GIS:

Theoretical and Conceptual tools, an applicatory example

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Abstract

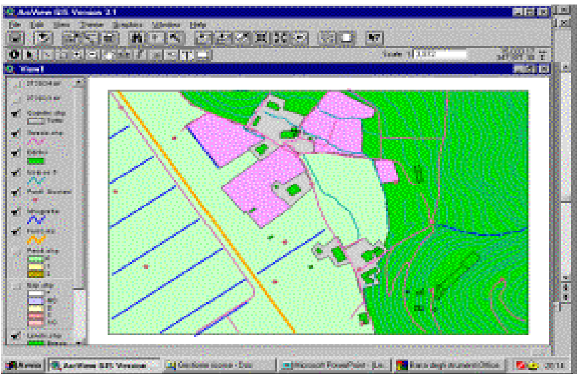
This paper provides to illustrate the role of the geographic information system for representation geographical elements of the real world.
Objective is to provide the learner the basic concepts of the processing of geographic information, supplementing the methodological elements with the technical ones, as well as the principles that subtend this processing and the evaluation of the impact that a GIS has in the organization of a public body or a private institution.
The GIS application consists in a serious of phases: readers will learn the basics of working with existing GIS data maps, how to build maps from GIS data and how to create, them add, graphs and reports to their maps and how create a thematic map using values of an external table. Finally work with editing features on existing themes, with a shape file joining new points and creating a new theme.
The aim is to georefer the records of an external table, connecting this to the attribute table of the layer of points through a common field (join), to identify the values of the chemical parameters.
The hypothesis is that the layer contains information about the location of the samples of sediments, and the external table contains the values of chemical analysis of the sediments in the context of Venice territory, so to verify illustrate role of petrochemical fabric of Marghera on the surrounding territory.
Elaborate matters are following:

1. **to load vector and raster layers, to set up colours, symbols and name,**
2. **to work with the tables, create a thematic map using values of an external table,**
3. **to editing features on existing themes, Creating a new theme. Editing a shape file joining new points.**

The used data for this applicatory departs come from the municipality of Venice and "defended association of Marghera".

1. Cartography and GIS

By the analysis of a drawn cartography, it is possible to understand how objects are drawn on the sheet with such as symbol to allow the association with physical entities that really exist on the territory[1].



Tipo: Archiviazione degli oggetti su strati dedicati

Su una carta le informazioni territoriali sono riportate secondo i modelli e gli strumenti espressivi del cartografo. Poiché il mondo GIS ha altri modelli e altri strumenti espressivi, la trasposizione di informazioni da una carta ad un DataBase territoriale richiede un'analisi attenta dell'informazione presente sulla carta.

Source: Mazzariol (2003)

The drawing technique allows recognizing the kind of identity of the real world.
In GIS logic, it is necessary to try to understand the meaning[2] of the various objects present on the map[3] so to be able to define classes of objects and to adequately represent them with informatics tools we have at our disposal. On the map we see different objects with the following features:
1) typology 2) localization 3) shape 4) attributes 5) spatial relations 6) drawing technique.
1. TYPE, on a map an object is identified by the way it is drawn: this information is contained in a GIS system, in the fact that the object is registered inside of a level which is dedicated to it and to objects of the same kind during the phase of the system design. (for example the definition of a layer where there will be registered the object "residential building" and another one for the industrial buildings).
2. LOCALIZATION, the localization of an object is defined by the place where the drawing of the object inside of a reference system is placed: in a GIS system, the

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[1]GIS is a computerized instrument that allows positioning and analysing objects and events that exist and happen on the Earth. See Andy, M (2005), Burrough, P. A. (1998), Majed, K. (2005).
[2] The symbol comes interpreted and produces a meaning, it may define a discourse Fondelli (1992, 73).
[3] If we need to localize a new activity , to individuate the best soil to cultivate a specific element, as to find the best way for an emergency vehicle to go, I mean, for every question which have a geographic component on the map.

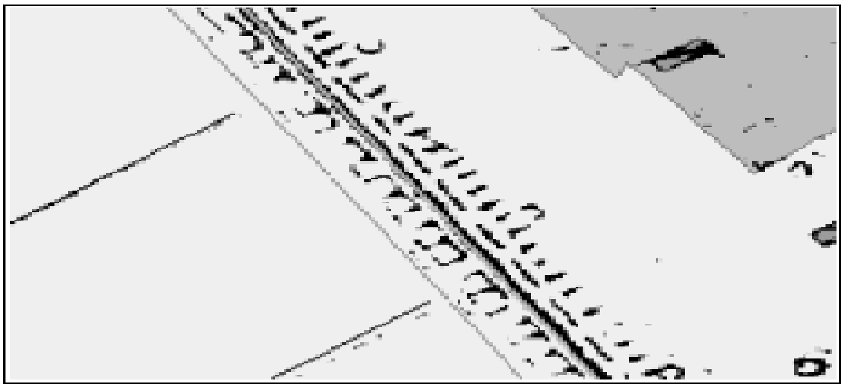
localization is completely defined by the coordinates of the graphic primitives which describe the object.

3. SHAPE, the shape of an object on the map is implied in its graphics (curves and segments) and, in the case of the segments, by the angles that they form with each other; inside a GIS system, the shape is memorized in the geographic part of the object; it is easily perceived by the operator in case of drawing, but it is much harder to go up again to the shape of the object directly by the analysis of the coordinates.

4. ATTRIBUTES, on the map are present, in general, just a few attributes associated with the objects, or those are inferable by the drawing technique or written as topography; those that are present are obviously inserted in the descriptive part of the object.

5. RELATIONS WITH DIFFERENT OBJECTS, the relations[4] of an object with different objects are perceived, on a map, by the closeness or NOT, between objects that are explicitly memorized in the geographic part of the datum. The way it happens, also depends on the kind of software we use.

6. DRAWNING TECHNIQUE, the drawing technique of an object, that is a primary information in the preparation of a map, is not connected to the semantics of the object, but to its representation according to a certain convention: therefore, it can not stay in a GIS system[5], neither in the attributes, nor in the geographic part. However the drawing technique allows us to define the type of an entity and, some time, attributes relative to the entity. The case of the painters is noteworthy: it is very circumstantial morphologic information.



Alcune entità territoriali non si trasportano con facilità dalla carta al mondo GIS: il caso tipico è quello delle "barbette" che indicano le scarpate.

Source: Mazzariol (2003)

Nevertheless, treating it as morphologic information, it would not be possible to Know how to represent it, as it is a qualitative information.

It could be an attribute of the object where they (the river or the road) lean on, but in reality this solution is not adopted. The object "painter" is generally acquired just to be redrafted or, more often, it is simply ignored.

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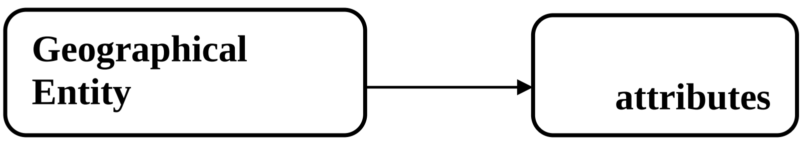
[4] The relational model is based on two fundamental concepts: relation and table. While the concept of table is easily intuit able, that of relation comes from mathematics and in particular from set-theory. In the opinion of the experts (Burrough, 1990), part of the success of the relational model comes from the contemporaneous presence of these two concepts, one of which is direct and the other one is formal.

[5] The components of the Geographical Information are two: space component: position, shape, dimensions, topographic properties/ not space component: descriptive data (attributes) associated to the space component.

When it is necessary to draw an object, we need to use some graphic elements. For the association between an object which is managed by a GIS tool and the graphic elements used to draw it, we avail ourselves of look-up tables. The look-up tables are not univocal and it is also possible to use different tables to draw the same object for the scale and/or the drawing aims. A look-up table, meant as an association between type and features of an entity and its representation, calls very much to mind the "LEGENDA"(map symbol) of a drawn map. Actually the two things are totally mutually opposed: on a drawn map, the map symbol allows to recognize the kind of object and its features, thanks to the drawing technique; in a GIS instrument the look-up table allows to define a drawing technique, given an object and its features. There are a lot of elements for which GIS technology exceeds drawn cartography. Leaving out the ones connected with digital data processing, the clearest are:
the capacity to manage a theoretically infinite[6] number of informative layers;
the capacity to manage an entity with a theoretically infinite number of attributes;
that means, practically, the possibility to manage greater amounts of information.
In conceptual terms, furthermore, GIS technology[7] allows an abstraction of the objects that leaves their representation technique out of consideration.
The operations which involve a geographical analysis are made thanks to the use of a map, or, more in general, through a geographical vision of the field of action. This approach is based on the principle of seeing "together different objects".
This phenomenon normally happens when we look at a map; in this condition we mentally execute operations of "spatial" kind, like being close, being adjacent, being inside, being visible, etc. The objects that we find on a map are characterized for owning geographical information and a descriptive one (attributes). For example a building brings geographical information consisting of its collocation on the territory[8] and a descriptive one, which consists of its typology; in the same way a road, a census section, a lake, a trellis, etc.



[6] These capacities differentiate the GIS from other informative systems and make them a very important instrument directed to a wide range of public and private users who need to visualize and analyse information with the purpose of explaining events, expecting results and planning strategies.
[7] Even if the acronym GIS will be generally used to indicate the technological component of the system, the so-called GIS technology: hardware, software, and data.
[8] For example, the maps of a municipal district, where there are shown the streets, the buildings and the type of buildings. Or, also there exists cartographic representations of less realistic objects, like the old cadastral papers of the borders of the properties.

In the "attributes" part[9], which contain "values" attributed to features of the object, we can apply operators of traditional kind. It means that we can compare different objects, comparing the values of the descriptive part: the E1 building has more rooms than the E4 one? How many roads in these areas are not asphalted?
On the "geographic" part we can apply different, and relatively new, in the informatics field, operators, such as the "closeness", the "adjacency", the "connection", etc. For example: Does the D1 municipality border with the R7 one? Is the A1 road connected with the A11? And, does the new structure allow developing the potentialities of a series of new operators, the so-called "spatial operators", as they operate in the space, rather than in the field of the alphanumeric normal numbers .
The objects of a map can be grouped in classes, each one contains homogeneous data (the class of the roads, that of the trellis, etc). Inside a class, are contained objects, which are not necessarily identified, on the contrary, normally each one of those has its own geographical (different position and shape), and descriptive (a section of a highway or provincial road, or not asphalted road, etc) characterization. The classes are also called layers or informative levels.
Let us considerate objects of different informative levels, for example roads and buildings. Each one of them has its own structure and it is easy to observe that the part called "attributes" has a different structure in the two classes. As the descriptive part of the "road" class, describing the kind of the covering of the road, its name, the width, etc, the descriptive part of the class "buildings" describes, on the contrary, which is the purpose of the building, its height, the number of rooms, etc.
If the "attributes" part is very different in the two classes, on the contrary the Geographic part has a very similar structure. In fact, whichever is the class, the geographic description is founded on the same reference system: the geographic coordinates, which express the growth of a house, are written in the same "language" of those which express the curve of a road.

2. Attributes and territorial representations

The most important element of a GIS data model is attributes[10]. As a matter of fact an application for cartography has the main aim of reproducing cartographies on paper, while a GIS principally aims to analyze data in order to become a support instrument for decisions.

A peculiarity which distinguishes GIS from the most traditional numeric cartography systems is the possibility to associate different kinds of attributes

[9] Other representations which give information on territori
defined as objects of the real world, because, for example,
represented (for example: a climatic map).
[10] Attribute or/ non spatial (descriptive) is the second co
and which characterizes it. Generally in the GIS it indicat
graphic ones which are non-performable in the scale of ac
a linear element (arc) in transit.

and pieces of information (alphanumeric data, texts, photos, drawings, and so on) with geometric elements which represent objects and areas on the territory.

Example of attributes associated with digital cartography

Source: ESRI (2001)

2.1 The representation of the real world in a GIS

The map is the main instrument for the representation of territorial information. On the map, through a system of symbols[11], is represented a model[12] of the real world (basically territorial information) and/ or phenomena located in the real world (thematic territorial information). It should be noticed that the necessity to represent non visible phenomena (for example the course of the temperature in a certain area, the damp, etc...), involves obvious difficulties. And it should be also pointed out that , in an Informative Territorial System, the map is not only the instrument of representation of the real, but also the interface for the use of the system, that means it allows us to access to the system and be able to use the functions. In a Territorial Informative System, besides, new possibilities are opened for the realization of maps, different from the paper ones, maps adaptable to the use, animated, three-dimensional also with representation[13] of the time.

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[11] for example, a rectangle represents a house, a line represents street…, point represents a well….

[12] Some entities of the real world are right and proper points from a semantic point of view; a trigonometric point "is" a point and likewise the top of a mountain "is" a point. Other entities have a real structure, but can be represented as points: this can happen for reasons of scale (we are operating to a scale to which the concerned object has a dimension smaller than about 0.5 mm)or for reasons that depend on the use that we intend to do of the data. Let's consider for example the case of a small town, which can have a diameter of about 1 km and so can be easily surveyed to a scale of 1:250.000. If the aim is to create a GIS application that deals with the flow of tourists, the town will be well represented by a point, although in the end maps to the scale of 1:250.000 will be produced.

[13] The representation of entities of the real world and of their reciprocal mechanisms of interaction through mathematical instruments is called modelling. In the world of graphic there are two modelling instruments which use the same above-mentioned concepts in a surprisingly analogical way: the vector primitives and the raster primitive. The vectors derive from the concepts of Euclidean geometry: on the plan they are points, lines, areas. The raster primitive (the pixel) originate from the idea of dwelling space totally and systematically with a small area which is rectangular most of the times but sometimes also squared. For more information, see Date (1981), Masri (1996), Majed (2005).

The maps can be on paper, on display on screen and they are anyways necessary to interact with the system. As every map they are structured with a title and a symbol system. We have to remember that it is possible to make a distinction between the maps used in order to report basic territorial information (they represent ate the real world, in a faithful or symbolic way, depending on the scale and the use), which constitute the cartography, and the maps used for the representation of the thematic territorial information, which are called thematic maps[14].

Inside the thematic maps it is possible to make a classification according to the type of representation used, identifying 4 basically type[15] of maps:

- **maps of points or of point symbols;**
- **line maps;**
- **maps of area ;**
- **Values maps.**

The points or point symbols maps allow representing discrete quantities or those observed in exact points.

In order to communicate the information wanted there are various possibilities. The points or the symbols can be: with dimensions proportional to the value of the size of various colours depending on the type of size, with various shapes depending on the type of size. We can observe how colour and shape variations are used in order to represent qualitative differences, while the dimensional variations are more suitable to the representation of quantitative differences. The line(ar) maps represent quantities distributed along linear elements, operating on the thickness of the lines, on the colour and the type of section. The areal maps represent two-dimensional phenomena. Operating on the weaving and on the colour, it is possible to distinguish quantities qualitatively different.

Comparison of two models of Representation
Source: Fondelli (1992)

On the contrary with the term values maps, we intend maps to represent digital sizes which change depending on the position. We always use areal maps, but in order to express differences under a quantitative point of view. The digital quantities are, for instance, elevation, temperature, density values, and statistic values. Weavings and colours of the areas are related to the values. Weavings are indicatively denser and/or the colours are more intense for higher values. It is

[14] An area represented in a vectorial way is described through its perimeter and, if other entities do not exist, space around it is irrelevant and therefore inexistent. If you represent the same area in a raster way, the whole space with which we deal will be codified; only some points will indicate the presence of the area, the most part of them will be of no value, but despite of this they also will be codified and recorded in the files.

[15] point, line and area (or polygon) are three elements of (geometric data) vector model, while value (with pixel unity) is for raster model.

necessary to pay attention, when we read and interpretive a map of absolute values and not of specifically values (as the density, for example) because identical absolute values of a quantity, referred to dimensionally different areas, can induce uncorrected meanings(interpretations)[16]. In order to represent absolute values for the quantities, it is opportune to use isoclines maps. These four typologies of maps do not considerate the problem of the representation of the time. In order to obviate to this problem it is possible to produce a series of maps[17] of the same territory in different moments, or it is also possible to produce animated maps.
It is not always possible to describe geometrically and easily a territorial entity through a primitive; for example the administrative limit of a municipality can be described by more than one polygon, if there are administrative islands. A more complicated case is the one expressed in the picture, where in order to represent the idrography it is necessary to use at the same time primitives Polygon and Line.

3. Construction of thematic maps

With every element and every group of elements it is possible to associate an infinite quantity of attributes and to define the relations subsisting between them[18]. The vectorial attributes are usually put into a relational data base, therefore the definition of tables and relations can be considered dynamic and flexible[19] in time, and this offers very wide potentialities in the structure of files and in the applications. In short, while the raster format, for the logic structure of information itself, is fit for managing thematic[20] data, the vectorial format is much more addressed to complex structures of relations between descriptive pieces of information connected to the objects which represent the territory.

With raster data it is possible to associate an infinite quantity of attributes with every elementary cell which represents a certain area of the territory. Besides, with classes of attributes further information can be associated. For example in a

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16 See Fondelli (1992), Jensen (2000), Biasini, Galetto (1992)

17 So, geometric space can be represented, according of two methods or models: the vectorial model and the raster model. The differences between them in philosophical terms make them suitable for different data types. Each of the two models expresses itself in its turn through several primitives: points, lines, areas for vectorial model (also volume if you operate in three-dimensional space); pixels for raster model (also vexes if you operate in three-dimensional space)

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offer a detailed representati
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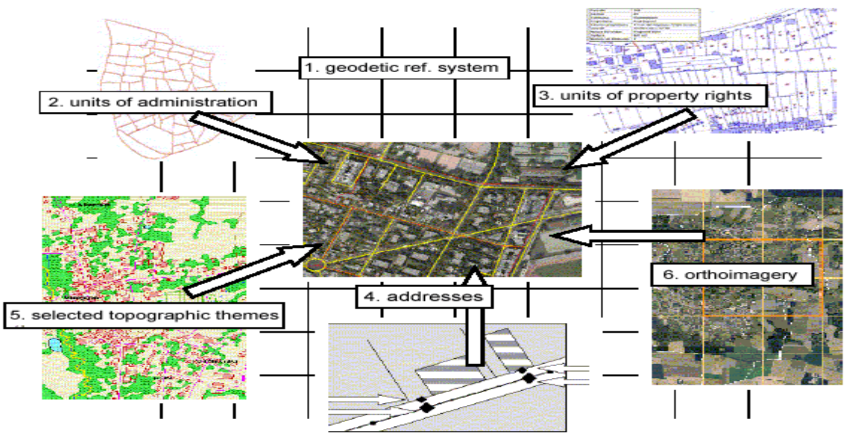

satellite image[21] the spectral responses of the different bands are associated with each of the cells, as well as the use class-value of the ground calculated with opportune algorithms on the grounds of the different spectral responses can be. As far as the vectorial format is concerned the objects that are present on the territory[22] can be represented by points, lines or polygons or by entire compound of these basic elements (objects).

Examples

of thematic maps

Source: Majed (2005)

4. Communication and integration of different data bases

The informative heritage is nearly always lacking in efficient organization, in many cases information exists but it is not univocal or it presents several kinds of trouble. In order that the different available data bases can be used in only one management system[23], it is necessary to homogenize and to standardize these data through a Data Fusion.

This system allows to find parametrically all the pieces of information, which can be very different one from another in nature and type, to deal with these data through standardization and homogenization processes, to relate internal and external data one to another, to get a univocal vision of the data[24].

The Data Warehouse comprehends all the processed data bases. Every variation of the different data sources calls for an updating process of the Data Warehouse.

[21] On the elaborations of satellite image see: Brewer (2005), Jensen (1986) , Foa (1993), and Elachi (1987)
[22] The themes that can be represented graphically are numerous and they can variate according to the form of the made representation and to the use that can be done of it.

[23] There is only one data base to manage the geometric and alphanumeric components of the datum, or two separated data bases, one for each component, or also a data base for the geometric data connected to several data bases for alphanumeric components.

[24] The data base depends on the physic representation of the pieces of information that it describes, it is easy to update and to rescale. Date (1981, 25-32)

Once the data that we consider necessary for the analyses that we intend to do are recovered and homogenized, we have to locate the cartographic object connected to them. This happens identifying at first roads, street numbers, and so on (stairs, interiors, cadastral parcels).

This first effort will later on allow to aggregate data on the grounds of the minimum units, which we have to consider as objects for territorial analyses (for example homogeneous territorial areas[25] of the urban planning: roads, buildings, taxable areas) to define on the grounds of the aim.

On the basis of these units we will have a more or less detailed representation of the problem. In many cases a very detailed definition becomes not very legible. So it is necessary to define from time to time the useful accountings.

The association of the different pieces of information with every single territorial unit, as use destination, density of population, state of property, yield, …, allows to produce thematic useful for the comparison between the different areas.

Supported by the use of indicators, which allow to translate and to provide in simple terms concise information, scientifically valid and comprehensive for all social levels, it is possible to classify the different morphologies of social structures and of urban areas.

5. Construction of an Informative System

Like all systems also Territorial Informative Systems provide for a stage in which data are put in the system, a stage[26] in which they are managed and elaborated and one in which results are brought outside.
In the case of Territorial Informative Systems the three phases can be divided in six parts, that we will call acquisition, pre-elaboration, management, elaboration, analysis and presentation[27].

The acquisition stage deals with:

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[25] for example, a municipality maps show land use of territory and there transformations. See Clarke (1990), Cina (2000)

[26] Many GIS projects you undertake will follow a similar sequence are aware that many considerations influence the design and implementation of a specific project. In brief add-in various operations: design the data base- input spatial data, edit and create topology, input attribute data, manage and manipulate the data-, analyze the data- project transformation, map join and new data relationships-, present the results of the analysis- map and report results. See Majed “Typical GIS project” (2005, 66)

[27] The results of geographic analysis can be communicated by maps, reports, or both. A map is best used to display geographic relationships, whereas a report is most appropriate for summarizing the tabular data and documenting any calculated values.

introduction into the data base starting from their natural format and transforming them to a format[28] which is directly manageable by a computer; this calls for the use of devices (digitizing table, scanner, and so on) and specialized software's; - acquisition inside the system[29] of data -already in numeric format- from third parties.

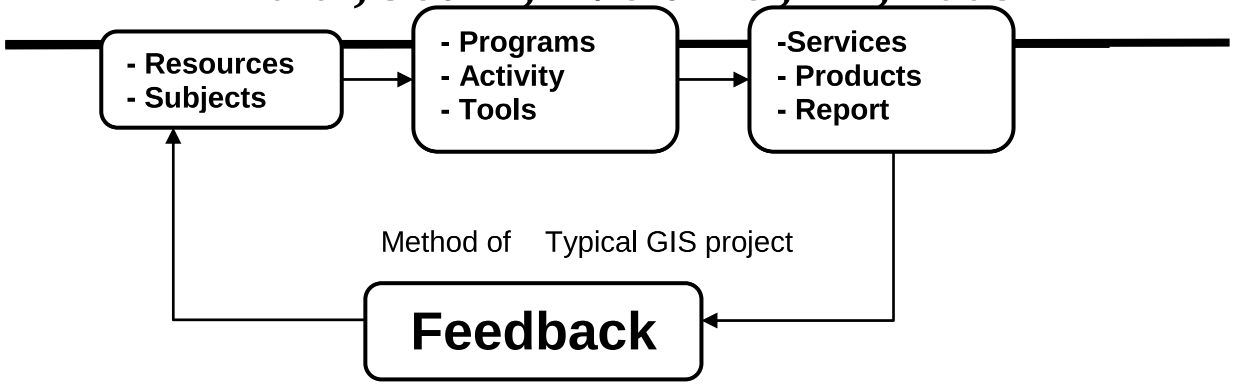
The pre-elaboration stage is a phase which is necessary to transform data into a numeric format and therefore to make them treatable by a calculator; these new data are suitable for being managed by the software that we are using in our specific installation and they are consistent with the other data in our possession. The pre-elaboration stage transforms a motley collection of data into an systematic and consistent collection of data.

The pre-elaboration stage provides for operations that in some cases are executed at the same time as the acquisition stage: therefore the two stages are not always clearly separable.

Making the acquired data consistent with the others that are managed by the system calls often for a process in which the two data groups are compared; this is highlighted by the arrow that starts from the management system and goes towards the pre-elaboration system.

[28] To georeference: shows the correct positioning of data and, in consequence, of the associated information, in a certain system of geographic reference. It is a software procedure which consists of the position, by points with known coordinates (points of control), vectorial data or a raster image in the respective zone of the real territory, in accordance with a determinate system of references.

[29] In the digital version of a geographical traditional map, the position and the description of the elements is memorized in a series of files on the computer. In order to locate the position of the geographical elements, is used a system of Cartesian coordinates x, y; every line is memorized as an orderly series of coordinates x, y. Every area is memorized as an orderly series of coordinates x, y, which defines the parametric segments of the closed figures. With the coordinates x, y is possible to represent points, lines and polygons as lists of coordinates, as a sketch.
In most of the cases, the memorization of the geographical elements uses coordinates of the real world: this coordinate represents real location on the surface of the earth, in one of the many systems of coordinates. The relationships among geographical elements are memorized in the computer in a file, generally called chart, as set of numbers and characters.



Method of Typical GIS project

Management is not a single moment in the life of a datum; it consists of the presence of a series of resources supporting the datum itself that take part in the various moments of the life of the datum: the moment of the introduction of the datum into the system, that of the recall of it for analyses and questions and finally that of its use to draw maps and to produce schedules.

The analysis and elaboration stages concern all operations that the user makes in order to manipulate, to transform data according to various criteria and to extract information from them which can be useful to our work. The operations that the systems are able to make are many and they depend on the system itself and from the data on which we operate.

The functionalities available in these two stages are many and they can be classified according to various criteria; in the picture one tends to separate the processes that transform data and create new informative levels from those that answer questions, complex questions too, formulated by the user.

The presentation stage is that in which the data that are present in the system, selected and/or manipulated by the user through an analysis action, are presented on a paper support (through printers or plotters) or on a volatile support (usually a display station).

6. An example of GIS APPLICATION

The characteristic of the GIS is the possibility to manage geographical elements - represented as points, lines or areas, with their spatial coordinates - integrated with tables of data, so to each graphic element corresponds one record into a table.
Using the principles of the relational databases and the graphic functions, is possible to connect tables among them, create thematic maps, perform spatial and tabular queries, spatial analysis (as distance, contiguity, and so on). Finally is

possible to create a thematic map classifying the values of a parameter, draw layouts for the print.
ArcView is the uses program for this applicatory exercise.
ArcVie creates every theme as a homogeneous set of element: for example can't exist a point in a polygonal theme.
The used data for this applicatory departs come from the Venice commune and defended association of Marghera.
Elaborate matters are following:

1. **to load vector and raster layers, to set up colours, symbols and name, save a project,**
2. **to work with the tables, create a thematic map using values of an external table,**
2. **to editing features on existing themes, Creating a new theme. Editing a shape file joining new points.**

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The hypothesis is that the layer contains information about the location of the samples of sediments, and the external table contains the values of chemical analysis of the sediments.

3. Conclusion

The GIS technology supplements the standard operations carried out on the most common database-like researches and statistic analysis- with the peculiar functions of the GIS like the memorization and the storage of data, the manipulation and the analysis of these ones, the creation of representations and copies of output (maps and tables), these specific advantages of the visualization and of the geographical analysis provided by maps.
The analysis of phenomena on the territory can point out the spatial correlation between them and then it allows to point out cause- effect relations which would not be otherwise revealed: health and environment, road accidents and street features, social and town planning variables, to explain behaviours and social reality, are only some examples of these kind of relations.
The GIS is an instrument used by individuals and organizations, by schools, by governments, by firms, to find innovative solutions to specific problems. A Territorial Informative System, or- more briefly- a GIS system, is basically made by four parts: data, people, instruments and organizational context.
The operations which involve a geographical analysis are made thanks to the use of a map, or, more in general, through a geographical vision of the field of action. This approach is based on the principle of seeing "together different objects", the "sources of territorial information".
Until a few years ago, the drawn map (today called "traditional" map) was the final product of a strict constructive process. Today the graphic expression, the paper map, to let you understand what I mean, is only one of the numerous forms that cartography in digital forms you can have. Besides reaching very high systems of precision, digital maps also synonym of data bank: all the constitutive elements

are classified in hierarchical levels and with codes that define homogeneous series of objects.
Through the structure of data, it is possible to create new elaborations through crossings, isolation, separation of the levels; to calculate perimeters, surfaces, volumes, to build derivative maps, three-dimensional images, sections, variable perspectives. It is important to say that we are not speaking about a digitised traditional paper: the geometrical basis is built up with data directly acquired in digital form through the operations of cartographic restoration.

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