

NEW CHALLENGES IN TEACHING CARTOGRAPHY AND GIS IN ENGINEERING ENVIRONMENT.

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Abstract:

We are in a permanent and rapidly changing world with changes of very varied nature that influence us both as professionals and as university's teachers. The main purpose of this paper is to focus its attention in how to face the new challenges of teaching Cartography and GIS in engineering environment.

Emerging technologies have increased quite a lot the availability of multipurpose geographic data: GPS, the full integration of Total Station and GPS in one equipment, the 3D Laser Scanners and the latest high resolution satellites (Ikonos II, EROS A, QuickBird, SPOT 5, etc) that deliver better images with higher spatial, spectral and temporal resolutions are good examples of this nature. All these developments enable a greater availability of geographical data to be used in a wide range of projects, where Cartography, GIS and Internet technologies will play a key role for modeling, analysis and final presentation of results. This approach is favoured by the increasing integration of the new computing and IT developments in order to address the spatial and spatial-temporal problems.

The above mentioned evolution of the GI and IT market makes clear the need of well-trained professionals in this area to satisfy their requirements. For this reason, universities and academic environments have the challenge to upgrade their programs accordingly. Recently, many efforts are taking place in this direction in order to get well-educated and well-prepared GI scientists and technologists. Socrates/Erasmus is the well-known European community programme in the field of higher education. Among their many programmed activities special emphasis is placed on the students and teaching staff exchanges, transnational curriculum development and pan-european thematic networks. One of these thematic networks, related to our knowledge area, is the so called European Education in Geodetic Engineering, Cartography and Surveying (EEGECS). In Spain, a working group of teachers belonging to all the Faculties in Engineering Surveying, Geodesy and Cartography has elaborated a proposal for a new university degree following the Bologna process, which aims at the creation of a European Higher Education Area by 2010. The new degree is named "Engineer in Geomatics and Surveying" and will replace the current Bsc degree in Surveying Engineering.

Finally, apart from the analysis of the key features in ongoing model curriculum development projects, the paper will present some results as obtained by our students in final projects while working with cartography and GIS related concepts and technologies.

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1. INTRODUCTION

Emerging technologies have increased quite a lot the availability of multipurpose geographic data: GPS, the full integration of Total Station and GPS in one equipment, the 3D Laser Scanners and the latest high resolution satellites (Ikonos II, EROS A, QuickBird, SPOT 5, etc) that deliver better images with higher spatial, spectral and temporal resolutions are good examples of this nature. All these developments enable a greater availability of geographical data to be used in a wide range of projects.

On the other hand, in Spain a great percentage of Surveying Engineers are related to civil engineering and building companies. This sector is very active at the moment in the whole country. Just to mention an example, over 800.000 living houses or flats were built up in Spain in 2005. This is a similar amount than in Germany, France and UK together.

The simplification of data capture techniques from the above general perspective, that will enable the availability of geodata in faster and cheaper manners, together with the logical decrease of constructions activities in our country, is demanding an appropriate upgrade of our teaching and training programmes. In this scenario the modeling, analysis and visualization activities will play a key role for our professionals in a very competitive market. In this respect, Cartography, GIS and Internet concepts and tools can help to accomplish the desired successful results.

2. THE SIGNIFICANT INCREASE OF CARTOGRAPHY AND GIS ACTIVITIES

The use and implementation of GIS technologies has experimented a significant increase during the last decade in many academic and application fields. As a consequence of that, nowadays a great number of companies and institutions from both, the private and public sector, are engaged in exploring the benefits of GIS and IT technology implementations. Utilities, market analysis, and environmental projects and companies are good examples in the private sector. On the other hand, all levels of the public administration, local, regional and central administration, have undergone important projects and activities in this field. The municipalities have made a great effort in the last decades integrating its large scale digital databases with GIS concepts and tools developing the so called "Territorial Information Systems". The urbanism, the Cadastre and town planning are amongst its most important applications. For those tasks large scale mapping (1/500, 1/1000 and 1/2000) for the urban areas and 1/5000 for the rural areas are being used. At the next level, the Regional Government have also proved to be very active with all the activities related to the different aspects of Territorial Planning and with the dissemination of information about its region. The so called *Sistema de Información Territorial de Navarra -SITNA-* [1] is a good example of this type. The impact and evolution of these Territorial Information Systems, carried out by the local and regional government, are analyzed through their annual technical meetings or workshops.

Another good Spanish example refers to the activities of the central government. The National Geographic Institute of Spain (IGN-E) carries on multiple projects in the fields of astronomy, geophysics, geodesy and cartography. In its Strategic Plan 2004-2007 [2], the application of high technology is a key component to achieve the different stated goals and objectives that are expected to be accomplished through 100 specific projects. Among those, the establishing of the NSDI of Spain is one of the most relevant ones. It will include the coverage of Spain with reference data different scales: 1:25.000 (IGN-E) and 1:5.000 (Regional Governments). It will also include high accuracy (1 m) and high resolution (0.5) digital orthophotography as produced in the National Plan for Aerial Orthophotography (PNOA) by the General State Administration and the Autonomous Government Administrations with a biannual periodicity. The National SDI Geo-portal [3] started to operate in June 2004. The metadata catalogue service, gazetteer service and WMS service of the IDEE Geo-portal as well as services from IGN-E, Catalonia, Navarra, La Rioja and Castilla la Mancha are now underway. The metadata catalogue service receives its data from several metadata catalogues. One of these is the Metadata database, DIGA, from the IGN-E. DIGA includes more than 30.000 entries of IGN-E cartographic products documented according to ISO 19115.

Webcartography has already shown a great impact in general purpose mapping. Nowadays, weather and street maps, routings and tourist maps, accessible through Internet, are used by citizens in their daily life. Location Based Services, and mobile and Ubiquitous Mapping are also amongst the recent developments.

The above mentioned evolution of the GI and IT market makes clear the need of well-trained professionals in this area to satisfy their requirements. For this reason, universities and academic environments have the challenge to upgrade their programs accordingly.

3. NEW INSTITUTIONAL CONTEXT IN HIGHER EDUCATION

The aspects dealt with in the previous paragraphs underline the need to update and upgrade our teaching and training programs. However, besides the technological changes, many other institutional issues are also taking place now, at least within the European framework. The main issue in this respect is the Bologna Process which main purpose is the creation of the European Higher Education Area (EHEA).

3.1 The Bologna Process

Though there has been a first meeting in Sorbonne the year before, it was in 1999 in Bologna where 29 European ministers in charge of higher education met to lay the basis for establishing a European Higher Education Area by 2010.

The Bologna Declaration [4], as signed by different ministers, is aimed to reform the structures of European higher education systems in a convergent way. To attain the Declaration's objectives they proposed the following measures:

- adopt a system of easily readable and comparable degrees
- adopt a system with two main cycles (undergraduate/graduate)
- establish a system of credits (such as ECTS)
- promote mobility by overcoming obstacles
- promote European co-operation in quality assurance
- promote European dimensions in higher education

The Bologna process aims at creating convergence of the European higher education systems in order to enhance the employability and mobility of citizens and to increase the international competitiveness of European higher education. To follow up the Bologna Process and assess the evolution of the different actions taken, regular meetings have been held in Prague (2001), Berlin (2003) and Bergen (2005) where Ministers responsible for higher education in 45 European countries were met. In all these meetings, comments, suggestions and new proposals came up with regard to the different objectives of the Bologna Declaration. As an example, in Berlin the Ministers also considered necessary to go beyond the present focus on two main cycles of higher education to include the doctoral level as the third cycle in the Bologna Process and to promote closer links between the European Higher Education Area (EHEA) and the European Research Area (ERA). Doctoral studies are the synergy between EHEA and ERA.

Socrates is the European programme for education and training [5]. Its aim is to promote the European dimension and to improve the quality of education by encouraging cooperation between the participating countries and thus provide a response to the major challenges of this new century: to promote lifelong learning, encourage access to education for everybody, and help people acquire recognized qualifications and skills. Amongst the different Socrates actions, Erasmus [6] is the European Community programme in the field of higher education. It was established in 1987 and currently 2199 higher education institutions in 31 countries are participating in ERASMUS. Since then, 1.2 million students have benefited of an ERASMUS study period abroad. It seeks to enhance the quality and reinforce the European dimension of higher education by encouraging transnational cooperation between universities, boosting European mobility and improving the transparency and full academic recognition of studies and qualifications throughout the Union. The main Erasmus activities are mentioned here [6]

- Student and teacher exchanges
- Joint development of study programmes (Curriculum Development)
- International intensive programmes
- Thematic networks between departments and faculties across Europe
- Language courses (EILC)
- European credit transfer system (ECTS)

The students' mobility has experienced a significant increase from around 3.000 students in 1987 to over 135.000 students in the regular course 2003-04. The figure 1 gives an overview of the evolution of these numbers and about the different participation of the member countries.

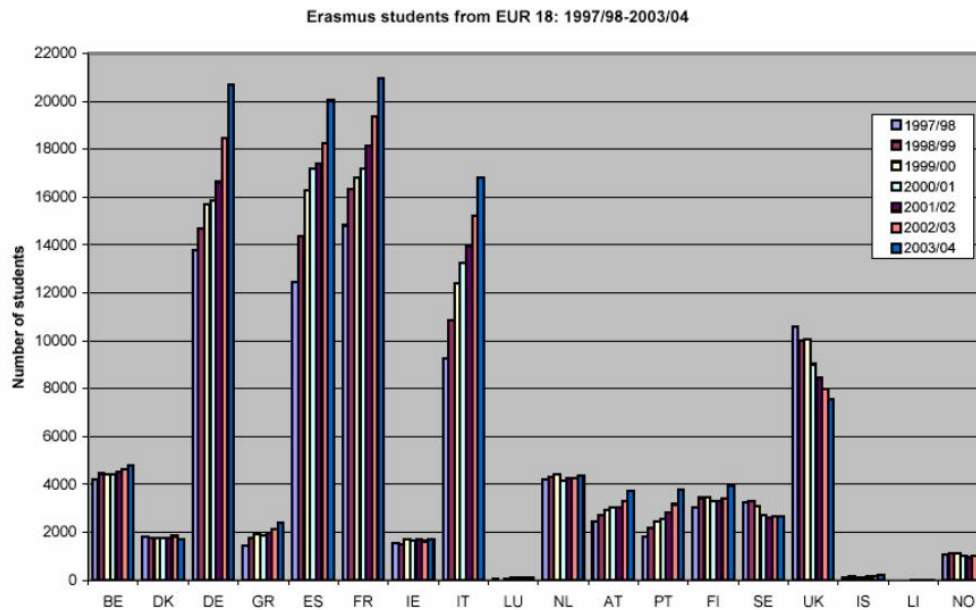


Figure 1. Erasmus Students in a recent 7 years period [7]

To have an idea about Erasmus activities, just to mention that during the academic year 2003/2004 the Commission financed 63 Curriculum Development projects, 202 Intensive programmes and 37 Thematic Networks between departments and faculties across Europe. One of these is Thematic Networks, EGECS, is related to our professional field and stand for “*European Education in Geodetic Engineering, Cartography and Surveying*”. It started its project in 2002 and has a partnership of 100 institutions from 28 different European countries. Currently, it is structured in 6 working groups as described below:

- WG1: Undergraduate Education
- WG2: Research
- WG3: Continuous Education, E-Learning and the European Dimension of Studies
- WG4: Enterprises-Private Sector
- WG5: Mobility, Languages, Culture, Citizenship, Social Cohesion
- WG6: Quality Assurance

Some reports about their progress and findings can be download from its web site [8]:

3.2 The new Spanish proposal of Engineer in Geomatics and Surveying

In Spain, following the Bologna process several actions have been undertaken. Firstly, in the year 2000 the Confederation of Rectors of Spanish universities, in their General Assembly, underlined the need to integrate our higher education system in the EHEA. In 2001 some pilot projects were conducted. Furthermore, a new Spanish law related to universities, the so called LOU (Dec/2001) contributed to officially support the convergence principles of the Bologna Directiva. Nowadays, several official decrees such as the related to the implementation of the Diploma Supplement and ECTS-compatible credit system, have already been published.

The National Agency for Evaluation of Quality and Accreditation (ANECA), of the Spanish Administration, financed a project aimed to establish the degree of Engineer in Geomatics and Surveying following the Bologna Directive. The working group was integrated by 12 related Spanish universities and 2 professional associations (Surveying engineers and Geodesy and Cartography engineers). Their first task carried out was to make a comparative analysis of the situation amongst European universities in relation to some aspects: the duration of the studies, the degree of implementation of the Diploma Supplement, the establishment of the ECTS system and the two cycle (undergraduate/graduate) system, the degree of specialization and the students training in companies amongst others. For this analysis were considered many of the findings and reports collected and published by the EGECS thematic network[8]. A short summary of the work done by its WG1 is included here:

- There are only 2 countries (Lithuania and Denmark) where their universities have implemented 3 main parameters related to the convergence in the EHEA (ECTS, Diploma Supplement and 2 Cycle system).

- Other countries like the Netherlands, Austria, Hungary, Norway and Slovak Republic are rather advance in the process, though their universities still need some extra effort for a better integration.
- The rest of the countries and universities still need an important effort to achieve the comparability and compatibility of their degrees. Though there are some exceptions such as the Polytechnic University of Valencia (Spain) and The Nottingham Trent University (UK) what are in a more advanced phase.

Two main models were identified at the initial stage: a continental model and a British model. The continental model offers two main options: one of basically 5 years plus a final project, and a short one of 3 years plus a final project. They both run parallel and the access for the students, from one to the other, is restricted what is a clear disadvantage. The British model offers a 3 or 4 years degree (Bachelor) and 1 or 2 years second cycle (Master). The students can follow one after the other, what is a clear advantage, and satisfy, at the same time, the cyclic criteria of Bologna process.

Apart from the model o structural differences, the big discrepancies in duration of the studies in Surveying Engineer, from 3 to 7 years, is a quite remarkable detail. Other distinct approaches were identified in relation to practical training of the students in companies, number of specializations, estimation of the number of hours per credit, the degree of adaptation to Bologna criteria, etc.

After this first comparative analysis carry out about the related universities in Europe and Spain, some labour market study was conducted in order to evaluate the ease of integration of our students. Besides that, the opinion of different social agents (employers, professional surveyors and university teachers) was collected through questioners. This served to identify the existing weaknesses and the desire knowledge and skills of the future surveying engineers and to design different professional profiles. In order to define the structure of the new degree some reference models were also considered:

- Technical University of Munich (Engineer in Geodesy and Geoinformation)
- Greek University of Tesalónica.
- The ETH University of Zurich (Engineer in Geomatics)

The first two belong to the European High Education Area but not the third one that was explicitly taken as another outside EHEA reference. As a result of all the works briefly described so far, it was submitted the new proposal to the National Agency for Evaluation of Quality and Accreditation (ANECA), of the Spanish Administration, for its final approval. The main characteristics of this degree are the next:

- Name: Engineer in Geomatics and Surveying
- Model: 2 cycles (undergraduate and graduate).
- Degree or first cycle (Bachelor): 4 years (240 ECTS)
 - 70% Credits (Main core)
 - 30% Credits (Free for each University)
- Final career Project obligatory
- Optional: Master (60/120 créditos ECTS)

As long as the ECTS is concerned, it was estimated a value between 25-30 hours/per credit. So, as each year will have 60 credits, this will mean an amount of about 1500-1800 working hours load for the students. The main core (70% or 168 ECTS) will consist of different subjects grouped in four thematic blocks as shown in the table below.

Table 1. Main structure and contents of the Degree in “Engineer in Geomatics and Surveying”

	Group of Subjects	Percentage	ECTS
Block 1	Basic Sciences	20 %	34
Block 2	Common subjects for Engineers	16 %	27
Block 3	Specific Subjects for the Degree	60 %	100
Block 4	Transversal Subjects	4 %	7
	Total	100 %	168

The block 1 includes subjects like Mathematics, Physics and Computer Sciences. Block 2 consists in subjects who are common in most of the engineering degrees: civil engineering, computer graphics, environmental engineering, and geomorphology and projects management. The block 3 will be integrated for all the subjects related to the main professional knowledge and skills: surveying, geodesy, geophysics, photogrammetry, remote sensing, cartography, GIS, etc. Finally, the block 4 will be devoted to economy, legal aspects and management.

The remaining 30% of the credits will be freely designed by each university depending on their geographical situation, socio-economical environment or their specific interests o, simply, to have some degree of specialization. Though, for this last purpose, different Master courses will be designed and implemented.

Besides this brief analysis of the European and Spanish academic situation, many other significant efforts are being made worldwide in relation to curriculum development. In this respect the “Strawman Report” [9] and the works done by the University Consortium for Geographic Information Science –UCGIS- [10] might be quite relevant in relation to model curricula development.

4.- DIGITAL MAPPING: A SHORT OVERVIEW AND NEW CHALLENGES

During the 80’s, it took place a great impact of computer developments that influenced Cartography with the appearance of CAD, DTP and GIS software packages This allowed the computer cartographer to design a great variety of production lines. Suddenly, it was possible to produce a great number of maps and atlases, in a very short time, compared with the traditional cartographic techniques.

CAD programs have been extensively used by surveyors in large scale mapping, engineering, urban and cadastral projects, to mention some examples. They also behaves as key components at the digitizing, editing and plotting stages within GIS projects when these environments were not so efficient in those tasks. DTP packages have often been connected to small scale thematic mapping and atlases. DTM packages within GIS environment, or in stand alone configuration, have also proved as efficient tools for the cartographers in order to obtain a great variety of map like products: hill shading, layer tints, slope maps, aspects maps and viewshed analysis are good examples of this type.

The GIS concepts and technologies produced a tremendous impact in cartographic world at its beginning. Many public and private institutions in each country produce a huge amount of statistics characterizing multiple phenomena. GIS packages appear to be the appropriate tools for modeling and analysis. However, the powerful communication capabilities of maps, as graphical images, make them unrivalled to convey spatial information in the form of patterns, distributions, interrelations, etc. Maps remain as the ideal form to present or outline a problematic situation in its spatial context; it also works very well as a control mechanism for evaluation of dynamic process and phenomena, or to set up target images of the future. This is still true no matter how is the evolution of GIS technologies.

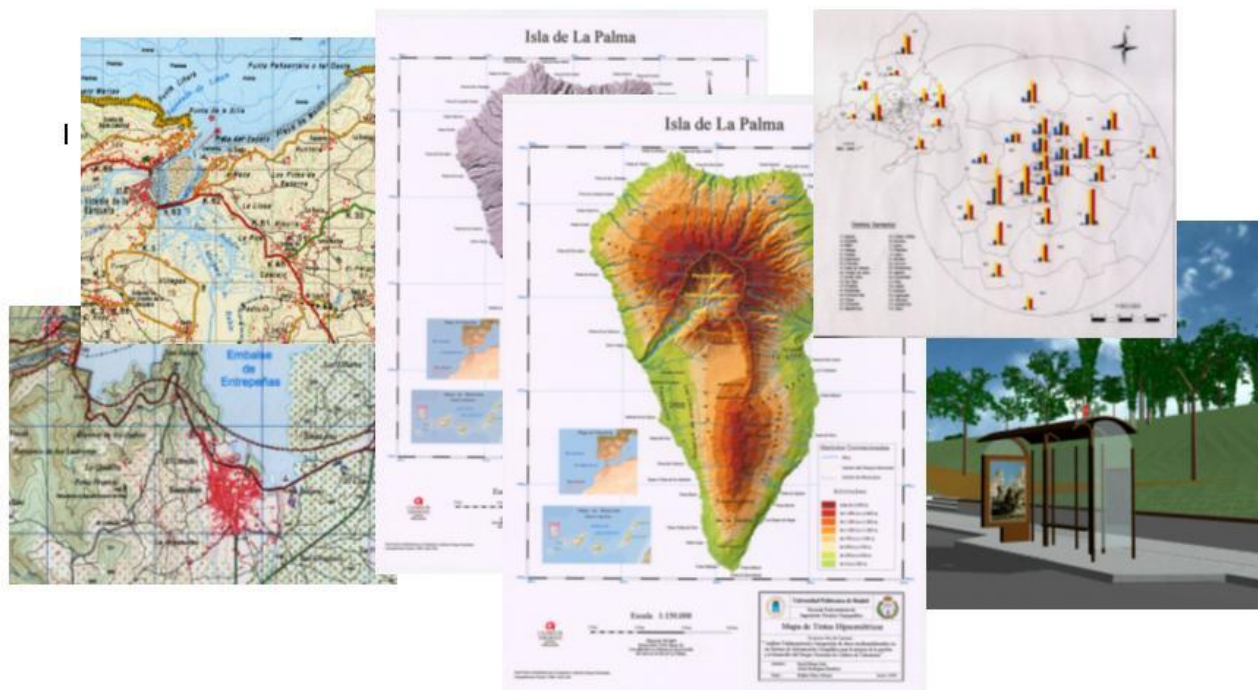


Figure 2. Maps and map-like products produced by the students with CAD and GIS packages

For their combined capabilities, the GIS packages have evolved into being the modern production tool for nowadays cartographers and surveyors. However, the traditional systems used to be based in proprietary formats and lacked of

interoperability. Besides that, the low availability of data, and the character of these complex and dynamic tools, have been obstacles for a much faster development.

Most surveyors deal with large scale mapping and processes of geographical data within engineering projects. In this context, 3D reconstruction or models constitutes a very efficient way to analyze and visualize the 3D space of the study area. Building up a detailed 3D reconstruction is a time consuming operation. However, once it is realized, a lot of applications and benefits can be obtained (plans, details, profiles, cross sections, perspective views, realistic photos, animations, volumes, etc.).

Webmapping can be mention here as one of the most innovative developments lately. Street maps, road maps, weather and tourist maps are among the most frequent published maps through the Web, as long as we refer to private companies. Other National Mapping Agencies, Cadastral Institutes and Statistical Organizations, are also actively involved in the dissemination of maps and geographical data through Internet, as a better service to the citizens.

The traditional role of maps to store and communicate spatial information has changed a lot in the last decades. Recently, maps have been applied to the exploration and analysis of complex and dynamic spatial problems of the environment and the society. Presently, the term “*Geospatial Solutions*” is often used to express the combined used of Geoinformation (GI) and Information Technologies (IT).

For the management of engineering projects have largely been appreciated the alternative process with GIS, because this method integrates all the data and considerations (environmental, human, social, economical, etc) at the beginning of the process rather than time-consuming post-processes. Besides that, all the data is presented in a single context, and all the departments or agencies involved in the decision process can ensure their data is considered as part o the design process. Furthermore, the decision making rules are more transparent and “what if” scenarios can be generated efficiently. Finally, the powerful communication tools enable to present the results successfully.

Lately, it has taken place the integration of GIS with Internet. This development has enhanced the value of GIS many times over. The idea behind Web-based GIS is to provide real-time access to geospatial databases online and equip users with GIS query, analysis, and visualization tools so they can build maps and extract meaningful information. Any user equipped with a standard Web browser can accomplish these tasks and more with no GIS training. The figure 3 represents some implementations of this type as developed by our students in their final study project, and by using the Geomedia Web Map environment.

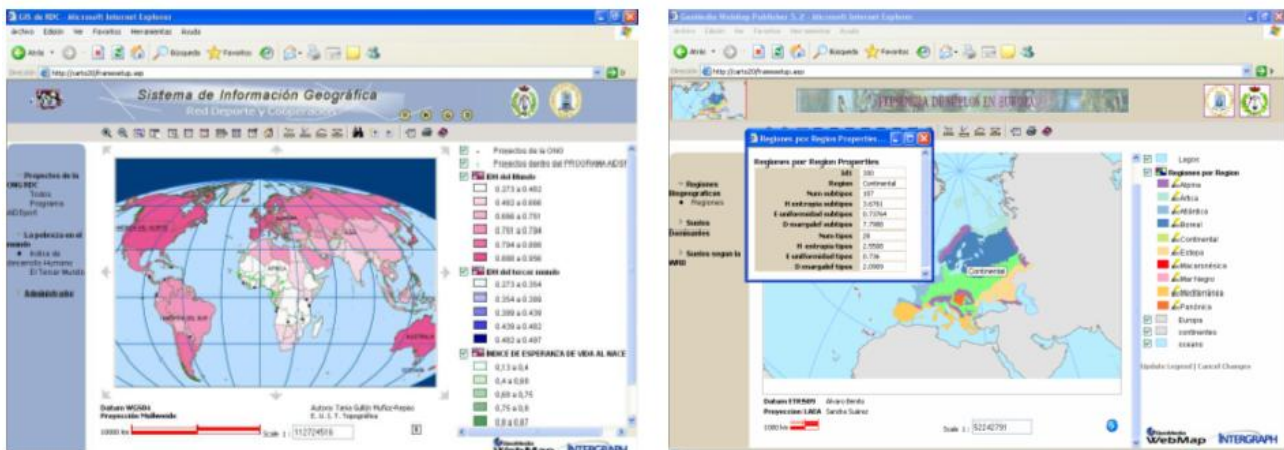


Figure 3. Maps and GIS capabilities integrated in Internet environment.

The last generations of GIS programs provide some enhanced features such as interoperability, increased viewing flexibility, more powerful analytical tools and scalability. The interoperability is related to the access of data, for analysis and mapping, in multiple native formats without conversion or translation. The standard raster viewing capabilities of Internet are further upgraded to enable raster and vector (ActiveCGM, SVG) display. This is normally accomplished through installing some ActiveX control, plug-in, or a Java applet in the client’s browser. The scalability refers to the possibility for the users to grow their systems without rebuilding them by linking as many GIS, CAD, digital mapping, and database systems they wish.

The interoperability in the commercial sector is achieved through their own developments. For instance, Intergraph accomplished this feature by inventing Geographic Data Objects (GDO) technology and building a separate GDO server for each of the popular GIS and CAD packages. Apart from the different commercial solutions available in the market, as provided by GIS vendors (ESRI, Intergraph, Smallworld, Bentley, AutoDesk, etc), there are a growing number of projects related to the Spatial Data Infrastructures (SDIs). This is still truer since the publishing of INSPIRE directive in July 2004 [11]. In this case, the interoperability is based on the concepts of the Open GeoSpatial Consortium [12]. The SDIs try to overcome some of the problems in the traditional GIS projects: gaps in availability of data, fragmentation of datasets and sources, duplication of information collection and lack of harmonization between datasets at different geographical scales. These problems make it difficult to identify access and use data that is available. Among the most outstanding implementations in Spain we should mention the Spatial Data Infrastructure of Spain [3] and Spatial Data Infrastructures of Catalonia [13]. US and European Union government data sources are increasingly offering their data through implementations of OGC standards [12].

So, in order to develop the so called *Geospatial Solutions*, it seemed there are two main diverging strategies: open source software, based in OGC standards, and those based in commercial GIS firms. However, the major GIS vendors in relation to web services tend to follow industry standards such as those related to geospatial matters (OGC, XML, GML) and those proposed by the World Wide Web Consortium –W3C (XML, SOAP, WSDL, SVG). At the same time, they are also participating very actively within the Open Geospatial Consortium, and their new products claim to be certified OGC compliant. This means that they will effectively apply the interoperability concepts of OGC (WMS, WFS, catalog, etc). The catalog services will enable the metadata search engine, or data locator, to discover the existing geographic datasets, who creates and owns them, and how to obtain data itself. Once this is done, the accessible data can be integrated in the appropriate workflow to built up the adequate geospatial solution.

So, from this new approach, both software tendencies are somehow converging, or at least, capable to work together more and more in the near future. If this is accomplished properly we, as teachers and professionals dealing with Cartography and GIS, could have a wider range of tools at our disposal to accommodate them in the different problem-solving scenarios. Nevertheless, the IT component in the final solution is all the time growing. This aspect should be considered carefully when developing new curricula or upgrading existing teaching programs.

5. CONCLUSIONS AND RECOMMENDATIONS

The greater availability of multipurpose geographic data, some simplifications in the data capture techniques, together with a possible decrease in the currently highly active civil engineering and building sectors in Spain, might suggest a new orientation in the training of our surveying engineers. We do need to change our perspective from geodata providers to geospatial solutions providers. We need to put the data in the context of modeling, analysis and planning in problem solving scenarios.

Apart from the private sector activities, the increasing implementation of Spatial Data Infrastructures (SDIs) at all administrative levels: local, regional and central governments, may suggest a growing number of professional opportunities for our students. Here, it can be also included all the thematic SDI as provided by any ministry, institution or departments. In this respect, a close cooperation of the universities with this administrations and companies, through fellowships and practical training of students, could help to increase the number of future Engineers in Geomatics and Surveying working in this area.

The institutional changes that are taking place in the European universities, as a consequence of the Bologna process, aimed to the comparability and compatibility of the degrees, together with employability of the citizens, clearly demand and suggest a well defined and active response of the university communities. In pursuing the Bologna objectives, an active participation in the Erasmus activities: student and teacher exchanges, joint development of study programmes (curriculum development), international intensive programmes, joint Master courses, participation in thematic networks (e.g. EEGECS), etc, may help us in our different roles as teachers, researchers and professionals. As an example, the development of teaching materials by joint groups, and its integration in Internet, looks pretty much the same that the reusability concept of geographical data when published through SDIs. In all these activities we should try to maximize the benefits of the web-based approach. Nevertheless, some obstacles remain to develop such scenarios: the requirement of speaking foreign languages and the growing IT component are not very attractive for people over a certain age, and sometimes there is also a deficit in research culture.


As long as the new technological developments related to Cartography, GIS and Internet, it might be useful to test, analyze and compare open source software versus GIS packages capabilities. By doing so, we would be able to integrate the strengths of any of them in effective production lines and solutions. This seems interesting now that GIS

vendors tend to support OGC standards and look to the SDI world in a converging way. For a better adaptation to continuously evolving needs and technologies, the above mention cooperation of university members within the EHEA may be quite beneficial.

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