What is a Geographic Information System?

This material is taken from the SAGE Introductory Guidebook, by Robert M. Itami and Robert J. Raulings, published by DLSR, Melbourne, Australia, 1993.

Definition

> *A Geographic Information System (GIS) is a computer program for storing, retrieving, analysing, and displaying cartographic data.*

In a GIS, the Earth's features are not only represented in pictorial form, as in conventional paper maps, but as information or data. This data contains all the spatial information of conventional maps, but when stored in a computer, is much more flexible in the way in can be represented. Spatial data in a GIS can be displayed just like a paper map with roads, rivers, vegetation and other features represented as lines on a map complete with legend, border and titles, or it can be represented as a set of statistical tables, which can be converted to charts and graphs. The most important feature of GIS is that spatial data are stored in a structured format referred to as a spatial data base. The way spatial data are structured will determine the how easy it is for the user to store, retrieve and analyze the information.

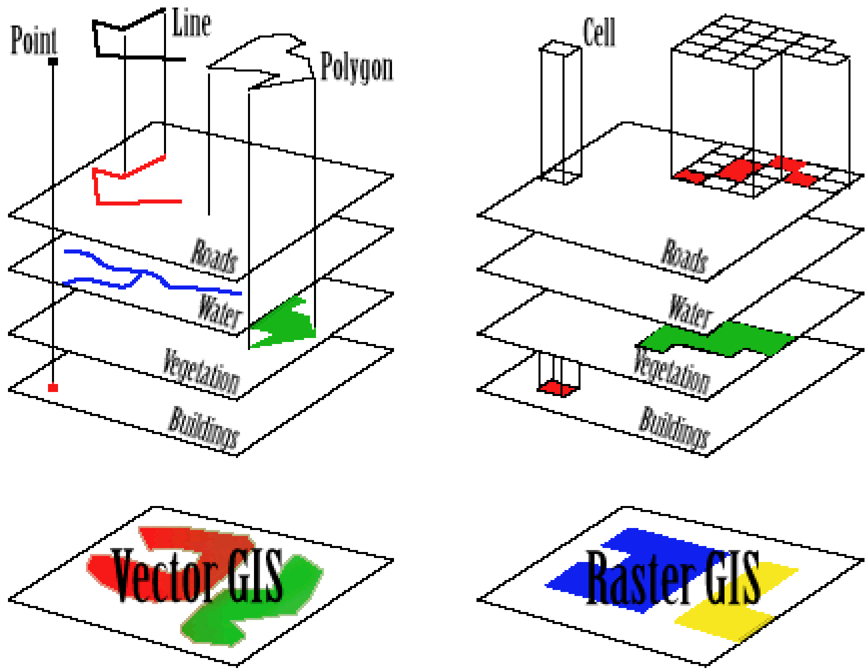
Vector and Raster GIS

There are two major methods of storing mapped information. Geographic Information Systems which store map features in **vector** format store points, lines and polygons with high accuracy. They are preferred in urban applications where legal boundaries and the analysis of networks are important.

Raster Geographic Information Systems, which store map features in raster or grid format, generalize the location of features to a regular matrix of cells. Raster GIS data structures are preferred for digital elevation modeling, statistical analysis, remotely sensed data, simulation modeling and natural resource applications.

Thematic Mapping

Maps in Geographic Information Systems are represented thematically. A standard topographic map will show roads, rivers, contour elevations, vegetation, human settlement patterns and other features on a single map sheet. In a GIS these features are categorized separately and stored in different map themes or overlays. For example, roads will be stored in a separate overlay. Likewise, rivers and streams will each be stored as a separate theme. This way of organizing data in the GIS makes maps much more flexible to use since these themes can be combined in any manner that is useful. The following illustration shows conceptually how maps are stored as themes in a GIS.



Each different theme is stored on a separate overlay. The overlays on the left represent a vector based GIS, where the information is stored as a series of points, lines and polygons. The overlays on the right represent a raster based GIS, where the information is stored as a series of discrete units called cells.

Geometric classification of spatial information

In addition to organising spatial data by themes, mapped information is also structured as points, lines and polygons.

Point Data

Examples of point data include location of wells, post office, man holes, stream gauges, bird nesting sites or control points.

Line Data

Examples of line data include road networks, utility lines, stream drainages, and fault lines.

Polygon Data

Examples of polygon data include land use, vegetation cover, electoral districts, soil types, and zoning.

Textual data base

Besides the spatial information in a map, the GIS can usually store non-spatial information which is related to the spatial entities. For instance an urban GIS database may have a map theme of property boundaries. Attached to each parcel will be a textual database which might store the name of the owner, the address, the assessed value of the property, or the type of services and utilities on the site.

Querying the GIS

The GIS stores both spatial and non-spatial data in a database system which links the two types of data to provide flexible and powerful ways of querying or asking questions about the data. An example of a spatial query might look like this:

'Locate and display all playgrounds downstream of landfills within 100 year floodplain'

This type of query is answered by a set of commands to the GIS that then generates a map display of all sites meeting the criteria expressed in the query. The user may also query the GIS by the textual attributes in the tabular database and then display the map features which correspond to these attributes. An example of this type of query is as follows:

'Display all water mains installed before 1950 with a diameter less than 12 inches'

This query results in a map display of the water mains in the study area with the specific mains in the query highlighted. Alternatively a report could be generated which lists the complete information on each segment of watermains which meet the criteria in the query.

GIS data integration

Many Geographic Information Systems handle both vector and raster data from a wide variety of sources including satellite imagery, cadastral information, hand digitised maps and scanned images.

Geo-referencing

In order to ensure that all maps in a GIS database overlay accurately, the data set is 'geo-referenced' to a common coordinate system. In many countries the Universal Transverse Mercator (UTM) projection is commonly used to define coordinates in the GIS.

Spatial analysis

Spatial analysis is a set of analytical procedures applied to GIS data to describe, predict, or assess environmental or social issues. Spatial analysis techniques include methods for:

- Reclassifying map overlay features
- Measuring distance, and area
- Interpolating values
- Identifying the co-occurrence of values on different map themes (overlay analysis)

Digital elevation modelling (DEM)

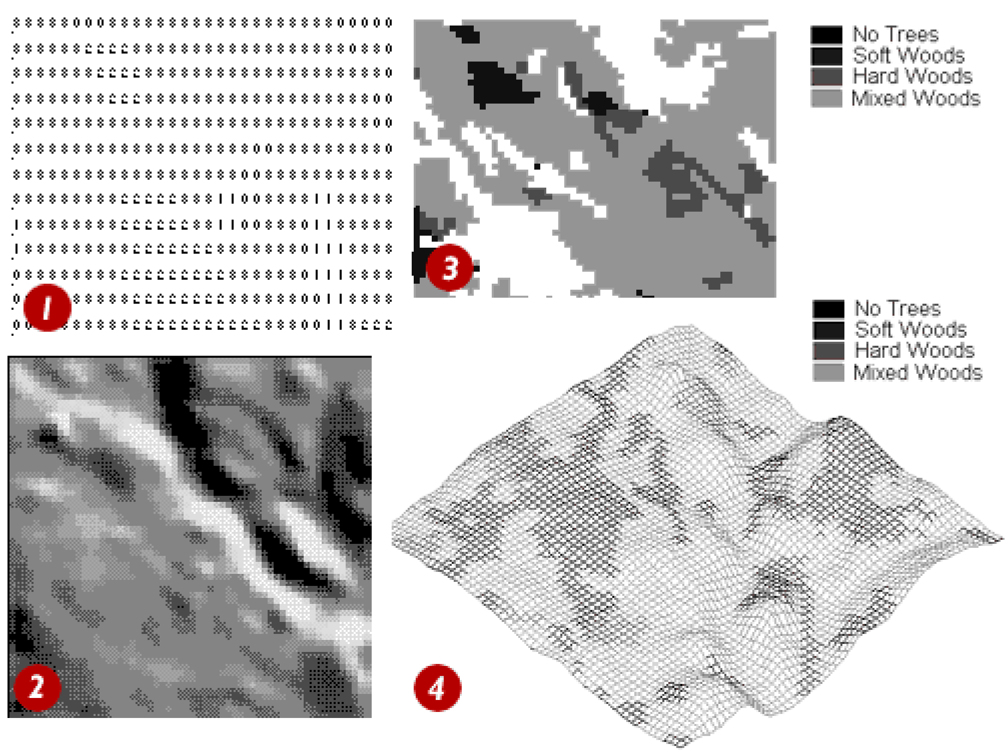
There are also specific methods for analysing terrain including:

- Calculating slope
- Solar aspect
- Viewshed analysis (calculating visibility)
- Runoff analysis

Automated cartography and data visualisation

Geographic Information Systems also have sophisticated graphic capabilities for map overlay production and data visualisation in plan and perspective. Conventional techniques for producing cartography are automated in Geographic Information Systems. In addition, most systems will provide methods for displaying maps in three dimensions. In the illustration below, the same region is depicted as:

1. a set of numbers
2. a shaded relief map overlay
3. a hatched drawing in plan view
4. a perspective drawing draped over an elevation map.



There are also other techniques for representing spatial data, including charts, histograms and statistical tables.

GIS applications

Because Geographic Information Systems are designed as a generic system for handling any kind of spatial data, they have a wide range of applications in urban and natural environments. Because SAGE is a raster based program it is generally more suited for modeling natural processes. Some examples of GIS applications in urban and rural settings are listed in the chart below:

Urban GIS	Applications might include the provision of utilities, management of storm water, location and allocation of critical resources such as hospitals, schools or fire stations, study of disease outbreak patterns, crime analysis, waste collection routing or hazardous waste transportation.
Natural resource GIS	Applications might include any of the following from different fields:
Agriculture	Agricultural capability analysis, land conservation, market analysis, or whole farm planning.
Forestry	Timber assessment and management, harvest scheduling and planning, environmental impact assessment, and pest management.
Wildlife	Habitat assessment and management, identification of rare/endangered species and habitats, and impact assessment.
Catchment management	Runoff and erosion modeling, sedimentation and water quality studies, evaluation of management alternatives, and integrated catchment management.
Archaeology	Mapping and prediction of prehistoric sites, site vandalism studies, and site management studies.
Geology and mining	Oil, gas and minerals exploration. Geologic mapping and terrain analysis, open pit mine design and reclamation, geologic hazard mapping

Further reading (Paper)

The concepts explained in this chapter are covered in greater detail in by the following authors:

Burrough, P.A. (1986) *Principles of Geographical Information Systems for Land Resources Assessment.*

Clarendon Press, Oxford University Press, New York.

Aronoff, Stanley (1989) *Geographic Information Systems: A management perspective* WDL Publications, Ottawa, Canada.

Star, Jeffrey, and Estes, John E. (1990) *Geographic Information Systems: An introduction,* Prentice-Hall inc., Englewood Cliffs, New Jersey

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