖‖‖‖‖‖‖ ‖‖‖	‖ ‖‖‖‖‖‖‖‖	‖ ‖‖‖‖‖ ‖‖‖
3. Catalog creation	‖‖‖‖‖‖‖‖‖	‖ ‖‖‖‖‖‖‖‖	‖ ‖‖‖‖‖‖‖‖
4. Internet services components	‖‖‖‖‖‖ ‖‖‖	‖ ‖‖‖‖‖‖‖	‖ ‖‖‖‖‖ ‖‖
5. Node creation	‖‖‖‖‖‖‖ ‖‖‖	‖‖‖‖‖‖‖‖‖	‖‖‖‖‖‖‖‖‖
6. Pilot project	‖‖‖‖ ‖‖‖‖‖	‖‖‖‖‖‖‖‖‖	‖‖‖‖‖‖‖‖‖
7. Interoperability and portability study	‖‖‖‖‖‖ ‖‖‖	‖‖‖ ‖‖‖‖‖	‖‖‖‖‖‖‖‖‖
8. Product analysis	‖‖‖‖‖‖‖‖‖	‖‖ ‖‖‖‖‖‖‖	‖‖‖‖‖‖‖‖‖
9. Promotion and dissemination.	‖‖‖‖‖ ‖‖‖‖	‖‖‖‖‖‖‖‖‖	‖‖‖‖‖‖‖‖‖

2 Measures of project success

2.1 *Participation in Standardization processes*

One of the main objectives of this project is to become representatives in the process of development of standards related to geographic data and metadata. It is considered interesting because this is one way to transfer research results to the industrial community and, on the other hand, this provides the possibility to gain first-hand access to key information, while standards are being formulated. (Without this inside access academic institutions are often caught constantly behind the wave…)

The participation of researchers from this project in national and international standardization processes can be summarized as following:
- The teams of the University of Zaragoza and the University Jaume I are members of the OpenGIS Consortium (hereafter **OGC**), and international organization with 230+ members from industry (Sun, Oracle, Siemens, etc.), public sector (JRC, Ordnance Survey UK, US Census, etc.) and academic institutions. Additionally, a princupal investigator from this project has been working with this consortium as external consultant and (during a sabbatical visit to USA 2000-2001) coordination of the OpenGIS documentation committee. Additionally project representatives have worked for the European section of this organization (OpenGIS Europe Ltd) as subcontractor.
- Participation in the Technical Committee CTN148 from AENOR (Spanish National Normalization Agency). This committee has it focus in digital cartography and geographic

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information in general, and is in turn the national body representing Spain in CEN, ISO and other international standards bodies.

- Participation in the expert committee for the redefinition/migration of the UNE 148001 EXP MIGRA (Spanish standard for geographical data and metadata) as an ISO profile.
- Working as editors and experts in the CEN/ISSS Metadata/Dublin Core Workshop (MMI-DC) Project Team: improving discovery of geographic information in cross-domain searching. 2002. The work in this workshop is focused in the definition of a semantic and operational crosswalk between ISO geographic metadata standard and Dublin Core. This work is financed by CEN/ISSS – Comitée Européen de Normalisation/Information Society Standarization System (European Union).
- Members of the Architectures and Standards Working Group of INSPIRE (a European Union initiative for the development of the European spatial data infrastructure).
- Members of the Spanish National Council for Geographic Information expert committee. This is the entity which has began to work for the development of the Spanish spatial data infrastructure; chaired by national mapping agency (IGN) subdirector.

This presence is completed by participating in national and international associations :

- Spanish Association for Geographic Information Systems (Asociación Española de Sistemas de Información Geográfica - AESIG). Members of the executive committee since 1997.
- European Umbrella Organization for Geographic Information (EUROGI, Unión Europea, DG-XIII).
- Association of Geographic Information Labs. in Europe (AGILE). Members of the executive committee (AGILE Council) and annual conference Scientific Programme Committee chair.

The work in this area has been satisfactory and should continue for the foeseeable future. The current situation of our teams give us the possibility of be considered as experts in future initiatives.

2.2   Scientific and technological results

The research work undertaken in this project became reality as a set of procedures, knowledge relations and software components. Most of these results where presented at the 6th Global Spatial Data Infrastructure (GSDI) conference (Sept 2002, Budapest) as a part of the workshop "Standards in Action", by invitation of Douglas Nebert (U.S. FGDC/ISO/GSDI technical chair). The main results are summarized below.

Metadata creation tool and metadata improvements
One of the main components developed is a tool for cataloguing geographic metadata. This is a user-friendly tool that allows users to create metadata according to one of the following standards:

- ISO/TC 211 (Draft International Standard ISO/DIS 19115, September 2001)
- Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998)
- Dublin Core applied to geographic information.

The current version of this tool is version 3. It is being used by the Spanish Cadastral Agency, Spanish Ministry of Environment (Ebro River Basin and Nature Data Bank), Andalusia Cartographic Institute (Junta of Andalusia) and Xunta of Galicia (Environment Department).

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Perhaps one of the main problems we have found is the need to demonstrate to and educate data providers on the necessity of having established, standards-based processes for metadata creation. A tool is not enough; it is necessary to develop training material for teaching users in the creation processes. Some ideas from the work-flow area are being studied in order to manage this problem from this point of view.

Besides typical software tool features (different database servers, access control, license control, friendly GUI, etc), the main component of this tool is a set of *metadata-crosswalks* developed with XML technology that allow the easy transformation of metadata from one standard to other. These *crosswalks* have been built by the definition of semantic and operational bridges among the these standards. Additionally, crosswalks to MIGRA (Spanish standard for geographical data and metadata) from ISO, FGDC and Dublin Core have been developed but they currently are not being used in the metadata creation tool.

Other work related to improving the metadata craetion task is under way. One task is related with the concept of *metadata aggregation*. Working in metadata creation, we have identified problems related with the joining of metadata in order to create higher levels of abstraction of the geographic information. There is a PhD thesis in progress which offers an important contribution to the solution of this kind of problem. This thesis will be completed in 2003.
Additionally, there are other research works in progress, related with semantic interoperability through knowledge organization and classification. This work is in its initial steps, but there are initial results that have been presented in conference papers.

Data access components
Several components are under development for accessing geographic data (for visualization or use). Currently, we have a component that implements the OGC Styled Layer Descriptor (Draft Candidate Implementation Specification, version 0.7.0, 7 Feb. 2001). Additionally, the latest version of our Web map server is in compliance with the OGC Web Map Service Interface Specification (version 1.1.0, June 2001) and the consortium has also implemented open source Web Map Servers, at two nodes of the nascent pilot project. Finally, there is a server that implements the OGC Web Feature Server Implementation Specification (version 0.0.14, 17 Oct. 2001) and two additional WFSs (commercial and open source) will be implmented before the end of 2002 as part of collaboration in OGC's Conformance and Interoperability Testing Exercise (CITE). We have also implemented standard Web clients that can access to these components, or any other which supports the OGC specifications.

Metadata catalogs
Another basic component that has been developed is metadata catalog services. The work of this project is based on two types of metadata catalogs: geographic metadata catalogs and Web service catalogs.

Currently, there is a geographic metadata catalog in use. This is a component that offers the necessary services for cataloguing geographic metadata and for searching and presenting results. (An example natural language query illustrating what a user would search for, might be: "Find me satellite images with little cloud cover, of between 01July and 31August2000, and overlay on them road maps in GDF format, for the following geographic extension <user defines with the mouse a rectangle on a map of Europe>").

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The catalog service implements the OGC Catalog Interface Implementation Specification (WWW profile, version 1.1, March 28, 2001). This is the first implementation of this particular profile of OGC standard in the world (OpenGIS has no notice of other implementations) and we are currently awaiting the creation of the OGC conformance test.

As an initial test of client-server interoperability based on the use of published standards –what this project is attempting to demonstrate should be the route toward creating an open SDI in Spain-- the catalog service server running at Univ Zaragoza was accessed using a catalog service client application (Java) developed by a student at Univ. Jaume I. These two components were developed entirely in isolation, each following OGC specifications documents, and then were "blindly" joined with only minor tuning at the client end, to form a fully operational client-server catalog query system. This test may be considered a first stage in the pilot project described below.

The service mentioned follows traditional digital library technology standards. Additionally, we have an implementation of a (stateless) Web Service catalog following the OGC Web Services Stateless Catalog Profile (was Web Registry Service, version: 0.06, 29 August 2001). This catalog is used for coordinating and linking GIS (web) services such as catalogs, Web map server, etc. and is experimental.

Both catalogs are being used in the development of some of the local and regional data infrastructure projects in which we are participating.

The main work we are doing in this area at this moment is related with the conceptual base for linking services, and the architecture of these mechanisms.

Pilot project
As a test bed, and to demonstrate the components necessary for an eventual Spanish National Spatial Data Infrastructure, we are building a set of Internet services with the technology described above. At this moment, there is an initial node in the University of Zaragoza (with access restricted to people from the project) with geographic metadata catalog service and Web map services. Next step will be to extend this node and to create two other server nodes at the Polytechnic University of Madrid and in the University Jaume I, all related through service links based on service catalogs. Components developed are also being used in projects to create specific software products and regional data infrastructures.

Through this pilot project and other projects where the components are being deployed, we are making a detail analysis of the functionality required for the development of spatial data infrastructures. This analysis process must be associated with the necessary abstraction in order to be able to propose new architectural models, and the adaptation of existing ones to the GIS context.

2.3   Promotion and dissemination

Certainly one of the more critical objectives of this project is the promotion and dissemination of the ideas, standards and philosophies that define and sustain the concept of a Spatial Data Infrastructure. Initially the GIS community in Spain was skeptical due to the lack of information

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on how this infrastructure could be implemented following open standards. Fortunately, there have been some important changes since this project began.

The INfrastructure for SPatial InfoRmation in Europe (INSPIRE) is a European Union initiative (sponsored by DG-Environment, Joint Research Centre, and Eurostat) that aims at making available relevant, harmonised and quality geographic information for the purpose of formulation, implementation, monitoring and evaluation of Community policy-making. In practice, this initiative is going to create a legal framework to guide every EU member state in creating its own national data infrastructure, according with a set of standards, processes and directives.

INSPIRE has attracted people's attention, and therefore has been extremely useful for us in our work of promoting open SDI concepts, because at this moment we are able to present an European Union initiative that directly supports our arguments. Additionally, because we are participating directly in INSPIRE, we have first-hand information.

In this context, we have made a series of presentations to organisations and companies. The most relevant ones are:

- 9/6/2001 – Presentation at the Ebro River Basin office (Zaragoza). The audience was integrated by people from different departments of the Ebro River Basin, Aragon Government and Geologic-Technological Institute.
- 5/3/2002 – First Workshop on Spatial Data Infrastructures (Madrid). The audience was integrated by people from the Spanish National Geographic Institute (IGN), National Center for Geographic Information (CNIG), Xunta of Galicia (Environment Department), Community of Madrid (Environment Department), Catalonian Cartographic Institute and some departments from de Spanish Ministry of Environment.
- 1/4/2002 – Presentation at the Xunta of Galicia Environment Department office (Santiago de Compostela). The audience was integrated by people from different departments of the Xunta of Galicia.
- 5/9/2002 – Presentation at the Spanish National Geographic Institute office (Madrid). The audience was integrated by people from the Spanish National Geographic Institute (IGN), National Center for Geographic Information (CNIG).
- 24/10/2002 – Presentation at the Aragon Government Computer Science Department office (Zaragoza). The audience was integrated by people from different departments of the Aragon Government.
- 25/10/2002 – Presentation at the La Rioja Government Environment Department office (Logroño). The audience was integrated by people from different departments of the La Rioja Government.

As a consequence of our work in promotion and dissemination, we are participating in all major initiatives launched in Spain for the development of spatial data infrastructures:

- We are working with the Spanish National Council for Geographic Information, the Spanish National Geographic Institute (IGN) and the National Center for Geographic Information (CNIG) to create some components as the initial kernel for the future Spanish National Data Infrastructure. Kickoff scheduled for December 2002.
- We are working with several departments of the Spanish Ministry of Environment, especially with the Nature Data Bank and Ebro River Basin.

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- Creation of the Catalonian Spatial Data Infrastructure (IDEC). We are working together with the Catalonian Cartographic Institute (which has the responsibility for its creation) as technological consultant and with software components.
- Creation of the Galicia Spatial Data Infrastructure. We are working together with the Xunta of Galicia Department of Environment (which has the responsibility of its creation) as technological consultant and with software components.
- We are also working with several departments of the Aragon Government (Agriculture, Environment, Miner) in order to assist them to develop tools that could be integrated into de Aragon Spatial Data Infrastructure.
- We are advising the Andalusia Cartographic Institute (Junta of Andalusia) in the process of geographic metadata creation. They are also using our metadata cataloguing tool.
- The team has recently received a small project funding to create a pilot regional environmental SDI for the agricultural area "Plana de Castellón", allowing environmental researchers to share and access data on-line.

Currently, we have a very good position in Spain, and our opinions are being taken into account at European level. We should continue work in this same line in order to become the reference research team in Spain in the field of Spatial Data Infrastructures.

2.4   Team consolidation

When this project was proposed, the intention of the researchers from the three universities was to begin collaboration in order to create a R&D team with some sort of critical mass. Several initiatives in this direction have been implemented during the first two years of the project. Perhaps the most relevant ones are the following:

- Celebration of the First Symposium of the Spanish Spatial Data Infrastructure (Zaragoza, Feb.15-16, 2002). This was a two-day meeting, restricted to people from the three universities, that served to create inter-personal relations among the research groups of the three universities.
- Creation of a consortium with a single identity, denominated *"TeIDE Consortium" (Tecnologias para Infraestructuras de Datos Espaciales)*, to facilitate joint participation in projects related with spatial data infrastructures. Snce TeIDE was established all public presentations have been made under this name instead of individual institutions.
- Coauthoring and publication of papers and reports by researchers from the three universities in collaboration (see 3.2).

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3 Result indicators

This section provides an enumeration of the different result indicators.

3.1   Teaching

Two doctoral courses are now offered in relation to the SDI concepts stemming from this CICYT project: at the Polytechnic University of Madrid denominated *Spatial Data Infrastructures.*, and at Univ. Jaume I a course officially titled "3D GIS" has evolved beginning in 2001 to now cover web services and SDI topics.

Additionally, an elective course for Topographic and Cartographic Technician Engineers at the Polytechnic University of Madrid denominated *Introduction to Spatial Data Infrastructures* has been created, and the undergraduate course "GIS" at Univ. Jaume I (5-year Engineering degree in Computer Science) now contains a good deal of SDI material.

Currently, there are three PhD students at the University Jaume I and eight more at the University of Zaragoza, working in areas directly related with this project. Two of these students will present their PhD thesis next year, and another one was presented in September 2002 (Dolores María Llidó Escrivá).

Additionally, so far about 20 final projects for engineering students (Computer Science) have been developed in areas directly or indirectly related with this project.

3.2   Professional publications

The following list of professional papers presents results directly related with this project (see bibliography for full references):

Journals and book chapters:

[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], 23] and [55].

Conference contributions

[24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53] and [54].

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3.3 Projects

As a consequence of this project, we have been in the position to participate in the following projects related with the same research area:

European Union:
- GETIS: Geoprocessing networks in a European Territorial Information Study (IST-1999-14146). 2001-2003
- PreANVIL: Interoperability Observatory (1999-2001). Joint Research Centre (JRC), Space Applications Institute, EU.
- CEN/ISSS Metadata/Dublin Core Workshop (MMI-DC) Project Team: improving discovery of geographic information in cross-domain searching. CEN/ISSS – Comitée Européen de Normalisation/Information Society Standarization System. 2002-2003.
- ACE-GIS : Adaptable and Composable E-commerce and Geographic Information Services. *Information Society Technologies* (IST-2001-37724), June 2002 – November 2004.

National Level:

- Advanced Territorial Information Public Services Development and Implantation. Evolution of SITNA to provide open interoperable internet services and electronic commerce capabilities on territorial information. Ministerio de Ciencia y Tecnología, project Profit FIT-150400-2001-20
- Integration of Location based services and OpenGIS standard compliant GIS capabilities into the CRM Vantive system "Field Service" component to access internet. Ministerio de Ciencia y Tecnología (PROFIT FIT-070000-2000-0827)
- Terrestial transport fleet control and tracking service centre with internet access. Ministerio de Ciencia y Tecnología (50% FEDER funding, objective 2 area). Project P4, reference: TIC2000-0048-P4-02

Regional Level:

- Project cofinancing: Internet oriented and open standard based services development for distributed geographic information catalogs. Effective steps toward the Spain National Geographic Information Infrastructure. Gobierno de Aragón, CONSI+D, project P089/2001
- Information technologies and Pyrenees territorial environment network. Gobierno de Aragón, Departamento de Educación y Ciencia. (Projects for the development and consolidation of thematic networks in the Pyrenees Working Community. Aragon, Navarre and Aquitaine regions)
- Implementation of an Environmental SDI: Pilot study for supporting Groundwater Research. Fundación Castellón-Bancaixa (local bank R+D funding). 2003-2005.

Technological transfer contracts:

- Geographical information visualization system to olive plot characteristics recognition. Diputación General de Aragón, Departamento de Agricultura. From: 2000, to: 2001

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- Plot raster images georeferentiation and georectification. Diputación General de Aragón, Departamento de Agricultura. From: 2000, to: 2001
- Technological assistance to a location based service demonstration prototype development on the CRM Vantive Field Service module, I phase. From: 2001 to: 2001
- Development of a computing tool to the management and diffusion of the technical and administrative information of the Dirección General de Energía y Minas. Diputación General de Aragón, Dirección General de Energía y Minas. From: April-2001, to: Dec-2001
- Functional analysis and migration processes design for the water point inventory geospatial and tabular data to an Oracle database. Confederación Hidrográfica del Ebro. From: feb-2001, to: Dec-2001
- Architectural patterns establishment and GUI design for the IPA information system infrastructure. Confederación Hidrográfica del Ebro. From: Feb-2001, to: Dec-2001
- Previous study for an Environmental Information Structuring and Storage System development. Xunta de Galicia, Conselleria de Medio Ambiente. From: ene-2002, to: jul-2002
- Development of the Galician Environmental and Geographical Information Network. Xunta de Galicia, Conselleria de Medio Ambiente. From: jun-2002, to: Dec-2002
- Map georeferenciaton and visualization adaptation. Diputación General de Aragón, Departamento de Agricultura. From: mar-2002, to: jul-2002
- Improvement and increase of the water point inventory system query component functionality. Confederación Hidrográfica del Ebro. From: Jan-2002, to: Dec-2002
- Water point inventory system infrastructure implementation. Confederación Hidrográfica del Ebro. From: Jan-2002, to: Dec-2002
- WMS client development to the managing and combining of geographic data arriving from several predefined servers. Institut Cartográfic de Catalunya – Generalitat de Catalunya. From: Oct-2002, to: Nov-2002

3.4 National and international cooperation with other R&D groups

In addition to the three project partners, along the duration of the project we have been in cooperation with several R&D groups at different levels of implication. Cooperation with groups of the University of La Rioja and University Carlos III has made a notable contribution to the research and to the project itself. Further cooperation has been established with R&D groups mainly derived from our membership in AGILE (Association of GIS Laboratories in Europe) emphasizing the University of Münster (Germany) where we have one of our PhD students as visiting scholar, and two of their students visiting Univ Jaume I; the Technical University of Vienna (Austria) and Luleå University of Technology (Sweden) where we have maintained cooperation in several EU projects and some papers, and the University of Bremen trying to establish collaboration for multilingual catalogue technology interchange.

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