CHAPTER - 2

Geographic Information System (GIS)

Learning Objectives

After completing this chapter students would be able to :

2.1 Understand Introduction about Geographic Information System (GIS)

2.2 Learn about GIS Data Element and Data Structure

2.3 Know about the Fundamentals of Database and its Concept

2.4 Understand about Data input to GIS system

2.5 Learn about GIS Data Editing

2.6 Understand Attribute Data Linking

2.7 Know about Spatial and Non Spatial Data Analysis

2.8 Understand about Map Projection and Coordinate System

2.9 Learn about Digital Cartography

2.10 Understand Advantages and Benefits of GIS

2.1 Introduction

GIS is a computer based system used to digitally represent and analyze the geographical features and events taking place. In Class XI we studied about the fundamentals of geographic information system (GIS). In ancient time people used maps as a tool to represent and share information about earth surface. Geographic surveyors, navigators, explorers have made many efforts to collect map data for various purposes. Science of map making has undergone many changes. Today there is a new dimension of spatial data handling with respect to various natural resources, and features.

> What is GIS?
> GIS is a powerful tool for solving real world problem. It is also called as Geo based information System. In another words it is a technology and a concept to manage the natural resources to improve the decision making.

A GIS is a collection of computer hardware, software, and geographic data for digitally capturing, managing, analyzing, and displaying all forms of geographically referenced information. It allow us to capture, view, understand, aquere, interpret, and visualize data. The various themes of the same area such as Land cover/ land Use, water, soil, street can be integrated to reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.

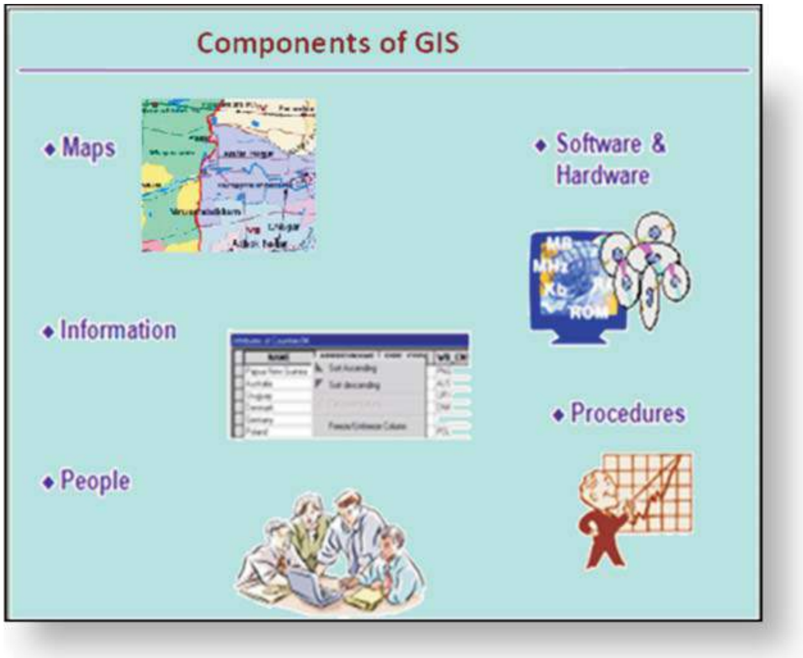


Fig. 64

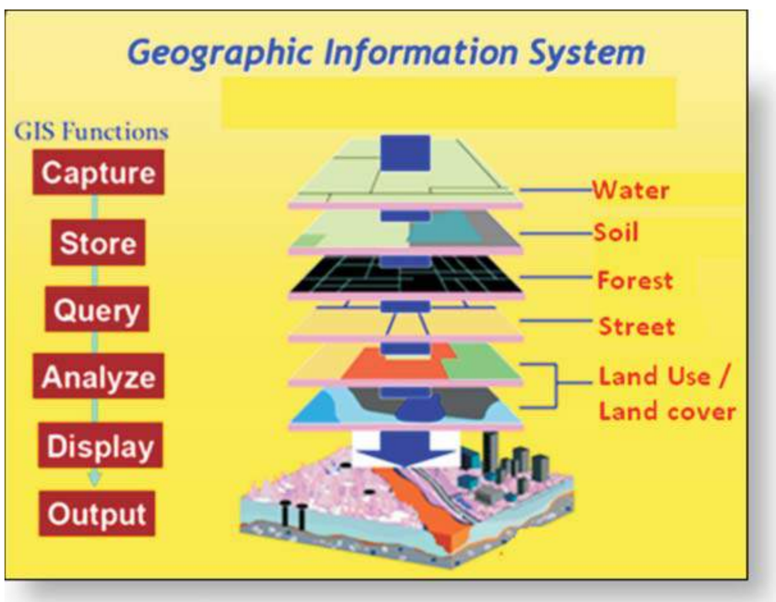


Fig. 65

A GIS is a computer application program that stores Spatial and Non-Spatial information in a digital form. Location Information describes where a particular geographic feature is situated on Earth. Attribute Information describes the feature details like what it is, how much it is, what it contains, etc. Non-Spatial data, also called as attribute data, which refers to information like demographic distribution of a town or a village, daily discharge of a river at a particular place, Traffic contiguity of a road etc.

The fundamental key of GIS is that, the association of Geographic features present on earth' surface, which can be geo-referenced with a database related to it. The figure shows the tree location and its description such as age, height, and species

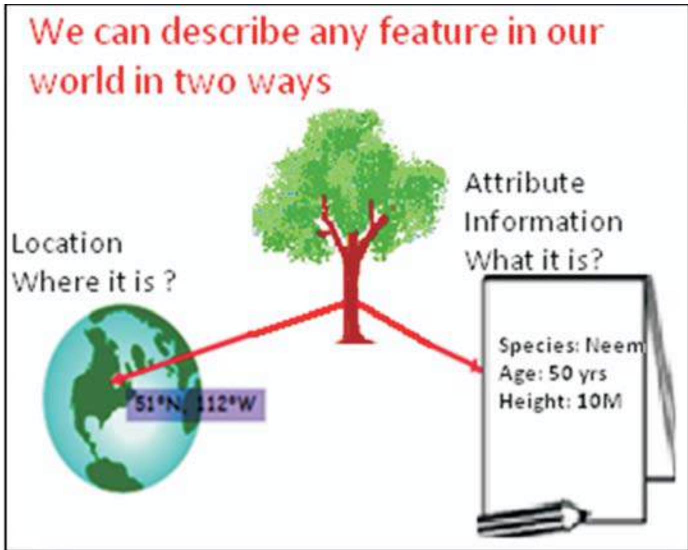


Fig. 66

Why GIS is needed?

- Makes dynamic maps
- Displays map information in detail about features Interactively
- Builds the spatial relationship between features
- Analyzes and answers real-world problems

GIS is used in detailed planning, decision making, better visualization and improving organizational integration.

The Geographic Information system is an effective tool for implementation and monitoring of municipal infrastructure, urban planning, public safety, utility services, transport services etc. as shown in figure 67.

Fig. 67

GIS Application

GIS manages all variety of data in a single electronic file in a computer by storing different spatial features as sub-files. These sub-files are called map layers / themes (soil, water, street etc) These map layers are conveniently stored and accessed with the computer in a same scale which are very much helpful for regional planner or any administrative body to accurate study of the earth features. GIS can open all the layers showing all features. It can be displayed and overlaid depending on the requirements. For example, the land-use layer may be displayed along with elevation contours by keeping other layer off.

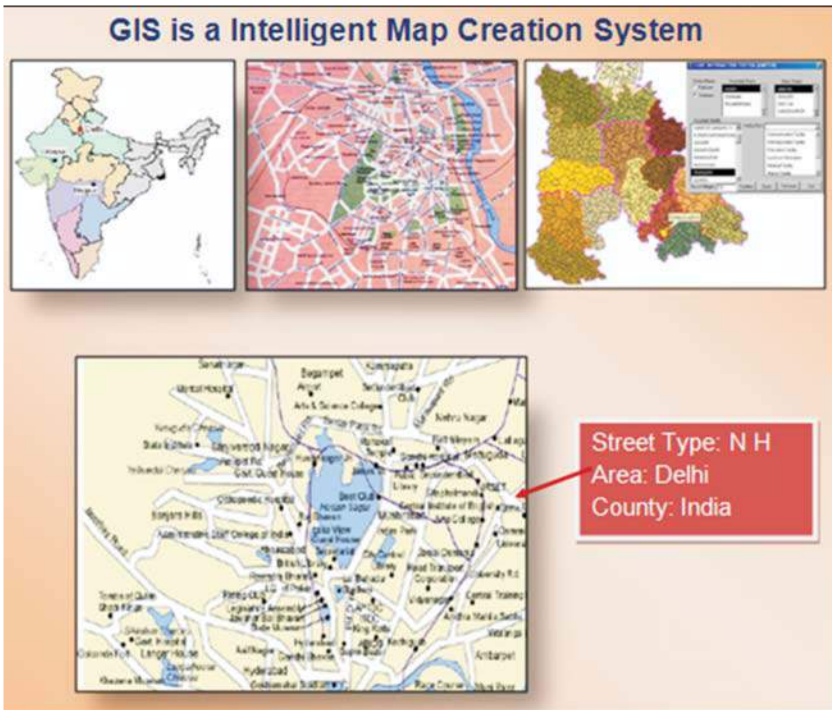


Fig. 68

GIS System

2.2 GIS System

A. GIS Functions

(i) Data Capture:

GIS is a tool which integrates the data from various sources into a common format which can be compared and analyzed. Various Input sources are mainly obtained from

- Manual digitization
- scanning of aerial photographs, paper maps
- Existing digital data sets
- Remote-sensing satellite imager
- GPS

ii) Data storage and Manipulation:

After data are collected and integrated into GIS it can store and maintain data. Data management includes data security, data integrity, data storage, retrieval, and data maintenance abilities.

iii) Data Analysis:

GIS has an ability to interpret and analyze the collected information quantitatively and qualitatively. For example, satellite image can assist an agricultural scientist to project crop yield per hectare for a particular region. For the same region, the scientist also has the rainfall data for the past six months collected through weather station observations. After integrating both the information farmer can get better idea to manage the crop yield.

iv) Data presentation: One of the most important functions of GIS is to present the data in the variety of ways such as maps, report and three dimensional images.

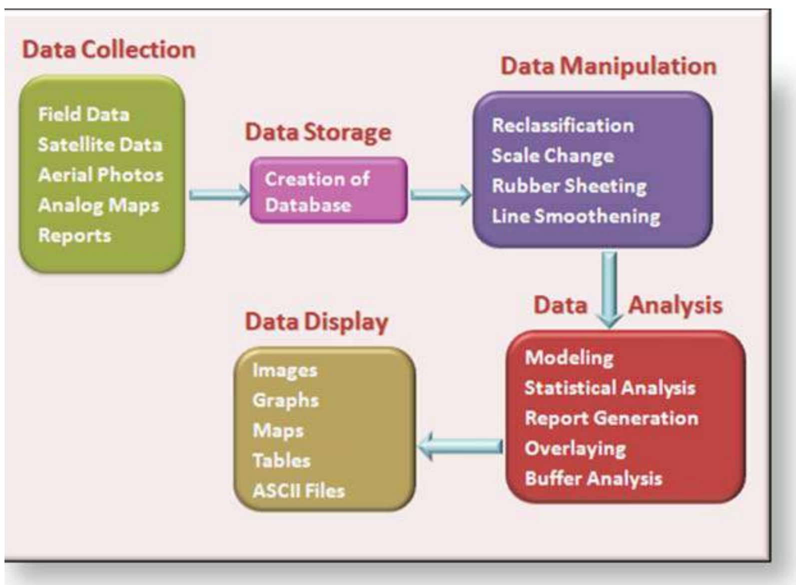


Fig. 69

The functions of GIS

B. Data Structure

As we discussed in Class XI the GIS stores the data in to two ways such as raster and vector format.

In Raster format the space is divided into a grid of cells, with a certain value attached to each cell according to the features. In vector format data stores the features in the form of Point, Line and Polygon with the coordinates of the location. The various feature representation with vector and raster format is shown in below figure.

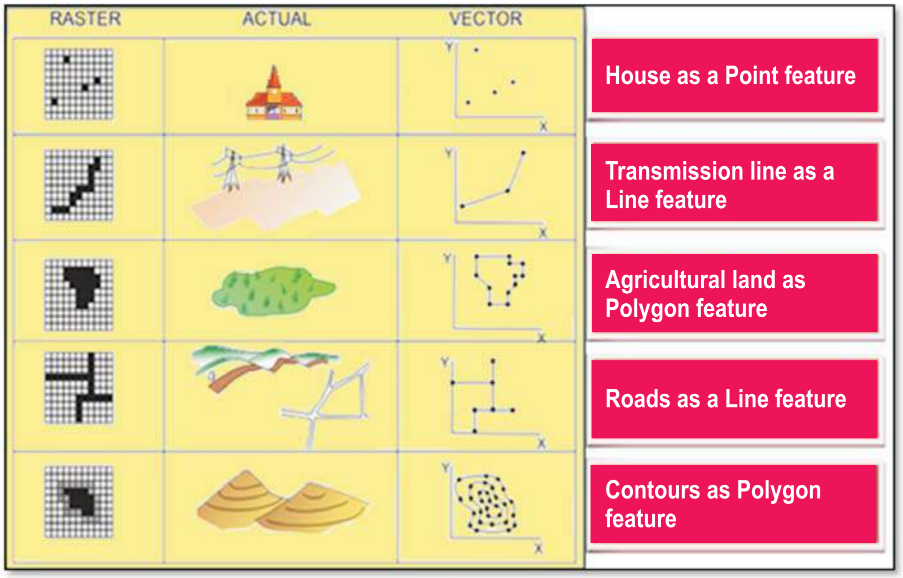


Fig. 70

Representation of various data storage by GIS system in Raster and Vector Formats

1. Vector Data Structure

In vector data structure attribute information is always associated with point , line and polygon as spatial entities that describe features occurring in real world. For example a point representing a city associated with its total population, number of houses, and number of schools and so on. A linear feature such as river represented by line is associated with name, mean discharge etc. A land use represented by polygon feature is associated with its past land use, soil type etc

Vector data structure is categorized as

(i) Spaghetti data structure

(ii) Topological data structure

(i) Spaghetti Data Structure

The spaghetti data model is the most simple data structure. In this model each entity on a map becomes one logical record in digital file and is defined as a string of x, y coordinates. Spaghetti vector data structure is not optimal because it does not take into consideration shared lines and points. All entities are spatially defined, without any spatial relationships. This creates a limitation to perform any type of spatial analysis. The spatial relationship between entities is derived through computation. Different lines and polygons are stored as independent objects. Lines between adjacent polygons must be digitized and stored twice. No clear topological information is coded to show the connectivity and neighboring relationship. This type of format is efficient for cartographic display for CAD Database.

(ii) Topological Vector data Structure

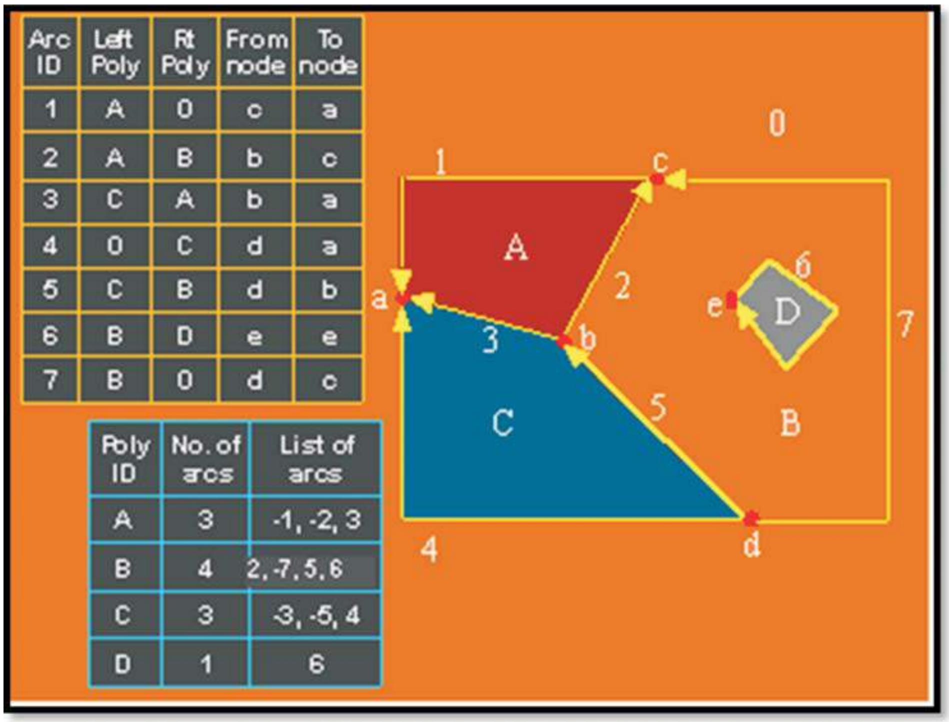
Topological model is the most widely used method to reveal spatial relationships. For example, an area or polygon is defined by a set of lines which makes up its boundaries. In this case the line is the border between two polygons. Each line can represent part of a path connecting other paths. For example, lines can be used to represent streets and the routes. The connectivity of these features is referred as their topology structure. Topology is the mathematical method used to define spatial relationships. The model is also termed Line / Arc - Node data model. The advantage of this method is data redundancy which is reduced because of shared nodes and lines which are stored only once. Attributes are linked to each feature. The attribute data is stored in separate relational tables therefore; more files are maintained for this purpose. Data Base Management System (DBMS) is used so access is more efficient.

Line (Arc): It is a series of point that start and end at a node.
Node: is an intersection point where two or more lines meet. A node can also occur at the end of a dangling line that is not connected to another line.
Polygon: It is comprised of a closed chain of lines that represents the boundary of the area.
Point: It is encoded as a single XY co-ordinate pair. Point is considered as the polygon with no area information

a) Properties of the Topological data structure

- **Connectivity:** Indicates which geographic features connect to others or which geographic features intersect each other. For example line 1 is connected to line 2, 3 and 4 as shown in figure below.
- **Adjacency:** Indicates which geographic features are adjacent to others. For example Polygon A is adjacent to Polygon C as shown in the figure below.
- **Containment:** Indicates which geographic features (node, arc, and smaller polygon) are contained within a polygon. For example, the polygon D is inside the polygon B as shown in the figure.

- **Proximity:** Indicates which geographic features are near to others. For example to travel from Node B to Node A the shortest path is Line 3 as shown in above figure.
- **Relative Direction:** It indicates the relative position between the geographical features. This can be used to study the direction of slope and water shed management.



Arc ID	Left Poly	Rt Poly	From node	To node
1	A	0	c	a
2	A	B	b	c
3	C	A	b	a
4	0	C	d	a
5	C	B	d	b
6	B	D	e	e
7	B	0	d	c

Poly ID	No. of arcs	List of arcs
A	3	-1, -2, 3
B	4	2, -7, 5, 6
C	3	-3, -5, 4
D	1	6

Fig. 71

An example of Connectivity, Adjacency, Containment, Proximity, Relative Direction

1.a Advantages of Vector data model

i) It is precise and allows no error in line area, perimeter etc.

ii) It requires less storage requirement as compare to raster format .

iii) This method is more appropriate for social economic, demographic and resource variation analysis.

1.b Disadvantages of Vector data model

i) It takes too much time in computing time for overlaying vector based information

ii) It cannot represent continuous data

2. Raster Data Structure

Raster model divides entire area into regular grids in a specific sequence. It is generally sequenced row by row from top left corner. Each grid cell contains a single value. In most cases, the values are to be assigned each and every grid in the raster data model as shown in the figure below. It is often coded in ASCII format. It is relatively a simple approach for data integration both conceptually and operationally. Digital elevation model use the cell by cell data structure because the neighboring elevation values are rarely same. Satellite images also use this method for data storage. The advantage of raster GIS model is easier to interface with remote sensing images

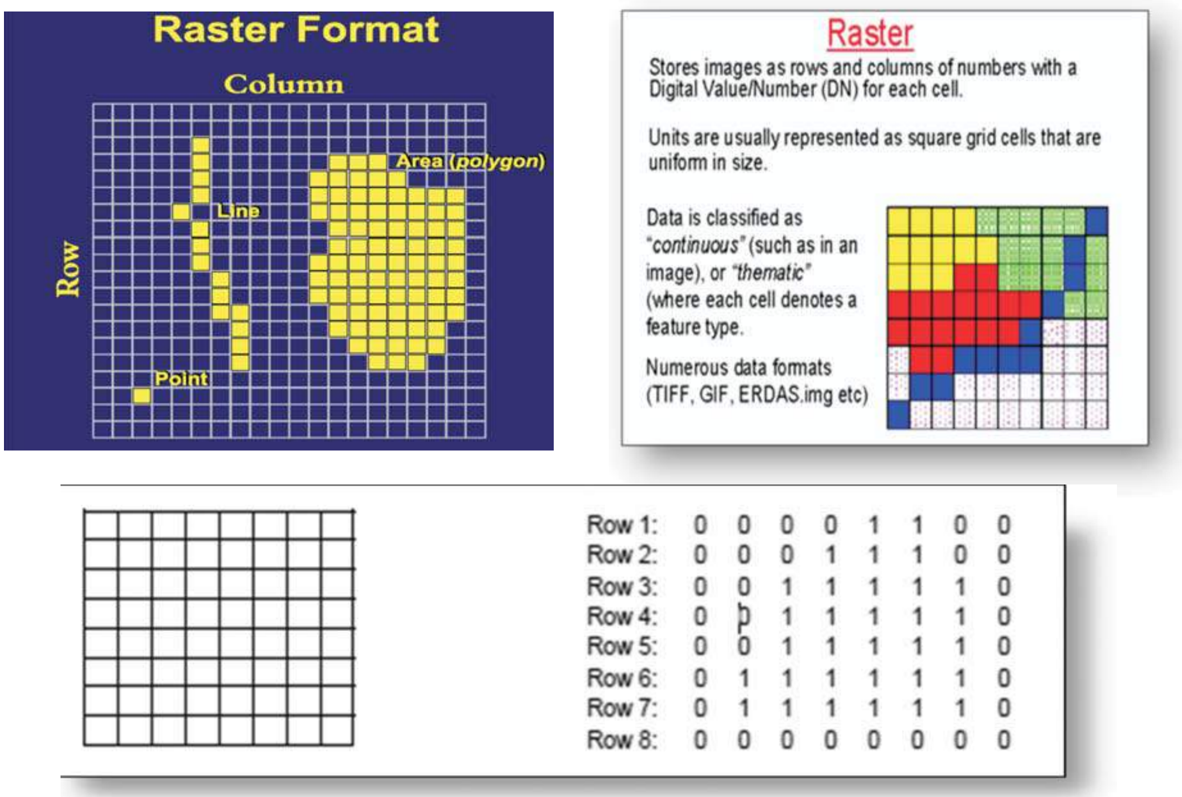


Fig. 72

The cell by cell data structure records each cell value by row and column

2.a Advantages of raster data structure

- Raster data quickly processes queries most analytical operations such as overlay, buffer, proximity and Boolean queries. .
- It is good for representing continuous surfaces.
- Raster data formats are appropriate for remote sensing data.
- It is easy to understand, read, write and draw on to screen.

2.b Disadvantages of raster data structure

- This format is poor at representing points, lines and area
- It uses pixel based data processing which affects the accuracy especially for point and linear features.
- Lines can become (vider) broader.
- It is good at localized topology such as adjacency and weak at others
- This format faces mixed pixel problem which creates the problem in identification of different features
- It includes redundant and missing data which affects the interpretation
- Each cell can be owned by one feature
- It requires more storage space.

2.3 Fundamentals of Database concept

Database creation is the most important, expensive and time consuming part of any GIS project. The database system is a computer based record keeping system to maintain information. Spatial database is a collection of spatially referenced data which can be utilized for querying and obtaining information to integrate different type's of analytical models and application.

Database creation in vector model involves three stages

i) Spatial data input

ii) Attribute data Input

iii) Linking spatial and attribute data

Spatial data or any thematic map can be captured via digitalization in the form of point, line and polygon. Once data has been captured editing and topology building is carried out for further process to remove overshoot and undershoot. Attribute data is key-in or imported from external platform such as excel sheet, word table, etc. Finally the spatial data is linked with associated attribute data with means of a common key called unique id. This attribute data is stored and used for analysis.

Spatial database is a collection of spatially referenced data. The GIS provides a linkage between spatial and non spatial data.

GIS is a computer system that links the database with spatial and their attributes through software tools that graphically display query and maintain those features and attributes.

The purpose of database design is to save time and resources. Unplanned or un designed database end up with a poorly constructed and functionally unsatisfied database which can result in

- Unnecessary data
- Missing data
- Unsupported application
- In appropriate feature representation
- Lack of consistency between various parts of the database

2.4 Data input to GIS system

Data input is the operation of encoding data into a database. The user of a GIS has to input Spatial data either in Raster or Vector formats. Spatial data are obtained from different sources with different formats. For example, maps would usually be supplied in a hard copy but the satellite image of an area in digital form. The digital data can be directly transferred to a GIS but the hardcopy maps have to be scanned and digitized. Non-Spatial data usually in the form of tables, reports as shown in the figure below.

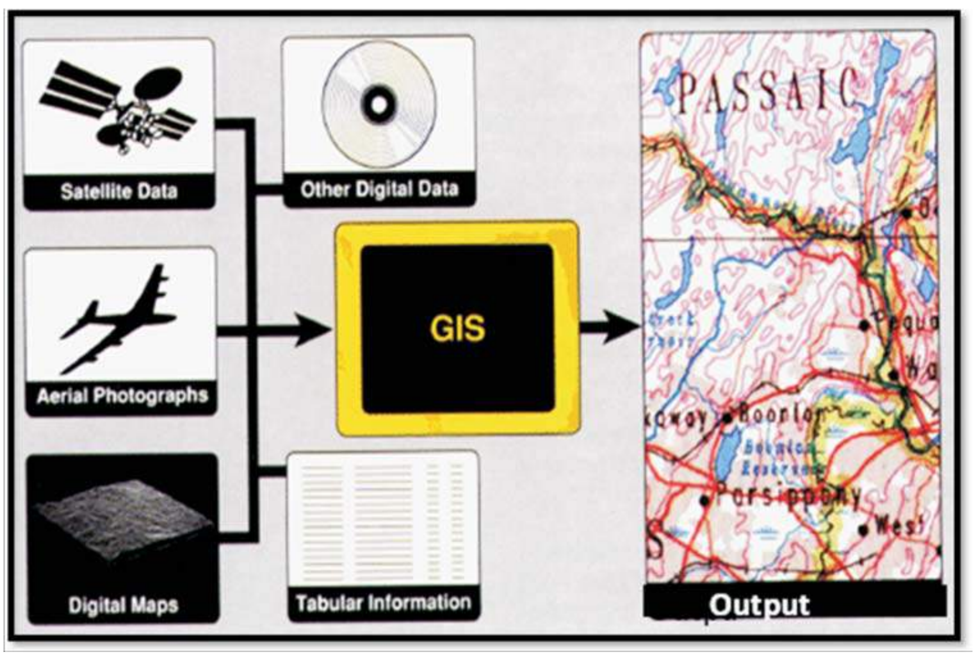


Fig. 73

Spatial and Non-Spatial data inputs to GIS Systems

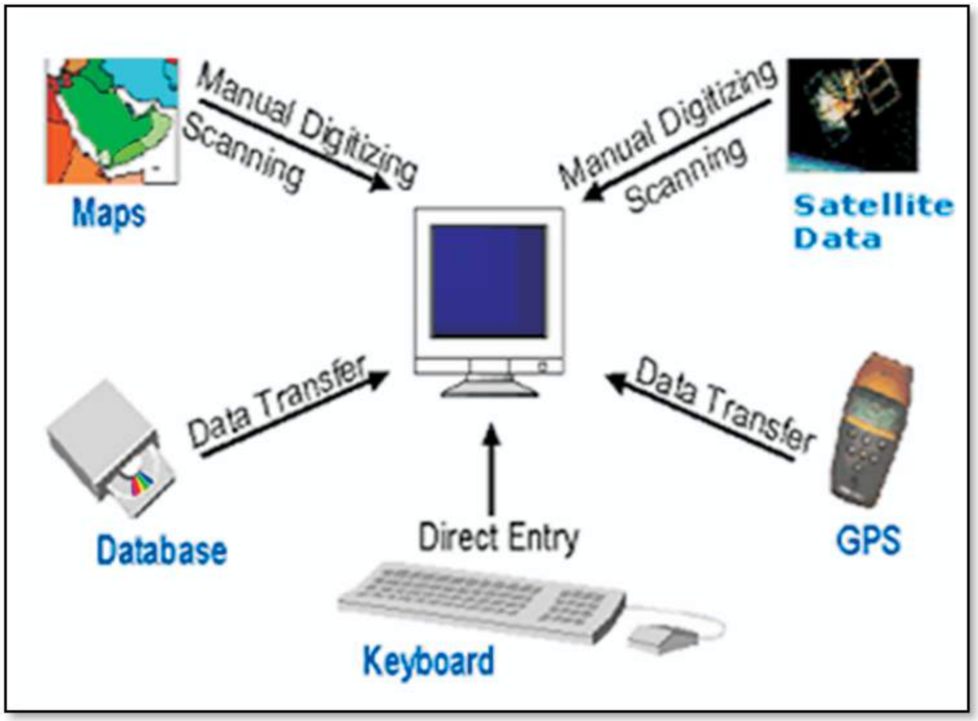


Fig. 74

Methods of data input in to GIS system

The spatial data can be entered into GIS system in following methods as shown in figures

A. Digitizing
   i) Scanning of analogue maps
   ii) Vectorization

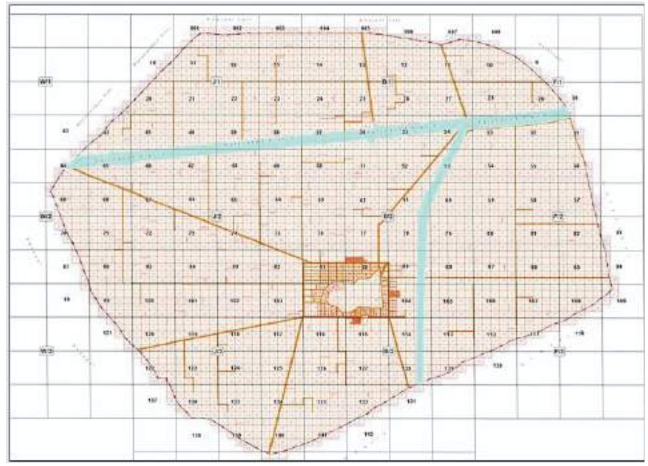
B Data Transfer
   i) From existing data
   ii) From Survey or GPS

C Key Board Entry

A. Digitization

Digitizing is the transformation of information from analog format (paper map) to digital format to store and displayed with a computer. The data collected from remote sensing such as satellite images and aerial digital photographs are fed directly to the GIS system for digitization. Paper maps (Top sheets, cadastral maps, geological maps etc), analog photographs (Taken from analog camera)need to be scanned and then fed to GIS system for digitization

Scanning the paper maps



Cadastral map (Paper map)

Manual Digitization using Digitizer table (Semi automated)

Existing map (Digital)

Manual Digitization using computer (Manual)

Satellite Imagery

Fig. 75

B. Data Transfer

Data collected from survey, GPS or with existing digital maps are directly transfer to the GIS system. GPS is a very effective tool for collecting spatial data. This data can directly import to the GIS system as shown below.

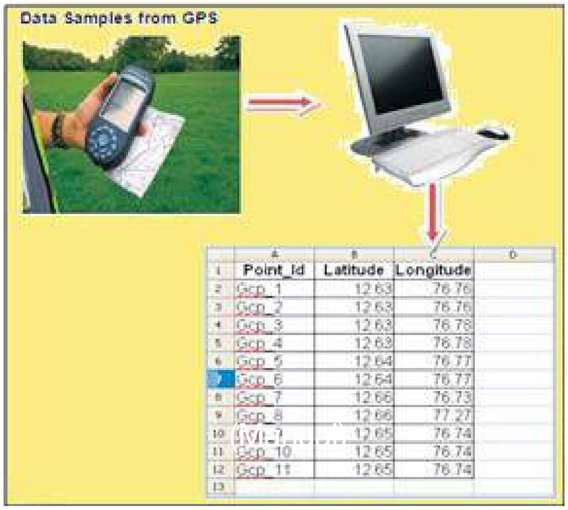
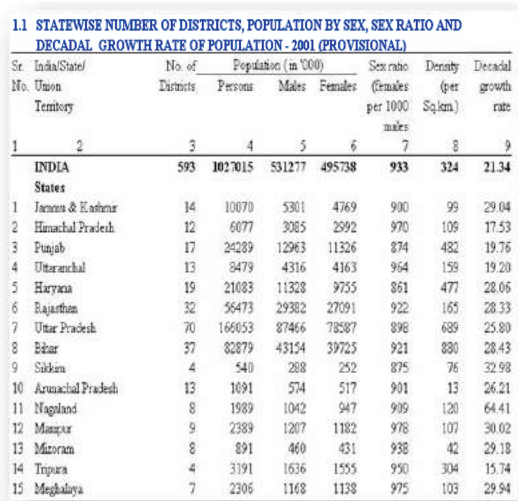


Fig. 76

GPS data transfer to the GIS system

C. Key Board Entry

Locational data and associated non Spatial Data (Attribute data) such as report/table are entered into GIS System by key board Entry.



1.1 STATEWISE NUMBER OF DISTRICTS, POPULATION BY SEX, SEX RATIO AND DECADAL GROWTH RATE OF POPULATION - 2001 (PROVISIONAL)

Sr. No.	India/State/ Union Territory	No. of Districts	Population (in '000) Persons	Males	Females	Sex ratio (females per 1000 males	Density (per Sq.km.)	Decadal growth rate
1	2	3	4	5	6	7	8	9
	INDIA	**593**	**1027015**	**531277**	**495738**	**933**	**324**	**21.34**
	States							
1	Jammu & Kashmir	14	10070	5301	4769	900	99	29.04
2	Himachal Pradesh	12	6077	3085	2992	970	109	17.53
3	Punjab	17	24289	12963	11326	874	482	19.76
4	Uttaranchal	13	8479	4316	4163	964	159	19.20
5	Haryana	19	21083	11328	9755	861	477	28.06
6	Rajasthan	32	56473	29382	27091	922	165	28.33
7	Uttar Pradesh	70	166053	87466	78587	898	689	25.80
8	Bihar	37	82879	43154	39725	921	880	28.43
9	Sikkim	4	540	288	252	875	76	32.98
10	Arunachal Pradesh	13	1091	574	517	901	13	26.21
11	Nagaland	8	1989	1042	947	909	120	64.41
12	Manipur	9	2389	1207	1182	978	107	30.02
13	Mizoram	8	891	460	431	938	42	29.18
14	Tripura	4	3191	1636	1555	950	304	15.74
15	Meghalaya	7	2306	1168	1138	975	103	29.94

Fig. 77

Attribute data entered into GIS by Key board

2.5 GIS data editing

Spatial data editing refers to the building relationship between the entities for the removal of errors and updating of digital maps. Spatial data editing includes;

a) Topology Building

b) Topological Errors

c) Locational Errors

d) Edge Matching

a) Topology Building

Topology is geometric relation of point, line & area which is used for establishing spatial relationships that exist between geographical data. Topology structures provide an automated way to handle digitizing and editing errors, and enable advanced spatial analysis such as adjacency, connectivity and containment. Building topology means setting rules and behaviors that model how points, lines, and polygons share geometry. When topological relationships help in performing analysis such as modeling network flow line, combining adjacent polygons that have similar characteristics and overlaying geographic features. Topological Editing process begins with constructing the topology of the map to be edited. This step ensures that the computer can recognize individual nodes arcs and polygons on the map. Building the topology between map features can remove some of the digitizing errors.

> Topology is the mathematical representation of the physical relationships that exists between the geographical elements.

The ability to create and store topological relationships has a number of advantages.

- Topology stores data more efficiently
- This allows processing of larger data sets
- Helps in faster processing.

b) Topological Errors

Topological errors emit the topological relationships. A common digitizing error occurs when two lines that are supposed to meet at a node, do not meet perfectly. If a gap exists between the It is called undershoot. If line is over extended as shown in below figure is called under-shoot. The result of both cases is a dangling line, which has the same polygon on its left and right sides. It is called dissolve polygons. Dangling node also occur when a polygon is not perfectly

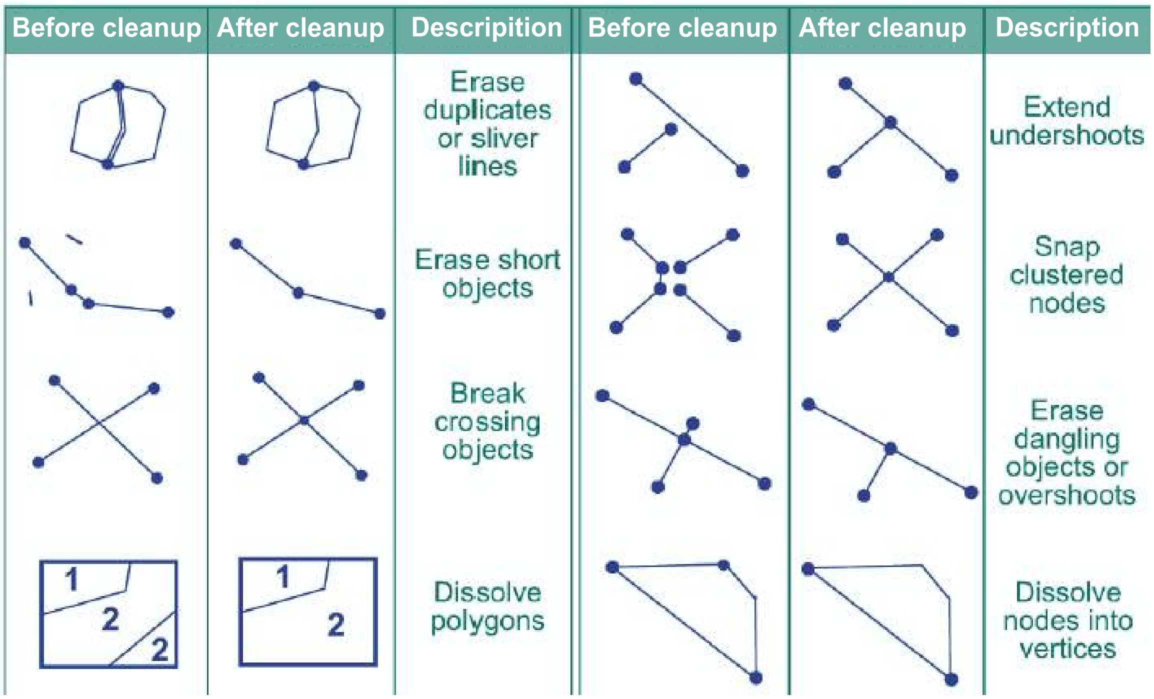


Fig. 78

An example for topological errors

c) Locational Errors

The shift in location and change in shape of the features is called as locational errors. These errors occur due to various reasons which are listed below

a) Geo-referencing Errors
b) Scanning Errors
c) Human Errors

Geo-referencing errors occur by selecting wrong control points and wrong source points during process of geo-referencing. It causes change in shape and scale of the resultant map. To correct such type of location errors, it must re-digitize or re-select control points and re-run geometric transformation.

The second scenario consists of errors in scanning and tracing. These errors occur because of intersection lines being too close, wide, thin or broken. Digitizing errors from tracing includes collapsed lines, misshapen lines and extra lines. To overcome this error one need to go for re scanning and re digitization.

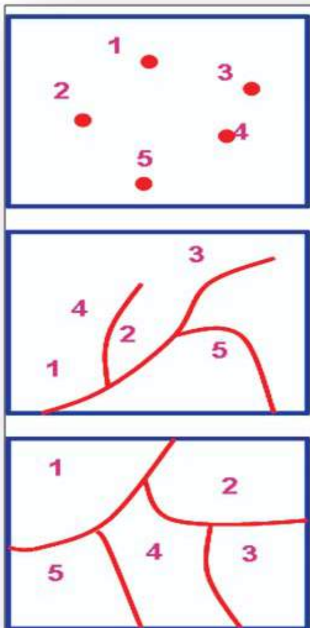
The human error occurs during the process of digitizing manually. Human error is not difficult to understand: When a source map has hundreds of polygons and thousands of lines, it can easily miss some lines or connect the wrong points. Duplicate lines occur frequently in tracing because semi-automatic tracing follows continuous lines even if some of the lines have already been traced. Quality checking and correction is needed to overcome these errors.

d) Edge Matching

GIS projects use multiple maps, which are digitized and edited separately. After all maps are finished, they must be mosaiced to make the final seamless map. Edge matching is a necessary operation before joining maps because lines from two maps rarely meet perfectly along the border.

2.6 Attribute Data Linking

GIS requires both spatial data and non spatial data, which are entered through various methods as discussed above. Before using spatial data as a basis for exploring attribute data it needs to be linked with each other. The geo-relational data model links spatial and non spatial (attribute data) by the unique feature ID. To "connect" data from another database (e.g., an



Point ID	Item1	Item2	......
1			
2			
3			
4			
5			

Line ID	Item1	Item2	......
1			
2			
3			
4			
5			

Polygon ID	Item1	Item2	......
1			
2			
3			
4			
5			

Fig. 79

Attribute data linked to Spatial data by the Unique ID

excel file) to the map and attribute table in the GIS it needs a linking field — a field with an identifying number or text string that matches the record from one database to a record from the other. Each map feature has a unique label ID Attribute data are stored in a attribute table, which contains the label ID and a default set of attributes, such as area and perimeter which are shown as item1 and item2 in below figure for point, line and polygon features. Each row of the attribute table represents a map feature and each column describes characteristics of the map feature. A row is also called record and a column is called field or an item. If the unique Id does not match it won't attach with the database.

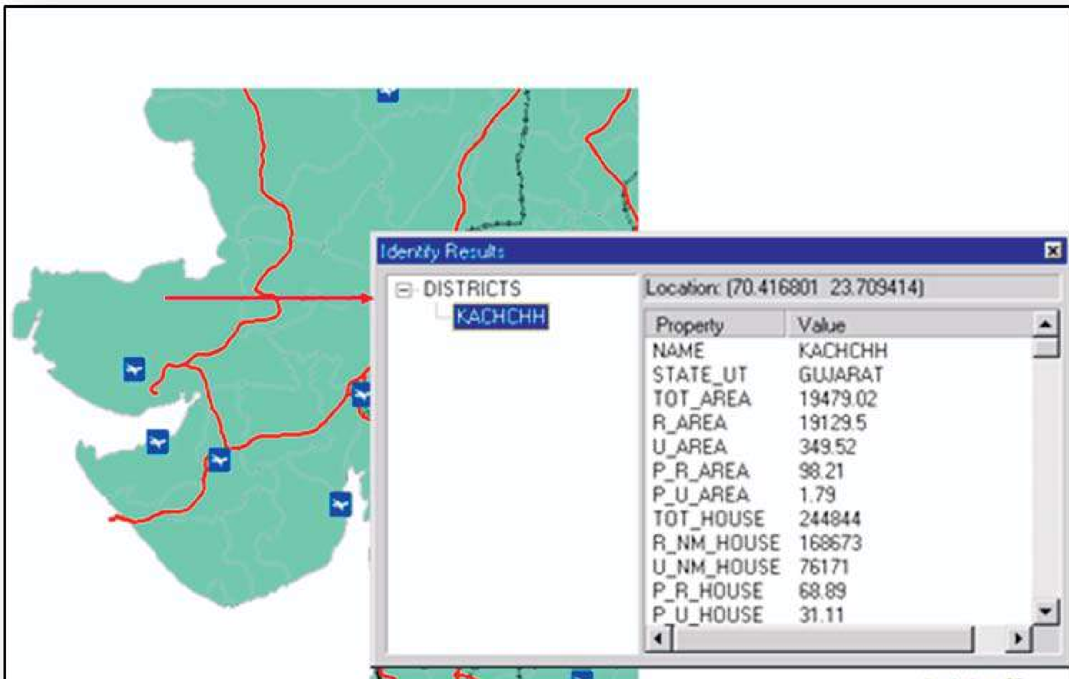


Fig. 80

Spatial data linked with non spatial Data

2.7 Spatial and non spatial data Analysis

It is a powerful tool for comprehensive, raster-based spatial modeling and analysis. Using this tool it can derive new information from existing data, through analyzing spatial relationships and building spatial models. It is used to increase better understanding of real world in different scenarios to take better decisions. To derive new information either one or more inputs and spatial operations can be used as shown in below figures.

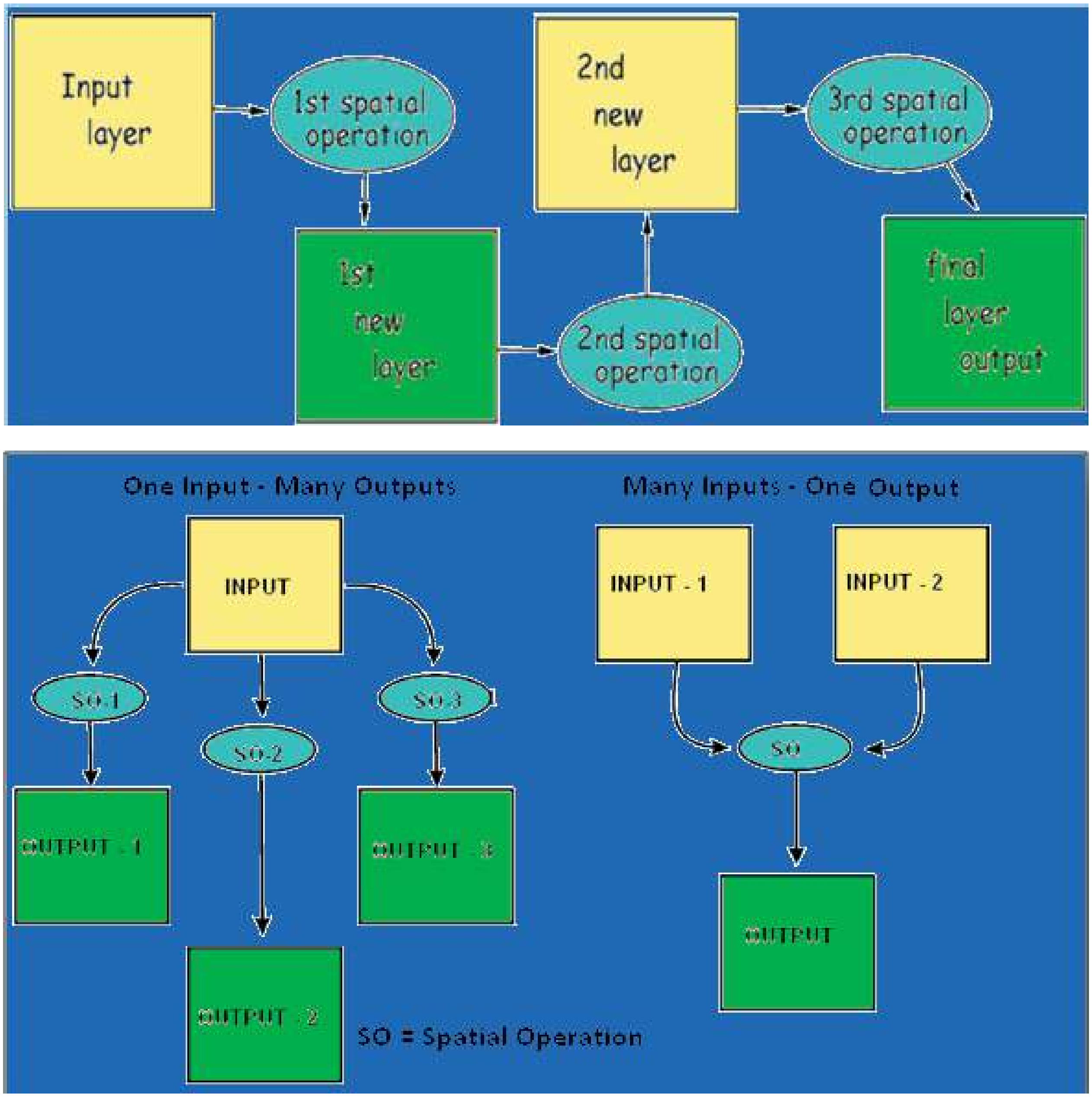


Fig. 81

Results of analysis can be communicated in the form of maps reports or both. A map is used to display geographical relationships, whereas a report document for summarizing the tabular data.

Spatial Data analysis is a process to look at geographic patterns in data and relationships between features.

a) Spatial data analysis usually involves manipulations or calculation of coordinates or attributes variables with a various spatial operations tools. Some of them are discussed below.

i) Query (based on spatial and non spatial data)

ii) Dissolve

iii) Overlay

iv) Merge

v) Buffer Analysis

vi) Triangulated Irregular Network (TIN)

i) Query:

Once GIS project is created, it is possible to apply different types of queries to obtain results to meet expectations. In GIS simple as well as complex queries are possible based on spatial and non spatial data.

A question or request used for selecting features. A query often appears in the form of a statement or logical expression.

These Queries can be applied using:

- On-screen
- Based on specific conditions
- Operations based on attribute tables: It selects the features based on their attributes. Below figure displays the resultant of various attribute queries

Following queries are used to select the features based on state name, area and population density.

State= Vermont (Based on specific condition)
State=Newyork (Based on specific condition)
Area =>1000 sq mi (Based on specific condition)
Population density <250 /sq mi (Based on attribute table)
The resultant map is shown in below figure.

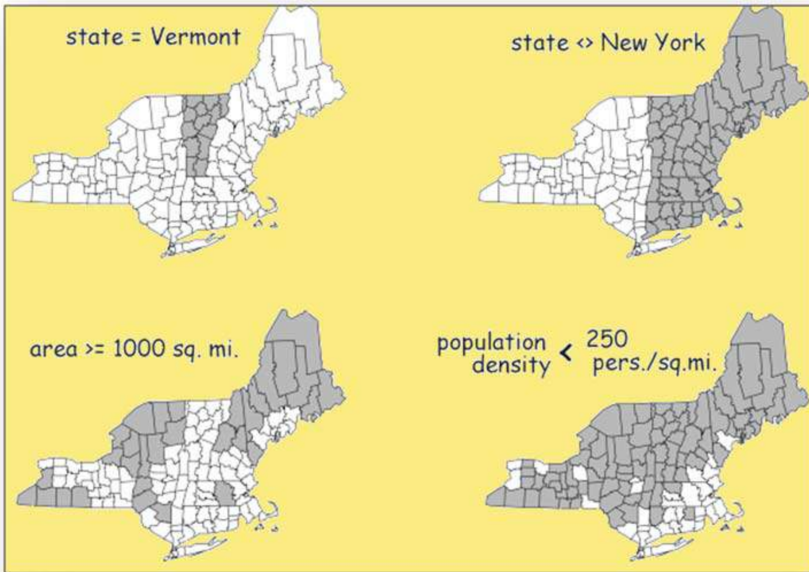


Fig. 82

An example for selection based on various query
Courtesy: Dr. Jawad Al-Bakri

Following are the different Boolean algebra expressions that are used to get output. Example are shown in figure 83.

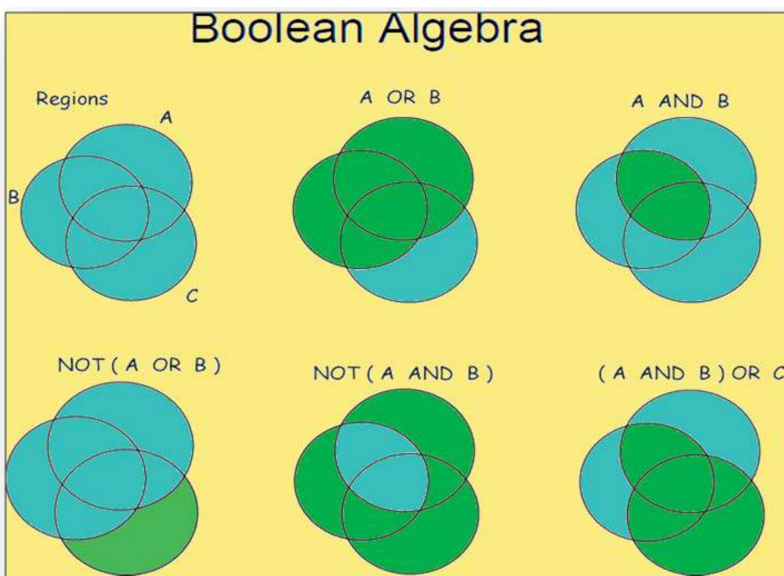


Fig. 83

An example for different Boolean expression
Courtesy: Dr. Jawad Al-Bakri

In spatial selection features are indentified based on spatial criteria such as Adjacency, connectivity, containment

The below figure 84 shows all the states adjacent to Missouri

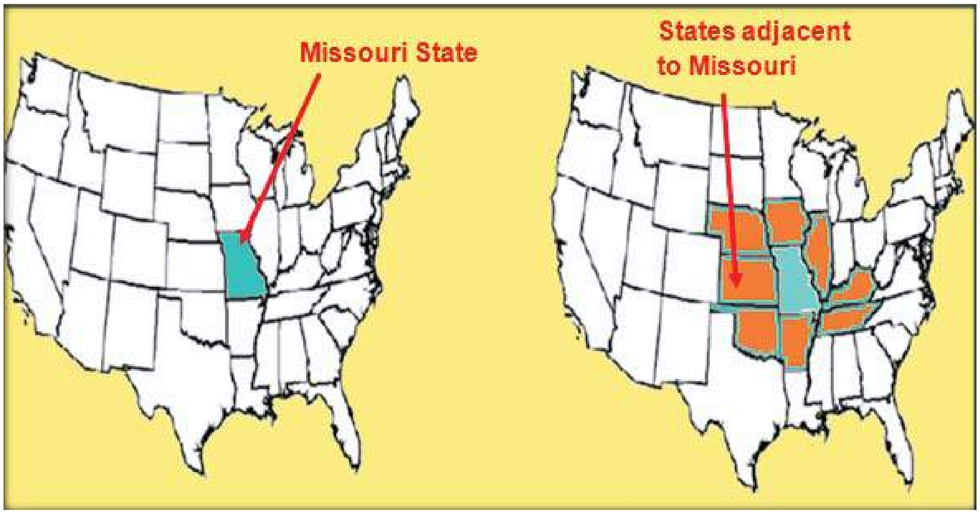


Fig. 84

An example for Adjaceny:

Courtesy: Dr. Jawad Al-Bakri

The states which are containing the river network are shown as an example of containment in this figure 85.

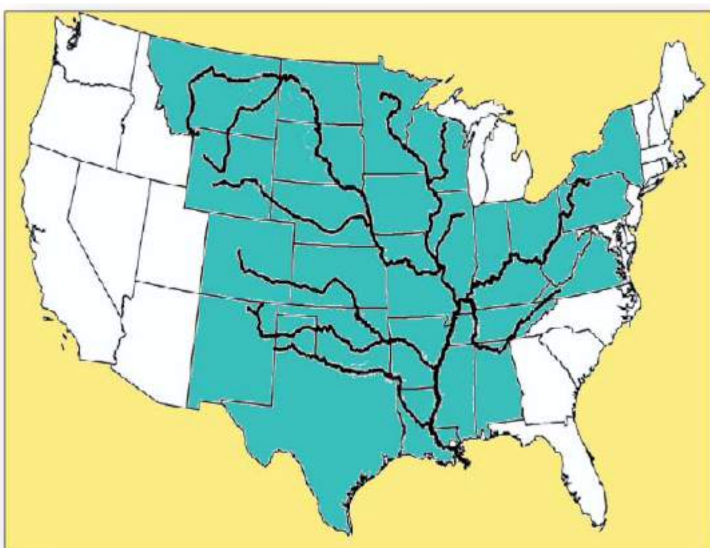


Fig. 85

An example for Containment

Courtesy: Dr. Jawad Al-Bakri

ii) Dissolve

Dissolve is a function which combines similar features within a data layer. Adjacent polygons may have identical values. Dissolve function removes the common boundary. Removing of common boundary of the same class reduces the number of polygons. Below figure shows an example of dissolve function. In this figure the numbering is done based on west and east side of the Mississippi river. West side is assigned number 1 and East side is assigned number 2. Then the dissolve function is applied. The resultant map will have only 2 polygons which are named as west and east side of the river.

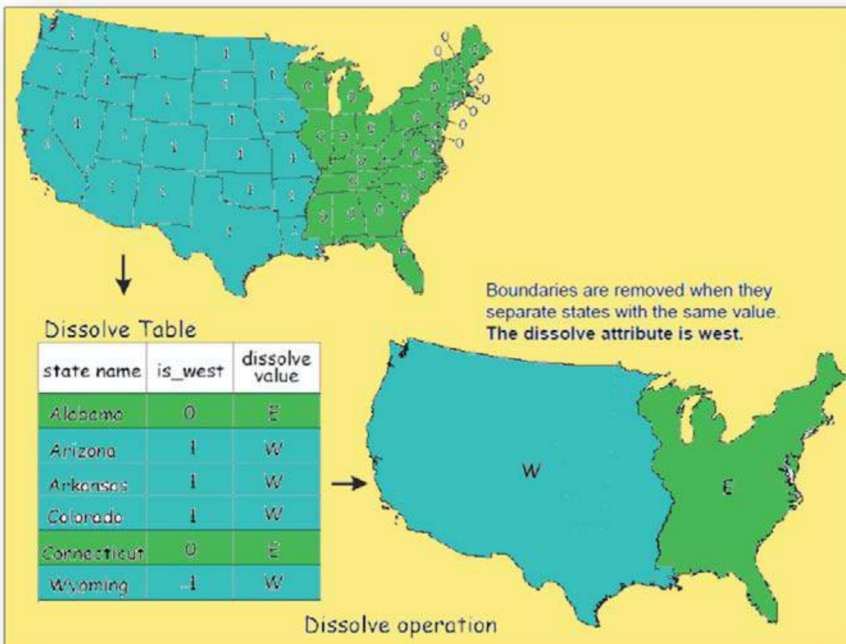


Fig. 86

An example for Dissolve Function

Courtesy: Dr. Jawad Al-Bakri

iii) Overlay

- Spatial Overlay

One basic way to identify spatial relationships is through the process of spatial overlay. Spatial overlay is accomplished by joining and viewing together different layers of same area. The result of this combination is creation of new data set that identifies the spatial relationships. figure 87 shows combination of layer - A & Layer - B and produce an overlaid map produced which has the information of both layer A & B. Overlay is the important part of GIS analysis and is performed in both vector and raster domain.

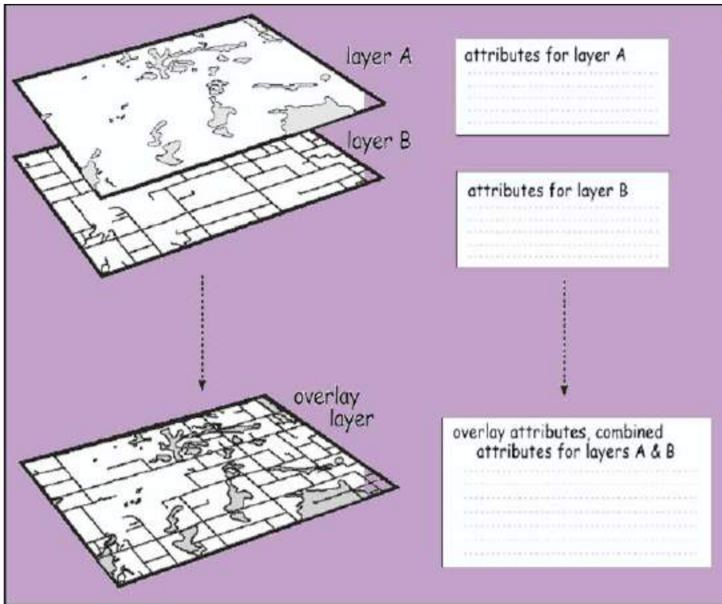


Fig. 87

An example for Overlay Operation

Courtesy: Dr. Jawad Al-Bakri

- **Raster Overlay**

Raster overlay mainly applied to nominal or ordinal data with cell by cell process which results in the combination of the two input layers. Two inputs layers are combined in raster overlay. Nominal variables for corresponding cells are joined and creating a new output layer for example soil layer is combined with land use layer to create a composite output layer as shown in below figure.

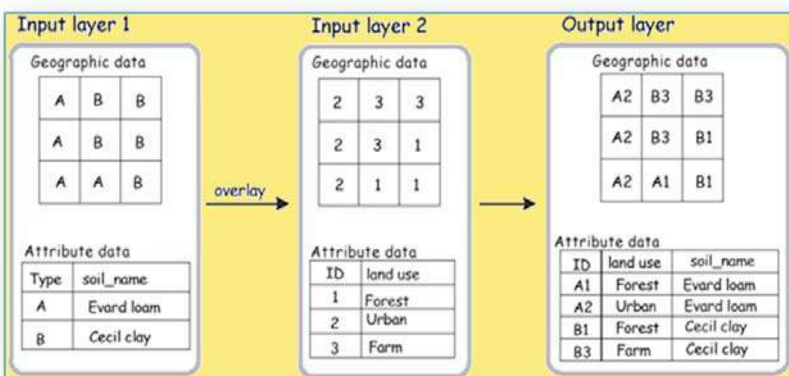


Fig. 88

An example for Cell - by cell Raster Overlay

Courtesy: Dr. Jawad Al-Bakri

- **Vector Overlay**

Vector overlay function identifies line intersection points automatically. Intersecting lines are split and a node is placed at the intersection point. Topology must be recreated for later processing. For example Polygon output from point & polygon overlay is shown in fig which results in uncertainty regarding the source for combining attribute data because there are many points corresponding to each polygon, where clarity is not there. But in case of point output resultant point is having one polygon and gives more clarity.

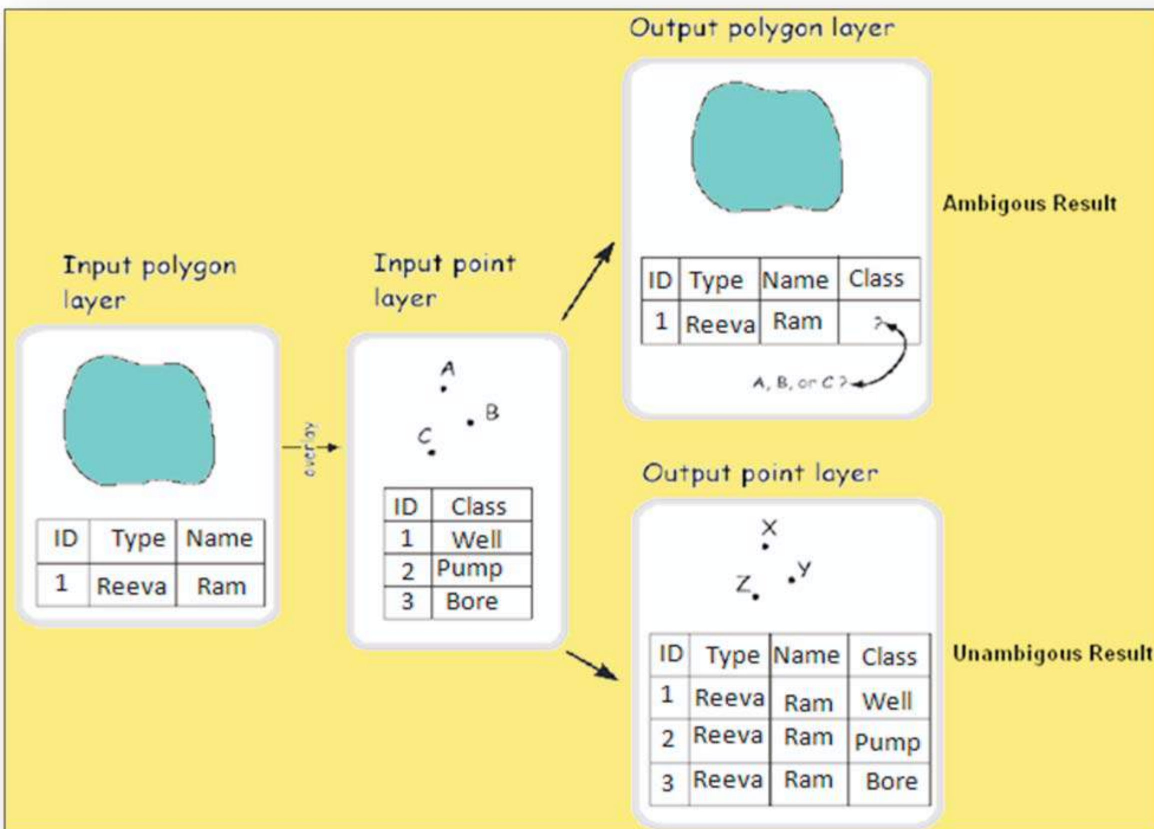


Fig. 89

An Example for Vector overlay

Common vector overlay methods are discussed below with illustration

a) Clip
b) Intersection
c) Union

a) Clip

The boundary polygon defines clipping area. The data layer elements are clipped from the boundary layer. In the output layer the features belong to data layer within the clipped area which are visible but boundary layer is not visible.

b) Intersection

It combines data from boundary layer and the features of data layer which falls within the boundary layer. The output layer shows boundary layer and the features of data layer within the boundary. Data outside the boundary layer is discarded.

c) Union

It includes all the data from boundary and data layer.

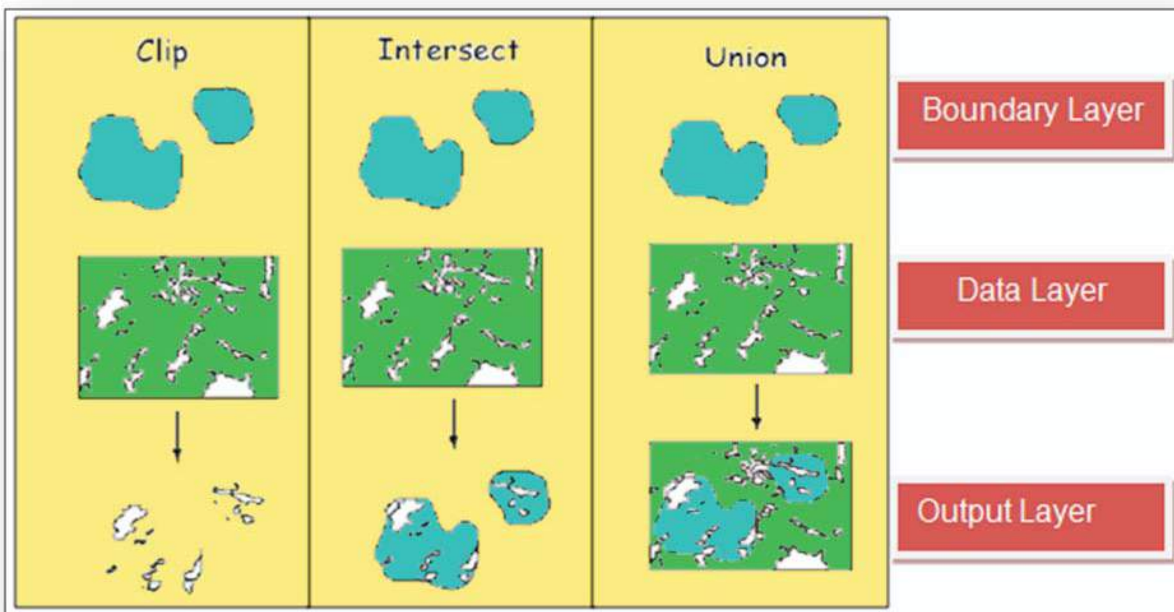


Fig. 90

An Example for Clip, Union and Intersection method

Courtesy: Dr. Jawad Al-Bakri

iv) Merge

This operation appends the features of two or more layers into a single output layer. Attributes will be retained if they have the same name otherwise discarded.

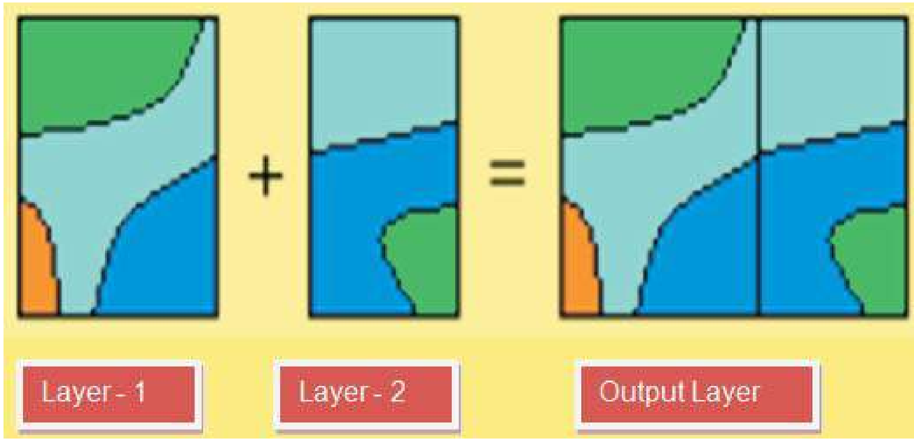


Fig. 91

An Example for Merge Operation

Courtesy: Dr. Jawad Al-Bakri

v) Buffer Analysis

Buffer analysis is used for identifying areas surrounding geographic features. The process involves generating a buffer around existing geographic features and then identifying features based on whether they fall inside or outside the boundary of the buffer. . Buffer operation is applied to points, lines and polygons. Buffer distance can differ among spatial objects based on requirements. An example is shown of buffering around points, lines and polygon. Buffering around points creates circular buffer zones. Buffering around lines create a series of elongated buffer zones. Buffering around polygons creates buffer zones extending outward or inward from the polygon boundaries.

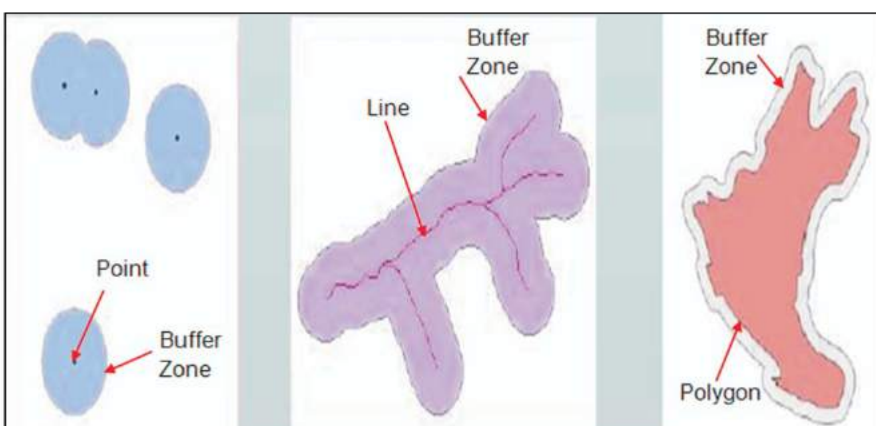


Fig. 92

Buffering around Point, Line & Area

How much area will be getting affected if Cyclone hits at Andhra Pradesh Coast? Buffer is created along with coast line at a distance of 5 km. The highlighted green area shows the affected region. Resultant map is shown in below figure.

Fig. 93

Example for Buffer

vi) Triangulated Irregular Network (TIN)

A TIN is a vector based representation of the physical land surface or sea bottom. It is generally used to create digital terrain models (DTM). A tin connects adjacent data point vertices by lines to create a network of irregular triangles. First the TIN of sampled location is computed then the triangle containing the specified unsampled location is determined from the TIN using the predicate point inside the triangle. The 3D distance between the data points along vertices and unsampled location computed using trigonometry. The value of unsampled location is the geometric mean of the

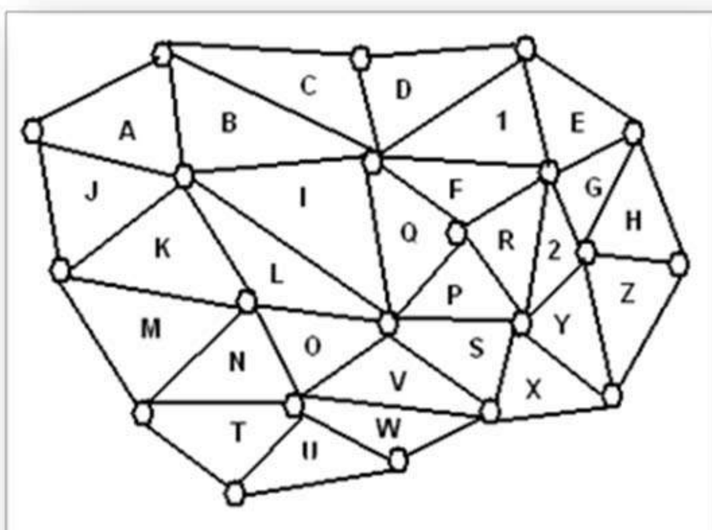


Fig. 94

TIN

values of the vertices of triangle containing. TIN's are often derived from the elevation data of a rasterized digital elevation model (DEM). A TIN can be used to analyze surface's slope and aspect.

There are basically two ways of storing triangulated networks:

- Triangle by triangle
- Points and their neighbors

The triangle by triangle method is better for storing attributes for each triangle for example slope and aspect. But it uses more storage space. Points and their neighbors methods is better for generating contours and uses less storage space, but slope, aspect , etc must be calculated and stored separately.

TIN is a series of triangles constructed using elevation data points taken from coverages. These triangles are used for surface representation and display TIN usually associated with 3-dimensional data (x,y, and z) and topography,

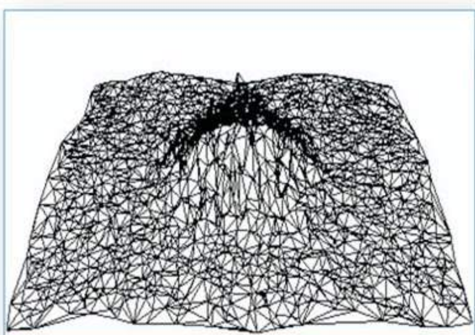


Fig. 95

TIN

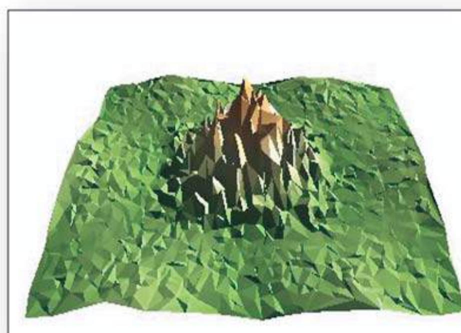


Fig. 96

Surface Model

Modeling

The process of creating new GIS product from existing products is known as "GIS Modeling" Models Integrate different data sources such as Maps, DEMs, GPS data, images, and tables. In models all these data displayed together & dynamically linked to generate valuable information for better decision, Models are vector-based or raster based. Raster based model is used where spatial phenomenon varies continuously for example, Soil erosion, snow accumulation, DEM etc. Vector data model is used in spatial phenomena that involve well-defined locations. For example, Travel demand modeling uses road network.

2.8 Map Projection and Coordinate System

"Map Projection is a procedure which transforms the features and locations from a 3D platform that is surface of earth to a 2D platform that on paper in a defined and consistent way."

GIS user works with map features on the plane surface. These map features represents spatial location on the earth surface. The location of the map features are based on coordinate system. In Class XI we have studied about Geographic Coordinates system where the location of the map features are defined in the form of latitude and longitude. Map projections are used to transfer geographical coordinates onto a flat surface. The outcome of the transformation is a systematic construction of lines on a plane surface representing the geographical grid. But the transformation from the Earth's surface to a flat surface always involves distortion no map projection is perfect. Several map projections have been developed for map making.

a) Some common types of Projection types

There are three types of projection system are available in the world.

- i) Cylindrical projection
- ii) Conical projection
- iii) Planar/Azimuthal projection

Globes are the most accurate way to represent the surface of the Earth. It is not practical to carry a globe into the field, That is why map makers figure out how to represent a round map on a flat piece of paper. That is called as Map projection.

b) Some of the common GIS Projection used

- i) Mercator
- ii) Transverse Mercator
- iii) Universal Transverse Mercator
- iv) Lambert Conformal

v) State Plane
vi) Lambert Equal Area
vii) Albers Equal Area Conic

c) Coordinate Systems

How we can locate our self on earth? There should be some system which can calculate the location information by some known reference point. This system is called as Coordinate system.

> Coordinate system which uses a set of numbers, or co-ordinates, to determine the position of any given point by using some references

Coordinate system ar divided into two types

i) Geographic coordinate systems.
ii) Projected coordinate systems

i) Geographic coordinate system

Geographic coordinate system is a three-dimensional reference system that locates points on the Earth's surface. The unit of measure is decimal degrees. A point at earth has two coordinate values, latitude and longitude. Latitude and longitude measure angles. Latitude is defined as the angle formed by the intersection of a line perpendicular to the Earth's surface at a point and the plane of the Equator. Points north of the Equator have positive latitude values, whereas points towards south have negative values. Latitude values

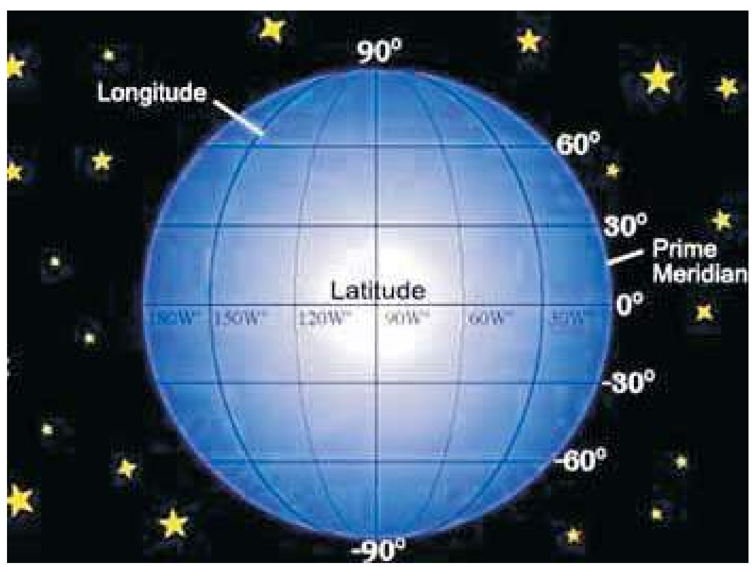


Fig. 97

Location information in geographic coordinate system

ranges from - 90 to + 90 degrees. Lines of latitude are also called parallels. A meridian is formed by a plane that passes through the point and the North and South poles. The longitude value is defined by the angle between that plane and a reference plane. The reference plane is known as the prime meridian. The most common prime meridian passes through Greenwich, United Kingdom.

ii) Projected coordinate system

A two-dimensional coordinate system is commonly defined by two axis. At right angles to each other, they form a **XY**-plane. As shown in figure below

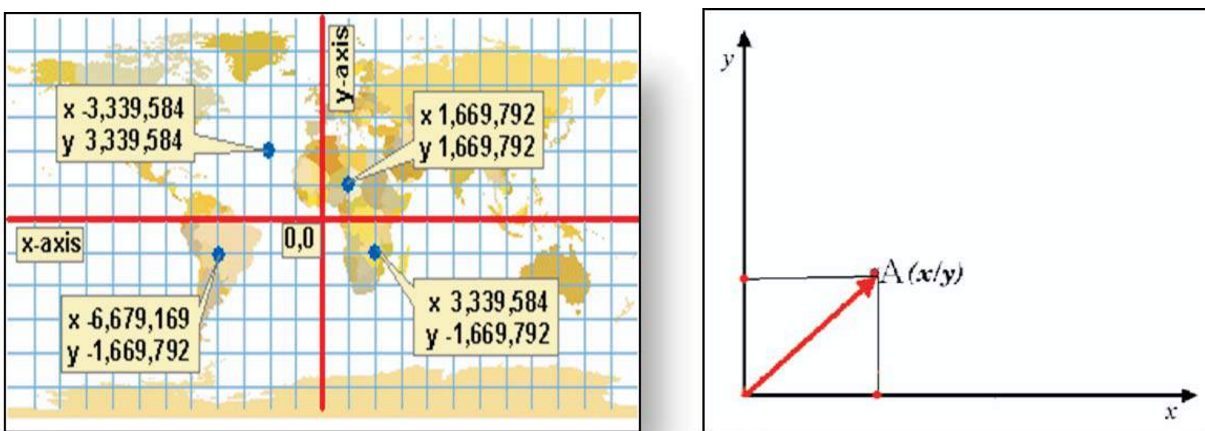


Fig. 98

Location information in projected coordinate system

A projected coordinate system in the southern hemisphere normally has its origin on the equator at a specific longitude. This means that the Y - values increase southwards and the X - values increase to the West. In the northern hemisphere the origin is also the equator at a specific longitude. Y - values increase northwards and the X - values increase to the East.

Some Examples of Popularly Accepted Coordinate System in the World.

a) Universal Transverse Mercator (UTM)

It is most comomnly used international plane coordinate system developed by the U. S Army. The Universal Transverse Mercator Coordinate (UTM) system provides coordinates on a world wide flat grid for easy computation. This system divides the World into 60 zones, each being 6 degrees longitude wide, and extending from 80 degrees south latitude to 84 degrees north latitude, the polar regions are excluded. The first zone starts at the International Date Line (longitude 180 degrees) proceeding eastward. High digree of accuarcy is possible due to separate projection for each UTM zone . India falls under 42 - 47 zone.

Fig. 99

Zone numbers of India

UTM is frequently used, consistent for the globe and is a universal approach to calculate accurate geo referencing

b) Datum

A reference datum is a known and constant surface which can be used to describe the location of unknown points. On Earth, the normal reference datum is sea level. There are many datum sytems are available. Based on projection and location we can choose realated datum system. For example for working India data set conical projection and Everest datum is used. But globally most commonly used projection type is UTM and WGS 84 datum.

c) WGS84 (world Geodetic System)

The World Geodetic System is a standard for use in cartography, geodesy, and navigation purpose. The origin of WGS-84 System is the centre of mass of the earth. This system has come into existence only towards the end of 20th Century, and prior to that the local coordinate system such as Everest or Indian System had been in use in India for more than 150 years.

2. 9 Digital cartography

In class XI we have studied about the cartography. Cartography is the art and science of map making technique. The person who prepares the maps is called as cartographer. The digital cartography is also called as map creation. The map features are map scale, north arrow, map Keys, cartographic grid etc.

Cartographic functions:

- It produces graphics on the screen or on paper that conveys the result of analysis to the people who make decisions about resources.
- Wall maps and other graphics can be generated, to visualize and understand the results of analysis
- Database information can be generated for further analysis. An example would be a list of all addresses within one mile of a toxic spill.

The below table shows the relationship between the map scale and the respective feature dimension on the ground

Sl No	Map Scale	Ground distance corresponding to 1cm on map
1	1:500	5 m
2	1:1000	10 m
3	1:5000	50 m
4	1:25,000	250 m
5	1:50,000	500 m
6	1:1,00,000	1 Km
7	1:250,000	2.5 Km
8	1:1,00,00,000	10 m

Table : 6

2.10 Advantages and Benefits of GIS

GIS is becoming essential tool for government and many large corporations to understand recent developments. Senior administrators and executives at the highest levels of government use GIS information products to communicate. These products provide a visual framework for conceptualizing, understanding, and better decision. GIS can be used in many areas such as land use, crime, the environment, and defense/security situations. GIS is a very popular tool in current era due to its various advantages as discussed below

i) Planning of project:

The maps generated by different agencies are likely to be in different scales and projections. In order to compare data from maps they have to be converted into same scale and projection. In past mapping of different scale and projection were done manually. But with the help of GIS, the maps can be stored in digital form in real world co-ordinates, therefore the conversions of map projections can be done easily and quickly. The spatial analysis functions of GIS applied to visualize the different scenarios to planner to facilitate the planning of different projects. The extensive data handling capabilities during the studies of different scenarios increase depth of knowledge and wide span of information.

- **Better decision making**

The better information leads to better decision. The various spatial and non spatial data analysis results better decision. Common examples include real estate site selection, route / corridor selection, zoning, planning, conservation, natural and resource extraction, etc.

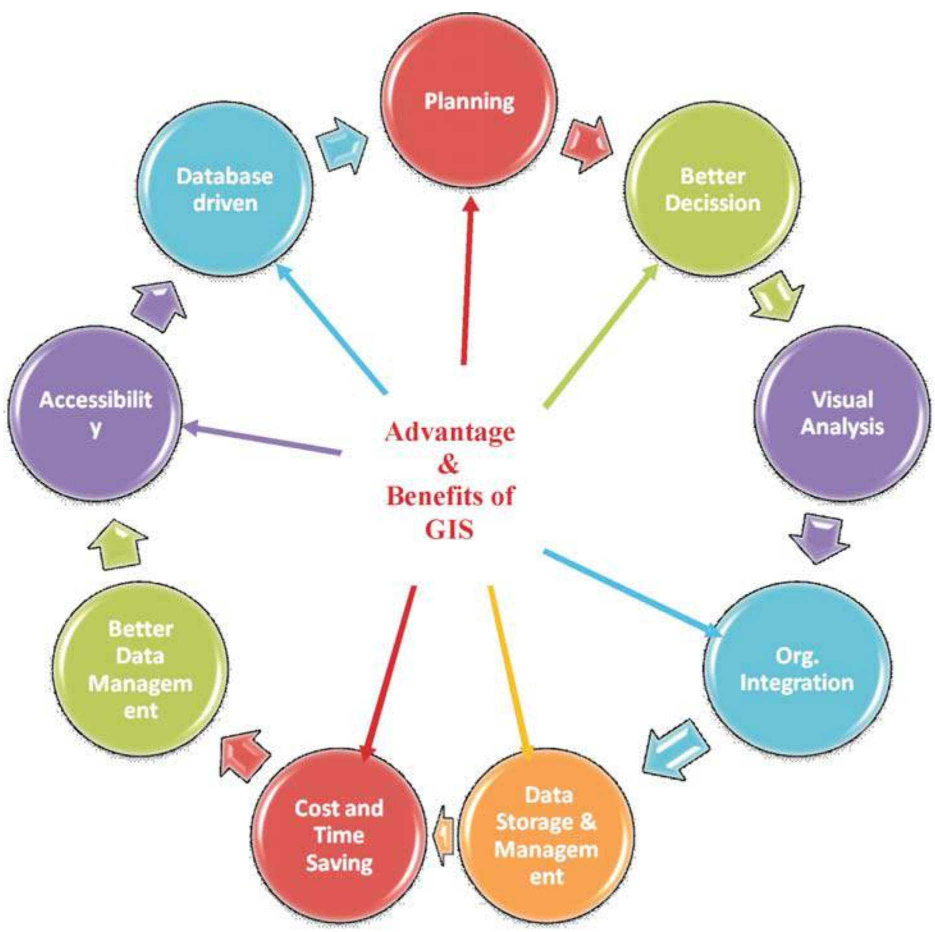


Fig. 100

ii) Visual analysis

Visualizations of GIS Based maps help in understanding different scenarios and situations. Maps improve communication between different teams, departments, disciplines, professional, organizations, and the public& private organization.. Digital Terrain modeling is an important utility of GIS. DTM, 3D modeling and landscape can be better visualized, resultse to better understanding of various features of the earth

iii) Improving organizational integration

Much organizations have implemented GIS to improve the management of their resources. GIS has the ability to link datasets. It facilitates intra departmental information sharing and communication. By creating shared database one department can benefit from the work of other department. Data can be collected and created once and used several times. Communication increases among individuals and different departments, therefore redundancy is reduced and productivity is improved and enhanced, which leads the overall organization efficiency

iv) Efficient data storage and management

In past people were using the paper maps which were static, covered limited area. It was difficult to update. It took lots of space to store data. Over a period of time it was detroited . It is unable to interpret the relationship between different features through static map. After implementation of GIS it is easy interpret the relationship of hidden features. Once the data are created through GIS it is in digital format which is easy to store, update interpret and manage.

v) Cost and time saving

GIS facilitates sharing data within the departments which reduce the cost and resources. Due to automated functionalities of GIS it saves the time of data processing.

vi) Better data management

GIS is increasingly being implemented as enterprise information systems. GIS enables the organization to organize and manage their resources and assets more efficiently. For examples utilities, forestry and oil companies, the assets and resources are now being maintained as an enterprise information system to support day-to-day work. GIS enables management tasks and provide a broader context for assets and resource management.

vii) Accessibility

To access data prepared by GIS is easy and faster as compare to conventional method which result in better decision making.

viii) Database driven

Paper maps represent earth features graphically without any attribute information. Since GIS works with different types of database with a attribute information which helps to understand geo features and their relationship efficiently. New information can be created with existing data to represent various scenarios for better decission

Let us wrap up what we covered in this chapter.

- GIS is a computer application program that stores spatial and non spatial information
- It is also called as Geo based information system
- GIS is a collection of computer, hardware, software system for digitally capturing, managing, analyzing, and displaying all forms of geographically referenced information
- GIS allows us to view, understand, question, interpret and visualize the data and its relationship, pattern and trends in the form of maps, globes, reports and charts.
- GIS is an effective tool for implementation and monitoring of municipal infrastructure, urban area planning, public safety, utility services, transport services etc.
- Non spatial data also called as attribute data, refers to information like demographic distribution of a town or a village, daily discharge of a river at a particular place etc.
- Inputs for GIS is obtained from, manual digitization, scanning of aerial photographs, paper maps, existing data sets, remote sensing satellite imagery and GPS.
- GIS data management includes data security, data integrity, data storage and retrieval and data maintenance abilities
- GIS has a ability to analyze the collected information quantitatively and qualitatively
- GIS present the data in various ways such as maps and three dimensional images
- GIS stores the data in Raster and Vector format
- Raster format the space is divided into grid cells, with a certain value attached to each cell according to the features
- Vector stores the data in the form of Point, Line and polygon with the coordinates of the location

- Vector data structures are categorized as Spaghetti structure and Topological structure.
- Spaghetti data structure is not optimal because it does not take into consideration shared line and points. Due to this problem analysis is not possible
- Topology is used to define spatial relationships between entities
- Properties of Topological structure are connectivity, adjacency, containment, proximity, relative direction
- Raster GIS model is easier to interface remote sensing images
- Raster data structure processes quickly to answer most analytical operations and it is good for representing continuous data
- Database is a computer based system to record and maintain the information
- Spatial database is a collection of spatially referenced data which can be utilized for querying and obtaining information to integrate different types of analytical models and application.
- Database creation in vector model involves Spatial data input, Attribute data input and Linking spatial and attribute data.
- The aims of database design is to save time and resources.
- Poorly constructed database results in unnecessary data, missing data, unsupported application, inappropriate feature representation and lack of consistency.
- Data input is a operation of encoding data into a database
- The digital data directly transferred to a GIS but the hardcopy maps have to be scanned and digitized.
- The spatial entered into GIS by manual digitization, scanning, direct data entry, survey, GPS, satellite data and transfer of data from existing map
- The non spatial data entered into GIS system by key board entry
- Spatial data editing covers topology building, fixing of topological & locational errors and edge matching
- Topology is the mathematical representation of the physical relationships that exist between the geographical elements
- Topological relationship helps in performing analysis such as modeling network, combining adjacent polygons with similar characteristics and overlaying
- Topological error includes overshot, undershoot, dangles, slivers etc.

- Locational errors occur during the process of georeferencing, scanning and digitization.To overcome these errors re digitization, rescanning or re georeferencing can be done. Quality checking and correction is needed
- To create a single seamless map from a multiple maps edge matching is required.
- Each row of the attribute table represents a map feature and each column describes its characteristics.
- The geo-relational data model links spatial and non spatial data by the unique feature ID.
- Spatial and non spatial data analysis includes analyzing of existing data and its spatial relationship through building spatial model to derive new information.
- Spatial data analysis involves various spatial operation tools such as query, dissolving, overlay, TIN, merge, buffering and GIS modeling
- Query is applied using on screen, based on specific condition and based on attribute tables through Boolean algebra expressions.
- Dissolve is a function which aims to combine similar features within data layer. Dissolve removes the common boundary and reduces the number of polygons
- Spatial overlay is accomplished by joining and viewing together different layers of same area. The result of this combination creates new dataset that indentifies spatial relationship
- There are two types of overlay Raster and Vector Overlay
- Vector overlay includes clip, intersection and union
- Merge operation appends the features of two or more layers into a single output layer
- Buffer analysis is used for indentifying area surrounding geographic feature
- TIN is made up of irregularly distributed nodes and lines with three dimensional coordinates
- TIN are derived from elevation data of a rasterized elevation model. TIN is used to create digital terrain models
- The process of creating new GIS products from existing products is known as GIS modeling. Models are vector or raster based.
- GIS model integrates different data sources such as maps, DEMs GPS data, iImage and tables. All these data displayed dynamically to generate valuable information for better decision.

- Map projection is a procedure which transforms the feature and location from a 3 D platform to a 2 D platform.
- Common types of projections includes Cylindrical, Conical and Planar/Azimuthal
- In general Geographic and Projected coordinate systems are commonly used to create maps
- Datum is known and constant which can be used to describe the unknown points. The common reference datum is Sea level
- Digital cartographic is an art and science of map making technique.
- Planning, better decision making, visual analysis, improving organizational integration, efficient data storage and management, cost and time saving, bettr data management, accessibility and database driven are the, advantages and benefits of GIS

Questions-

Vey Short Questions

1. What is GIS?
2. Only spatial data is stored in GIS. True or false?
3. What is non spatial data?
4. Name some application of GIS
5. What are the data sources to GIS?
6. How the data stored in GIS?
7. What is the basic element of vector data structure?
8. Topology is used to define the spatial relationship between the entities. True or false?
9. What is database?
10. List the stages involved in database creation
11. Paper maps are directly fed into GIS system. True or False.
12. What data can be directly transferred to GIS system?
13. What data can be entered into GIS thru key board entry? Name it.
14. Buffer can only applied to pint data layer. True /False.
15. Overlay is used to create digital terrain model. True/ False.

16. What is a map projection?
17. List the common types of projections. Name them.
18. How we can locate our self on earth?
19. What is the range of Latitude values?
20. What are parallels?
21. How many zones are in UTM?
22. India falls in which zone?
23. What is datum?
24. What is cartography modeling?
25. GIS is based on database driven. How it helps user to understand the relation between the geo features.

Short Questions

1. What are the difference between paper and GIS map?
2. What data management includes?
3. Define the following
    a. Raster data structure
    b. Spaghetti data structure
    c. Topological data structure
    d. Row
    e. Column
4. Why database is required in GIS?
5. Name the methods used for digitization?
6. What are the advantages of building Typology?
7. How spatial data can be links with non spatial data? Explain the method?
8. Spatial selection features are identified based on spatial criteria. What are these name them?
9. Define the following
    a. Query

b. Dissolve

c. Overlay

d. Merge

e. Buffering

f. TIN

g. GIS Modeling

10. Define the following

a. Clip

b. Intersection

c. Union

d. Merge

11. What is Geographic coordinate system?

12. What is projected coordinate system?

13. How GIS helps in improving organization integration and saving cost & time?

14. How GIS helps in managing data efficiently

15. How GIS helps in planning and better decision making?

Long Questions

1. Why GIS is needed?
2. Explain in detail about GIS functions with flow chart.
3. Define the properties of spaghetti data structure
4. What are the properties of topological data structure?
5. What is difference between vector and raster data structure?. Specify what applications are used in each data structure.
6. What are the advantage and disadvantages of Raster data?
7. What is the purpose of database designing? How it helps in GIS? What are the affects of unplanned and undersigned database?
8. Describe in detail about different types spatial query
9. What is buffer analysis? Why it is used?

10. How much area is getting affected by Cyclone? What type of spatial analysis will be used to get answer? Explain with diagram.
11. North East Government would like to prepare Digital Terrain model of the area. What method would you suggest to prepare and why? Describe in detail.
12. You want to study about spatial phenomena such as soil erosion, rainfall and road net work. What type of model is helpful to analysis the phenomena and provide better decisions?
13. Explain in detail the advantage and benefits of GIS