ACC DAR Adapting to Climate Change in Coastal Dar es Salaam

Technical Workshop on Monitoring Seawater Intrusion in Coastal Groundwater

INTRODUCTION TO G.I.S.

Dar es Salaam, 15 November 2011

CENTRO INTERUNIVERSITARIO DI RICERCA PER LO SVILUPPO SOSTENIBILE - CIRPS

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What a GIS is?

"Information System implemented to store, manage, analyze and present data in a topological and spatial context"

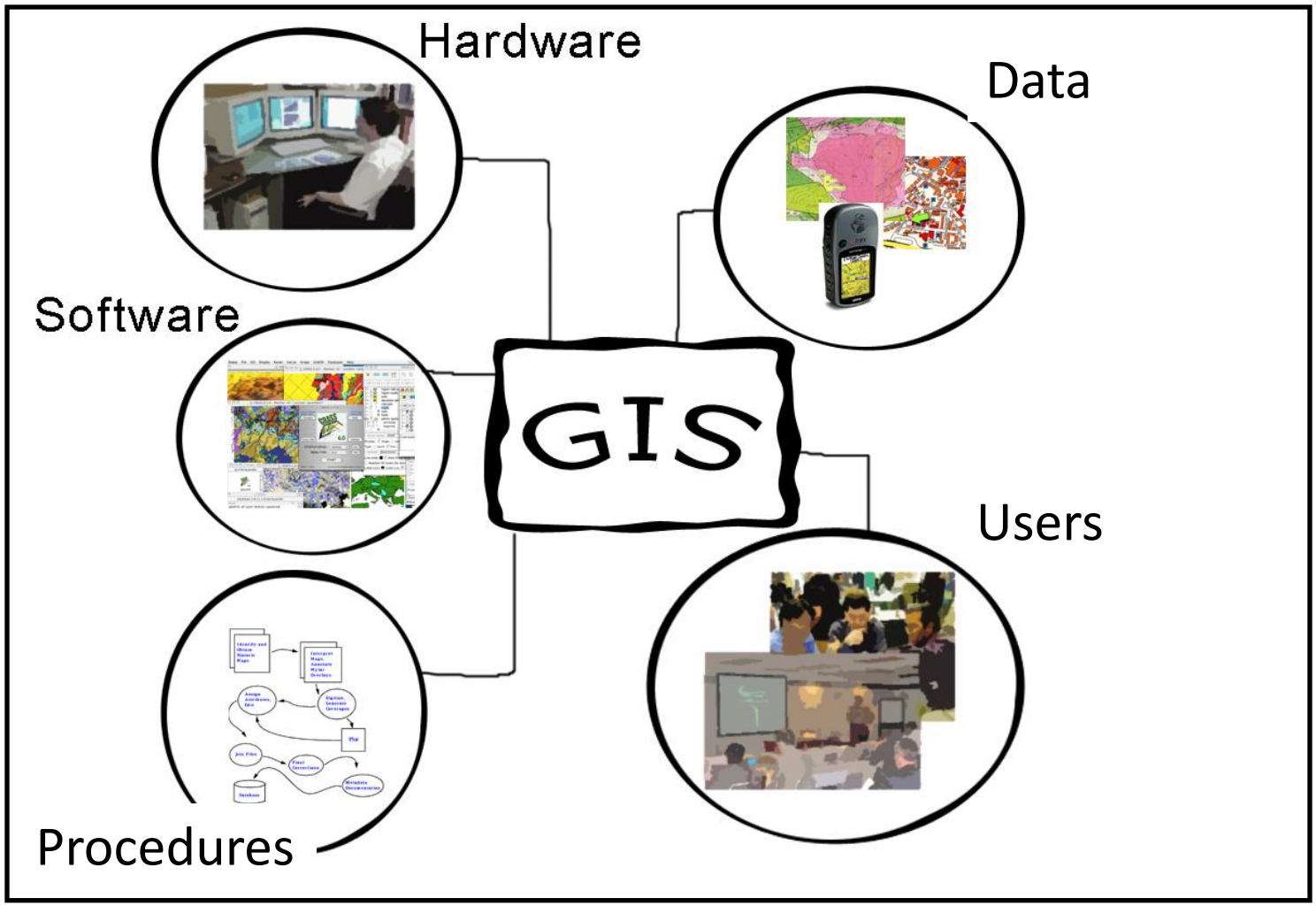
Collection, pretreatment and processing of multi-source spatial data

Maintenance and retrieval of spatial information, with the possibility of editing and updating

Manipulation and analysis, aggregation and disaggregation of data, parameter estimation, modeling

Production of reports and summary data

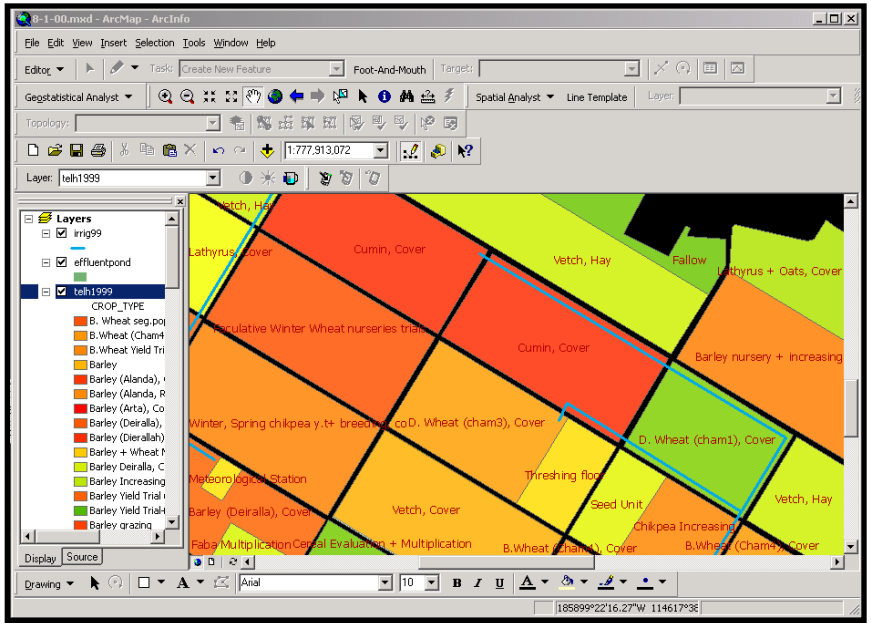
GIS components

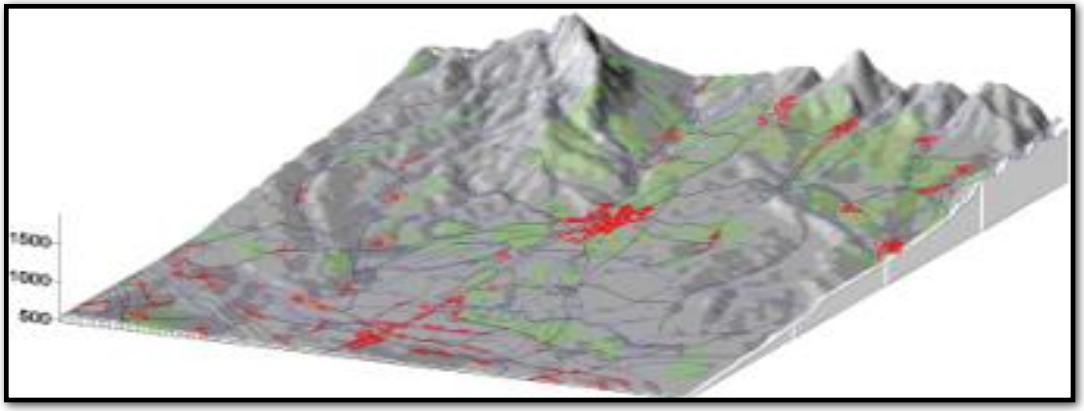


What GIS can be used for

AGRICULTURE

- Farm management
- Pest/Disease tracking
- Crop monitoring
- Yield prediction
- Soil analysis

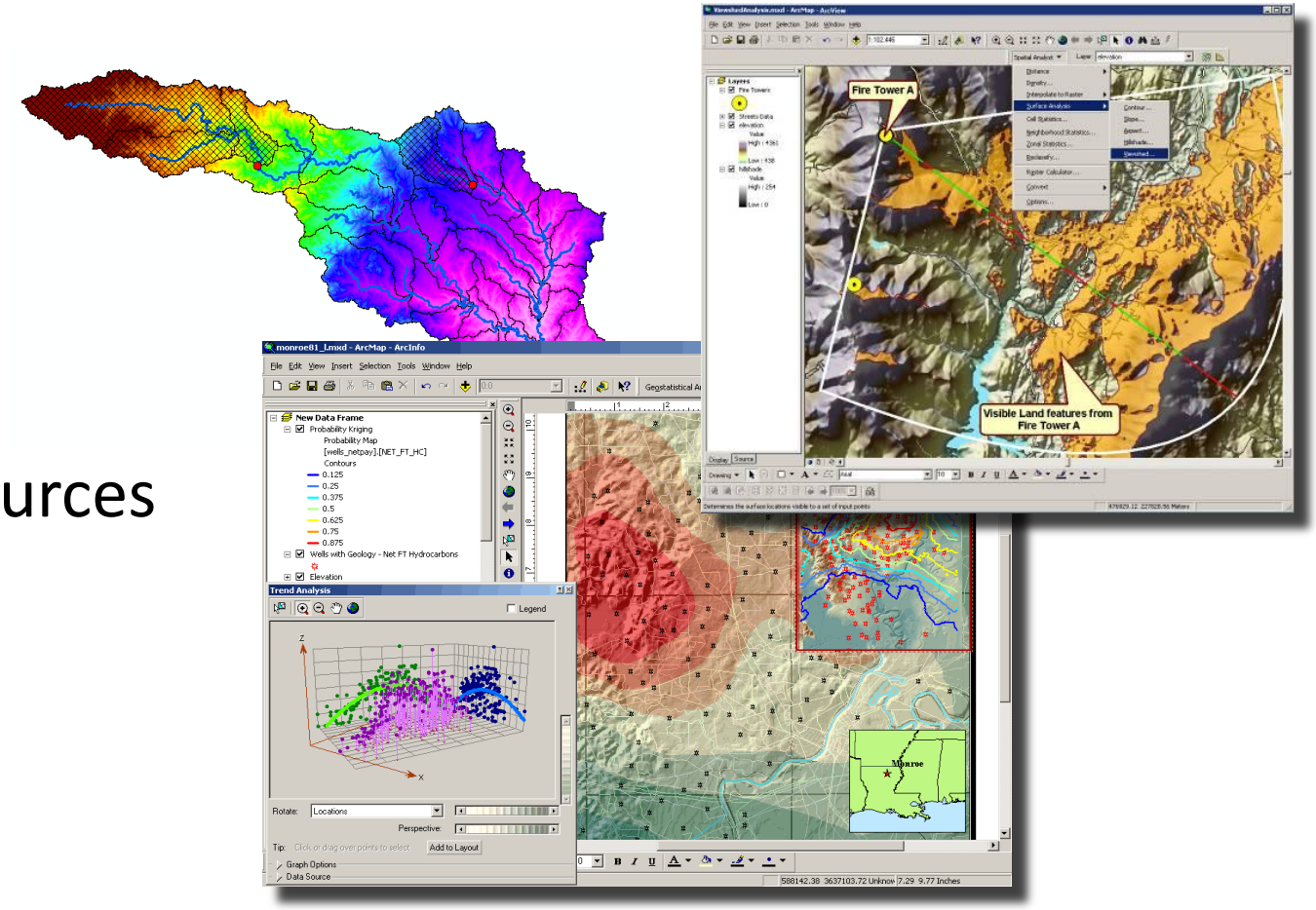




What GIS can be used for

NATURAL RESOURCES MANAGEMENT

- Forestry
- Ecology
- Mining
- Petroleum
- Water Resources

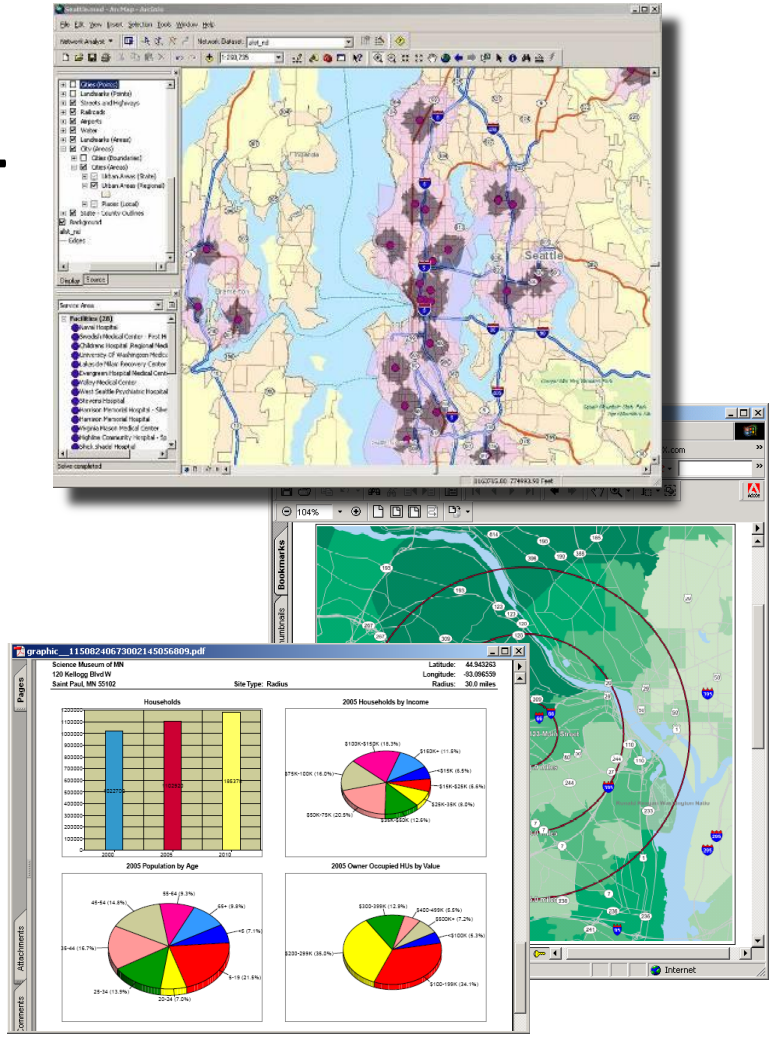


What GIS can be used for

PLANNING AND

ECONOMIC DEVELOPMENT

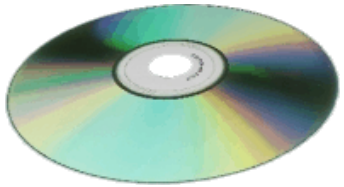
- Land Use/Zoning
- Emergency Preparedness
- Population Forecast
- Market Analysis
- Property Tax Assessment
- Transportation



Sources of data

Maps

Digital data



GIS

Coordinates

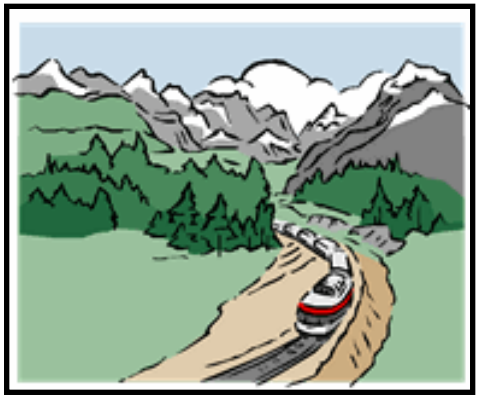
5092218	1585921
5051660	1550442
5051873	1551146
5053749	1548144

GPS

Synthetic diagram of a GIS

Users

Model



Real world

Software + Database

Results

Principles of GIS

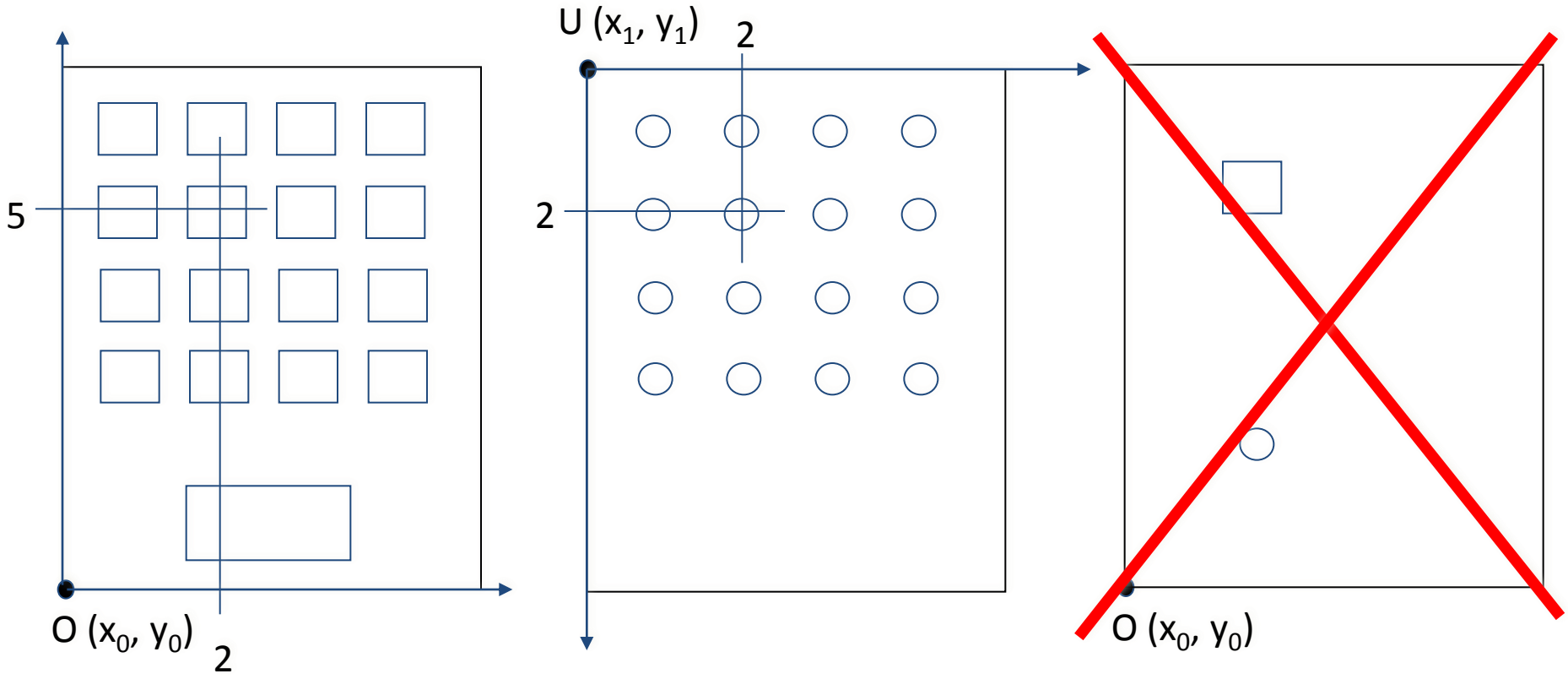
DATA MODEL

Compared to the **geometric** representation of real objects, a GIS has to maintain and manage all information concerning the mutual spatial relationships between different elements, such as connection, adjacency or inclusion: that is to structure the data defining their **topology**. In addition to these two aspects the data model, to be effective, must consider the inclusion of the descriptive data of the individual real objects, defined as **attributes**.

GEOREFERENCING

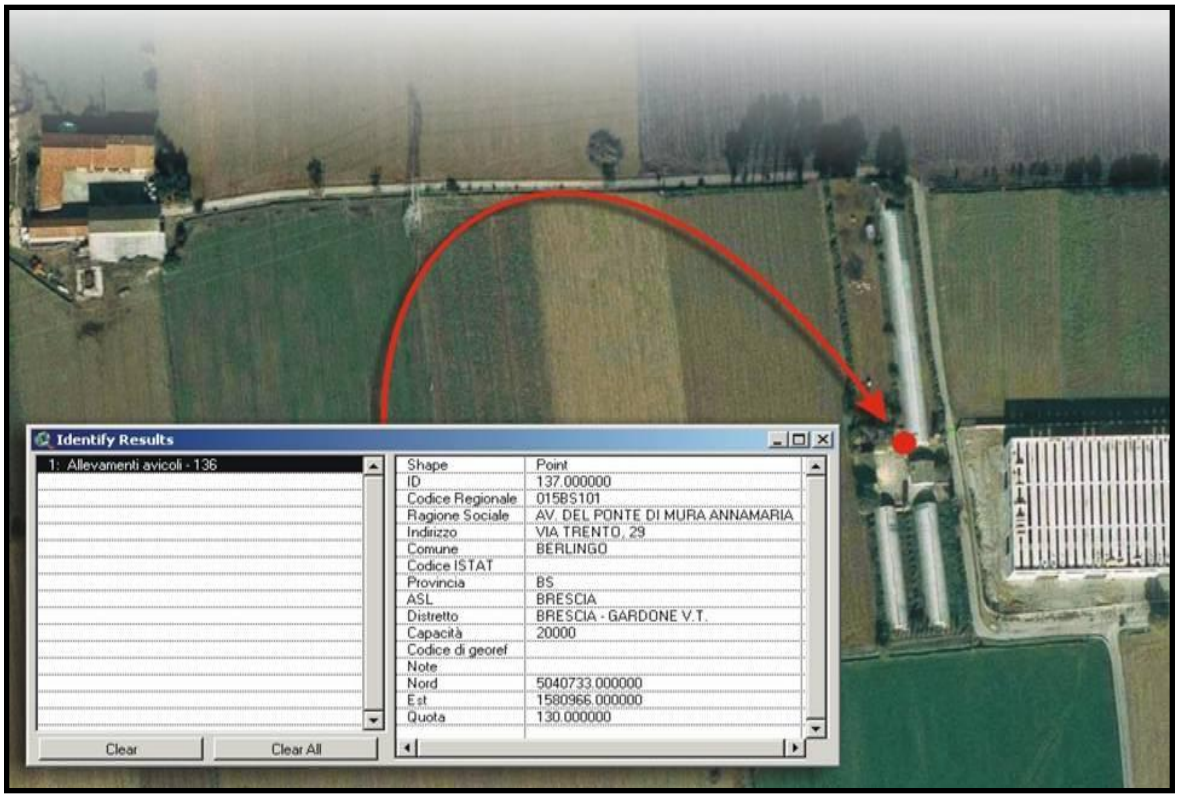
A fundamental characteristic of a GIS is its ability to **georeference** data, or to assign to each element its real space coordinates. In other words, the coordinates of an object are stored with respect to any arbitrary reference system (for example 12 cm and 5 from the bottom edge of a map from the left) or relative to the coordinate system of the device used, as the tablet digitizer or video, but they are stored according to the coordinates of the reference system in which the object is actually located (such as 121 ° 27 'lat. E and 41 ° 53' long. N using the geographic system).

The importance of the reference systems congruence



How does it work?

- **Link map features to Relational Databases**
- **Locate items from the map or by attributes**
- **Manages sets of elements and attributes as layers**



"One to one" relationship between the graphic items and the alphanumeric database records

How does it work?

A GIS model is based on the "layer" concept;

Layers…

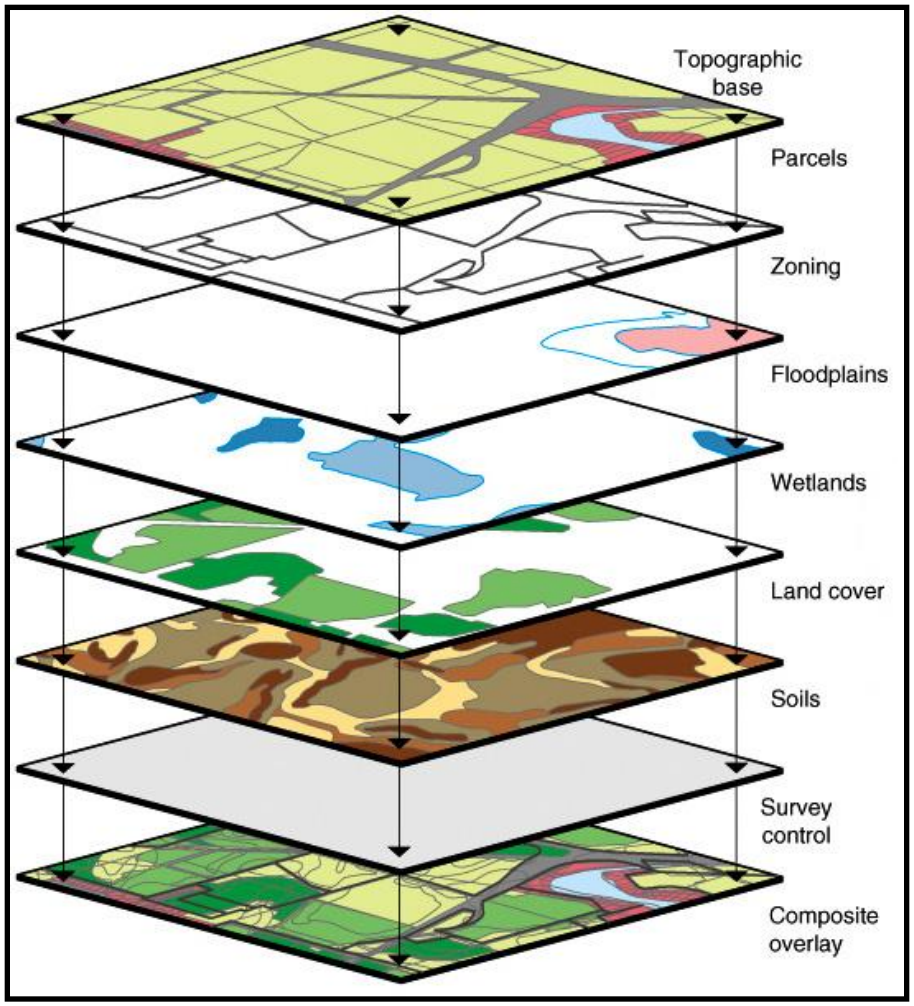
… can be superimposed

… are connected by the mapping (geocoding)

…contain consistent information (ie, lithology, hydrography, road network …)

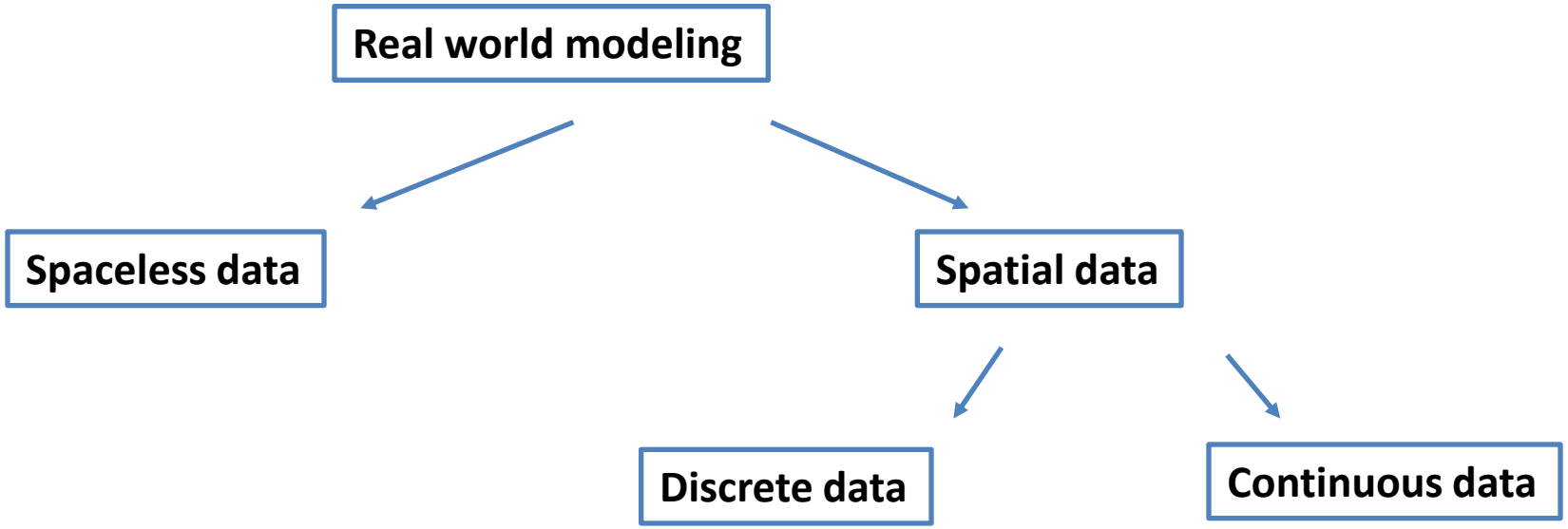
"Is the geographic world a jig-saw puzzle of polygons, or a club-sandwich of data layers?"

Couclelis 1992

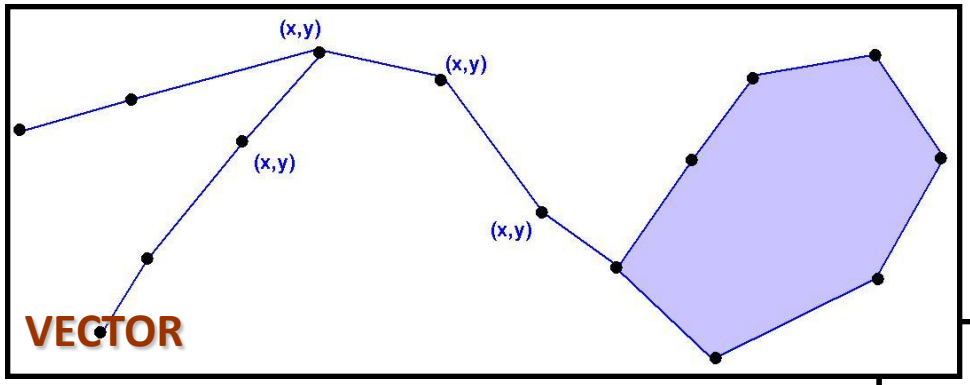


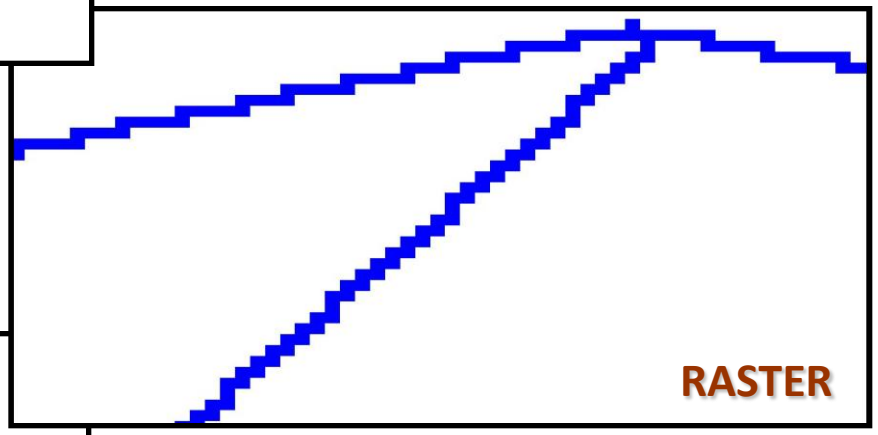
Types of data managed by a GIS

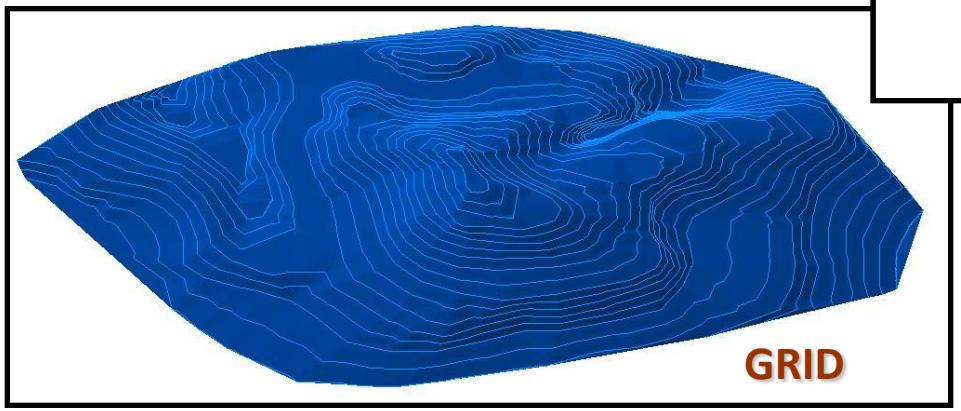
Spaceless: do not depend in any way by a spatial context
Discrete: finite entities that have value only in a given spatial location
Continuous: taking different values in the space



Spatial data typologies







Vector structure

Identify the main territorial elements representing them through points, lines and / or polygons

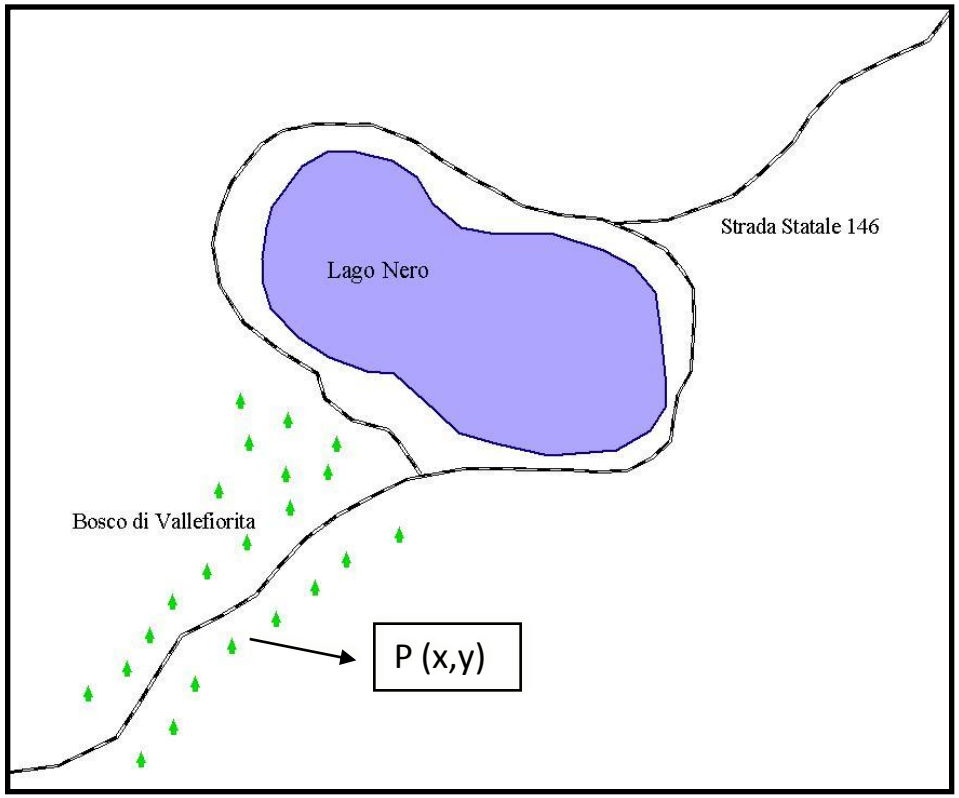
- All points of geographical entities are geo-referenced.
- Through the topological structure the attributes and information are associated to the geographical entities.
- The topological structure also allows spatial analysis in the study area

Vector structure

POINT elements: entities, activities or events distributed in space identified by a single pair of coordinates

Reality

Into GIS

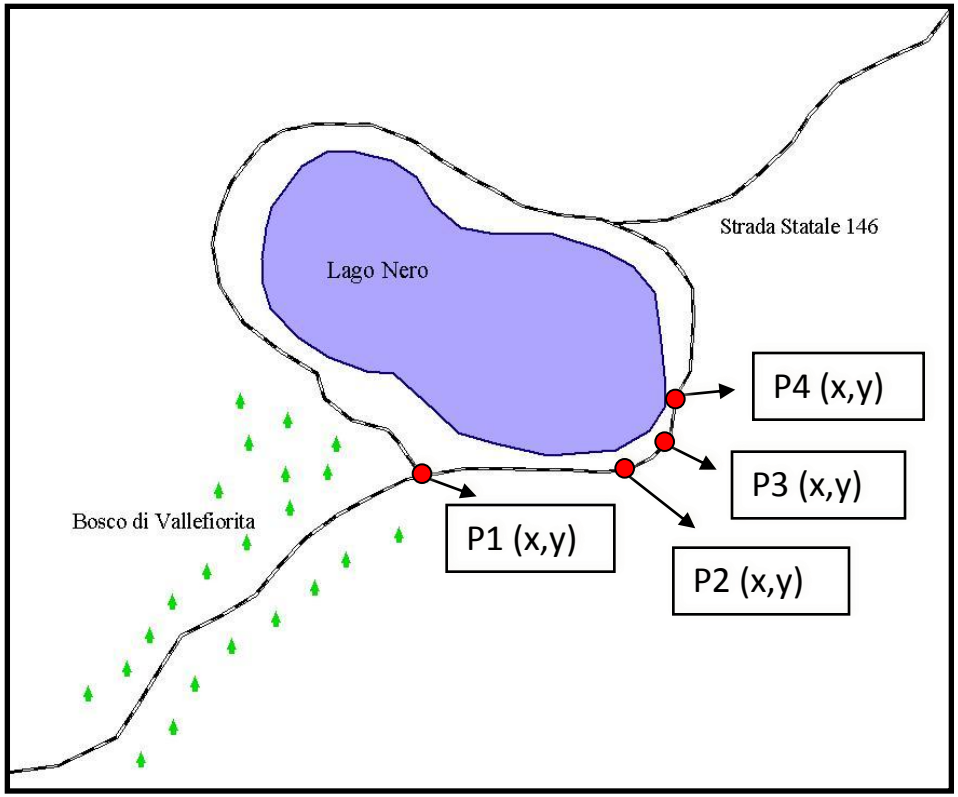


Vector structure

LINEAR elements: represented by a series of points of known coordinates, united to form a line

Into GIS

Reality

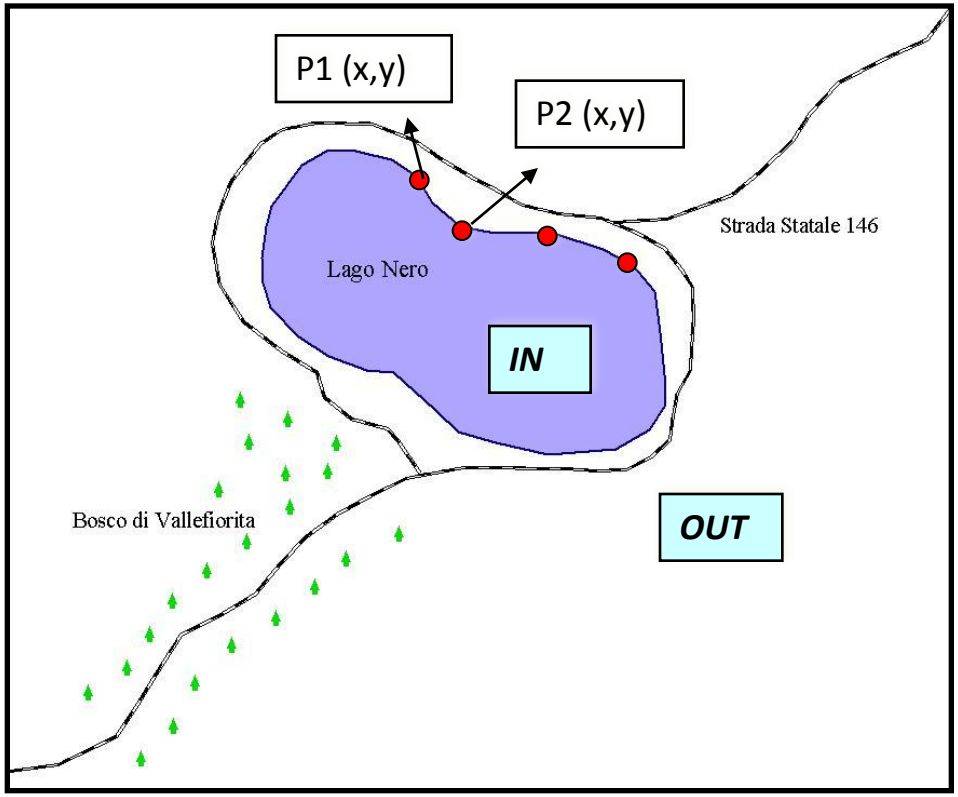


Vector structure

SURFACE elements: represented by a series of lines (combining points) joined in turn to form a closed polygon

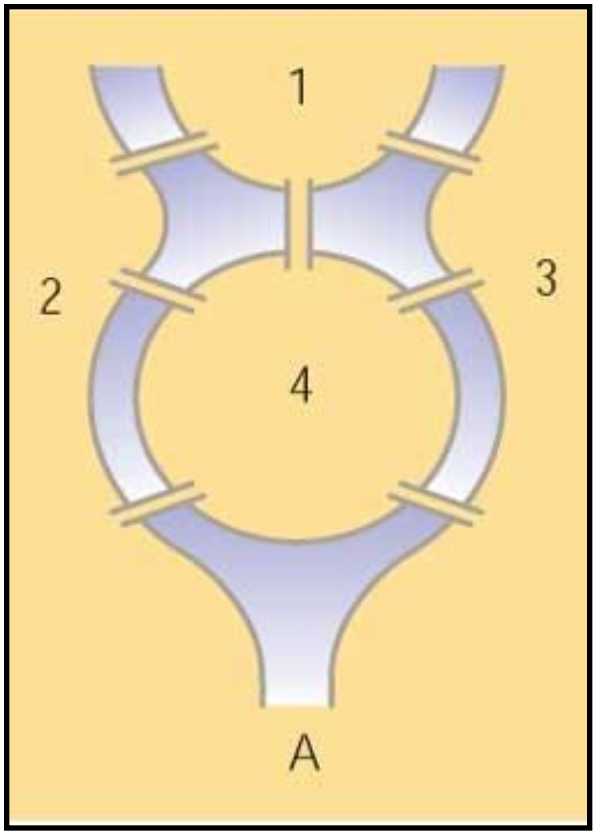
Into GIS

Reality



Topology

In a GIS environment, is defined as the set of spatial relations that bind together neighboring or nearby objects



"The Seven Bridges of Königsberg", Eulero 1736

The topological rules GIS features that are required to comply, are a prerequisite for proper data analysis and for their integrity

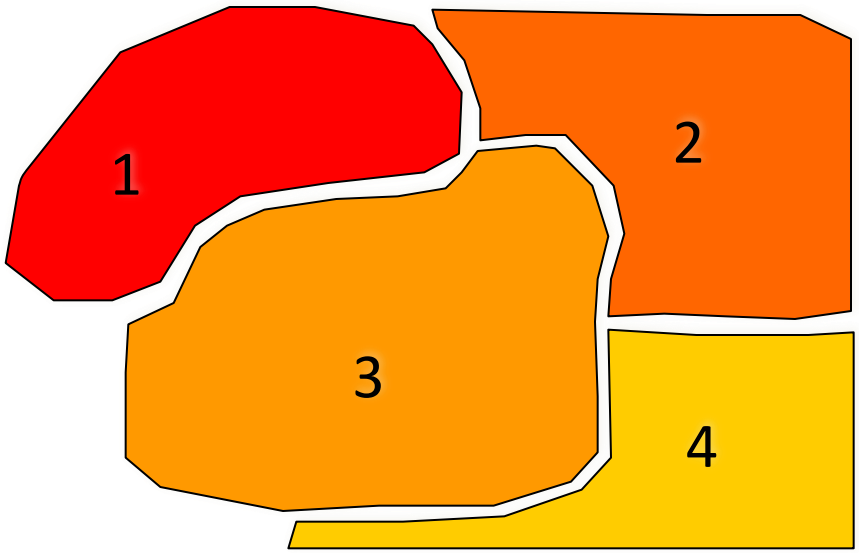
The analysis and processing of NOT topologically correct geographic data may lead to false results or undermine the procedure implemented

The topology is particularly useful in GIS because many spatial analysis procedures do not require the spatial location but only topological information about objects. Eg, to find the shortest path between two points, it is sufficient to know the list of arcs joining the two points.

Topology

Poligonal topology

Each layer is divided into a series of polygons, which are stored as independent elements and represented by the sequence of points that define the contours



ID	punti
1	P1(x,y), P2(x,y),P3(x,y),...
2	P7(x,y), P8(x,y),P9(x,y),...
3	...
4	...
...	...
...	...

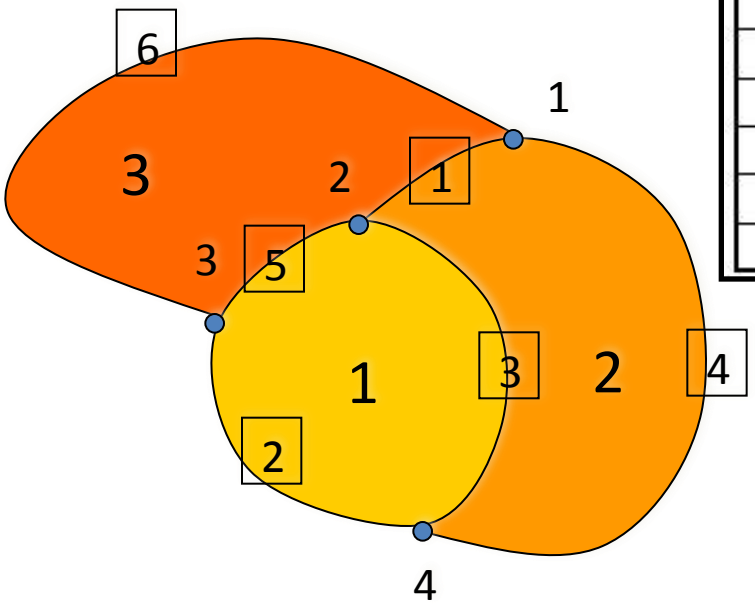
Disadvantages

- No relations
- Junction lines are stored twice

Topology

Arc-node topology

In this kind of topology all geometries (points, lines and polygons) are recognized. Each element is stored through the polygonal arcs (lines) that make it up which are stored through the points of passage.



ID	node_start	node_end
1	1	2
2	3	4
3	2	4
4	1	4
5	2	3
6	1	3

ID	linee
1	5,2,3
2	1,3,4
3	5,1,6

ID	x	y
1	x1	y1
2	x2	y2
3	x3	y3
4	...	...
...	...	...
...	...	...

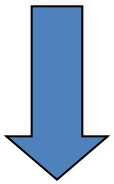
Topology

Arc-node topology

It ’s a more complex topological organization, but softer in terms of memory required for data storage.

The lines common to adjacent polygons are not duplicated.

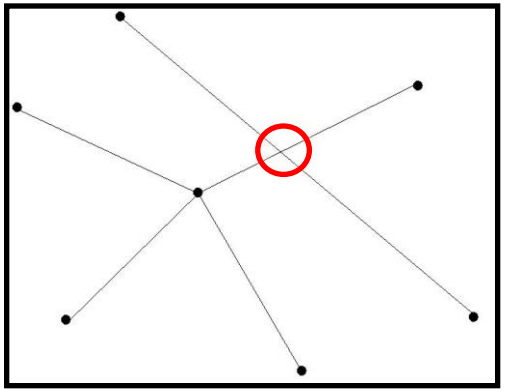
Through this organization, you can create relationships between adjacent polygons.



Relational topology

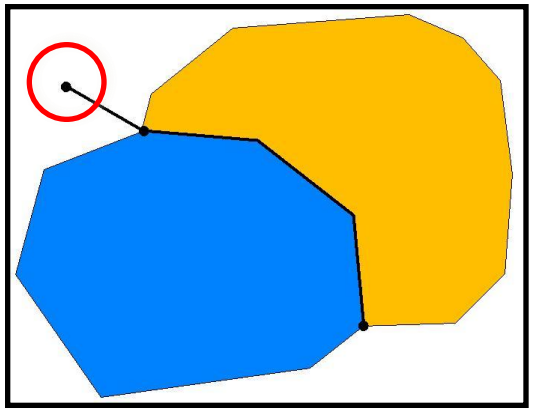
Topology

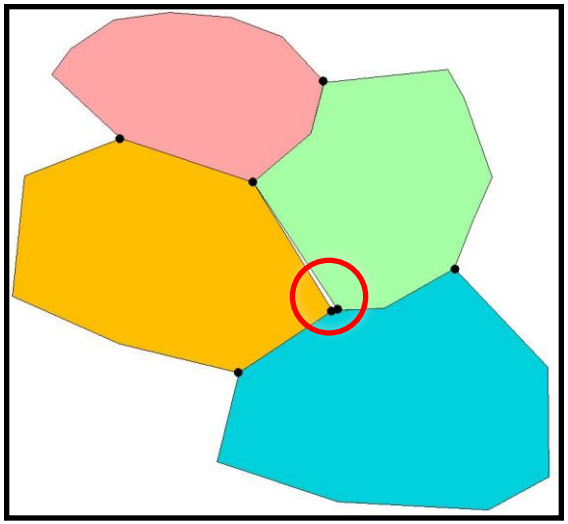
Some examples of common topological errors in GIS fixable through proper functions of "cleaning" or "building".



False intersection of two strings

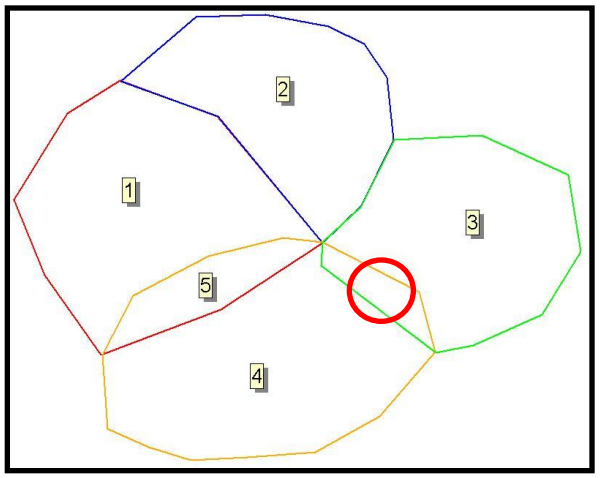
"Dangling" node





False polygon origin

False intersection between polygons

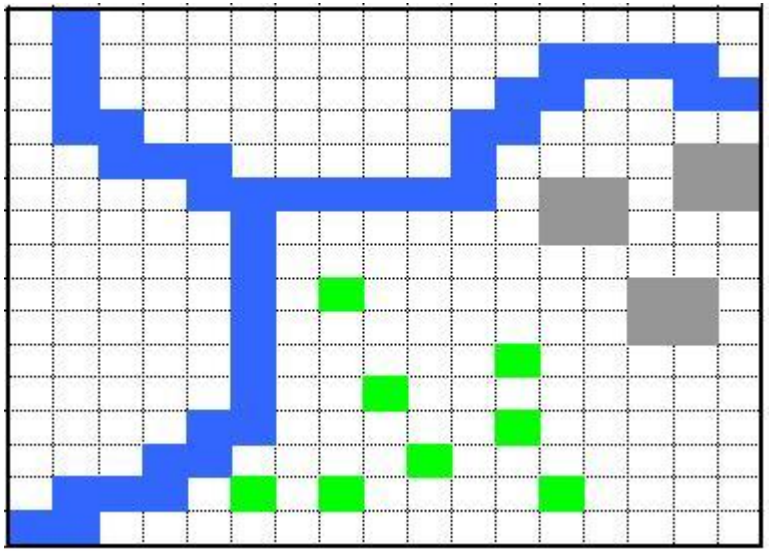


Raster structure

It 's probably the most simple and intuitive organization of geometric data

The data are represented through matrixes of rectangular elements, whose dimensions are dependent on the resolution of the layer

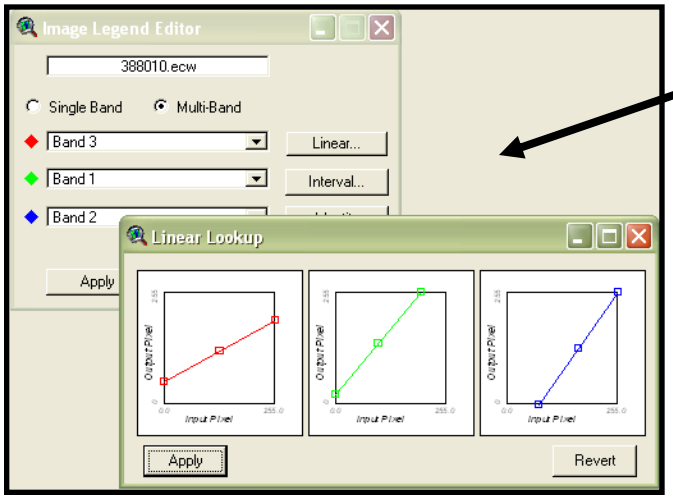
The position of the cell in space is the number of row and column with respect to an origin fixed (usually the cell down-left)



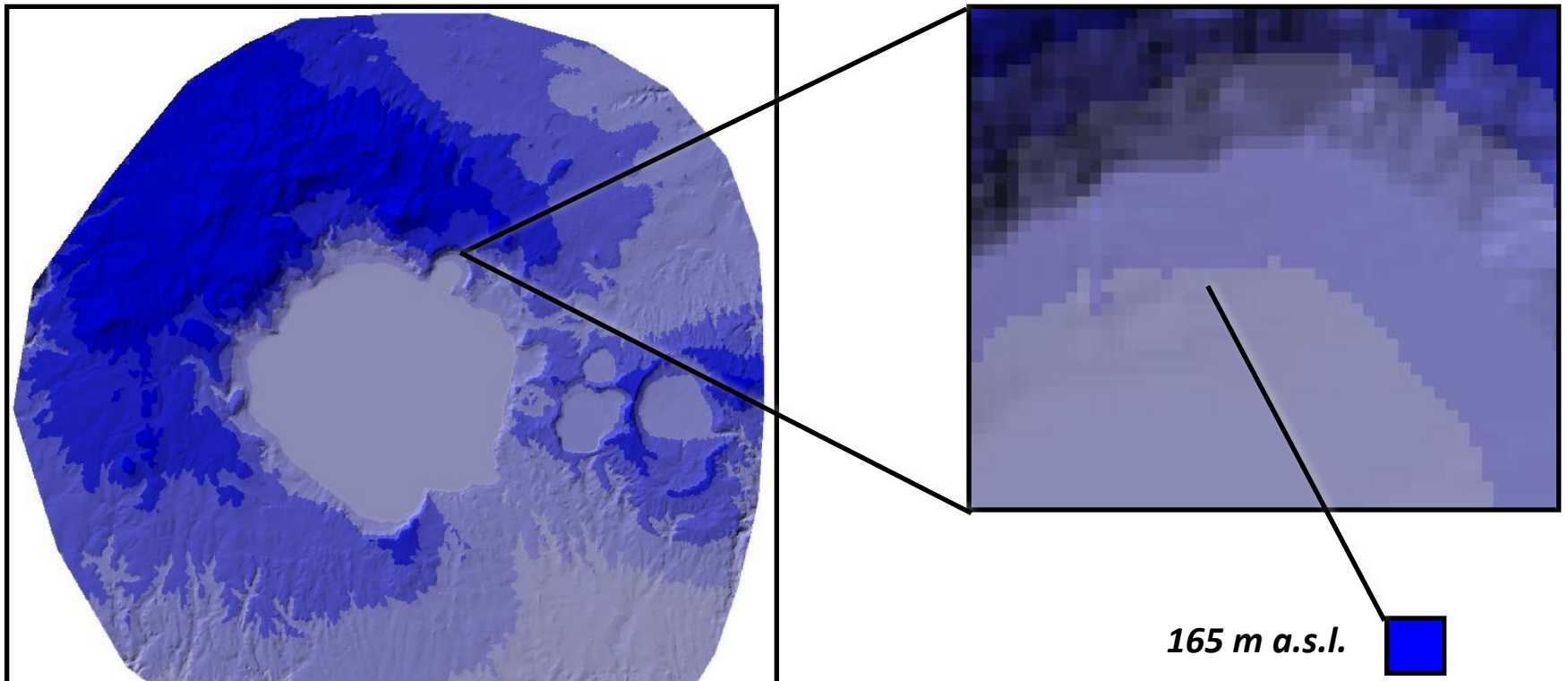
It ’s a representation modality requiring a significative use of memory, so that even the “empty” cells are still considered as belonging to the matrix and therefore included.

Raster structure

Eg a digital photo is nothing more than a matrix of pixels.
Each pixel store an information consisting in the position taken by the three bands in the spectrum of the visible.

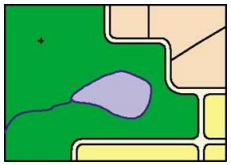


Raster structure



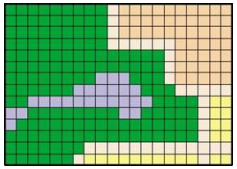
Another example may be a Digital Terrain Model: each pixel stores an information consisting in the average altitude of the land into the cell

Data structure comparison



VECTOR

RASTER

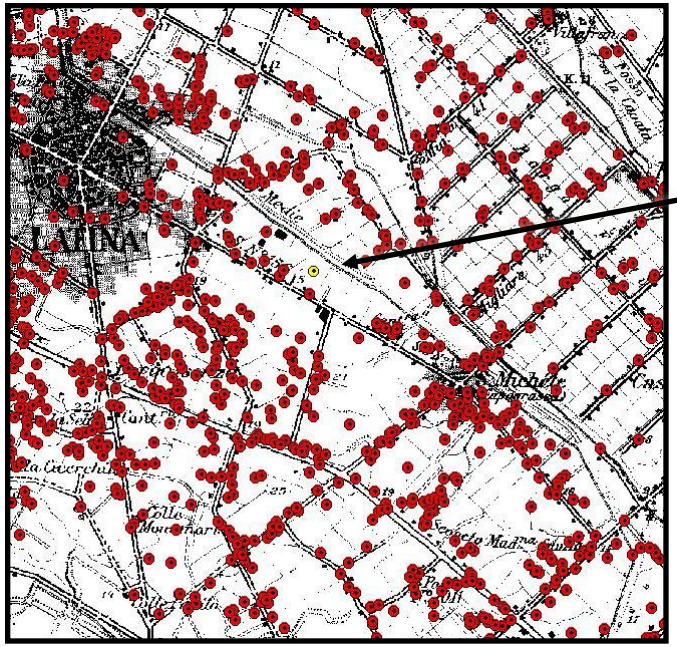


	VECTOR	RASTER
Memory usage	☺	
Topology	☺	
Graphic precision	☺	
Cost of calculation	☺	
Image analysis and remote sensing		☺
Update		☺
Visualization	☺	

Spaceless data (attributes)

"One to one" relation between spatial geographical data and spaceless informations (attributes)

It's then possible to access to the informations from geographic data or, at the contrary, visualize the object that satisfies certain characteristics based on specific requests (queries) made about the attributes of the data.



Attributes of Fabb_domestico.shp

Shape	Idnew	Utm_e_del	Utm_n_del	Dom_mca	Dom_ls
Point	13147	322371	4590436	100	0.00317
Point	13149	325847	4595475	250	0.00793
Point	13152	329203	4588207	150	0.00476
Point	13154	[illegible]	4591440	100	0.00317
Point	[illegible]	331953	4593418	250	0.00793
Point	13158	331182	4587354	200	0.00634
Point	13159	319297	4593539	250	0.00793
Point	13162	329196	4599877	180	0.00571
Point	13163	320602	4590548	50	0.00159
Point	13164	324166	4598188	100	0.00317
Point	13171	322912	4598355	250	0.00793
Point	13179	321357	4596936	100	0.00317
Point	13180	326858	4596342	150	0.00476
Point	13181	319592	4596149	200	0.00634
Point	13182	331966	4587554	108	0.00342
Point	13183	321116	4597931	100	0.00317
Point	13188	328207	4585525	175	0.00555
Point	13189	327095	4587733	105	0.00333
Point	13190	325946	4590226	105	0.00333
Point	13195	324008	4595608	500	0.01585
Point	13197	320429	4592535	100	0.00317
Point	13200	321235	4597860	100	0.00317
Point	13203	331636	4587285	200	0.00634
Point	13206	321635	4592961	250	0.00793
Point	13208	326043	4590934	90	0.00285
Point	13209	317880	4592104	432	0.01370
Point	13211	323833	4591533	324	0.01027
Point	13213	322996	4599204	100	0.00317
Point	13214	330318	4589605	250	0.00793

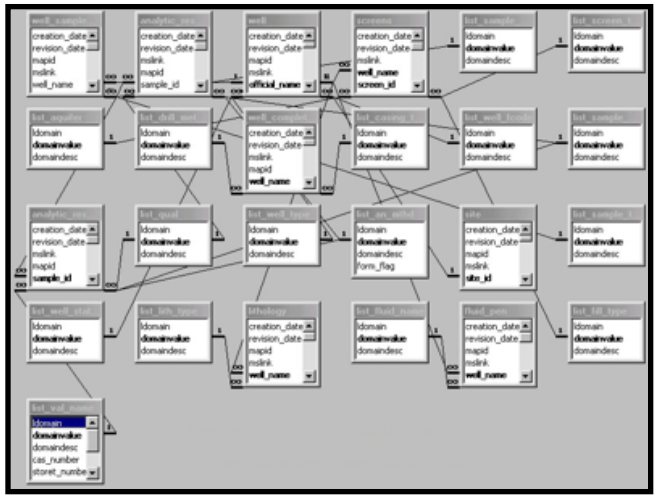
It's virtually possible to store an unlimited amount of information relating to geographic data

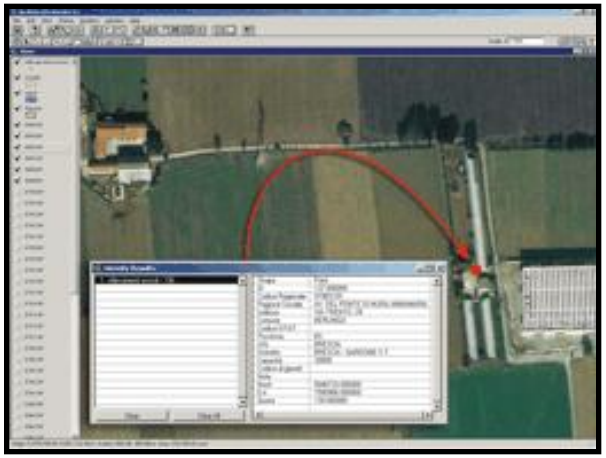
Eg. for a Borehole:

Coordinates
Depth
Yield
Diameter
Altitude
…

Spaceless data (attributes)

Using relational database to store attributes





Make the storage easier and lighter

Increase the efficiency of data queries (querying)

Allowing multiple users

Allow remote management

Increase the security of data access

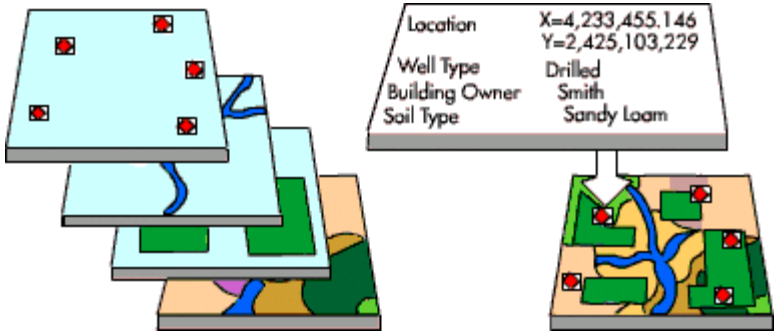
A query example:
What are the wells belonging to the company X that pump yield more than Y mc / h?

Spatial analysis

Using relational database to store attributes

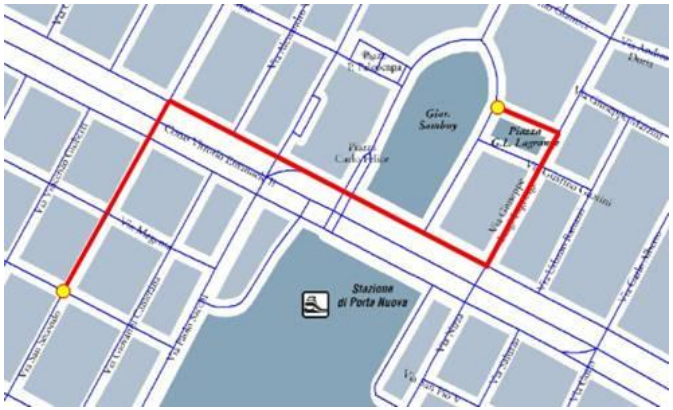
Proximity

Which countries are 3 km and 10 km from the well?



Layers overlay

I want all the information on a given property: land use, owner, type of soil, etc..



Networking

What is the best way to reach the station from the hotel?

References

- Longley, Goodchild, Maguire, Rhind *Geographic Information Systems and Science* 2nd Ed. Wiley, 2005
- Chang, *Introduction to GIS* McGraw-Hill, 3rd ed. 2006 (used also in GISC 6384)
- Lo, C.P. and Albert Yeung *Concepts and Techniques of GIS* Prentice Hall, 2nd Ed. 2006 (best technical intro.)
- Worboys, Michael *GIS: A Computing Perspective* Taylor & Francis, 2nd Ed 2004 (Computational focus)