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Introduction

Geographic Information System (GIS) is a computer based system designed to accept large volume of spatial data derived from a variety of sources and to store, retrieve, analyse, manipulate and display these data according to use specifications. Geographical objects include natural phenomena such as railways, canals, roads, rivers, soil type etc. Geographical data describe objects from the real world in terms of their position with respect to known co-ordinate system, their attributes that are unrelated to position and their spatial interrelations with each other, which describe how they are linked together. Conventionally, mapping map analysis, measurements were done manually. With the advent of computer technology software were written to handle geographic data on the computers. This has resulted in GIS which represents now rapidly developing field lying at the intersection of many disciplines namely cartography, computing, geography, photogrammetry, remote sensing, statistics, surveying and other branches concerned with handling and analysing spatially referenced data.

Basics of GIS

Mapping Concepts, Features

A map represents geographic features or other spatial phenomena by graphically conveying information about locations and attributes. Locational information describes the position of particular geographic features on the Earth's surface, as well as the spatial relationship between features, such as the shortest path from a fire station to a library, the proximity of competing businesses, and so on. Attribute information describes characteristics of the geographic features represented, such as the feature type, its name or number and quantitative information such as its area or length. Thus the basic objective of mapping is to provide

- descriptions of geographic phenomenon
- spatial and non spatial information
- map features like Point, Line, & Polygon.

Map Features

Locational information is usually represented by points for features such as wells and telephone pole locations, lines for features such as streams, pipelines and contour lines and areas for features such as lakes, counties and census tracts.

Point feature A point feature represents as single location. It defines a map object too small to show as a line or area feature. A special symbol of label usually depicts a point location.

Line feature A line feature is a set of connected, ordered coordinates representing the linear shape of a map object that may be too narrow to display as an area such as a road or feature with no width such as a contour line.

- Points (cities, wells, villages)
- Line (rails, roads, canals)
- Area (reservoir, watersheds, land use class)

Data Model

Geographic data are represented in GIS in a particular manner and the approach is called model. There are two models- raster and vector

Raster: The geographic data are divided in grid cells
Data Structure-run length encoding, chain coding and quad tree

Vector: represented by points and lines
Data Structure -spaghetti & topological

To know why and how a GIS can help us, we must know what a GIS is and what it can be used for

What is a GIS?

—Questions a GIS can answer
— Applications of GIS
—The elements of GIS

What Is a GIS

- An organised collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information
- A programme is a GIS only if it permits spatial operations on the data
- A GIS typically links data from different sets. A GIS can perform this operations because it uses geographic or space as the common key between the data sets

Questions A GIS Can Answer

- Location (What is at particular location?)
- Condition (where is it…..?)
- Trends (What has changed since….?.)
- Patterns (What spatial patterns exist ?)
- Modelling (What if…….?)

Application Areas

- Water resources planning
- Land use planning
- Geodesic mapping
- Environmental applications
- Cadastral mapping
- Urban and regional planning
- Route selection of highways
- Mineral exploration
- Census and related statistical mapping

- Automatic cartography
- Natural resources mapping
- Surveying

Components of GIS

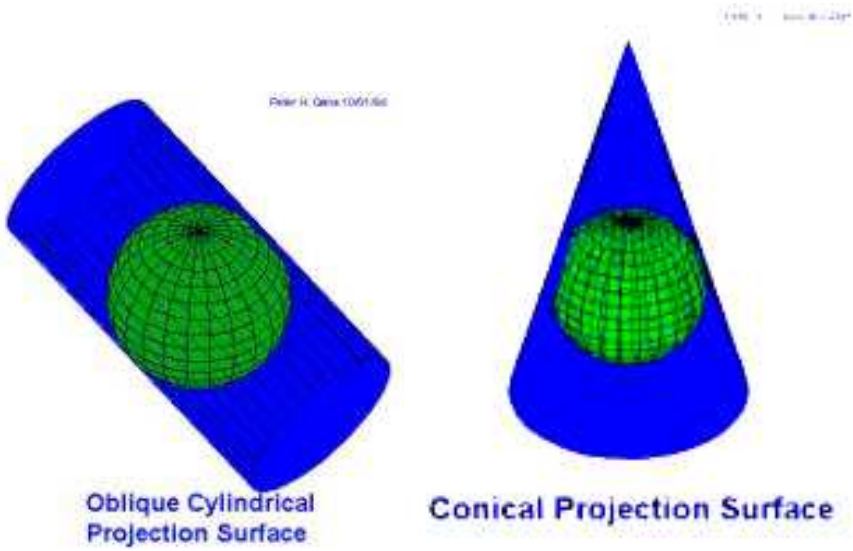
- Data encoding and input processing - (Digitizer, scanner, computer files)
- Data manipulation
- Data management
- Data retrieval
- Data analysis, modelling and cartographic manipulations
  (Overlay, intersection, identity, union, search, neighbourhood, distance, dissolve, classification reclassification, query etc)
- Data output(maps, graphs, photographs)

Map projection-

Map Projection is a systematic drawing of parallels of latitude and meridians of longitude on a plane surface for the whole earth or part of it on a certain scale so that any point on the earth surface may correspond to that on the drawing. A network of latitude and longitude is called ***graticule.***

- Map Projection is preparation of *graticule* on a flat surface.
- *Projection* means the determination of points on the plane as viewed from a fixed point.
- A flat surface will touch globe only at one point and other sectors will be projected over the plane in a distorted form. The amount of distortion increases with the distance from tangential point.

- Equal area or *homolographical* Projections
  (In this case graticule is prepared in such a way that every quadrilateral on it may appear proportionately equal to in area to the corresponding spherical quadrilateral.)
- Correct shape or *orthomorphic or Conformal* Projections
- True bearing or *azimuthal* Projections



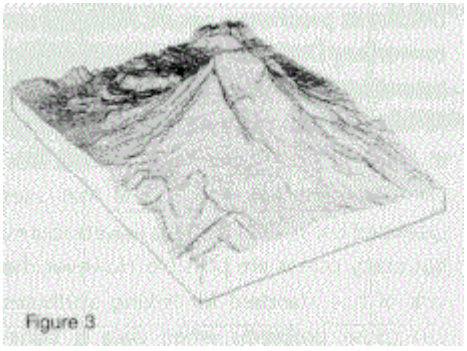
Polyconic, UTM etc.

Geometric rectification/ geo-referencing

Statistics- measurement, summary

DEM and Visualisation

Contouring, Hill shading, Perspective viewing, Fly through
Slope and aspect, extracting drainage



DEM

GIS packages

ARC/INFO (1969-ESRI Redlands California, USA), PAMAP GIS, SPANS (spatial analysis System- TYDAC Tech, USA,)

Modular GIS Environment (MGE)

IDRISI, GRASS, MAP/INFO, PROGIS

Indigenous GIS Packages- ISROGIS (12 modules) such as

Create, Edit, Make, Analyse, Attr-DB, Layout, Query, Map mosaic, 3D Module, Symbol Manager, Graphic User Interface (GUI)

GRAM^{++}, GEO-SPACE – RRSSC

Geographic Database

- A GIS does not hold maps or picture-it holds a database
- If one has to go beyond making pictures, one need to know three things about every feature stored in the computer; what it is, where it is, and how it relates to other features
- GIS gives the ability to associate information with a feature on a map and to create new relationships

Hardware and Software Resources

- The rapidly increasing power and the relative affordability of workstations now provide the user access to powerful machines for GIS operation dealing with large and complex data set and other decision-support tools such as hydrologic models, statistical packages, and optimisation programs
- With advancement in software development relating to GIS application more and more features are getting available on PC version of GIS packages
- Commercial GIS packages like Arc-Info, MapInfo, Intergraph, Spans etc. available in the market
- Most of the packages function under open GIS system
- Before a GIS package or peripheral is acquired, inter-compatibility should be confirmed.

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Issues Pertinent to WRD&M

- Critical role of water in human and natural environment. Role of GIS is important in management of the precious resource
- Water related data can have high precision (canal location) or can be Fuzzy (wetland perimeter)
- surface representation by DEM using GRID, TIN or contours required for hydro-geologic application of GIS
- Length, area and quantity computation, overlay of thematic layers and buffer zone generation important for WRD application

Application in Water Resources

1. Hydrologic/hydraulic modelling for basin Planning
2. WR and Irrigation potential assessment
3. Identification of WRD project sites
4. EIA studies and environmental monitoring
5. Command area monitoring
6. Disaster management

Network Analysis

Network models are based on interconnecting logical components, of which the most important are:

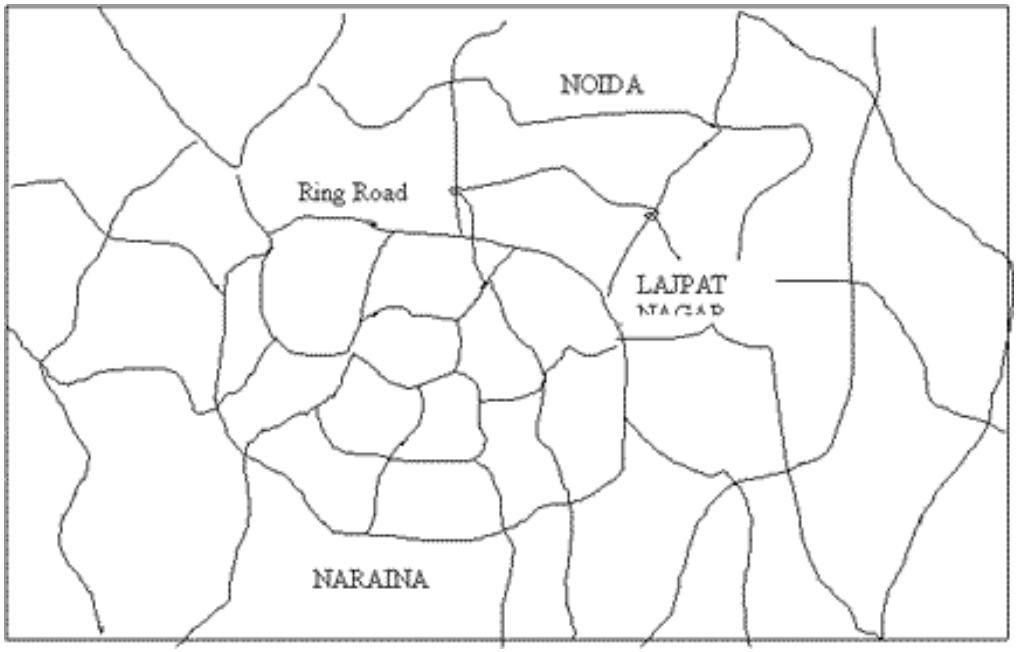
1. "Nodes" define start, end, and intersections
2. "Chains" are line features joining nodes

3. "Links" join together points making up a chain.

This network can be analyzed using GIS.A simple and most apparent network analysis applications are:

- Street network analysis,
- Traffic flow modelling,
- Telephone cable networking,
- Pipelines etc.

The other obvious applications would be service centre locations based on travel distance. Basic forms of network analysis simply extract information from a network. More complex analysis, process information in the network model to derive new information. One example of this is the classic shortest-path between two points. The vector mode is more suited to network analysis than the raster model.



A Road Network *Image*

Capabilities of GIS

- Presentation Graphics
- Data Query
- Spatial Query
- Routing and Minimum path
- Buffering
- Overlay
- Distance, Adjacency and Proximity analysis
- Misc. analysis likes neighbour analysis, network analysis, 3D Analysis etc.

Presentation Graphics

- Thematic mapping is a means offered by GIS to draw map elements using patterns or colour based on a particular attribute
- Thematic mapping can be classified as
  - Polygon thematic
  - Line thematic
  - Point thematic
- Thematic maps usually involve only a few map layers and limited amounts of data

Data Query

- Much of the data collected by businesses are spatially referenced
- Non GIS user querying such a data base are limited to tabular views of the results of query
- A GIS user can view the results on a map apart from the regular tabular view
- Most important benefit is that the GIS user can see the spatial distribution which is hidden for the non GIS user
- Thus the GIS user is offered a "*powerful lens*" which makes hidden data visible to him
- This type of data base query is also called the "*show-me*" query
- Most available GIS packages are designed to effortlessly perform data queries

Spatial Query

- In this form of a query the user relies on the map as a querying tool
- Typically the data base is accessed by pointing to specific map feature
- GIS will then search the data base, and find those records that qualify, for presentation
- Spatial queries can be through
  - Pointing a feature
  - Spatial windows (Circular/Rectangular)
- Spatial queries are also called "tell-me" queries

Routing and Minimum Path

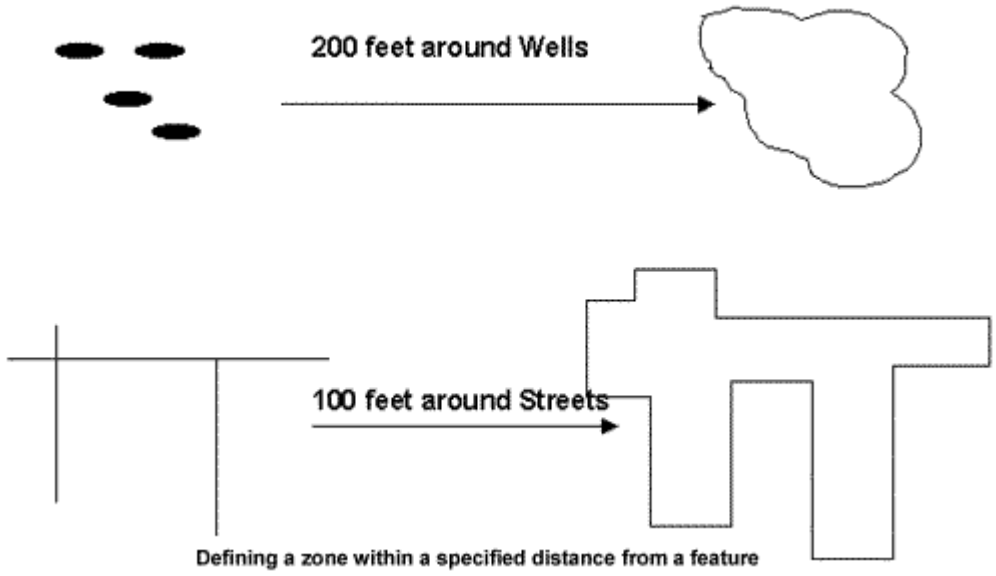
- Answer lies in the ability to find the shortest-path along a transportation network
- Routing involves "legal" travel from one point to another along a designated network
- Minimum path analysis involves finding out the shortest, fastest or most appropriate route

Buffering

- A buffer is a zone of fixed width around a map feature
- Buffer around a point takes the shape of a circle
- Buffer around a line takes the form of a corridor
- Buffer around a polygon taken the form of a bigger polygon
- Most of the GIS packages can buffer points, lines and polygons
- Very few packages are capable of handling concave polygons

Using these operations, the characteristics of an area surrounding in a specified location are evaluated. This kind of analysis is called proximity analysis and is used whenever analysis is required to identify surrounding geographic features. The buffer operation will generate polygon feature types irrespective of geographic features and delineates spatial proximity. For example, what are the effects on urban areas if the road is expanded by a hundred meters to delineate a five-kilometer buffer zone around the national park to protect it from grazing.

Using Buffer



Defining a zone within a specified distance from a feature

Overlay Operations

The hallmark of GIS is overlay operations. Using these operations, new spatial elements are created by the overlaying of maps. There are basically two different types of overlay operations depending upon data structures:

Raster overlay It is a relatively straightforward operation and often many data sets can be combined and displayed at once.

Vector overlay The vector overlay, however is far more difficult and complex and involves more processing.

Logical Operators The concept of map logic can be applied during overlay. The logical operators are Boolean functions. There are basically four types of Boolean Operators: viz., OR, AND, NOT, and XOR.With the use of logical, or Boolean, operators spatial elements / or attributes are selected that fulfill certain condition, depending on two or more spatial elements or attributes.

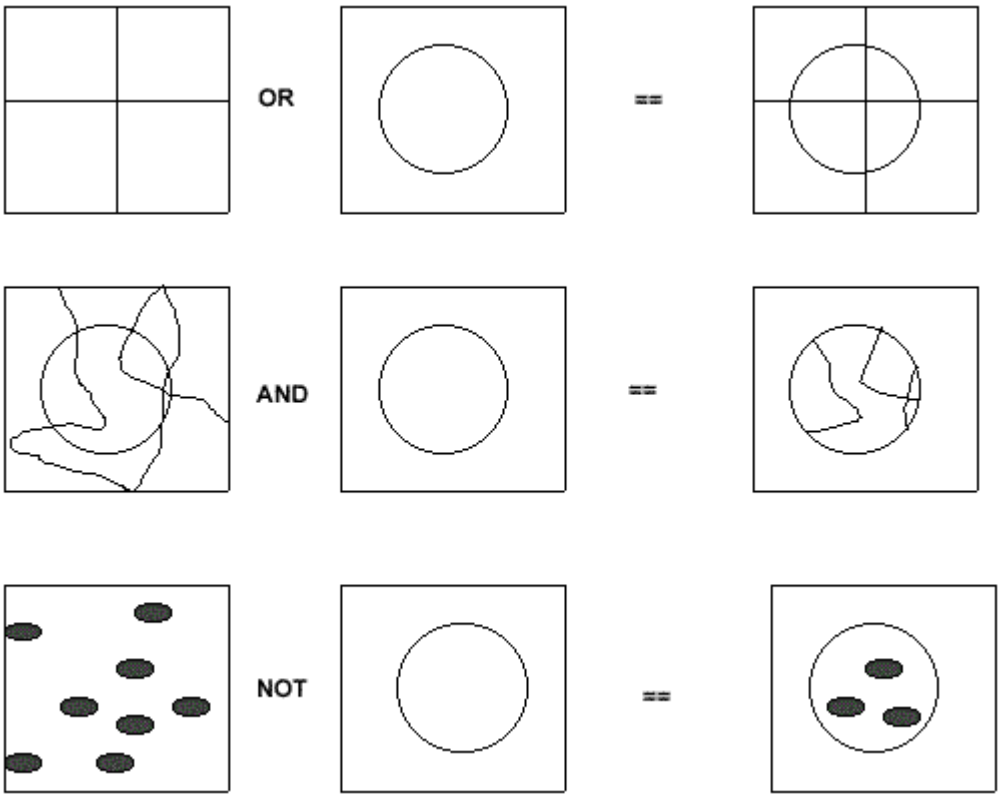
Vector Overlay During vector overlay, map features and the associated attributes are integrated to produce new composite maps. Logical rules can be applied to how the maps are combined. Vector overlay can be performed on different types of map features: viz., Polygon-on-polygon overlay

Line-in-polygon overlay

Point-on-polygon overlay.

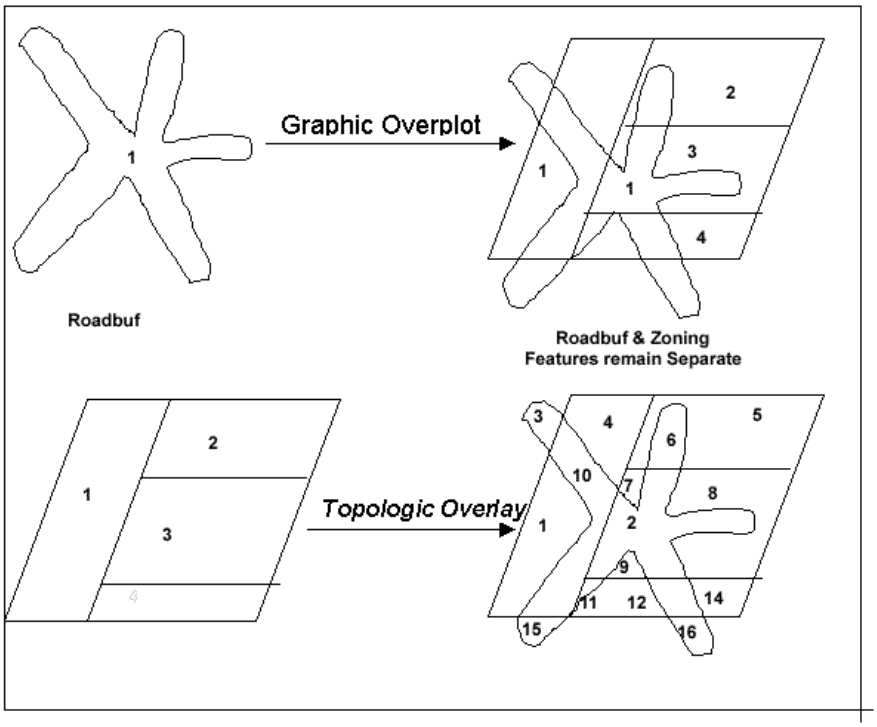
During the process of overlay, the attribute data associated with each feature type id merged. The resulting table will contain both the attribute data. The process of overlay will depend upon the modelling approach the user needs. One might need to carry out a series of overlay procedures to arrive at the conclusion, which depends upon the criterion.

Polygon-on-Polygon Overlay



Polygon-on-Polygon Overlay

Difference between a Topologic Overlay and a Graphic Over plot



Distance, Adjacency and Proximity Analysis

- Distance analysis refers to the ability to calculate *distances* from a map or along a transportation network
- Adjacency analysis refers to the ability to determine which of the map features TOUCH or are adjacent to other map features
- Proximity analysis refers to the ability to determine which of the map features are NEAR or in the neighbourhood of the referred map features
- All available GIS packages can estimate aerial distances
- A more limited set can estimate distances along road network
- Very few GIS packages can "*directly*" perform adjacency/ proximity analysis

Analysis of Geographic Data

ANALYSIS - What? & Why? The heart of GIS is the analytical capabilities of the system. What distinguish the GIS system from other information system are its spatial analysis functions. Although the data input is, in general, the most time consuming part, it is for data analysis that GIS is used. The analysis functions use the spatial and non-spatial attributes in the database to answer questions about the real world. Geographic analysis facilitates the study of real-world processes by developing and applying models. Such models illuminate the underlying trends in geographic data and thus make new information available. Results of geographic analysis can be communicated with the help of maps, or both. The organization of database into map layers is not simply for reasons of

organizational clarity, rather it is to provide rapid access to data elements required for geographic analysis. The objective of geographic analysis is to transform data into useful information to satisfy the requirements or objectives of decision-makers at all levels in terms of detail. An important use of the analysis is the possibility of predicting events in the another location or at another point in time.

ANALYSIS - How? Before commencing geographic analysis, one needs to assess the problem and establish an objective. The analysis requires step-by-step procedures to arrive at the conclusions. The range of geographical analysis procedures can be subdivided into the following categories.

- Database Query.
- Overlay.
- Proximity analysis.
- Network analysis.
- Digital Terrain Model.
- Statistical and Tabular Analysis.

Spatial Analysis

It helps us to:

- Identify trends on the data.
- Create new relationships from the data.
- View complex relationships between data sets.
- Make better decisions.

Geographic Analysis

Analysis of problems with some Geographic Aspects.

- Alternatives are geographic locations or areas.
- Decisions would affect locations or areas.
- Geographic relationships are important in decision-making or modelling.

Some examples of its application:

- Nearest Neighbour.
- Network distances.

Planar distances

Tabular Statistical Analysis

If in the above road network we have categorised the streets then in such a case the statistical analysis answers questions like

- What unique categories do I have for streets?
- How many features do I have for each unique category?
- Summarize by using any attribute?

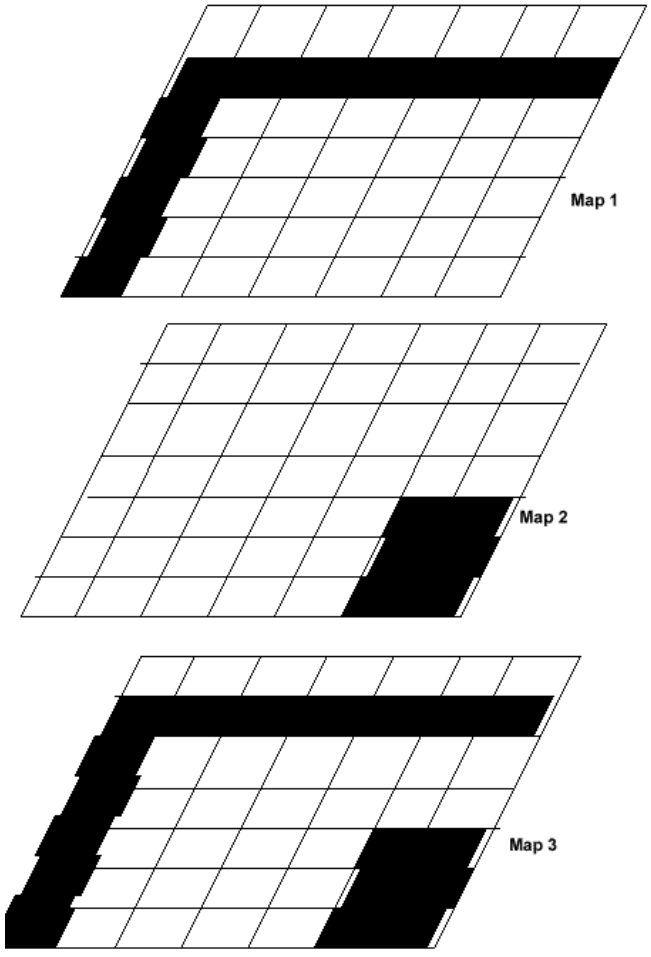
Database Query The selective display and retrieval of information from a database are among the fundamental requirements of GIS. The ability to selectively retrieve information from GIS is an important facility. Database query simply asks to see already stored information. Basically there are two types of query most general GIS allow: viz., Query by attribute,

Query by geometry. Map features can be retrieved on the basis of attributes, For example, show all the urban areas having the population density greater than 1,000 per square kilometer, Many GIS include a sophisticated function of RDBMS known as Standard Query Language (SQL), to search a GIS database. The attribute database, in general, is stored in a table (relational database mode.) with a unique code linked to the geometric data. This database can be searched with specific characteristics. However, more complex queries can be made with the help of SQL. GIS can carry out a number of geometric queries. The simplest application, for example, is to show the attributes of displayed objects by identifying them with a graphical cursor. There are five forms of primitive geometric query: viz., Query by point, Query by rectangle, Query by circle, Query by line, Query by polygon, A more complex query still is one that uses both geometric and attributes search criteria together. Many GIS force the separation of the two different types of query. However, some GIS, using databases to store both geometric and attribute data, allow true hybrid spatial queries.

Conditional Operators

Conditional operators were already used in the examples given above. The all evaluate whether a certain condition has been met.

= eq 'equal' operator<> ne 'non-equal' operator< lt 'less than' operator<= le 'less than or equal' operator> gt 'greater than' operator>= ge 'greater than or equal' operator. Many systems now can handle both vector and raster data. The vector maps can be easily draped on to the raster maps.



Raster Overlay

Current and Future Role of GIS

- Users should periodically examine the requirement for GIS and whether their system continues to meet those needs
- GIS is yet to be used in a large way for terrain visualisation, 3-D analysis, resource information and organisation planning.

Reference

Sankhua, R N (1999 to 2010), Lecture notes on GIS training courses, NWA