Geographic information systems (GIS)

Software components

Operating systems

The operation of a computer is based on its operating system. It assures that all parts of the computer function in liaison. Most common are Microsoft's operating systems for PCs.

In *MS-DOS* (Microsoft Disk Operating System) the operation is regulated by text lines. This permits the administering of files by name. More modern are *Windows* operating systems such as Windows 3.1, Windows 95, Windows 98, Windows NT, Windows 2000, Windows ME and Windows XP, utilizing graphic symbols (icons). Windows acts as a graphical user interface (GUI). Windows is now a network compatible system.

An operating system for workstations is UNIX, which has been adapted for the computers of specific manufacturers: HP-UX by Hewlett-Packard, AIX by IBM and Linux, which is generally available. Unix development dates back to the 1960s. It was originally designed for the operation of mainframe computers with multitasking. It contains a great number of data security features regulating access.

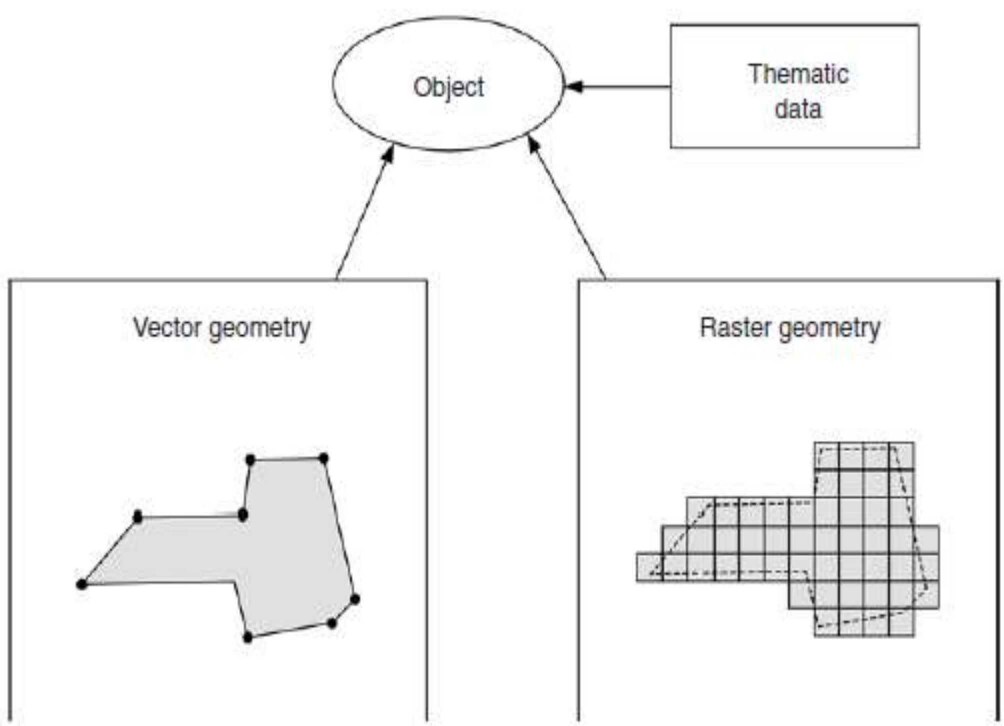
GIS application software

Based upon an operating system, augmented by additional programming tools and standards, various vendors (ESRI, Intergraph, Siemens and many others) have developed GIS software packages. They have a great number of elements in common:

- Translation (translation, rotation and scale change in the two dimensions of the screen).
- Polygon creation (linking a line network to the origin of the line string).
- Adjustment of polygons (observing conditions of right angles and parallel lines).
- Line smoothing (connecting line strings by curves).
- Vector to raster conversion (for display of vector information).
- Raster to vector conversion (line derivation of vectors from pixels representing a line).
- Edge cut-off (to fit a seamless data set to the screen).
- Edge matching (to fit lines of adjacent tiles together).
- Geometry edit (to change point and line information).
- Intersections (between point locations, lines and polygons) in one layer.
- Intersections between layers.
- Buffer zone generation for points, lines and areas.

- Counting of points in areas.
- Measurement of point coordinates, distances and areas.
- Interpolation.
- Modelling functions.
- Network analysis.
- Symbol and text generation.
- Generalization.
- Map annotation.

These tasks will be discussed for vector and for raster systems see figure below:



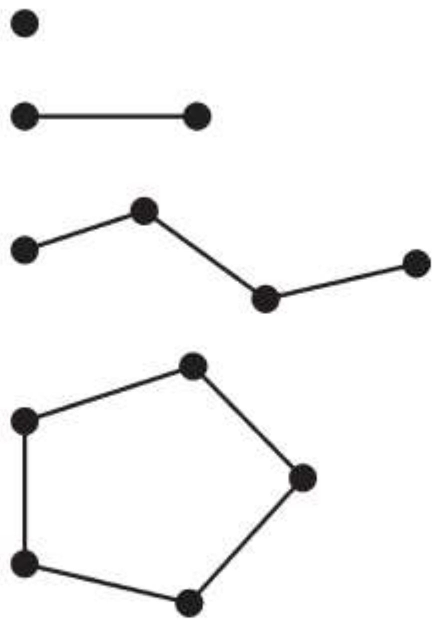
Vector systems

Object representation

The modelling of vector geometry depends on local or georeferenced coordinate systems. The advantage of vector systems lies in the possibility of recording and displaying coordinates with full measurement accuracy of ground surveys or of photogrammetric point and line measurements. In

, vector systems also contain less data volume than raster images of the same area. Furthermore, it is easy to attach alphanumeric attributes to the defined elements of a vector system (see Figure below), such as:

- Points.
- Lines.
- Areas.
- Objects.



A point is defined by its coordinates, x, y, and by its node number. A line is defined by the coordinates of its end points, $x1$, $y1$ and $x2y2$ and its line (arc) number. A line string is defined by the coordinates of all points forming the line string: x_1y_1, x_2y_2, . . .x_ny_n. An area is defined by the coordinates of the line string ending at the initial points: x_1y_1, x_2y_2, . . .$x_{n-1}y_{n-1}$,
x_1y_1. To points, lines and areas, attributes with alphanumeric thematic data may be attached (see Figure below).

In the next Figure the different ways in which an area may be represented are shown.

B shows the digitization in the computer-aided design (CAD) form of ‘spaghetti graphics’. CAD systems such as Autocad or Microstation in their simplest form do not automatically snap adjacent lines to common end and intersection points. Their result is a visual area representation, which cannot be analyzed for adjacency.

C shows the representation of areas by formation of closed individual polygons and by selection of additional line strings. Intergraph's MGE software provides this partial topology model.

D shows the generalized attempt to digitize areas through the formation of polygons and by intersecting them with lines. In this way, a relational geometry model may be built up if the rules of topology are observed.

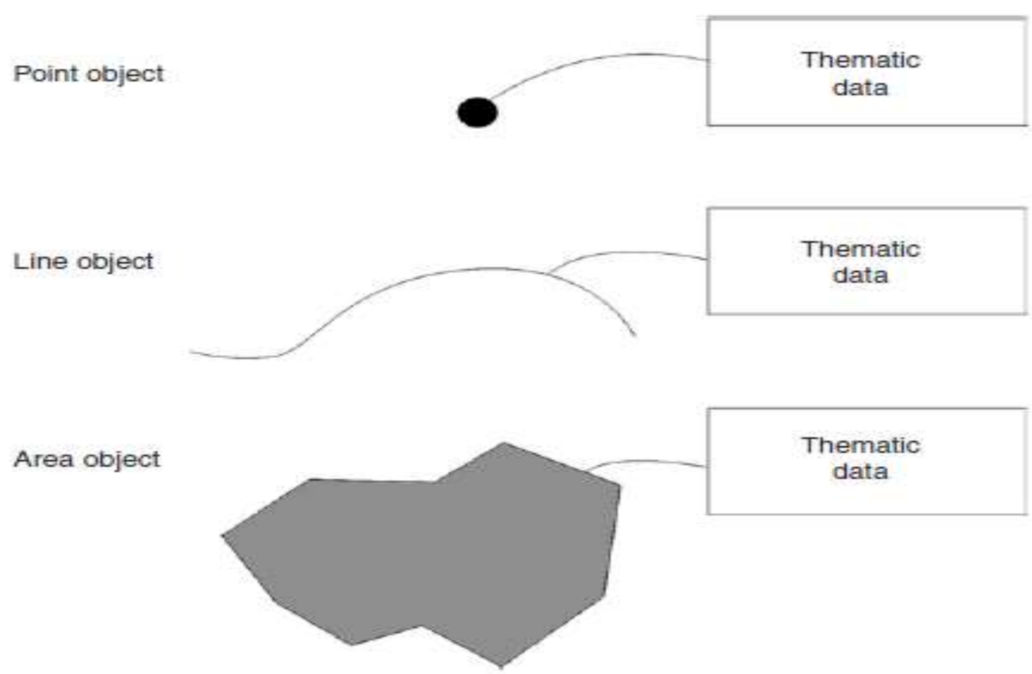


Figure illustrate Attribute links.

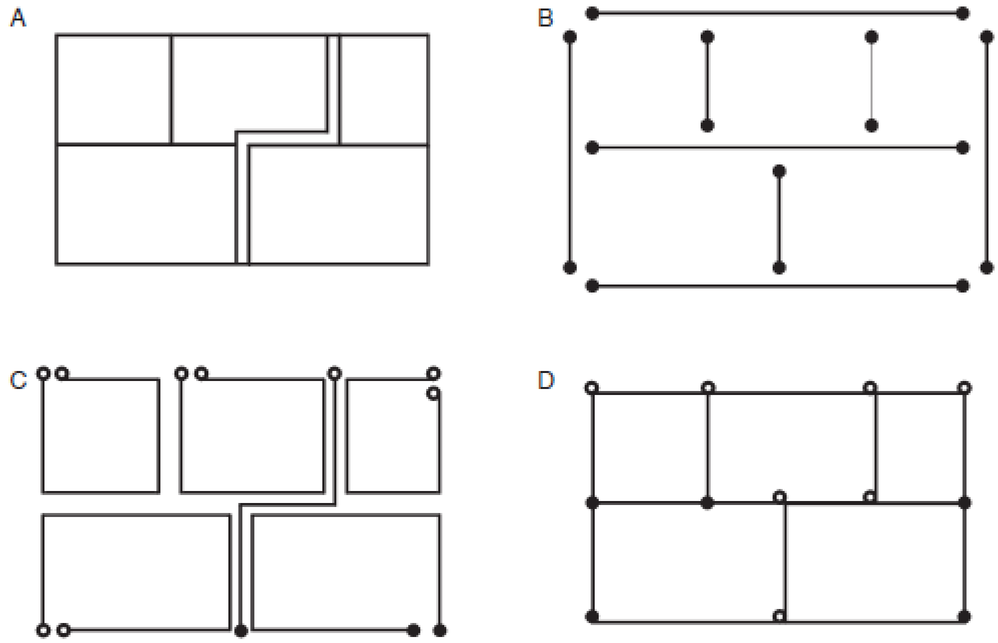
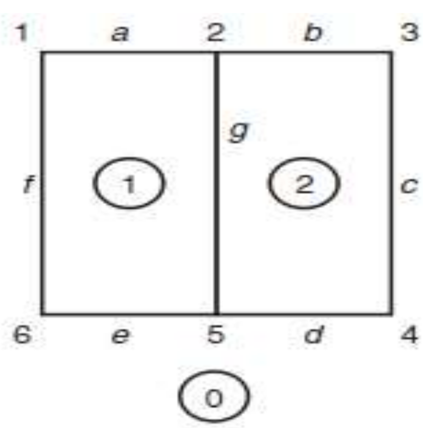


Figure illustrate Graphic representation of an area.

The relations are expressed in three relational tables. These relate to Figure below



A line-area table

Line	*Area left*	*Area right*
a	⓪	①
g	②	①
e	⓪	①
f	⓪	①
b	⓪	②
c	⓪	②
d	⓪	②
g	①	②

A coordinate table for all points

Point	*Coordinates*
1	x_1y_1
2	x_2y_2
3	x_3y_3
4	x_4y_4
5	x_5y_5
6	x_6y_6

A line-point table

Line	*From point*	*To point*
a	1	2
b	2	3
c	3	4
d	4	5
e	5	6
f	6	1
g	2	5

Note that the outside area is also identified, and that the direction of the line must be indicated to assure full topology. The relational model may be contained in a large relational database (Oracle Spatial, Siemens) or it may be administered separately (ArcInfo by ESRI).

The knowledge of the topological relations permits neighbourhood queries. Non-graphic attributes may be directly attached to the identifiers of points, lines and areas or to objects composed of areas or line strings.

Early GIS developments favoured the CAD or partial topology models, because they needed less computing power and could operate on larger databases. Attributes were then attached to 'pointers', which consisted of points identifying the graphic placement of an area (parcel) number, constitutingthe link to the non-graphic database content.