Introduction to GIS
(Basics, Data, Analysis)
&
Case Studies

13th May 2004

Content

- Introduction to GIS
- Data concepts
- Data input
- Analysis
- Applications – selected examples

What is GIS?

Geographic Information System (GIS) is defined as an information system that is used to

input, store, retrieve, manipulate, analyze and output

geographically referenced data or geospatial data, in order to support decision making for planning and management of land use, natural resources, environment, transportation, urban facilities, health services so on.

What is GIS?

GIS is a set of tools that allow for the processing of

spatial data into ***information***.

This set of tools is open ended, but will include data input, data storage, data manipulation, and a reporting system.

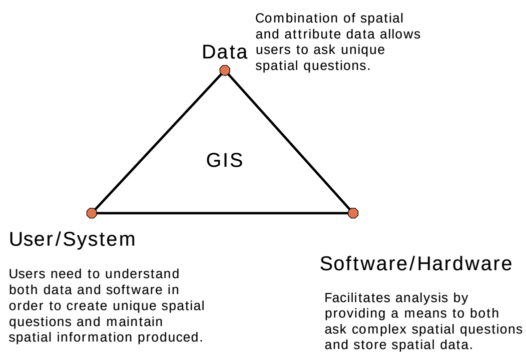
Other definition of GIS

'A GIS is designed for the collection storage, and analysis of objects and phenomena where geographic location is an important characteristic or critical to the analysis.'

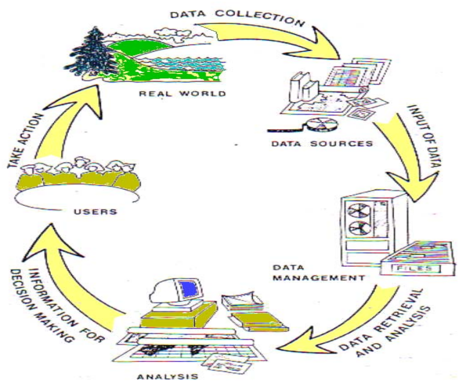
"Computer tool for managing geographic feature location data and data related to those features."

GIS is a tool for managing data about where features are (geographic coordinate data) and what they are like (attribute data), and for providing the ability to query, manipulate, and analyze those data.

Characteristics of GISystem

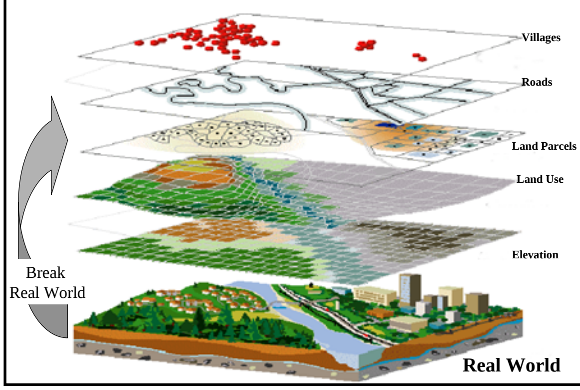


Planning & GIS

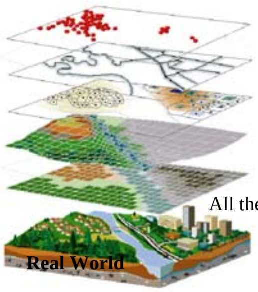


Interpretation of Real World in GIS Terms

Ex:Locate a New Bus Terminal



Questions to Answer



What is the need
How far the present users location
Where is the present location
Why the present need is
What will be the future
Where can we have a facility
What will be the size

All the above related to space or location

Interpretation of Real World in GIS Terms
Ex:Plan for a New Road

- Identify the two terminals/cities
- Define the centerline based on topography
- Identify possible routes
- Compare with landuse
  - Land prices
    - Land usage – restrictions
      - Land suitability
- Integrate current routes
- Integrate with rivers and streams
- Rough cost evaluation
- Identify the best route for detail study

Spatial data can be used to answer these questions

We need to categorize the real world to ***generalize*** reality so that we can make sense of it. That is we need to do some sampling collecting spatial data and we consider these sample represent the whole study area under investigation.

Geographic Information System & Data

Spatial Data	Features that have a known location on earth.
Attribute Data	The information linked to the geographic features (spatial data) describing them
Data Layers	Are the result of combining spatial and attribute data. Essentially adding the attribute database to the spatial location.
Layer Types	A layer type refers to the way spatial and attribute information are connected. There are two major layer types, vector and raster.
Topology	How geographic features are related to one another, and where they are in relation to one another.

Spatial Data

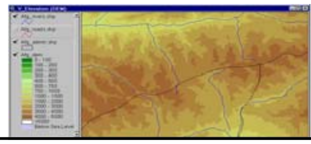
Spatial data in GIS represents features that have a known location on the earth.

Points: X & Y Locations

Line: Connected X & Y Locations

Polygon: Connected X & Y Locations making a close figure.

Raster: Row and column matrix represent geographic space.



Data types

The data model represents a set of guidelines to convert the real world (called entity) to the digitally and logically represented spatial objects consisting of the attributes and geometry.

There are two major types of geometric data model

a. Vector Model

Vector model uses discrete points, lines and/or areas corresponding to discrete objects with name or code number of attributes.

b. Raster Model

Raster model uses regularly spaced grid cells in specific sequence. An element of the grid cell is called a pixel which contains a single value of attributes.

Vector Data Structures

- The method of representing geographic features by the basic graphical elements of points, lines and polygon is said to be the **vector method**, or **vector data model**
- Vector data represent geographic space that is intuitive and reminiscent of analog maps.

Rasters

- A raster is a *tesselation* of a surface.
- (A *tesselation* is defined as the process to cover a surface through the repeated use of a **single shape**.)

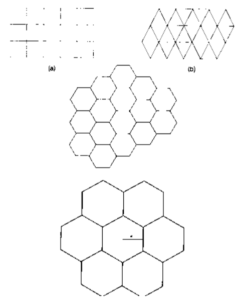
What is a raster data?

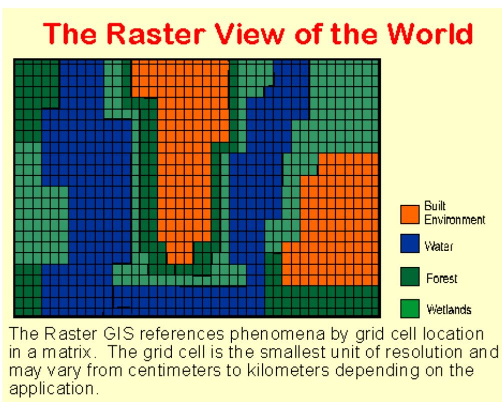
- a raster based system stores data by using a grid of cells
- a unique reference coordinate represents each pixel either at a corner or in the middle of the cell
- each cell or pixel has discrete attributes assigned to it
- raster data resolution is dependent on the pixel or grid size and may vary from sub-meter to many kilometers.

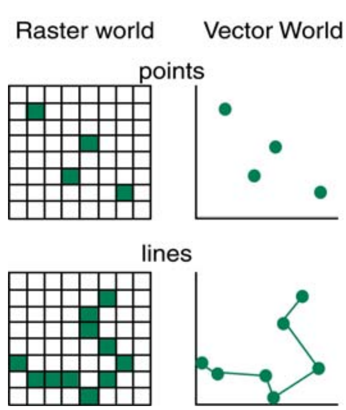
- raster data stores different information in layers; elevation, soil type, geology, forest type, rainfall rate, etc.
- generally, raster data requires less processing than vector data, but it consumes more computer storage space.
- remote sensors on satellites store data in raster format
- digital terrain models (DTM) and digital elevation models (DEM)
- continuous data (FIELD) suit a raster structure

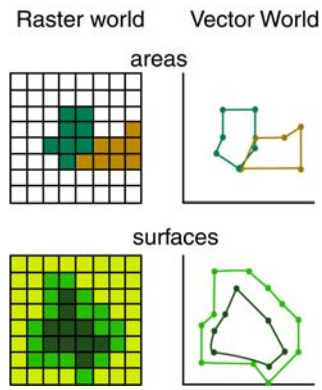
Rasters

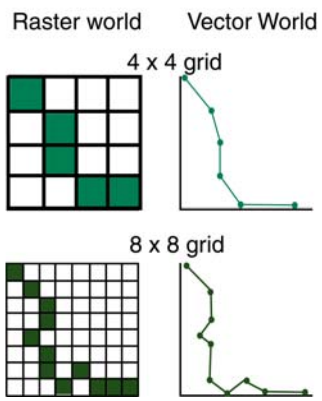
- A raster can use any ***reasonable*** geometric shape, as long as it can be connected in such a way as to create a ***continuous*** surface.











Comparison of Raster and Vector Data Models

Raster Model

Advantage:

1. It is a simple data structure.
2. Overlay operations are easily and efficiently implemented.
3.High spatial variability is efficiently represented in raster format.
4.The raster format is more or less required for efficient manipulation and enhancement of digital images.

Vector Model

Advantage:

1. It provides a more compact data structure than the raster model.
2. It provides efficiently encoding of topology and as result more efficiently implementation of operations that require topological information, such as network analysis.
3.The vector model is better suited to supporting graphics that closely approximate Hand-drawn maps.

Comparison of Raster and Vector Data Models

Raster Model

Disadvantage:

1.It is less compact therefore data compression techniques can often overcome this problem.

2.Topological relationships are more difficult to represent.

3.The output of graphics is less aesthetically pleasing because boundaries tend to have a blocky appearance rather than the smooth lines of hand-drawn maps.

Vector Model

Disadvantage:

1.It is a more complex data structure.

2.Overlay operations are more difficult to Implement.

3.The representation of high spatial variability is inefficient.

4.Manipulation and enhancement of digital images cannot be effectively done in vector domain.

Attribute Data

Attribute data are the information linked to the geographic features (spatial data) that describe them. That is, attribute data are the "[n]on-graphic information associated with a point, line, or area elements in a GIS."

Attributes of Dtm

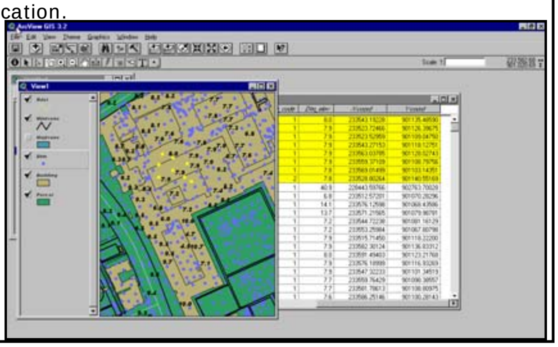
Perimeter	Dtm#	Dtm-id	Dtm_code	Dtm_elev	X-coord	Y-coord
0.00000	*****	*****	1	8.0	233543.19228	901135.4859
0.00000	*****	*****	1	7.9	233523.72466	901126.3967
0.00000	*****	*****	1	7.9	233523.52959	901109.0475
0.00000	*****	*****	1	7.9	233543.27153	901118.1275
0.00000	*****	*****	1	7.9	233563.03785	901128.0274
0.00000	*****	*****	1	7.9	233559.37109	901108.7975
0.00000	*****	*****	1	7.8	233569.01499	901103.1435
0.00000	*****	*****	2	7.8	233528.80264	901140.5516
0.00000	34	34	1	40.9	228443.59766	902763.7002
0.00000	*****	*****	1	6.8	233512.57201	901070.2829
0.00000	*****	*****	1	14.1	233576.12598	901068.4358
0.00000	*****	*****	1	13.7	233571.21565	901079.9878
0.00000	*****	*****	1	7.2	233544.72238	901081.1612

Attributes

- **Labels** affixed to data points, lines, or polygons.
- Used to describe the **feature** that you want to map.
- Can include text or numeric descriptors: i.e. nominal, ordinal, or interval/ratio data types.
- Must be careful in how the different data types are integrated and used – dangerous to mix and match.

Data Layers

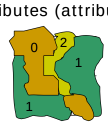
Are the result of combining spatial and attribute data. Essentially adding the attribute database to the spatial location.



Layer Types

A layer type refers to the way spatial and attribute information are connected. There are two major layer types, vector and raster.

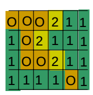
Vector: Points, lines and polygons (spatial data) associated with databases of attributes (attribute data) are considered vector layer types.



Attributes of Theme2.shp

Shape	ID	LANDUSE
Polygon	0	WATER
Polygon	1	HIGHLAND
Polygon	2	WETLAND

Raster: A row and column matrix (pixels) of X & Y space with attribute information associated with each pixel is considered a raster layer type.

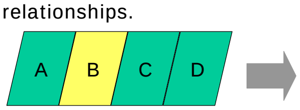


0 : WATER
1 : HIGHLAND
2 : WETLAND

Topology

Topology is the “way in which geographical elements are linked together”. Topology is how geographic features are related to one another and where they are in relation to one another.

Topology is the critical element that distinguishes a GIS from a graphics or automated cartography system. It is essential to the ability of a GIS to employ spatial relationships. Topology is what enables a GIS to emulate our human ability to discern and manipulate geographic relationships.



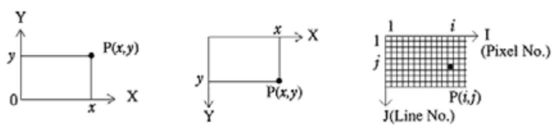
Parcel B is surrounded by Parcel A and Parcel C

Data Projection and registration

- Geographic projections and their parameters (datums, geoids etc) are ways to model the earth's curved surface to a flat plane
- Registration is necessary to "tie" geographic data to specific points on the Earth's surface to allow accurate mapping and analysis between different GIS layers

Coordinate system

Geospatial data should be geographically referenced (called georeferenced or geocoded) in a common coordinate system. The reference points are called tic masks or ground control points. One of the most convenient way of locating points is to use plane orthogonal coordinates with x (horizontal) and y (vertical) axis.



(a) Plane coordinates - Right hand system -

(b) Plane coordinates - Left hand system -

(c) Image Coordinates

Latitude, Longitude, Height

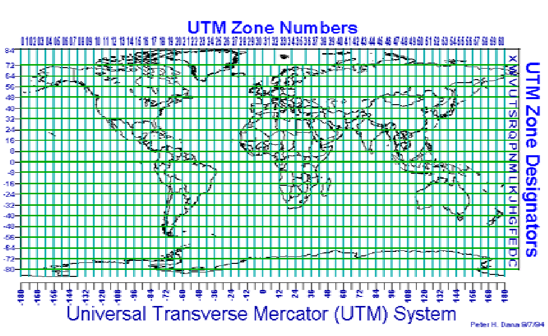
- the most commonly used coordinate system
- the Prime Meridian and the Equator are used to define latitude and longitude
- latitude and longitude are defined as:
  - **degrees, minutes, seconds**
  - 360^{o} around the earth
  - each degree is divided into 60 minutes
  - each minute is divided into 60 seconds
  - **decimal degrees**
  - a degree expressed as a decimal (in degree units)

Map Projections

- all map projections are attempts to portray the surface of the earth on a flat surface
- distortions of shape, distance, direction, scale, and area result from this process
- some projections minimize certain distortions while maximising others
- other projections are attempts to moderately distort all of the above properties.

Universal Transverse Mercator (UTM)

- UTM projection is used to define horizontal, positions world-wide by dividing the surface of the Earth into 6º zones, each mapped by the Transverse Mercator projection with a central meridian in the center of the zone.
- UTM zone numbers designate 6 degree longitudinal strips extending from 80 degrees South latitude to 84 degrees North latitude.
- UTM zone characters designate 8 degree zones extending north and south from the equator



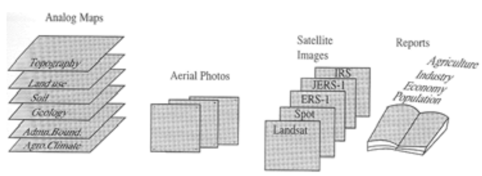
Data acquisition

As data acquisition or data input of geospatial data in digital format is most expensive and procedures are time consuming. In GIS, the data sources for data acquisition should be carefully selected considering the application and scale.

The following data sources are widely used:

- Analog maps
  - Elevation, soil, landuse, climate, etc.
- Aerial photographs
  - DEM, landuse (Urban)
- Satellite image
  - Landuse (regional), vegetation, temperature, DEM
- Ground survey with GPS
  - Detailed information
- Reports and publications
  - Attributes, statistics

Data source for GIS



Users / Systems

Users need to understand both data and software in order to create unique spatial questions and maintain the spatial information produced.

Data Input	Refers to the creation of digital spatial data.
Data Management	Refers to unique issues in the maintenance of spatial data such as error or level of accuracy; storing data; retrieving data; and metadata. Data management is one of the key issues determining the usability of spatial data.
Data Analysis	Is what allows users to answer questions that may not be explicitly stated in the data.
Data Output	Refers to the method used to visually display analysis performed using GIS. Output can be in the form of jpg to large plotted images.

Data Input

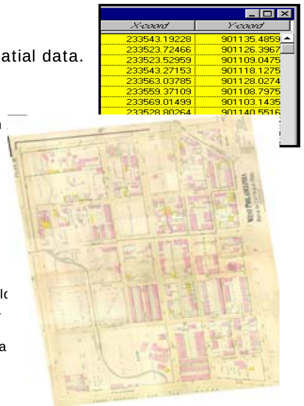
The creation of digital spatial data.

X & Y Coordinate: Used when a user has spatial data in & Y coordinates.

Database Entry: Commonly used when a user has attribute information related to common spatial locations, such as the census.

Digitize: Used when a user has a paper map that they woulc like to convert into a digital file.

Scan: Used when a user has a paper map that lends itself to reading spatial features in a rasterized format.



Choice of data acquisition method

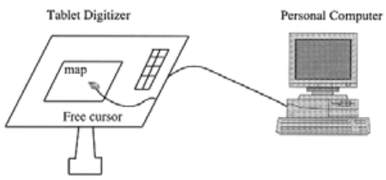
Data Sources	Method	Equipments	Accuracy	Cost
Analog Map	Manual Digitizing	Digitizer	±0.1 mm (on a map)	cheap
	Semi-automatic Scanning	Scanner	±0.1 mm (on a map)	high
Aerial Photos	Analytical Photogrammetry	Analog Stereo Plotter	±10 cm	high
	Digital Photogrammetry	Digital Phot. Workstation	±10 cm	very high
Satellite Images	Visual Interpretation	Image zoom scope	±30~50m	cheap
	Digital Image Processing	Image Processing System	±10~30m	high
Ground Survey	Field Measurement	Total station, GPS	±1 cm	very high
Reports	Keyboard Entry	Keyboard, PC		cheap

Scanning - paper maps

- Paper Map > Digital Raster > Vector
- Resolution – accuracy of data c.f. file size
- Initial accuracy; scanner integrity

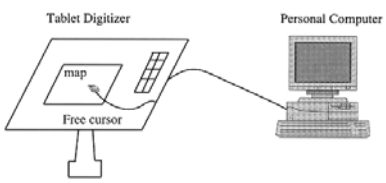
Digitising - paper maps

- Digitizing Tablet + “Mouse” + PC
- Directly captures vector data of interest from a paper source
- Time consuming, tedious work



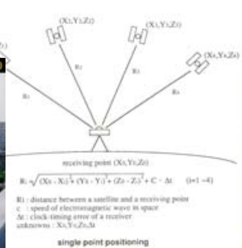
Vector data input (map digitizing)

The digitizing operation is as follows:
Step 1 : affix a map to a digitizing table
Step 2 : add control points or tics at four corners and input coordinates
Step 3 : digitize map contents according to the map layers
Step 4 : edit the errors and clean the data set
Step 5 : convert from digitizer coordinate to map coordinate and store in a spatial database



Direct input

- Built from attribute data e.g. GPS points
- Use software extensions for add to GIS database



Aerial Photographs

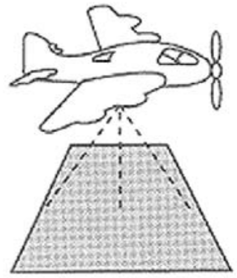
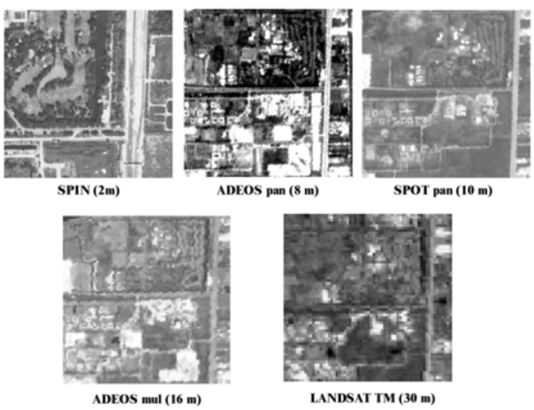


Image scale = focal length / flying height

Satellite Data



Data Management

Refers to unique issues in the maintenance of spatial data. Data management is one of the key issues determining the usability of spatial data.

Data Errors / Level of Accuracy	• Errors in digitizing • Errors in original data • Errors in data entry • Method of data entry • Scale of data
Storing Data	• Upkeep of historical data sets • Warehousing state and city data
Retrieving Data	• How can users access stored data
Metadata	• Using national standards to record and maintain key information about data creation, scale, projection, and attributes.

Data Analysis

Is what allows users to answer questions that may not be explicitly stated in the data.

- **Retrieval**
- **Map Generalization**
- **Map Abstraction**
- **Map Sheet Manipulations**
- **Buffer Generation**
- **Polygon Overlay & Dissolve**
- **Measurements**
- **Digital Terrain Analysis**
- **Network Analysis**

What is spatial analysis?

Spatial analysis is done to answer questions about the real world including the present situation of specific areas and features, the change in situation, the trends, the evaluation of capability or possibility using overlay technique and/or modeling and prediction.

Spatial analysis ranges from simple arithmetic and logical operation to complicated model analysis.

- Query
- Reclassification
- Coverage rebuilding
- Overlay

Query

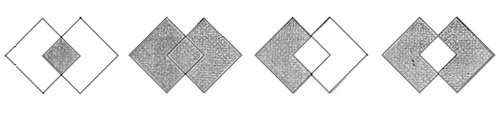
Query is to retrieve the attribute data without altering the existing data according to specifications given by the operator.

The conditional statement is represented by the following three types of operation.

Relational: >, <, =,>=,<=

Arithmetic: +, -, *, /¸

Boolean (logical): AND, OR, NOT, XOR (exclusive OR)

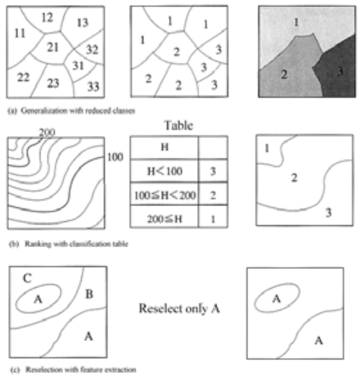


Reclassification

Reclassification is to reassign new thematic values or codes to units of spatial feature

Reclassification is executed in the following cases:

Generalization
Ranking
Reselection

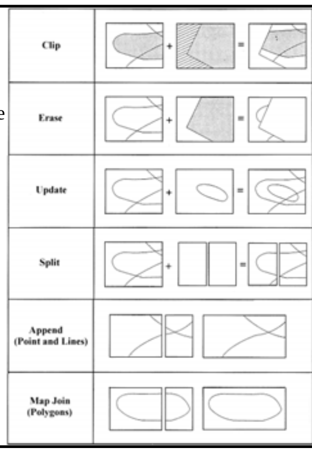


Coverage rebuilding

Coverage rebuilding is a boundary operation to create new overages, which are identified and selected by users

Boundary operations are:

- Clip
- Erase
- Update
- Split
- Append
- Map Join

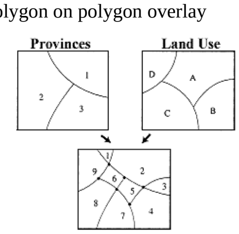


Vector overlay

Overlay of vector data results in the creation of new line and area objects with additional intersections or nodes.

There are three types of vector overlay:

- point in polygon overlay
- line on polygon overlay
- polygon on polygon overlay



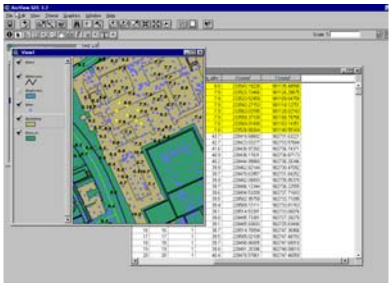
Polygon on Polygon Overlay

Polygon Topology

ID	Provinces	Land Use
1	1	D
2	1	A
3	1	B
4	3	B
5	3	A
6	2	A
7	3	C
8	2	C
9	2	D

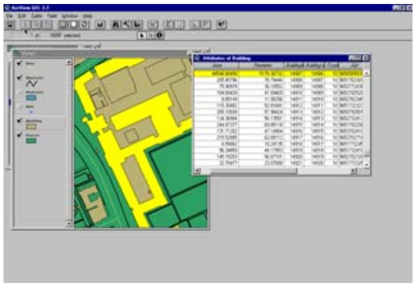
Retrieval

Allows a GIS user to reproduce existing information from a database by browsing through the data or windowing the database.



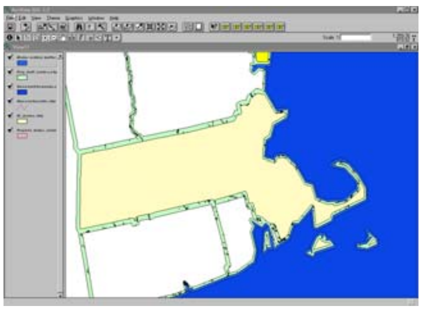
Map Generalization

Removing unnecessary data to save space for data files.



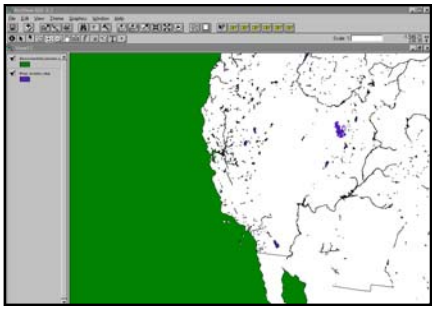
Buffer Generation

Creates new polygons by expanding or shrinking existing polygons or by creating polygons from points.



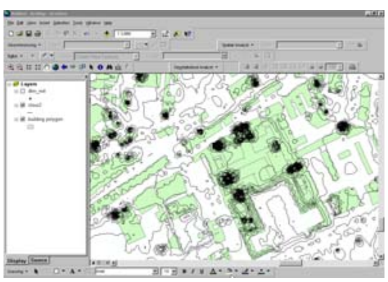
Polygon Overlay and Dissolve

Used when comparing two or more data layers.



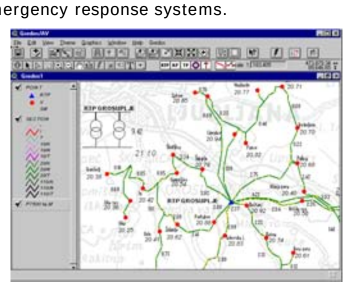
Digital Terrain Analysis

Allows for interpolation from point data (usually elevations), derivation of slopes and slope aspects, watershed computations and identification, and construction of view sheds**.**



Network Analysis

Are techniques for routing resources along a set of linked linear features. Optimal path routing predicts the best route between two or more points based on distance, time, effort, or another measure. Often used for emergency response systems.



Hardware

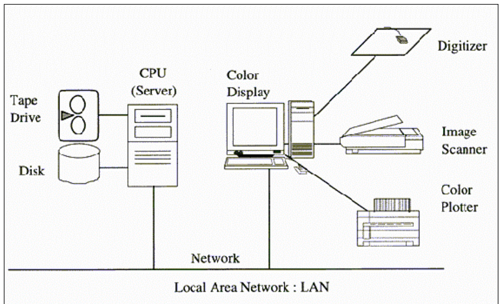


Figure 1.5 Components of GIS Hardward System

Software

- •ESRI product:ArcView, ArcInfo, ArcGIS
- •IDRSI
- •MapInfo
- •LIWIS
- •GRASS
- •Intergraph
- •PAMAP
- •GRAM++
- •ERDAS
- •R2V
- •Ermapper
- •ENVI

Thank you for attention