TEACHING EXPERIENCES IN COMPUTER ASSISTED CARTHOGRAPHY AND GIS FOR AN INFORMATICS ENGINEERING COURSE

Maria Antonia Brovelli and Raffaella Brumana
DIIAR - Politecnico di Milano (Italy)
Piazza Leonardo da Vinci, 32 – 20133 Milano, Italy
maria@ipmtf4.topo.polimi.it and brumanar@idra5.iar.polimi.it

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Abstract

The course named "Digital cartography" started up in the academic year 96/97 at the Como branch of the Politecnic of Milan. It belongs to the programme of studies of the informatics engineering students specializing in geomatics. Users like these, having a good informatics background yet lacking competences for topography and cartography, require that first of all attention is paid in correctly defining the problem related to the rappresentation of the earth. The Theoretical lessons were completed by computer assisted practical lessons which took place at the "Geomatics Laboratory" of the University. In this laboratory the hardware is represented by three Pentium PC, two SGI-INDY and an IBM RISC 6000 workstation. Referring to the GIS software the ARCVIEW, ARC/INFO and GRASS systems are available.

1. Introduction to cartography

The course started with an outline of the cultural and scientific-technological developments which brought from the first qualitative maps to scientific cartography, and from this to the introduction of digital cartography and geographic information systems. From a teaching point of view we thought it was effective to include in this part some iconographical material in order to show the different vision of the earth surface in the different ages, pointing out the relation between the history of cartography and the characteristics of the corresponding societies.

The main goals of cartography were presented and we also pointed out that maps may be distinguished by a set of criteria not necessary mutually exclusive. Discussing the carthography characteristics we introduced as basic elements of a map the representation of the position of discrete points of the earth surface in a plane coordinate system (the two dimensional space X,Y) and the attributes (qualities and quantities) associated to the points. So we pointed out how, starting from these two elements, all kinds of topological and metrical properties of the relationships may be defined (distance, network, interactions,...).

We also focused the relevant aspects of maps:

the transformation of the earth surface (approximately a curved surface) to a bidimensional surface (the computer screen or a flat map sheet) may be obtained by means of mathematical or geometric relationship (map projections). Because of the double bend of the earth the resulting map is intrinsically distorted and the goal is to define the criteria we would like to adopt in order to mantain unchanged some properties of the datum surface (definition of equidistant, equivalent and conformal projections);

the map is a reduced portrayal of the datum surface: so we need to define the concepts of scale factor and map scale and the relationship among scale, spatial resolution and feature detection (precision and accuracy);

the map is an abstraction of reality, in which we consider only the classes of information that serve its purpose (selection) and in which we fit portrayal of selected features to the map scale and to the need of effective communication of information (generalization, regarded as the four operation of classification, simplification, exaggeration and symbolization).

Regarding the categories of maps, we highlighted the fact that the number of possible combinations of map characteristics is boundless, so we can immagine an infinite variety of maps. Nethertheless we tried to class them taking into account the following point of view:

a) classification by map projections and geometric transformation;

b) classification by scale;

c) classification by function;

d) classification by subject matter.

As referring to point (a) if we consider as basic elements the datum surface (projected object), the projection surface and the projection itself, we get the following classification scheme(P. Richardus and R.K. Adler, 1972):

Classes	Varieties		
Nature	Plane	Conical	Cylindrical
Coincidence	Tangent	Secant	Polysuperficial
Attitude	Normal	Transverse	Oblique
Properties	Equidistant	Equivalent	Conformal
Generation	Geometric	Semigeometric	Mathematical

in which the varieties, as subdivisions within each class, are mutully exclusive. Notice that in the table the first three classes refer to the projection surface, the last two to the representation, while regarding the datum surface we will examine later its characteristics later.

A regular projection may be identified by a combination of varieties, one from each class.

About the classification (b) by scale (depending on the portion of the earth we would like to portray) we observed that it is not unique, because there is no consensus on the quantitative limits for small, medium and large scale maps. Nevertheless we adopted the classification proposed by the Italian Military Geographic Institute (IGMI), which is the official Italian cartographic organization:

geographycal maps: scale smaller than 1:1000000;

chorographyc maps: scale from 1:1000000 to 1:200000

topographyc maps: scale from 1:200000 to 1:5000

technical maps: scale from 1:5000 to 1:500

plans: scale bigger than 1:500

Trying to class maps based on their function (c), we may distinguish:

general reference maps, in many cases used as legal documents and in which accuracy standards are applied to the metrical horizontal and vertical properties;

thematic maps, which focus attention on the distribution of a single attribute we are interested in (e.g.: population density, temperature,...);

charts, specific maps used in nautical and aeronautical navigation.

The previous classification is not so clearcut: just to have an example, we may consider that topographic maps (general reference maps) often show also the distribution of particular attributes, such as, for example, woodiness.

The last classification we examined (d) is related to the dominant subject matter (soil maps, geological maps, economic maps,...). Among these we recall in particular the cadastral maps and their characteristics.

2. References suggested

The references suggested to the students were the following:

- for the first part of the course (geodesy, reference frames and coordinate systems, sources of information) lectures notes were distributed;

- for the lessons devoted to map projections we suggested:

P.Richardus and K.K.Adler, 1972, Map Projections (for geodesist, cartographers and geographers), North-Holland, Amsterdam-London;

- for computer assisted cartography and GIS we proposed:

G.Comoglio e R.Boccardo, 1996, Dispensa per il Corso di Cartografia Numerica del Dipartimento di Georisorse e Territorio, Politecnico di Torino;

R.Galetto e A.Spalla, 1992, Cartografia Numerica, Dispensa per il Corso di Fotogrammetria del Dipartimento di Ingegneria del Territorio, Universitá degli Studi di Pavia;

M.F.Goodchild, D.Maguire, D.Rhind, 1991, Geographical Information Systems, Longman Scientific & Technical, vol.1-2;

R.Laurini and D.Thomson, 1992, Fundamental of Spatial Information Systems, The Apic Series, San Diego, Ca;

A.H.Robinson, J.L.Morrison, P.C.Muehrcke, A.J.Kimerling, S.G.Guptill, 1995, Elements of Cartography, John Wiley & Sons inc., NewYork-Chichester-Brisbane-Toronto-Singapore;

Grass 4.1 Programs Manual, 1993;

Arcview GIS, 1996, Environmental Systems Research Institute inc.,Redlands,Ca;

Understanding GIS, The Arc/info method, 1990, Environmental Systems research Institute inc., Redlands, Ca.

3. Basic geodesy, reference frames and coordinate systems

Mapping implies the determination of the position of the points on the earth surface. The first problem is to determine shape and size of the earth. Because of the irregularity of the earth but, at the same time, the smoothness of his geometrical figure, cartographers adopt different aproximations. So we introduced the geoid (definition, properties and the basic concept of computation of regional geoid) and its approximations, the sphere and the ellipsoid (definition, dimension,...). On the ellipsoidal surface we identified and studied lines (having special properties) of interest in map projections (like the geodesic, the great circle, the orthodrome, the loxodrome,...). Aiming at the determination of the locations of points on the earth surface, we needed to introduce a reference frame which fixes the degrees of freedom of the system. We examined:

inertial reference frame;

conventional celestial reference frame;

conventional terrestrial reference frame;

WGS84 reference frame.

In geodesy and topography the determination of the geometrical relationship between the points of the surface is pratically and historically connected to the description of the gravity field.

We introduced several coordinate systems taking into account in different ways the a-priori knowledge of the gravity field:

cartesian coordinate system (X,Y,Z);

geodetic (or geographic) coordinate system (φ, λ, h);

astrogeodetic (or astronomical) coordinate system (Φ, Λ, H);

intrinsic coordinate system (Φ, Λ, W).

and we examined the transformations of these coordinate systems.

4. Sources of cartographic information

We decided to deal with the following topics:

- regarding ground survey and positioning, we introduced:

  the classical vectorial observation equations and their linearization and we specified (as examples) the case of geocentric reference frame and geodetic coordinate system (useful to jointly compensate classical and spatial observations) and the case of the local spherical approximation of the gravity field and local cartesian coordinate system;

  the spatial positioning methods, particularly the Navstar GPS (observations, preprocessing and processing);

  the basic concepts of geodetic and topographic network compensation;

  the geodetic and topographic Italian networks;

- regarding raster information from digital photogrammetry, after introducing the principles of aerial and spatial photogrammetry we paid attention to the digital methods and techniques (digital image processing system to geometrically rectify the image, to enhance the contrast, to create thematic maps by extracting information from image data). We also introduced cartographic products, as the ortophotomaps;

- finally, on the digitization of maps we examined the digitizing process (advantages and disavantages) versus the previous ways to collect data. Related to the method itself, we introduced both the manual digitization technique (point mode and stream mode) and the scanning systems.

4. Map Projections

After illustrating the purposes and methods of projection and the general transformation formulae (theory of distortions) we considered:

the azimuthal and equidistant projections (gnomonic, stereographic, orthographic, azimutal equidistant, Cassini-Soldner projections);

the conformal projections (Lambert conical, Mercator, polar stereographic, Gauss projection);

the equivalent projections (Lambert conical, Lambert cylindrical, Bonne pseudo-conical, Sanson-Flamsteed, Werner projections).

We studied also the applications of map projections to the Italian cartography: cartography of the Italian Military Geographic Institute (IGMI), cadastral cartography, technical maps of the Italian administrative Regions.

5. Digital databases and geographycal information systems

We presented the main problems related to digital databases:

the use of standard codes to describe natural and artificial entities;

the standard formats for spatial data transfer;

selection and generalization;

managing large databases.

We introduced the following cartographic Italian databases:

the official cartographic database (IGMI) at the 1:50000 and 1:25000 scale;

the hypsography - contours and spot elevations (IGMI);

the hydrography - streams, water bodies and wetlands (IGMI);

the administrative boundaries;

the cartographic cadastral databases;

some county and city databases (examples).

Regarding the geographical information systems the following subjects were discussed:

- component of a GIS;
- data models and data structures in GIS for raster and vector data;
- different DBMS structures

hierarchiacal systems

network systems

relational systems

extended relational systems

object-oriented systems.

The different systems were presented with examples and simple exercises;

- overview of the existent GIS:

ARCVIEW

MAPINFO

IDRISI

GRASS

XMAP8

ARC/INFO

6. Practical lessons

In the first part of the practical lessons we considered some problems related to geodesy, topography and classic cartography.

In particular we proposed the following exercises:

rototranslation and scale variation

(example:converting local machine (digitizer) coordinates to a geographical reference system);

transformations between different coordinate systems (local cartesian $\leftrightarrow$ geocentric cartesian $\leftrightarrow$ geodetic $\leftrightarrow$ astrogeodetic);

connection of local GPS networks to the Italian cartographic coordinate system (datum shift and coordinate system transformations);

transformations from Cassini-Soldner Italian cadastral coordinate system to Gauss-Boaga coordinate system;

map digitizing with digitizing table.

Regarding digital cartography, we presented:

an example of spatial data transfer format: the NTF (National Transfer Format) standard;

the NTF applied to Italian cadastral data

and we prepared a traslation program from NTF Italian cadastral to DXF format.

Regarding the training in the ARCVIEW system, after introducing how to get spatial and attribute data, to manage, query and display data, we considered the following projects:

a GIS for planning problems in environmental risk areas;

a GIS for archaelogy;

a GIS to be used in restoration works;

managing and mapping the global geopotential model EGM96.

while in the training in the GRASS system we examined:

the directory structure and file management (raster, vector and sites data file);

the main commands.

After some simple exercises we completed a project aiming at the study of the sea surface topography in the Mediterranean sea by using as input data the radaraltimetric observations of satellite ERS1 and the geoid computed in the European project GEOMED.