# A long term educational experience in GI Science & Technology by combining high quality and interoperable data with professional software developed by teachers, researchers and practitioners

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**Abstract.** This paper describes a long term (since 1998) educational experience in a second graduate course on GIS. Combining ancient and modern high quality and interoperable data with professional software developed thanks to the contributions of teachers, researchers and practitioners has allowed a successful design and application. Through an intensive work with a complex thematic and topographic map, different for every student, conceptual and practical topics related to metadata, georeferencing, advanced digitizing and topology building, spatial interpolation and spatial analysis are visited. Alumni work on data they have introduced into the GIS, taking care of every detail about data, metadata, data models, formats, file relationships, etc. The experience can be easily adapted to other courses, software is available, and contents of the course have been extensively checked in time with hundredths of students and even adapted to the European Higher Education Area (Bologna process).

**Keywords:** GI Science & Technology teaching, GIS Workflow, Software development, MiraMon, Georeferencing, Digitizing, Topology building, Spatial interpolation, Spatial Analysis.

## 1 Introduction and objective

Teaching Geographic Information (GI) Science and Technology (S&T) has been enriched with very important contributions worldwide, from the NCGIA (National Center for Geographic Information and Analysis) [1] GIS Core Curriculum [2], to the very valuable contributions of the European GIS in Education Seminars (EUGISES)

[3] or the USA University Consortium for Geographic Information Science (UCGIS) [4], with “summer workshops on GIS/Remote Sensing and Teaching in the Field” and a notable GIS&T Body of Knowledge [5], etc.

Nevertheless, these and other approaches often have a partial implementation experience, in the sense that they hardly include, in an active way, all the different actors involved. Indeed, GIS&T has some special features causing that the design of a certain course cannot be fully defined by several reasons. Among these we must include:

- A too academic focus.
- A too practical approach.
- Geographical material (paper maps, digital datasets, etc) unavailability.
- Software unavailability (either it does not exist with the needed functionality or it is too expensive for the available resources).
- Lack of vision of the real possibilities of application of what is explained with real data, especially when there is a massive amount of data.

To these basic necessities for a right and feasible teaching design other, more subtle, must be added, both from a theoretical and from a practical point of view. For example, availability of quality metadata for the datasets will not only help to illustrate the metadata issue itself (with obvious derivations depending on whether it is a course on GIS or on RS, for example), but also to illustrate the importance to avoid blunders and other serious errors (*e.g.*, those caused by ignorance about the value used to encode NODATA values, differentiate 0 from NODATA, etc), to perform the calculations correctly or to detect that they cannot be performed without a prior metadata completion (*e.g.*, when knowing height units when proceeding to obtain variables derived from Digital Elevation Models), to properly record the lineage and subsequent processes on a dataset, etc.

The aim of this paper is to show, from a long term real educational experience, the contributions of the different actors involved in a GIS&T teaching design that, as we have said, requires multiple inputs to obtain a successful result.

Despite this, to be concrete, the paper is based on a specific course, so the ideas we want to transmit (theoretical, from data or software resources, etc) should be considered general and, therefore, useful both for the application to similar courses, and for the design of other courses in the GIS&T world.

Finally, and as the entire classroom sessions are developed with computers (up to two per student), the software component is especially important, and we will indicate what specific educational aspects have been incorporated into it to fulfill the teaching requirements.

## 2 A second course on GIS as example

Introductory courses on GIS for undergraduate students have no major problems regarding contents, software or data. Perhaps the most controversial point could be the selection of contents as a function of the student’s background, intended professional future and available time. But a second course on GIS, also for undergraduate students, is something else. Very good books covering largely more contents than those of a primer are available (*e.g.*, [6], [7], [8], [9], [10]) and many Internet pages are within the reach of everybody. The problem is that, obviously, we must choose the contents in which we want to go further.

In the Geography Department of the Autonomous University of Barcelona, in Catalonia, Spain, we decided to cover a second level GIS university trainee; we decided to cover a full GIS cycle from georeferencing to the analysis of spatial data based on real, professional, examples serving the purpose of illustrating the underlying theory and the practical methods and best practices. The goal is to analyze the land information of a quarter of an standard 1:50000 cartographic sheet containing both thematic (detailed land use and land cover, including even percentages of crown coverage or age for forests, agricultural classes, etc) and relief information.

This allows covering the following main topics:

1. Georeferencing.
2. Advanced digitizing and complex topology building.
3. Metadata fully completion.
4. Spatial interpolation.
5. GIS Analysis.

Of course more topics could be added, but this is our tradeoff for about 15 weeks, each one composed of 2 sessions of 1:30 h and 1 h of tutor-supervising homework, all of them in the computer classroom. The maximum number of students is 25.

Students receive the paper sheet (*Mapa de cultivos y aprovechamientos,* Map of crops and exploitations, made by the Ministry of Agriculture of Spain) and they learn how to scan and georeference it following rigorous cartographic and GIS criteria (from scan procedures and criteria, to formats, to advisable planimetric accuracies, etc), and also to understand the value of “ancient” cartography (field work of the maps is from 1970s) as a valuable source for understanding land dynamics (not all is new, fashion, and digitally available!) and the problematic in map production 40 years ago; they also download updated digital information from the same area and understand advantages, problems, etc, of some interoperable Internet sources, as will be shortly commented later. Complementary exercises with other materials (nautical charts, ancient orthophotos, etc) serve to use geographic calculators (for example, some maps are in UTM but the coordinates are only provided in longitude-latitude at the map corners) and to reinforce knowledge about projections, reference systems, etc. Of course, the georeferenced raster map must be correctly metadated (for example the planimetric accuracy information has to take into account the Root Mean Square of the georeferencing process *versus* the nominal accuracy of the series they are using).

After that, alumni digitize both the categorical land use - land cover information and the relief-related data (height spots, contour lines, rivers, etc). During this process, emphasis is laid in the understanding of the multi-field (several attributes are entered per each polygon) and the multi-record (due to scale, some polygons have several sets of attributes, and an indication of the fractional cover is also given in the original map) nature of the categorical part of this complex map.

Digitizing contour lines and rivers, height spots and polygon limits, entering the multi-attribute and multi-record information of polygons, etc, is a long work that serves to gain a professional ability in digitizing and vector editing, as well as a way to valuate the real effort for building accurate geographic datasets.

Emphasis is also introduced in the different kind of attributes of the boundaries and the polygons themselves (boundaries as “sheet limits”, “shoreline”, etc, in front of area information as “urban areas”, “rice crops”, etc).

As in the case of the georeferenced deliverables, a detailed metadata editing is also compulsory for all these vector layers (land use-land cover limits, land use-land cover polygons, contour lines, etc).

Regarding relief-related data, it serves as a very good basis for interpolation lessons: from points (regularly and irregularly distributed), from contour lines, considering break lines, etc, so they learn and practice with methods as bilinear and bicubic interpolators, inverse distance weighting approaches, splines, contour line interpolation, etc. A detailed metadata editing is also compulsory for interpolated outputs.

Finally, a GIS Analysis section completes the course. This part has two extra developments on what was shown during the first course. The first one is the fact that students work on data they have introduced into the GIS, taking care of every detail about data, metadata, data models, formats, file relationships, etc; this is very valuable point, appreciated by the students that realize that the analyses previously done are not exercises that have to produce the same result than the ones of the rest of the classmates (or even of that of previous academic years), but really new ones and that they are the first ones to “discover” this geographic reality. The second one is that, in the case of the land use - land cover map, the presence of more than one record per polygon introduces the need of adequate proportional area computation, the possibility of thinking about the consequences when rasterizing, etc.

It is important to note that as there are more than 1000 sheets 1:50000 in Spain, and that each student works with a quarter, each pupil has to work with a material that is unique for him/her (not only among classmates, but also inter-annually), and that enriches the lessons because different cases appear, and these nice and real examples are shown to the whole group, as a source of near-professional experience.

Students enrolling our undergraduate second level on GIS are mainly future geographers, but the course is also attended by students of environmental sciences, biology, geology, etc, and in the contents selection this reality has been taken into account through a variety of complementary examples; in fact, this attendance by students from other disciplines agrees with the vision of GI as a transversal key competence across a majority of disciplines and professions [18].

The experience of this second course in GIS started in 1998; from this moment on it has been progressively modified according to the contributions explained below. Having its own educational law (*Ley Orgánica de Educación*, LOE), Spain is under the Bologna Process [16] so some procedures and so some educational aspects had to be adapted two years ago; nevertheless, the development and structure of the lessons is quite similar to the previous versions we already applied: theoretical-practical sessions, always in the computer classroom, a maximum of 25 students per classroom, 25% of classroom time devoted to tutor-supervising homework, about 50% of the student time devoted to homework (theory lectures, hands-on the computer for georeferencing, digitizing, etc) and continuous evaluation (theoretical and practical) after each part of the course. A final report with the complete process done over the

1:50000 quarter sheet plus all the digital material generated is the final deliverable to be evaluated.

## 3 The contribution of the academic and the practitioner

The previously exposed design of a second course on GIS benefit from the contribution of several actors, namely:

- Experienced GIS educators. The Geography Department of the Autonomous University of Barcelona was founded in 1969. From the very beginning, quantitative geography interested several members of the Department, being GIS and Remote Sensing quickly added as important matters. Of course, Cartography also received special attention, notably with the establishment of a complete Map Library. In the Spain arena, UAB is the university offering the degree on Geography with more subjects related to GIS&T, completed with two masters with 12 editions each one (one with a more professional orientation [12] and other targeted to more scientific and Remote Sensing contents [13]). As you can see, then, this staff continually has promoted and influenced the availability of adequate teaching resources as well as a curriculum design in which contents as GIS or Remote Sensing are always present. One example is the importance and application of data and metadata models.
- Researchers that incorporate their theoretical and practical point of view as well as the state-of-the-art problematic in the different related fields. Indeed, with nearly two hundred papers, symposium proceedings, book chapters, etc, leading or participating in near 100 projects (international -mainly from the EC and ESA-, national or from local Governments and in collaboration with private organizations) and more than one thousand citations by other colleagues, our research group on GIS&T, called GRUMETS, has contributed very directly in the conceptualization of what a second course should contain. One example is the choice of the spatial interpolators to be explained in detail.
- Government/Administration actors providing real world examples of the main challenges faced in land planning and management. We have been lucky to contact, through numerous projects and professional links, with several people in this field: planners, managers, technicians and high-level managers. The direct knowledge of the concerns, needs, objections, etc, of these professionals in their relationship with the GIS&T has greatly helped us (and it continues helping right now) in the selection of contents for the course. The main contributors in this case have been the Ministries of the Catalan Government, particularly Environment and Housing, Agriculture and Fisheries, Governance and Public Administration, Land Policy and Public Works and Innovation. One example is the importance of interoperability and feasible standards.
- Private sector inputs, ensuring practical approaches to what is more demanded and used. As in the previous point, the contact with the private sector in congresses, professional contacts, etc has also been positively contributing to the contents of the course. One example is the importance of covering de-facto standards.
- Software developers that are conducted by a team where teachers, researchers and practitioners vividly exchange their experiences to provide an integrated, original and useful set of tools satisfying the body of knowledge derived

from the previous actors. One example is the choice of a set of modules that, conveniently chained, provide a complete set for working without interruption from primary data to analytical results.

## 4 The usage and development of the MiraMon GIS as example

As can be easily imagined, this program course requires software being able to perform a lot of operations and, to facilitate the student homework, to be easily available. In our case we had the possibility of using MiraMon [14]. MiraMon is a GIS and Remote Sensing software permitting visualization, query, edition and analysis of raster (remote sensing images, orthophotos, Digital Terrain Models, thematic maps, etc), vector (topographic or thematic maps containing points, lines or polygons) and OGC compliant data (WMS, WMTS, WFS, and WCS). MiraMon has been developed since 1994 at the Autonomous University of Barcelona (UAB); it is available in Catalan, Spanish and English and is used nowadays by more than 100,000 users in 37 countries. In the first years, students wishing to develop their homework at home instead of at the computer classroom could purchase a complete license for 45€, but since 2006, the software is freely distributed among students of all levels, Public Administration, research centers, universities and educational centers of Catalonia.

The chance of synergycally using MiraMon and simultaneously partially contributing to its development has been invaluable. Indeed, many of the improvements performed in the software are pedagogically driven to accommodate our teaching needs. For instance, some of the outstanding properties developed this way and being now available for this GIS&T course are:

- Georeferencing with statistical information about the planimetric quality achieved. Also a complete geodetic calculator is incorporated, especially useful for georeferencing when coordinates in the paper map are in a different reference system than the map itself.
- Advanced digitizing techniques including topology editing and building. Some of the facilities implemented have been arc direction symbolization, show vertices, explicit and hot snap digitizing (to illustrate these two connection modes), node colors according to their nature, keyboard digitizing (to enter sheet frame by coordinates), multi-record per object entry, unlimited undo levels, etc.
- Spatial interpolation techniques as trend surfaces, inverse distance weighting, splines, kriging, etc. Dialog boxes have been designed to facilitate the best comprehension possible of the rich variety of parameters when running these algorithms.
- Relief-derived computations (slopes, incoming solar radiation, etc). Computation of slopes in degrees or percentage or automatic reclassification of aspects in 4 or 8 directions accounting for an extra class not being “absolutely flat” but “flat if slope is less than a threshold”, are some examples of what has been implemented to illustrate these topics.

- Several analytical tools, eased whenever possible (for example, layer crossing can produce the resulting tables computed in 5 forms to better illustrate the "from" and "to" percentages of co-occurrence).
- Complete metadata information and editing tool (ISO 19115-19139) including the usage of this metadata to do certain processes (units of fields when interpolating accordingly to planimetric units, accurate and conscious NOTADA usage, etc).
- Professional plotter printing, including taking data from WMS servers even in large plots (A0), etc.

For some procedures Idrisi software [15] is also used, either to complement some functionalities or simply to show another environment and philosophy.

To conclude this point, it could be argued that GI desktop applications are almost obsolete in front of new services [17], but our opinion is that most procedures learned and applied during this course are still not available as interoperable standard services (and we are developing WPS[1] as well!).

## 5 The role of the Internet in this synergy and the future

As said before, GIS is integration, and Internet provides a very convenient way for that purpose. Nevertheless, for this integration to take place with the best results, high quality and interoperable data and metadata, aware of the more convenient standards, both official and de facto, are needed. The experience of our group in this way is important (we have recently being the main editor of the new OGC international standard Web Map Tile Service, WMTS [16]), but especially relevant for the topic of this paper have been the lessons learnt from:

- 12 years of high quality, freely downloadable, spatial data (climate, environmental variables, etc) in Internet promoted by the authorities of our country (International Möbius Award in 2000), directly readable in MiraMon prior to the OGC standardization initiatives, and now also accessible through them.
- 3 years of complementing the previous point by the fact that all official cartography in Catalonia is now also freely available in MiraMon format (not only WMS services, but full downloads of the original data). This includes detailed 1:5000, 1:25000 and 1:50000 topographical maps, orthophotos, etc, following the highest quality criteria regarding quality (topology, 3D, etc), metadata (ISO 19115, etc), and not as "simple" CAD or non-topology compliant GIS formats.

Obviously the introduction of the Internet usage in the course has been gradual. Today students access for metadata querying, data visualization and downloading (when possible) the updated digital information from the same area; this way they understand advantages, problems, etc of the interoperable Internet sources and acquire

[1] WPS: Web Processing Service: An interoperable procedure to do on-line running of processes as analytical operations, format transformations, etc.

a necessary critical vision about the capabilities of this new world for their future professional work. In this sense, the myriad of available information on the Internet gives the possibility to transform the teacher into a coach [17]. Nevertheless, and although acknowledging this vast world of opportunities and materials, our vision is that there is also an important role for the "teacher as teacher"; in other words, in our humble opinion one hour of a student with the professor is often more clarifying than the same hour browsing Internet pages; and of course we recommend to look at these "other" materials too!

Finally, and regarding MiraMon itself, challenges to improve it are still going on. On 2010 fall, version 7 of the software has introduced integrated zoom by toponyms as well as collections of favorite datasets that greatly help in preparing sets of information (local, in the LAN or on the Internet) for the course sessions and themes. But we also want to develop an environment for easily defining reference systems that are not currently predefined (a problem that arises when using MiraMon in "new" countries or to perfectly georeference datasets of ancient cartography, etc), sophisticate digitizing facilities, etc. This way, the feed back from other colleagues is enthusiastically encouraged!

## 6 Conclusions

Combining high quality and interoperable data with professional software developed thanks to the contributions of teachers, researchers and practitioners has allowed a successful long term educational experience in a second course on GIS. One of the most positive things is the fact that students work on data they have introduced in the GIS, taking care of every detail about data, metadata, data models, formats, file relationships, etc. Another important point is that these that have been made publicly available in digital GIS form for certain sheets for the first time.

Working on real, useful, data, allows students to perform their task as an unique and valuable process, to deal with real "professional" data problems occurring when creating or entering new information for analysis, and teachers to realize, and adapt to their curricular material, the new incidences.

The experience can be easily adapted to other courses as similar data exist in other countries (or, in the worst case, the Spanish data could be used), software is available, and contents of the course have been extensively checked in time with hundreds of students and even adapted to the European Higher Education Area (Bologna process).

**Acknowledgments.** I wish to express my gratitude to the colleagues and students that every day provides ideas and motives to rethink and improve my teaching. This work has been partially supported by the Catalan Government, under Grant SGR2009-1511.

## References


1. National Center for Geographic Information and Analysis, http://www.ncgia.ucsb.edu/
2. The NCGIA Core Curriculum in GIScience, http://www.ncgia.ucsb.edu/giscc/
3. EUGISES, http://www.eugises.eu/
4. University Consortium for Geographic Information Science, http://www.ucgis.org/
5. GI S&T Body of Knowledge, http://www.ucgis.org/priorities/education/modelcurriculaproject.asp
6. Burrough, P.A., McDonnell, R.A.: Principles of Geographical Information Systems. Oxford University Press, New York (1998)
7. Bonham-Carter, G.F.: Geographic information systems for geoscientists. Modelling with GIS. Pergamon, Kidlington (1994)
8. Laurini, R., Tompson, D.: Fundamentals of Spatial Information Systems. Academic Press, London (1992)
9. Santos Preciado, J.M.: Sistemas de información geográfica. UNED, Madrid (2004)
10. Panigrahi, N.: Geographical Information Science. CRC Press, Boca Ratón (2010)
11. The Bologna Process - Towards the European Higher Education Area, http://ec.europa.eu/education/higher-education/doc1290_en.htm
12. Màster en tecnologies de la informació geogràfica, http://ligit0.uab.es/mtig/index.htm
13. Master in Remote Sensing and GIS, http://www.creaf.uab.cat/master/index_en.htm
14. Pons, X.: MiraMon. Geographic Information System and Remote Sensing Software. Centre for Ecological Research and Forestry Applications, CREAF. Bellaterra. ISBN: 84-931323-4-9 (2004)
15. Clark Labs – IDRISI GIS and Image Processing software, http://www.clarklabs.org/
16. Masó, J., Pomakis, K., Julià, N.: OpenGIS® Web Map Tile Service Implementation Standard, v. 1.0.0. Open Geospatial Consortium Inc. Document reference number 07-057r7, http://www.opengeospatial.org/standards/wmts. (2010)
17. de Bakker, M., Toppen, F.: Changes in the geospatial education landscape. Vision paper EUGISES 2010. (2009)
18. Strobl, J.: Geospatial Competence as Cross-Disciplinary Qualification. Vision paper EUGISES 2010. (2009)