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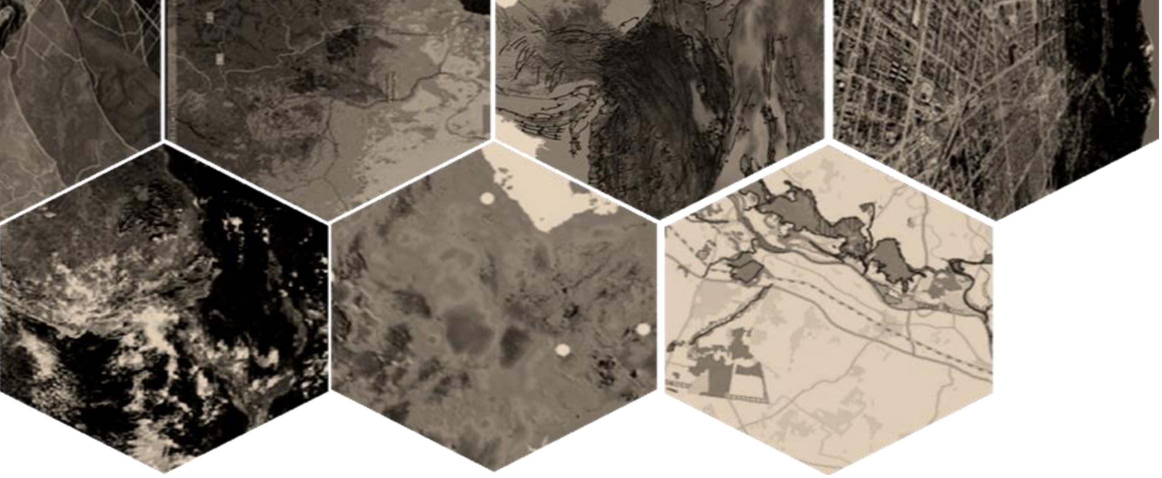


CHAPTER 1

Introduction

CHAPTER Outline

- **1.1 Overview of GIS**
- **1.2 History of GIS**
- **1.3 Scope and Application of GIS**
- **1.4 Purpose and Benefits of GIS**
- **1.5 Functional Component of GIS**
- **1.6 Importance of GPS and Remote Sensing Data in GIS**

What technology can be useful for routing 911 vehicles, easing traffic, and providing food aid to disaster victims? And what career allows you to explore new places, to work on the computer, and to be outdoors in the city or country side? Answer to both questions is geospatial technology. Geospatial technology covers a number of fields, including remote sensing, cartography, surveying and photogrammetry. To integrate data from these different fields in geospatial technology, we rely on geographical information systems.

1.1 Overview of GIS

A geographic information system (GIS) is a computer system for capturing, storing, querying, analyzing and displaying a geospatial data. Also called geographically referenced data, geospatial data are that describe both the locations and the charactereristic of spatial features such as roads, land parcels, and vegetation stands on the earth's surface. The ability of a GIS to handle and process geospatial data distinguishes GIS from other information systems. It also establishes GIS as a technology important to such occupations as market research analysts, environmental engineers and urban and regional planners.

1.1.1 What does GIS stand for?

Geographic Information Science

It is the science concerned with the systematic and automatic processing of spatial data and information with the help of computers. It is the theory behind how to solve spatial problems with computers. It presents a framework for using information theory, spatial analysis and statistics, cognitive understanding and cartography.

- **Geographic** relates to the surface of the earth.
- **Information** is a knowledge derived from study, experience, or instruction.
- **Science** is the observation, identification, description, experimental investigation, and theoretical explanation of phenomena.

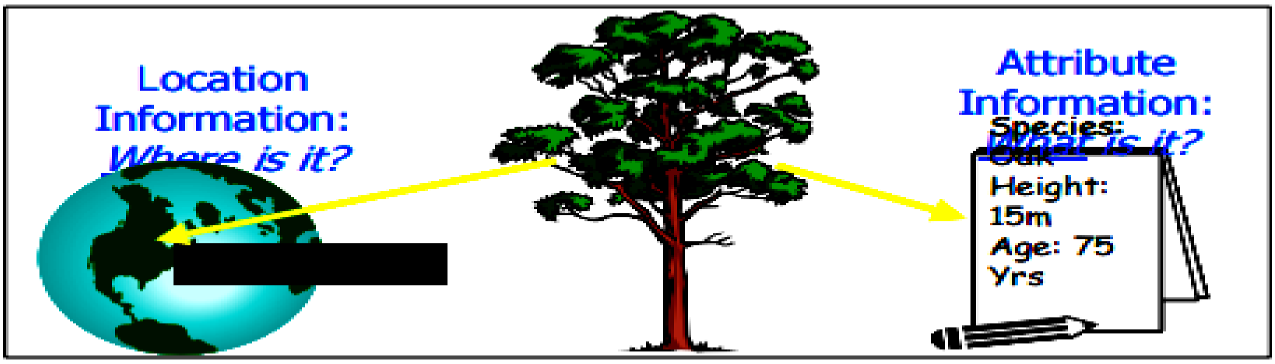
Geographic Information System

It is a system designed for storing, analyzing, and displaying spatial data. It is the use of hardware, software, people, procedures, and data. It focuses on the processes and methods that are used to sample, represent, manipulate and present information about the world.

GIS is an organized collection of computer hardware, software, geographic data, procedures, and personnel designed to handle all phases of geographic data capture, storage, analysis, query, display, and output.

- **Geographic**: Spatial data, geo-referenced.
- **Information**: Database, representation.
- **System**: Users, hardware, software.

According to the Environmental Systems Research Institute (ESRI), a GIS is defined as "an organized collection of computer hardware, application software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographic referenced information." Kang Tsung Chang describes GIS is a computer system for capturing, storing, querying, analyzing and displaying geographically referenced data. GIS is essentially a marriage between computerized mapping and database management systems. Thus, a GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working with the data. Geographically referenced data separates GIS from other information systems. Let us take an example of road. To describe a road, we refer to its location (i.e. where it is) and its characteristics (length, name, speed limit etc.). The location, also called geometry or shape, represents spatial data, whereas characteristics are attribute data. Thus a geographically referenced data has two components: spatial data and attribute data.



Spatial Data:

Describes the location of spatial features, which may be discrete or continuous. Discrete features are individually distinguishable features that don't exist between observations. Discrete features include points (wells), lines (roads) and areas.

Attribute Information:

What is it? Species: Oak Height: 15m Age: 75 Yrs Attribute Information: What is it? Species: Oak Height: 15m Age: 75 Yrs Location Information: Where is it? 51°N, 112°W 5 (land-use types). Continuous features are features that exist spatially between observations (elevation and precipitation). A GIS represents these spatial features on a plane surface. This transformation involves two main issues: the spatial reference system and the data model. Attribute Data: Describes characteristics of spatial features. For raster data, each cell value should correspond to the attribute of the spatial feature at that location. A cell is tightly bound to a cell value. For raster data, the amount of attribute data is associated with a spatial feature can vary significantly. The coordinate location of a Land parcel would be spatial data, while its characteristics, e.g. area, owner name, vacant/ built-up, land use etc., would be attribute data.

1.1.2 Definition of GIS

A collection of hardware, software, geographic data, and personnel designed to capture, store, organize, update, manipulate, analyze, and display geographically referenced information.

1.1.3 Why Use a GIS?

- Maintain and retrieve large quantities of data
- Manipulate spatial and related tabular data
- Perform complex spatial analysis
- Rescale data for analysis
- Create thematic maps (maps which depict a specific theme such as “Soil Type”)

1.1.4 GIS Capabilities

Map production. Allowing the user to design and display maps, charts, tables and images on screen and print maps to a variety of printing and plotting devices.

- Integrating maps, images, tabular data, graphics, and charts into cohesive displays for viewing and evaluation.
- Changing map colors and symbols.
- Viewing and printing geographic data at user designed scales and size.

Searching and selecting geographic features of interest based on subject queries, logical queries, arithmetic queries, and spatial relationships.

- Selecting and displaying map features based on location.

Analyzing spatial data based on conditions of proximity, adjacency, and containment.

- Interactively measuring distances between mapped locations.

Calculating summary statistics such as count, sum, average, and variance.

Editing spatial layers and their attribute tables.

- Importing spatial layers from a variety of other sources.
- Creating new spatial layers via. digitizing from the screen or digitizing tablet.
- Intersecting and “clipping” of vector spatial layers.

1.1.5 GIS Data Structures

Vector: Point, line, and area features, such as wells, streams, and ponds, which have discrete positions (or series of positions) stored in an X,Y coordinate system.

Raster: Spatial data stored in a two dimensional matrix or “array,” much like a checker board. Each raster, or cell, contains a value. Images such as photographs are in raster format and cells are called “pixels”.

1.2 History of GIS

GIS id not new. Since the late 1960s computers have been used to store and process geospatial data. Early examples of GIS-related work from the late 1960s includes the following.

- **1964 : Canada Geographic Information System (CGIS)**

The first computerized GIS were introduced as a project under Rehabilitation and Development Agency Program in Canada, in the year 1964. This formation system was named as the Canada Geographic Information System (CGIS). The main task of CGIS was to analyze the land inventory of Canada to provide a kind of aid in land development for agriculture point of view. The CGIS software is still in use.

- **1960-1970 : Harvard Lab for Computer Graphic**

The Harvard Lab for Computer Graphic was established to promote GIS technology. The Harvard Lab developed several GISs in which SYMAP (Synagrapic Mapping System), CALFORM, SYMVU, GRID, POLVRT and ODYSSEF are the main. The ODYSSEY was the first modern vector GIS; its feature form a kind of basic for commercial applications.

- **Late 1960s : Central Intelligence Agency (CIA)**

In the late 1960s the Automatic Mapping System was introduced by the Central Intelligence Agency (CIA), United States, America and based on which the CAM software was developed to create maps at different scale.

- **1980s-1990s**

From 1980s-1990s, many GIS applications have been made, worldwide. And simultaneously several packages/software have also been developed/refined for better use or friendly use. At now, the most common software of GIS are the Arc Info, Arc View, Map Info, SPANS GIS, PAMAP GIS, INTERGRAPH and SMALL WORLD.

1960 – 70s Innovation	First GIS – Canada Land Inventory
	DIME US Bureau of Census
	Harvard Laboratory for Computer Graphics
	Major vendors started (e.g. ESRI, Intergraph)
	Landsat satellite launched
	Key academic conferences (e.g. AutoCarto)
1980s Commercialization	Commercial GIS software (e.g. ArcInfo)
	First GIS textbooks
	First global data sets
	Clinton Executive Order
2000s Exploitation	Internet becomes major deliver vehicle
	More than 1 million active users

For many years, though, GIS has been considered to be too difficulty, expensive, and proprietary. The advent of the graphical user interface (GUI), powerful and affordable hardware and software, and public digital data broadened the range of GIS application and brought GIS to mainstream use in the 1990s. Various trade reports suggest that ESRI Inc (ArcGIS, ArcView, ArcEditor, ArcInfo) and Intergraph Corp (GeoMedia, MGE) lead the GIS industry in term of the software market and software revenues.

1.3 Concepts of GIS (Geographic Spatial Object)

GIS studies regions, resources, people etc. Earth has a spatial component. The land extend in all directions, within which all things or attribute exit. Anything happening or existing in space in spatial or spatially distributed. It must have a geographic reference that is, be geo-referenced. Also, there must be definable boundaries or limits in space. Information is simply any facts or data about a given space on earth. Examples include slop, rainfall amount, population, road network and vegetation. These may collectively be referred to as attributes, factors or variable within a defined space on earth e.g. the location, country, drainage basin etc. Systems are a structured set of objects or parts that are related to one another or which operate together as one whole unit following a defined pattern.

UNIT-2

UNIT. 2

~~Coordinate System~~:

Georeferencing systems:

It is defined as positioning objects in either two-or-three dimensional space
There are two principle methods of georeferencing.

(1) Continuous georeferencing systems
(2) Discrete georeferencing systems

(1) Continuous georeferencing systems

It implies continuous measurement of the position of phenomena in relation to a reference point with no abrupt change or breaks. It involves resolution & precision.

Many geographical phenomena, including property boundaries, manhole locations, building details, and many map details, are measured on continuous basis.
It includes direct georeferencing which involves

(a) ~~Datm~~ Datum
(b) Coordinate system
(c) Map projection System

Other continuous system is relative georeferencing which includes

(a) offset distance
(b) Measurement along (road) networks.

(2) Discrete Georeferencing Systems.

In this ~~metho~~ systems the positions of phenomena are measured relative to fixed, limited units of the surface of the earth. This method is also known as spatial georeferencing by geographical identifiers.

—x—

(a)
~~Dawm~~ DATUM

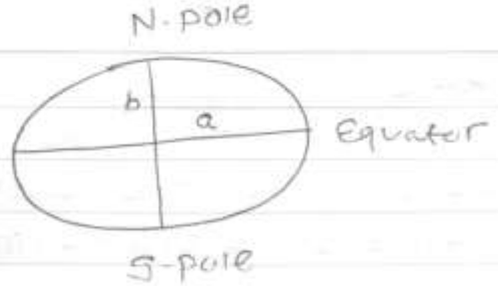
To determine an exact position on the Earth's surface one has to know the shape & size of the Earth. As we know, the earth is not perfect sphere, but more like an ellipsoid with flattening (ellipticity) at the poles. The shape of earth is therefore, for practical purposes, often expressed by the shape of the ellipsoid.

Ellipsoid of various sizes have been used, depending on the degree of accuracy with which it was possible to measure the shape of the earth.

Datum is a mathematical model of earth which serves as the reference or base for calculating the geographic coordinate of a location on earth. It is defined by

(i) size & shape: (Semi-major axis a, & semi-minor axis b) of the ellipsoid

(ii) positioning of the ellipsoid in relation to physical surface of earth by an anchor point



~~Spheroid~~ Ellipsoid has its major axis-(a) along equator and its minor axis(b) connecting the poles
A parameter called flattening (f) is defined by

$$f = \frac{(a-b)}{a}.$$

A country must have their own local datums where there are specific coordinate for the datum origin (anchor point).
Therefore datum is reference system in which the coordinates can be expressed, which is realized physically through monumentation of point with known coordinate.

Some countries have adopted global datum called WGS84 (world Geodetic System 1984) which ~~it~~ is based on earth's mass as the anchor point.
WGS84 is actually military reference system.
Georeferencing by GPS is based on WGS84.

Ellipsoid	Semimajor axis(a)	Flattering $f = \frac{(a-b)}{a}$
WGS84	6 378 137.0	298.257223563

(b) Coordinate Systems

The locations of map features are based on a

* plane coordinate system: It is expressed in x-y- coordinates.
* Geographic coordinate system:

plane Coordinate System:

The locations of map features are based on a plane coordinate system It is expressed in x-, y- coordinate

Geographic Coordinate system:

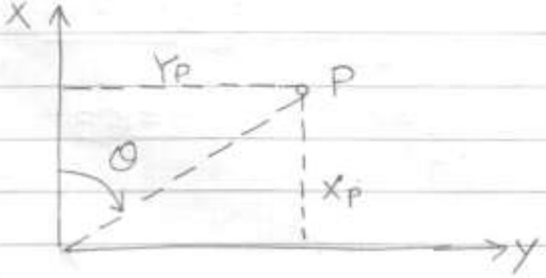
Location of spatial features on earth's surface are based on geographic coordinate system. It is expressed in longitude & latitude values.

The location of point may be designated

* As an angle and distance
* As Coordinate in right-angled cartesian Coordinate System.

Polar coordinate system:

The position can be indicated by distance and direction from the origin.



It can be transformed relatively easily to Cartesian coordinates without loss of precision, provided one is operating within same datum.

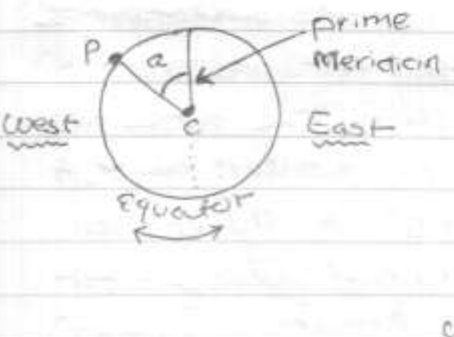
In geodsy, the most usual rt.angled coordinate systems are:

* Geocentric Coordinate :- where x, y, z are given in a triple-axle system with origin in the earth's center.
* Geographic Coordinate :- where latitude & longitude are stated on earth's sphere.
* Map projection Coordinate :- where North & East, or x and y are given on one plane.

(1) Geographic Coordinate system.

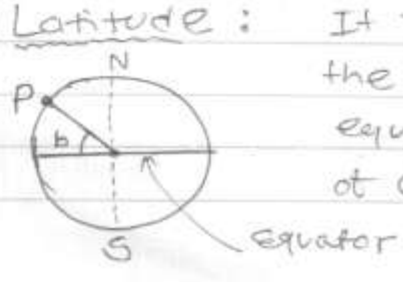
It is location reference system for spatial features on earth's surface. It is defined by longitude & latitude.

(a) Longitude : It is angular measures, it measures the angle east or west from the prime meridian,



prime meridian passes through Greenwich (England) which has reference reading of 0°. Using prime meridian as reference, we can measure longitude of point on earth's surface 0° to 180° east or west of prime meridian. In figure point 'P' is $\angle a^{\circ}$ west of prime meridian. Longitude value is (+ve) in east hemisphere & (-ve) in west hemisphere.

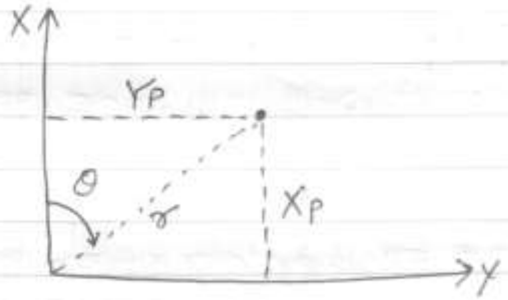
(b) Latitude : It is also angular measures, it measures the angle North or South from the equator. Equator has reference reading of 0°. Using equator as reference



we can measure latitude of point on earth surfce 0° to 90° North or South of the equator. Eg figure ∠b° north of an equator. latitude value is (+ve) if north of equator, and (-ve) if south of the equator.

(ii) Map projection Coordinates System:

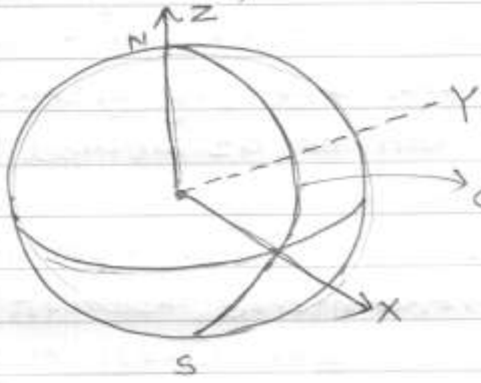
This gives the position of points relative to two mutually perpendicular axes in a plane as shown in figure below.



In figure, the position of a point forms a rectangle with the axis, therefore the system is therefore also known as a rectangular coordinate system. The axes are called 'Northing' and 'Easting' and are often written as x & y. The orientation of coordinate systems may differ, so coordinate should always be identified unambiguously - for example, in terms of compass direction (Northing, Easting) from the origin. Many countries have national, and even local, georeference system of rectangular coordinates.

(iii) Geocentric Coordinates System :

These are based on rectangular coordinate system with an origin at the center of the earth. The z axis is coaxial with the axis of earth's rotation and is positive in the direction of the North pole. The x axis goes through the zero meridian in Greenwich the y axis is orthogonal to the positive x & z axes, as shown in figure below



Geocentric coordinate are also known as cartesian coordinates.

Advantage: It covers the entire earth, which is why it is used for GPS georeference.

Limitation: Are however of limited practical use, and when introducing the ellipsoid for height referencing, one will only get ellipsoid height, which is not the same as for normal national elevation systems.

(C) Map projection system

Georeferenced data may be drawn on maps only when referenced to the plane surface, not to the curved surface of the earth. Various projection are used to represent the curved surface of the earth on the plane surface of a map. Map projections can sometime be more closely related to map drawing than to position finding. Cartographer, group map projection by preserved property according to the underlying geometrical conversions involved : cylindrical, conical, azimuthal (plane surface)

The three different projection surfaces can be unfolded to one plane and thus function as a plane map. It should be remembered, however, that curved surface are always distorted when imaged into a plane, and the deformations multiply with the increasing size of the area represented.

A map projection can be defined as a "mathematical flat surface representation of the geodetic ellipsoid"

(a) projection by preserved property:

* Conformal projection
* Equal area or equivalent projection
* Equidistant projection
* Azimuthal or True Direction projection

(i) Conformal projection

* preserves local angles & shapes
* Global properties, they apply to the entire map projection.

(ii) Equal Area/ ~~Equidistance~~ Equivalent projection

* Maintains consistency of scale along certain lines.

* Represents areas in correct relative size

* It is also global properties.

(iii) Equidistant projection

* Maintains consistency of scale along certain lines.

* Is local properties and may be true only from or to the center of the map projection.

(iv) Azimuthal projection.

* Retains certain accurate directions.

* It is also local properties

The preserved property is important for selecting an appropriate map projection for thematic mapping. Example: population map of the world should be based on an equivalent projection. By representing area in correct size, the population map can create a correct impression of population densities.

In contrast, an equidistant projection would be better for mapping the distance ranges from a missile site.

(b) Constructing Map projection
(projection by surface)

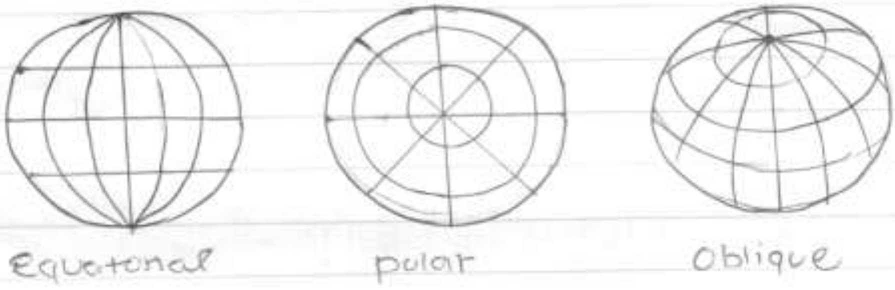
(i) Cylindrical projection

Placing a cylinder tangent to a lighted globe, one can draw a projection by tracing the lines of longitude

(C) Aspect & projection

Aspect describes the placement of a geometric object relative to globe. A plane, for example, may be tangent at any point on a globe.

* polar aspect refers to tangency at pole,
* equatorial aspect at the equator
* Oblique aspect anywhere between equator and the pole.



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4.1 Different Methods of Data Capture

(i) Digitizing:

It is process of converting data from analog to digital format. Manual digitizing uses a digitizing table which has built-in electronic mesh, which can sense position of curser

(ii) Scanning:

It is digitizing method that converts analog map into a scanned file, which is then converted to vector format through tracing on it.

(iii) Field Data:

These are Survey & GPS data, survey data Consist primarily of distance, direction, elevations.

GPS receiver can determine its precise position on earth surface using GPS satellite in space

(iv) Aerial photograph:

The combination of aerial photography and photographic interpretation provide information on relatively large areas without necessitating survey on ground.

(V) Spread Sheet Data:

It is text file with x- y- coordinate, geographic data can be generated from text file that contains x- y- coordinates.

(vi) Remote sensing:

Satellite remote sensing of earth envolves two observation modalities:

* Passive optimal: Deals with reflected sunlight and emitted thermal radiation.

* Microwave: Deals with transmission & reflection of energy into microwave portion of radio frequency spectrum.

4.2: Quality Aspects of Spatial Data

The final accuracy of data depends on qualities of original data and on the precision with which input data are processed.

Higher accuracy entails higher initial data quality and more precise processing, both of which increases system costs.

(1) Aspects of data acquiring comprise the criteria for selecting data accuracy

(i) Needs

(ii) Costs

(iii) Accessibility

(iv) Time Frame.

Quality can be defined as one or more characteristic of geographical data that describe the extent to which it is fit for use.

(2) Elements to describe quantitative quality of data set.

(i) Positional Accuracy
* Absolute or external accuracy
* Relative or Internal accuracy
* Gridded data position accuracy

(ii) Attribute Accuracy
* Classification Correctness
* Non quantitative attribute Correctness
* Quantitative attribute Correctness

(iii) Temporal Accuracy
* Accuracy of time measurement
* Temporal Consistency- corretness of ordered events or Sequence, if reported
* Temporal Validity - Validity of data with respect to time.

(iv) Logical Consistency
* Conceptual consistency: Adherance of rules of Conceptual scheme
* Domain Consistency: Adherance of Values to Values domains.

* Format Consistency: Degree to which data is stored in accordance with physical structure of data set.

* Topological Consistency: Correctness of explicity encoded topological characteristics of data set.

(V) Data Completeness:

* Commission: Excess data present in data set
* Omission: Data absent from Dataset.

(3) Elements to describe non-quantitative data set Indirect goal of accuracy:

(i) Purpose: Describes rationale for creating data set & contain information about its intended use.

(ii) Uses: Describes application(s) for which data set has been used.

(iii) Lineage: Describes history of data set, origin comprises description of source material.

4.3 Global positioning System (GPS)

- GPS Comprises 29 satellites with 24 operational in 6-orbit levels and at an height of 2020 km out in space.
- It principle, 4 to 6 satellite are available 15° over the horizon at any time, everywhere on earth.
- Each Satellite is equiped with 4-very accurate atomic clocks.
- The satellite's clock and orbits are Controlled by 5-ground Station [Colorado, Hawaii, Ascension Island, Diego Garcia, Kwajalein Spring Island) that transfer data on changes in orbit parameters and time to satellite.
- Contineous signals transmitted from Satellite contains updated data of orbit parameter, Signal leaving satellite at point in time.
- Based on WGS84-Datum on geocentric Coordinate System, which may be transformed to other Coordinate system.
- GPS allows position of points throughout the world to be determined 24 hour in day in all kind of weather Condition.
- Transmitted radio signal (with exact orbit parameter) Captured in exact time by a mobile receivers on ground determines location on ground.
- Based on Signal we Can Calculate
  * The satellite position in space (x,y,z) in relation to earth's Center-based on orbit parameter.

* The distance between satellite &
receiver on earth-based

* The point of intersection between
rotation circles around satellite.

- Position of receiver is calculate in 3D as

$$(x-x_i)^2+(y-y_i)^2+(z-z_i)^2 = c^2(\Delta t_i - b)^2$$

$x, y, z \Rightarrow$ unknown coordinate of receiver
$x_i y_i z_i \Rightarrow$ Observed position of Satellites
$c \Rightarrow$ Speed of light
$\Delta t_i \Rightarrow$ time difference between sent & received signal from each Satellite
$b \Rightarrow$ Unknown clock error.

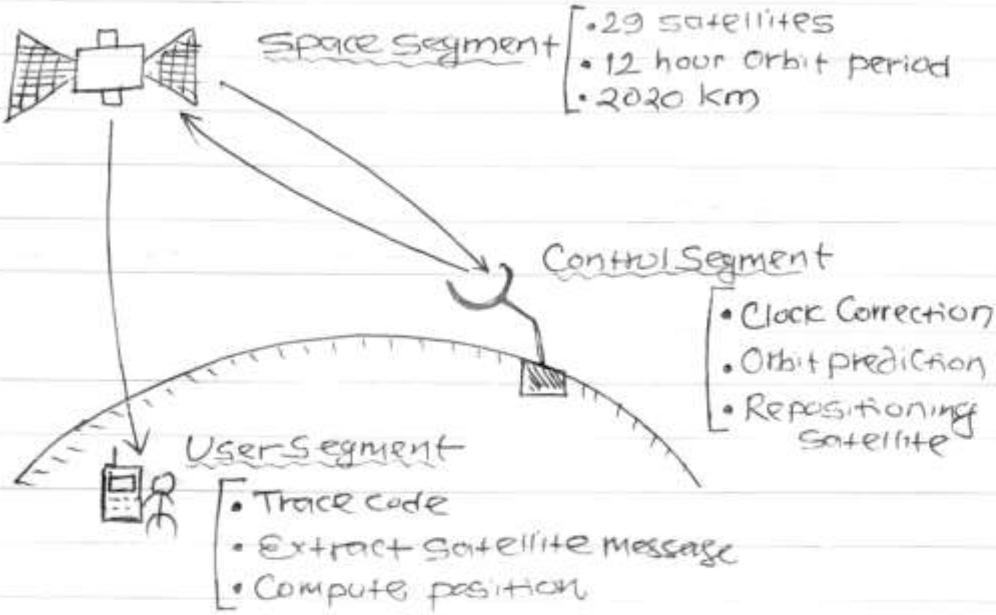
- At present, GPS is entirely Controlled by US Department of Defense (DoD), it implemented GPS for civilian use with certain degradation in accuracy of position.

- GPS yelds an accuracy of approximately ±25 m with no further Correction

- GLONASS is russion equivalent GPS with 24 Satellite and no militery interference with civilian signals, accuracy of ±25 m.

4.3.1 Components of GPS:

Segments of GPS are required to perform positional determination.



(1) Control Segment:

- Consists of 5 monitoring station (Colorado Springs, Ascension Island, Hawaii, Diego Garcia, Kwajalein Island)

- Ascension, Diego Garcia, Kawajalein Island for uplink for transmitting data to satellite, clock correction, broadcast message.

- Colorado Spring as master Control Station.

- USDoD undertake construction, launch, maintenance, monitor all GPS Satellites.

- Monitoring station trace satellite data and sents to master control station to process and compute clock correction and satellite ephemerides.

- Master Control Station controls orbital correction when any satellite strays too far from its assigned reposition & necessary reposition.

(2) Space Segment

- Consits of constellation of earth orbiting 29 satellites.

- 24 satellite operational in 6-orbit level at heigh 2020 km out in space, 55° to equator, orbit period of 12 sidereal hour (determined from star ≈ 12 hr)

- 5 satellite at 15° over horizon any time, everywhere on earth.

- Four precise atomic clocks (Rubidium, Censium standard) in satellite, has microprocessor on board for limited sef-monitoring & data processing.

- Equipped with thrusters to maintain modify their orbit.

(3) User Segment

- Are both user civilian, military

- Consists of earth-based GPS receiver.

- Receiver consists of antenna, radio signal processor, control unit, display unit, recording unit mainly.

- GPS decode signal from visible satellite (4+) and calculates distance, latitude, elevation.

- This is continuous process to update position second by second basis.

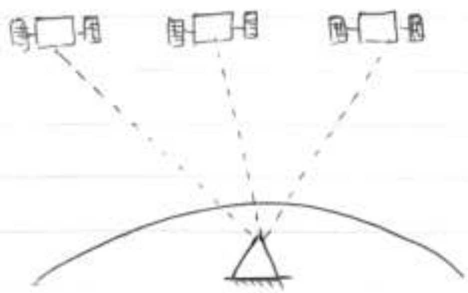
- Output is displayed and stored in logging unit.

- Coded-based receiver : It calculates distance, by measure of time of travel of electro-magnetic signal, Accuracy ±5

- Carrier-based receiver : Calculates distance by number of whole wavelength with accuracy of ±3.

4.3.2. Positioning

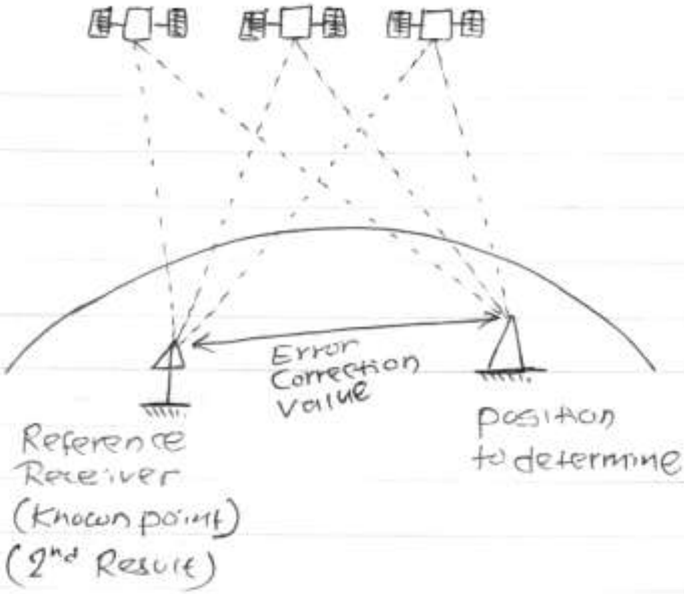
(i) Absolute positioning



* This positioning relies upon single receiver station
* Referred as 'Stand-alone' GPS
* Ranging between satellites & receiver station only, not on ground basic.
* overall accuracy 50 to 100 m.

(ii) Differential positioning

- This carries triangulation principle with 2nd receiver at known reference point.
- Further determines point's position relatively to known
- This method relies on established control point
- 90 % error correction



4.3.3 Application of GPS

* Locating new survey control station and upgrading (geodesy)

* Determining points in property boundaries

* Measuring terrain feature that is difficult to measure by conventional means.

* positioning offshore platform.

* Vehicle routing / Car navigation

* Marine navigation

* Positioning Camera-carrying aircraft used in aerial photography

* Determine difference in elevation.

* Military application.

4.3.4 GPS Errors

(i) Satellite Error :
Caused by inaccuracies in time keeping by Satellite, drifting of Satellite from its orbit

(ii) Atmosphere :
Charge particles & water Vapour delays GPS signals

(iii) Multipath Error:
Caused by reflection of signal by local obstructions.

(iv) Receiver Error:
Caused by its clock or internal noise.

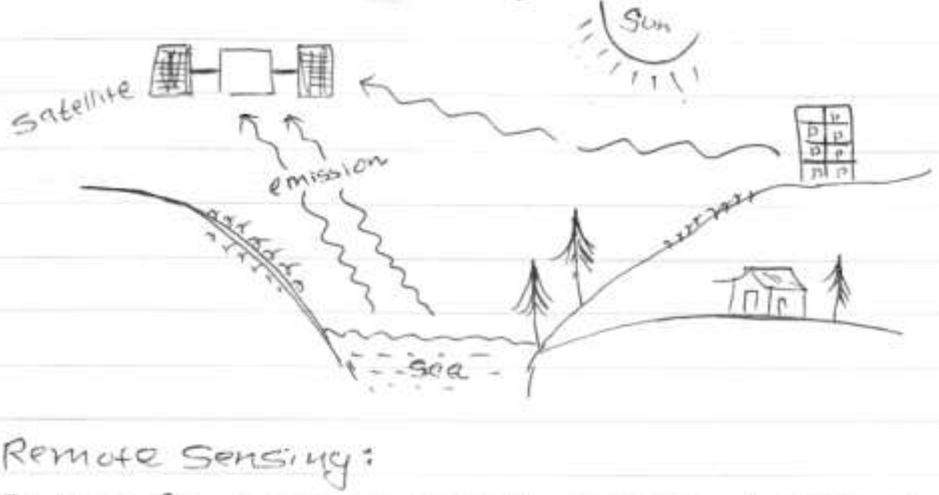
(v) Selective Availability:
Introducing noise to GPS Satellite clocks.

4.4 Remote Sensing (RS)

It is the science and art of acquiring information (spatial, spectral) about material object, area or phenomena through the analysis of data acquired by a device from measurement made at a distance without comming into physical contact with object, area or phenomena under investigation.

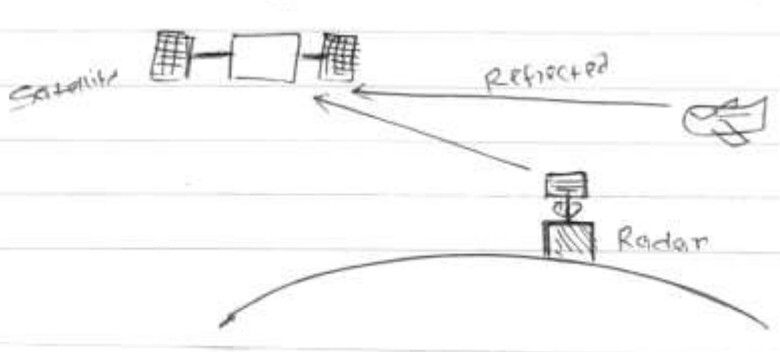
(i) Passive Remote sensing :

In this RS, sensors detect the reflected or emitted electro-magnetic radiation (EMR) from natural sources (Building, sea)



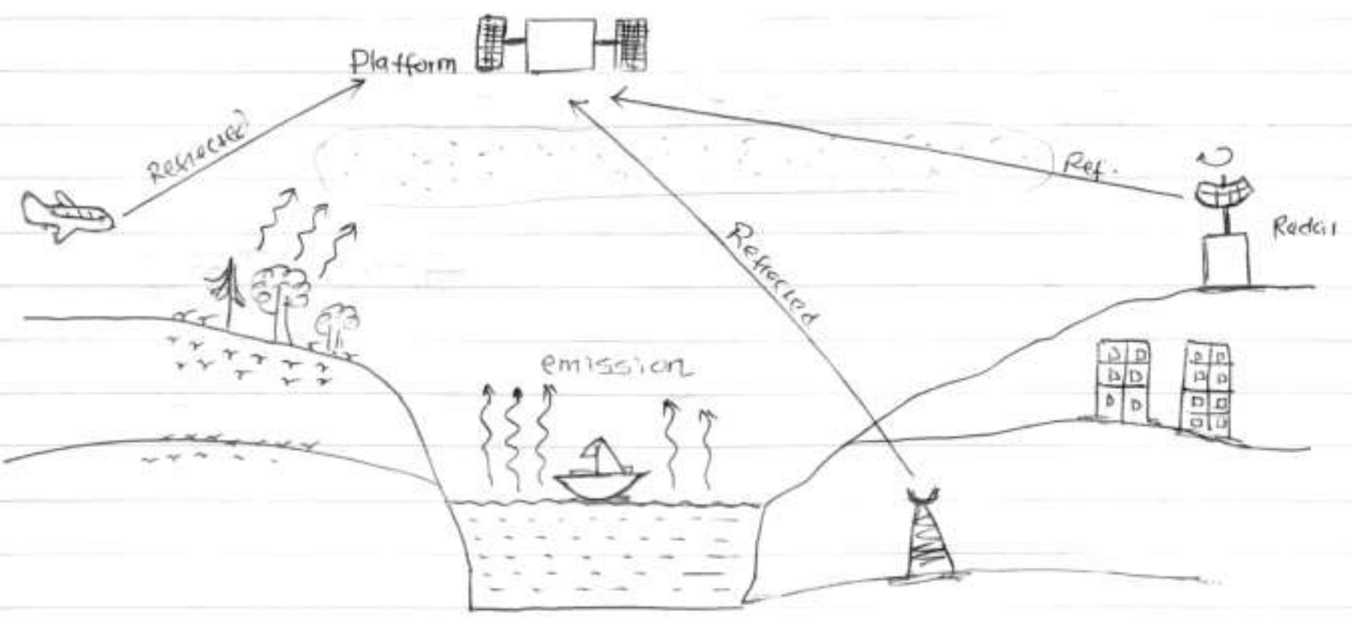
(ii) Active Remote Sensing:

In this RS, sensors detect reflected responses from objects that are irradiated from artificially generated energy sources (eg. radar)



Rs technology makes use of wide range of EM-spectrum that have different wave length value (Eg: gamma ray = very Short, Radio wave = very long)

4.4.1 Working of Remote Sensing

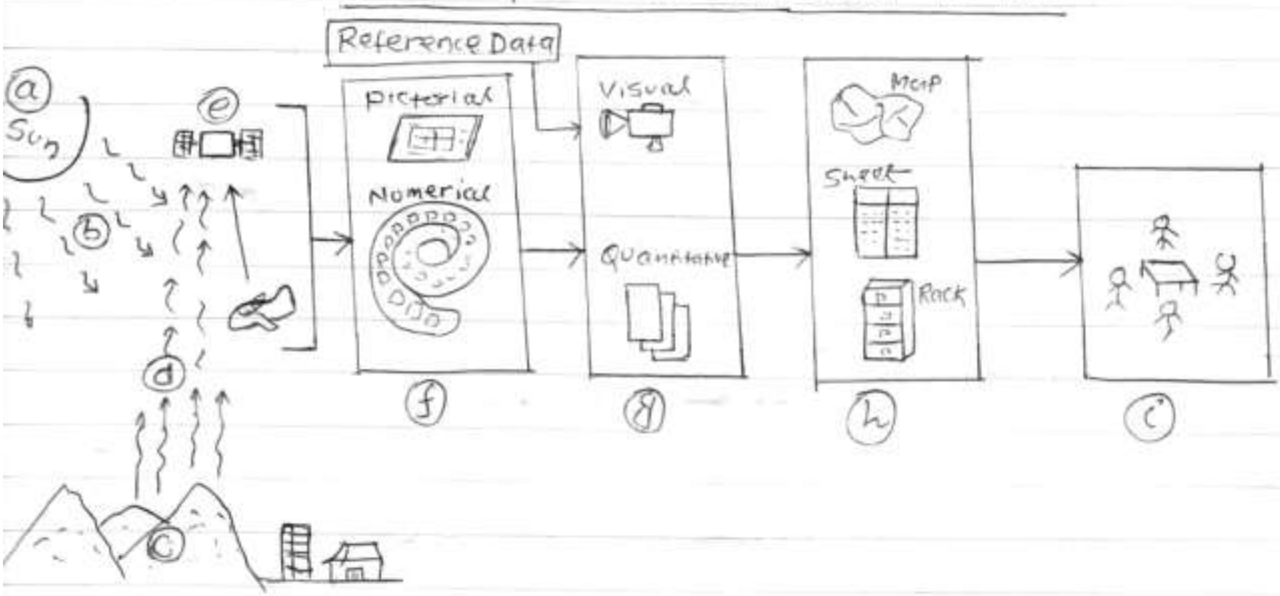


Electromagnetic radiation (EMR) which is reflected or emitted from an object is the usual source of RS data. A device to detect the EMR reflected or emitted from object called 'remote sensor' or 'Sensor' (Eg: Camera, Sanner).

A vehicle to carry sensor called platform (eg. Satellite) The characteristic of an object can be determined, using reflected or emitted EMR, from the object ie. each object has unique & different characteristic of reflection or emission if the types of object or environmental condition is different.

Remote Sensing is the technology to identify and understand the object or environmental condition through the uniqueness of the reflection or emission.

4.4.2 Basic process Involved in RS



Two basic process involved are
(1) Data Aquisition.
(2) Data Analysis.

In figure,
a) Source of energy (sun)
b) propagation through atmosphere
c) Earths Surface feature (mountain)
d) Re-transmitted through atmosphere
e) Sensing System (satellite)
f) Data product
g) Interpretation procedure
h) Information product
i) Users

(1) Data Aquisition process :
Following are the elements of this process.

* Energy Source (a)
* Energy interaction with the earth surface features (b), (c)
* Re-transmitted energy through the atmosphere (d)
* Airborne / spaceborne Sensors (e)
* Resulting in the generation of sensor data in pictorial and/or digital form, (f). In Short we use sensors to record variations in the way the earth's surface features reflect and emit EM-energy.

(2) Data Analysis process :
This process involves examining the data using various viewing & interpretation devices to analyse pictorial data and/or Computer to analyse digital sensor data (g).
Reference data on the resources being studied are required (such as soil map). With the aid of reference data the analyst extracts information about the type, extent, location, condition of various resources from which sensor data were collected.
The information is then compiled, generally in form of hard copy maps & tables or Computer files to be merged with other layers' of information in a GIS (h)
The information is presented to users who apply it in their decision making process (i).

4.4.2 Component of Remote Sensing

(i) Energy source :

* passive System - Sun, irradiance from earth's material
* Active System - Irradiance from artificially generated energy Sources of radar.

(ii) platform :

Vehicle to carry sensor

Platform	Altitude
Geostationary Satellite	36,000 Km
Circular orbit Satellite	500-1000 km
Space shuttle	240-350 km
Jet-plane	10-12 km
Hang-plane	50-500 m
Hang-Balloon	800 m
Crane car	5-50 m

(iii) Sensors :

Device to detect EMR; camera, Sonner are example of sensors. They are present on platform.

(iv) Detectors :

To convert electro-magnetic radiation into recorded signal (film, silicon detectors)

(v) Processing : Handling signal data (photographic, digital)

(vi) Institutionalisation :

Organization for execution at all stages of RS technology. International & national organization, Centers, Universities etc.

UNIT-5

5.1. Spatial Analysis:

Analyzing data normally comprises three principle phases

(I) Stating the problem
(II) Choice of data
(III) Analyses of the data Chosen.

All GIS provide functions for analyses of data chosen and for storing results of such analyses. Data may be selected according to:
(i) Geographical location and/or
(ii) Thematic content.

All GIS provide functions for analyses of data Chosen and for Storing results of such analysis. Data may be analyzed at various levels.

(i) Data in attribute table: Are sorted for presentation in reports or for use in other computer system.

(ii) Operation: Are performed on geometric data, either in search mode or for computational purpose.

(iii) operation like arithmetic, boolean, statistical are performed in attribute tables

(iv) Geometry & attribute table are used jointly to:
(a) Compile new set of data based on original & derived attributes.

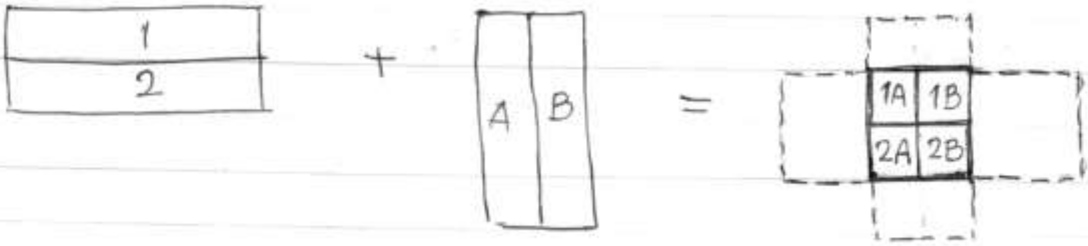
(OVERLAY-VECTOR)

(b) Compile new sets of data base on geographic relationships.

5.2: Vector overlay

* An overlay operation combines the geometries and attribute of two feature layes to create the Output.

* The geometric of output represent the geometric intersection of features from the input layers.



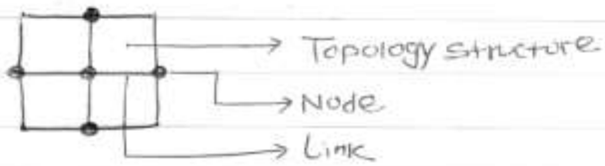
* Figure above shows, overlay combines the geometrics and attributes from two layeres into singe layers. The dashed lines are for illustration only and not included in the output. Attributes of above figure is shown below.

ID	Parcel NO	Area
101	1	$12 m^2$
102	2	$12 m^2$

ID	Parcel NO	Area
201	A	$12 m^2$
202	B	$12 m^2$

ID	Parcel NO	Area
301	1A	$1 m^2$
302	1B	$1 m^2$
303	2A	$1 m^2$
304	2B	$1 m^2$

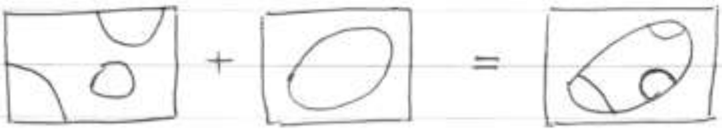
* Each feature on overlay contains a combination of attributes from input layers and this combination differs from its neighbours ie. New intersection are identified as nodes and line between the nodes as links. The new nodes and links then constitute new topological structure.



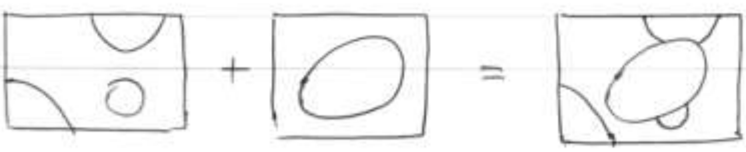
* Feature layers to be overlaid must be spatially registered and based on same coordinate system. In UTM (Universal Transverse Mercator) and SPC (State plane coordinate) System must be in Same zone with same datum.

* A common error from overlaying polygon layers is Silvers, a very small polygon along Correlated or shared boundary lines of the input layers.

* Computing intersection of large number of polygons can be very time-consuming. Example: Township border in one thematic layer must be used to clip all other thematic layers in order to produce a collection of data for that township only.



(i)

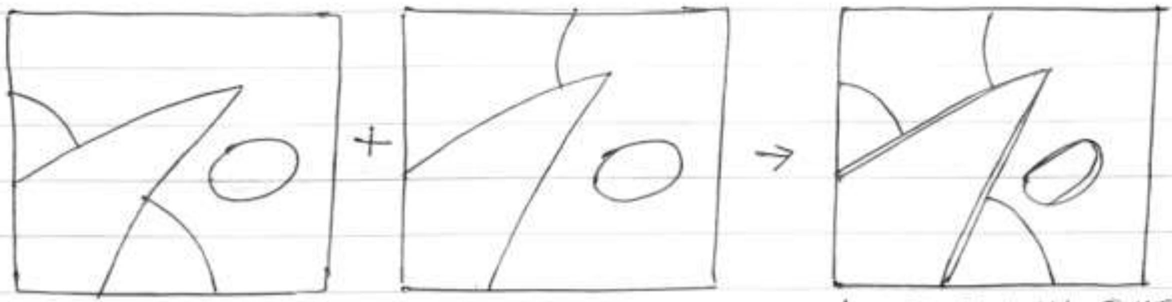


(ii)

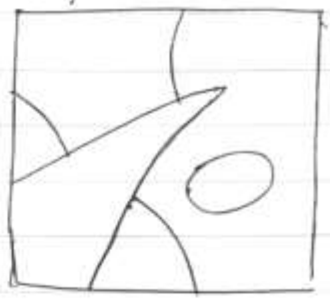
* Silvers :

Each new polygon is a new object that is represented by row in attributes table. Each objects has new attribute, which is represented by column in attribute table.

Superimposing & comparing two geometric data sets of differing origin & accuracy often give rise to large number of small polygons called silver.



Layer-1 layer-2 Layer-3 with silvers



Two polygon representing land area may have slightly differing geometric border on a lake, yet on a piecemeal basis the border may concide. Superimposing the two polygon can then produce an unduly large number of smaller polygon called 'silver'. These smaller polygon may be counteracted automatically by laying small zone (fuzzy tolerance).

These silver, an error in the input can propage to the analysis output.

Vector
5·3: Overlay and its Feature Type

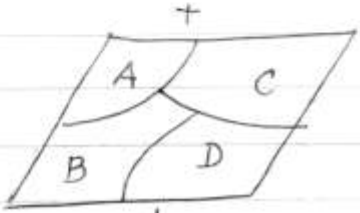
* First consideration for overlay is 'feature type'.
* Overlay operation group
    * Uses two polygon layers (polygon-on-polygon)
    * Uses one polygon layers on one point / line (point-in-polygon), (line-in-polygon)

(1) Point-in-polygon overlay:

=

ID	Point No.	Land Mark
101	1	Temple
102	2	Church
103	3	Tap
104	4	Chautara

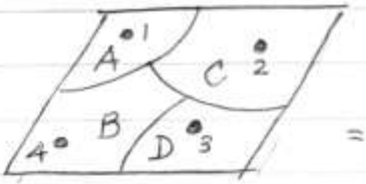
\+



=

ID	Polygon No.	Parcel Type
201	A	Goverment
202	B	private
203	C	Institutional
204	D	Coperative

↓



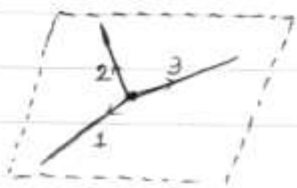
=

ID	Point No	polygon No.	Land Mark	Parcel Type
301	1	A	Temple	Government
302	2	C	Church	Institutional
303	3	D	Tap	Coperative
304	4	B	Chautara	Private

* Points superimposed on polygons.
* So many points be superimposed on polygon.
* points are then assigned the attributes of polygons on which they are superimposed.
* Relevant geometric operation carried to associate point within polygons.
* Attribute table are updated after all points are associated with polygons.
*

This overlay method can find association between point and parcel landmark and parcel type, building & parcel. etc.

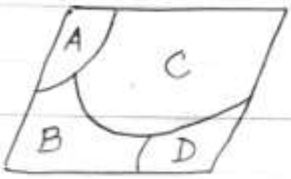
(2) Line-in-polygon overlay



=

ID	Line No.	Road Name
101	1	Arnico HW
102	2	Mahendra HW
103	3	prithivi HW

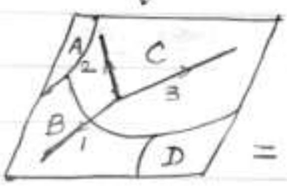
+



=

ID	polygon No.	Zone
201	A	Sagarmatha
202	B	Bagmati
203	C	Janakpur
204	D	Narayani

↓



=

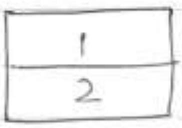
ID	Line No	Road Name	polygon No	Zone
301	1	Arnico HW	B	Bagmatic
302	1	Arnico HW	C	Janakpur
303	2	Mahendra HW	C	Janakpur
304	3	prithivi HW	C	Janakpur
305			A	Sagarmatha
306			D	Narayani

* Lines superimposed on polygons.
* As a result, new set of lines contains attributes of both original lines & put plus polygon on which it falls.
* Intersection are computed, nodes and links are formed, topology is established and attribute table is updated.

* Example:

A line-in-polygon overlay can bind soil data for proposed road. The input layer includes the proposed road. The overlay contains soil polygons. And the output shows dissected proposed road, each road segment having different set of soil data from its adjacent segment.

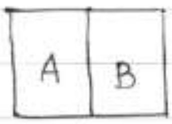
(3) Polygon-on-polygon Overlay:



=

ID	Polygon NO	Height
101	1	200 m
102	2	500 m

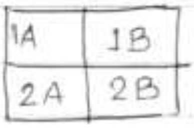
+



=

ID	Polygon NO	Vegetation type
201	A	maize
202	B	Potato

↓



=

ID	Polygon NO	Height	Vegetation type
301	1A	200 m	Maize
302	1B	200 m	Potato
303	2A	500 m	Maize
304	2B	500 m	Potato

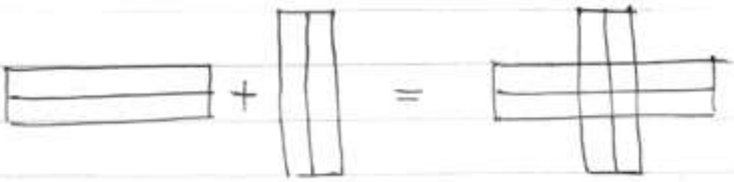
* Most common overlay
* Output combines the polygon boundaries from the input and overlay layers to create a set of polygons.
* Each new polygon carries attributes from both layers, and these attributes differ from these of adjacent polygon. * Example above shows, association between elevation zone & vegetation type

5.4 Vector Overlay Methods:

Overlay methods are based on 'Boolen connector' AND, OR, XOR.

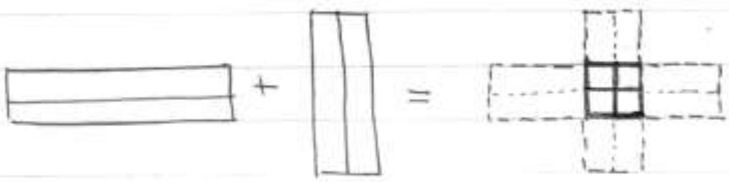
AND ⇒ Intersection
OR ⇒ Union
XOR ⇒ Difference / Symmetrical Difference.
Identity or Minus ⇒ [(Input layer) AND (Identity layer) OR (Input layer)]

(1) Union:



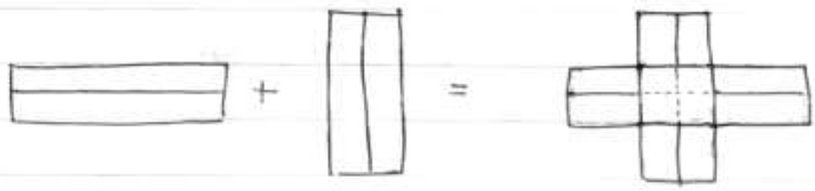
preserves all feature from the inputs. The area extent of output combines area extends of both input layers. It requires that both input layers be polygon layers.

(2) Intersection:



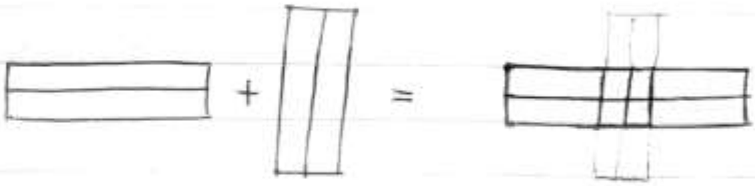
It preserves only those features that fall within the area extent common to inputs.
we prefered it because, any feature on its output has attribute data from both of its inputs.

(3) Symmetrical Difference:



Preserve features that fall within the area extent that is common to only one of the input.
It is opposite to intersect in terms of output's area extent. This method requires that both input layers be polygon layers.

(4) Identity:



Idenity preserve only features that fall within the area of layer defined as the input layer. The ~~outer~~ other layer is called identity layers.
Input layer is called identity layer.
Input layer may contain point, lines, polygon & identity layer is polygon layer.

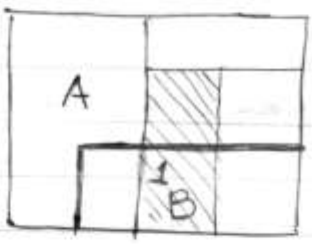
5.5: Application of Vector Overlay:

* An overlay operation combines features and attributes from the input layers.

* ~~The~~ An overlay output is useful for query & modeling purposes.

* A more specific application of overlay is to help solve areal interpolation problem that involves transferring known data from one set of polygon to another

* Example:



Thick lines represent census tracts and thin lines school districts. Census tract 'A' has known population of 4000 & B has 2000, overlay result shows that areal proportion of census tract 'A' in school district '1' is 1/8 and areal proportion of census tracts 'B' 1/2.
Therefore, population in school district 1 can be estimated to be 1500 or $\left[\left(4000 \times \frac{1}{8}\right) + \left(2000 \times \frac{1}{2}\right)\right]$

5.6 : Error propagation in Vector overlay

* Slivers are examples of errors in the inputs that can propagate to the analysis output.

* Error propagation refers to the generation of errors that are due to inaccuracies of input layers.

* There are two types of error

(i) Positional : It can be caused by inaccuracies of boundaries that are due to digitizing or interpretation errors.

(ii) Identification: It can be caused by inaccuracies of attribute data such as incorrect coding of polygon values.

* Every overlay product tends to have some combinations of positional & identification errors.

* It depends on number of input layers and spatial distribution of errors in input layers.

* The accuracy of an overlay output decreases as number of input layers increases.

* Accuracy decreases if the likelihood of error occurring at the same location in input layers decreases.

(OVERLAY-RASTER)

5.7 : Raster Overlay :

* Raster overlay is simpler than vector overlay and can be carried out directly on cell values.

* It is more efficient than vector overlay, as extent of calculation is much less

* Both raster layer must have identical geometry . ie. cell size must be same, there must be no relative rotation or transfer between grids.

* Attribute are representation of thematic layers.

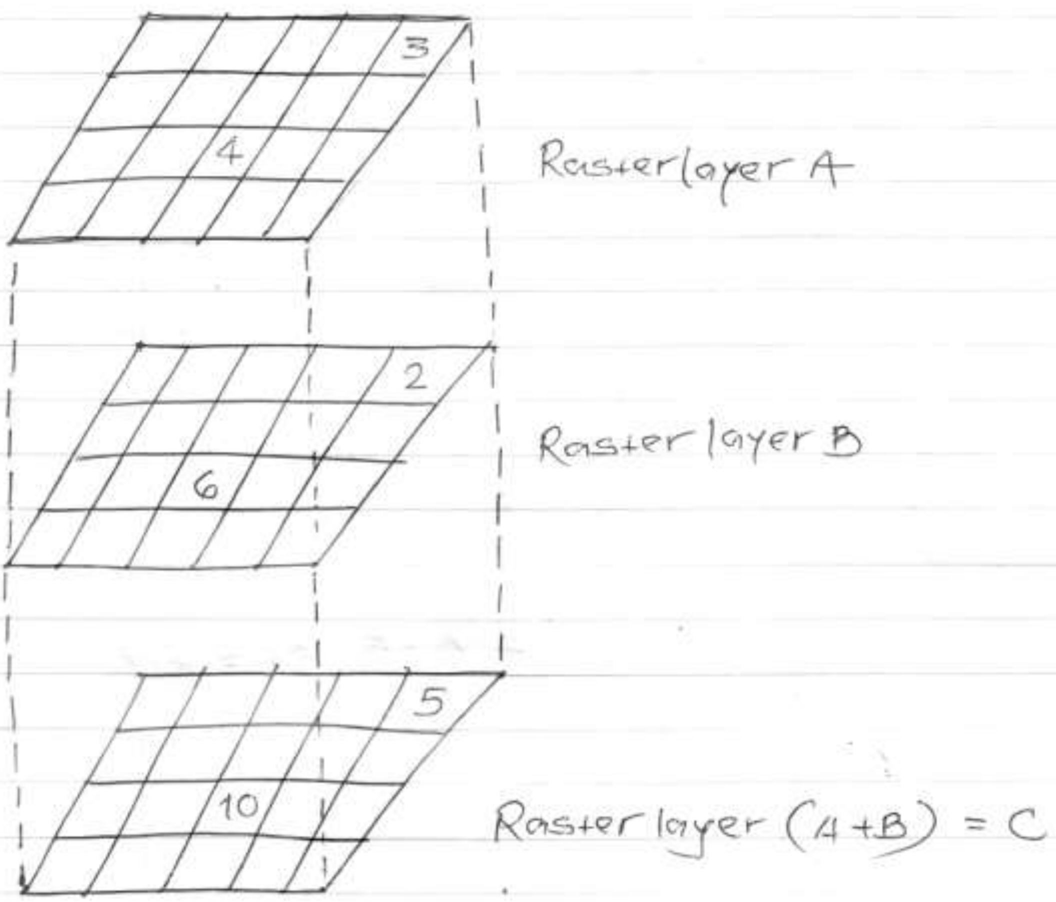
* There is no need to distinguish between polygons, lines, points because all raster data comprise cells.

* Arithmatic, logical, statistical operation may be + performed directly during overlay process.

* Deviation is carried by transformation and resampling to the same cell size.

* New composite cells are computed from original cells & registered as a new thematic layer.

* There is no formation of smaller erroneous polygon.



* The arithmetic operation of two thematic layers A & B produce a new layer C through operate

$$\boxed{C = A + B}$$

other operation are,

$$C = (A - B)$$
$$C = A/B$$
$$C = A \times B$$

logical operation is.

$$\text{if } A > 100, \quad \begin{cases} C = 10 \\ \text{else}, \quad C = 0 \end{cases}$$

5.8 Operators & Function Used in Raster Overlay

(i) Arithmetic operators:

The operators (+, −, /, *) allows for addition, subtraction, division, multiplication of two raster maps or numbers or combination of the two.

A

5	2	2
5	5	2
6	6	6

B

4	4	3
1	4	3
1	1	3

$C_1 = A + 10$

15	12	12
15	15	12
16	16	16

$C_2 = A + B$

9	6	5
6	9	5
7	7	7

$C_3 = A * B$

20	8	6
5	20	6
6	6	18

(ii) Bowlen operator:

The operator (AND, NOT, OR, XOR) uses bowlen logic (TRUE or FALSE) on the input values. output value of true are written as '1' and false as '0'

a OR a ⇒ a or b TRUE (All true included)
a AND b ⇒ a & b both TRUE
a XOR b ⇒ (OR − AND) ⇒ a true
b tre
But not both true.

~~AND~~

AND

A	B	output
0	0	0
0	1	0
1	0	0
1	1	1

OR

A	B	output
0	0	0
0	1	1
1	0	1
1	1	1

XOR

A	B	output
0	0	0
0	1	1
1	0	1
1	1	0

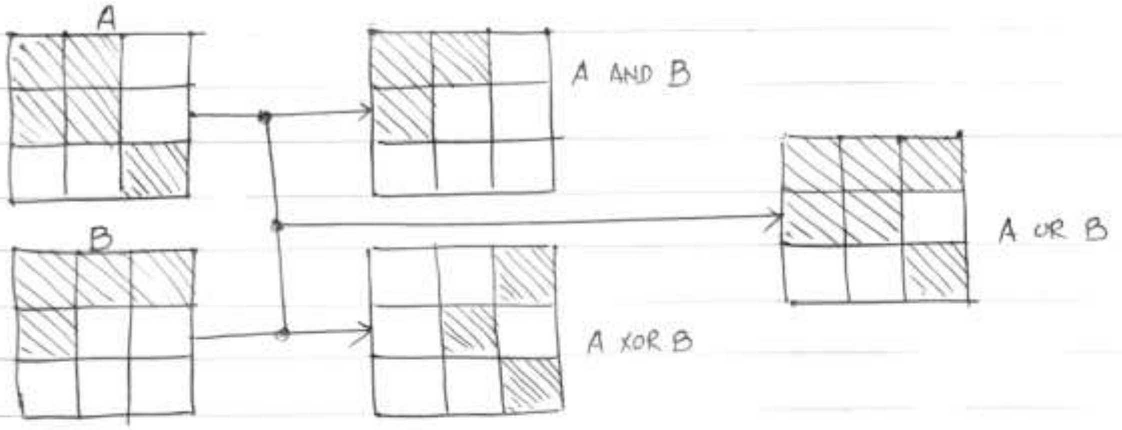
NOR

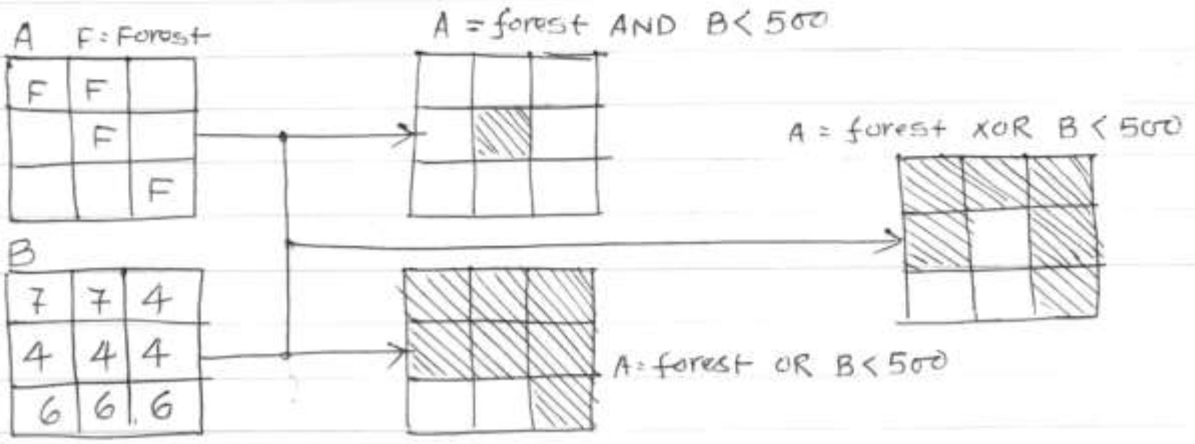
A	B	output
0	0	1
0	1	0
1	0	0
1	1	0

NAND

A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0

Examples of Boolean operators



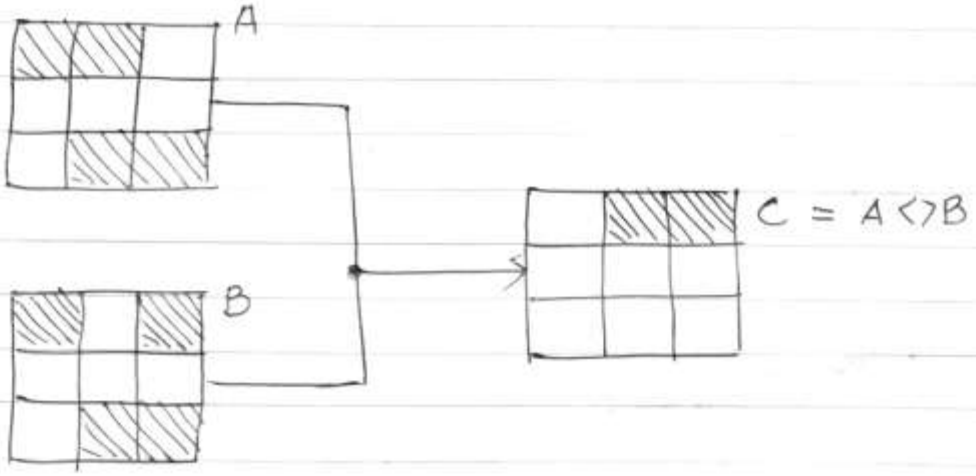


7: 700m, 6: 600m, 4: 400m

(iii) Relational/ Comparison Operator:

This operator (<, <=, <>, =>, =,) evaluate specific relational conditions. If the condition is 'TRUE' the output is assigned 1, if the condition is 'FALS' output is assigned 0.

example: $(A <> B \Rightarrow A \neq B)$



(BUFFERING)

5.9. Buffering

It is defined as GIS operation that creates zones consisting of area within a specified distance of selected feature.

Based on the concepts of proximity, buffering creates two areas:

(i) one area that is within a specified distance of selected features

(ii) other area that is beyond.

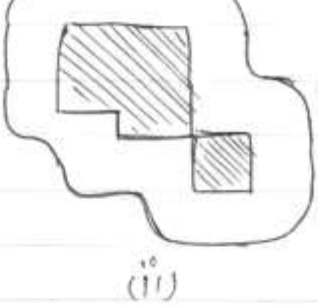
Features of Buffering:

(i) points: Buffering around points creates a series of elongated buffer zones

(ii) Polygon: Buffering around polygon creates buffer zones that extend outward from the polygon boundaries.

(iii) Lines: Buffering around lines creates circular buffer zone.

(i)



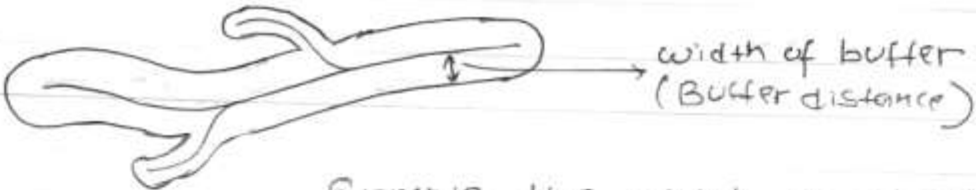
(ii)

(iii)

New, polygons have the attributes of original objects, can be given new attributes For each elements coordinate are calculated for buffer zone limit.

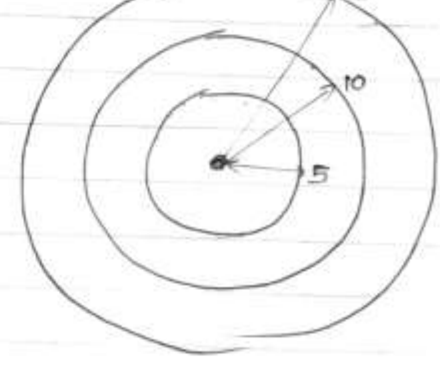
5.10 Variation in Buffering

* The buffer distance of buffer size does not have to be constant, it can vary according to the values of given field

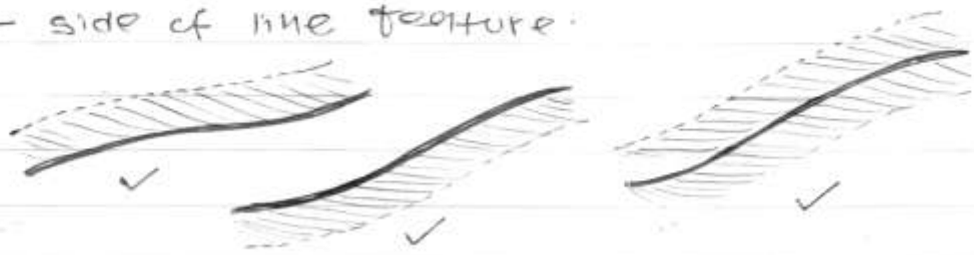


Example, the width of riparian buffer can vary depending on its expected function and the intensity of adjacent land use as shown in figure above.

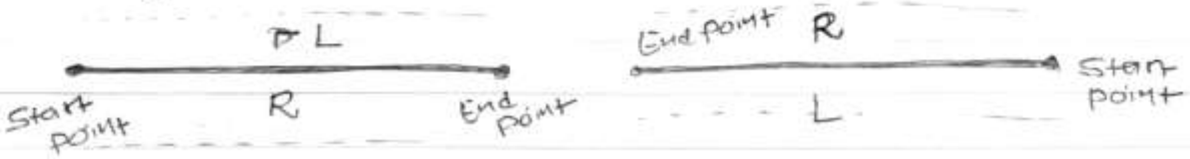
* A feature may have more than one buffer zone. Example, A nuclear power plant may be buffered with distance of 5,10,15 miles, thus forming multiple rings around the plant are not equal in area as shown below.



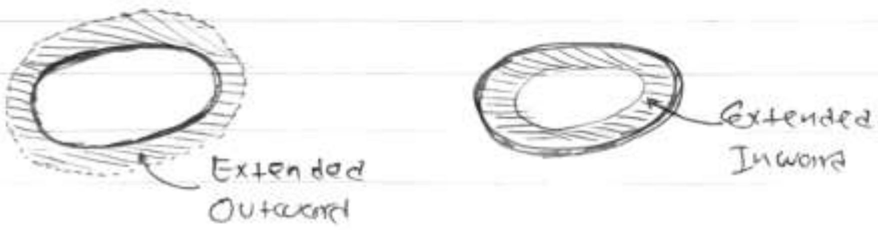
* Buffering around line features does not have to be both sides of the lines. It can be on either left or right side of line feature.



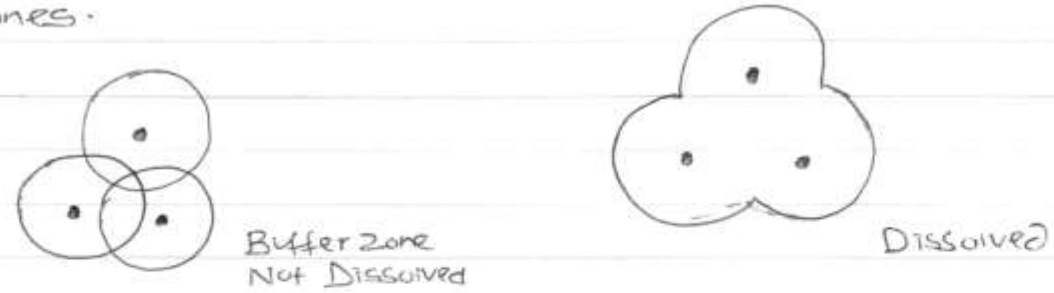
* The left or right side is determined by the direction from the starting to end point of a line.



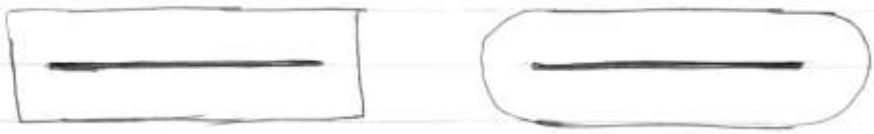
* Buffer zones around polygon can be extended either outward or inward from the polygon boundaries



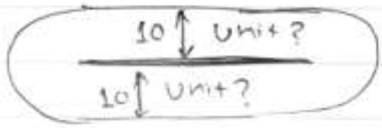
* Boundaries of buffer zones may remain intact so that each buffer zone is a seprate polygon. Or these boundaries may be dissolved so that there are no overlapped areas between buffer zones.



* The end of buffer zone can be either round or flat. But round is best for.



* We must know measurement unit (eg meter, feet) as buffering uses distance measurement



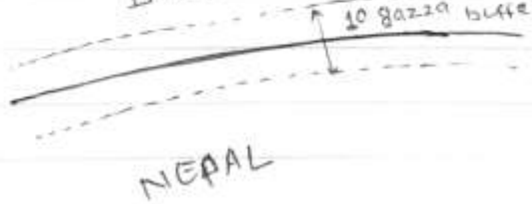
* Accuracy of buffer zones is determined by positional accuracy of spatial feature, if buffering uses distance measurements from spatial feature.

* Must GIS package offers buffering as an
  - Analysis tool
  - Buffer tool
  - Editing tool
  - Multiple ring buffer tool

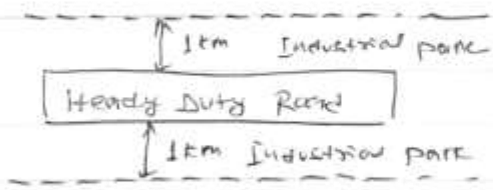
5.11 Application of Buffering

(i) Used in planning or regulatory purposes, as buffer zone is often treated as protected zone.

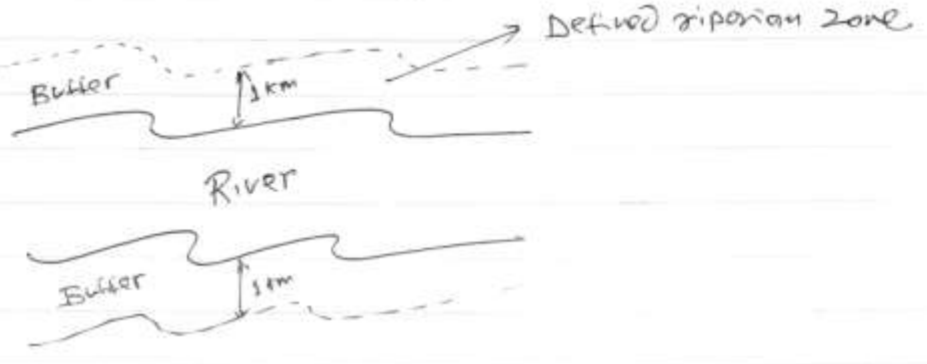
(ii) Used in Conflict resolution by treating buffer zone as neutral zone



(iii) Used to represent inclusion zone, eg. industrial zone around heavy duty road.



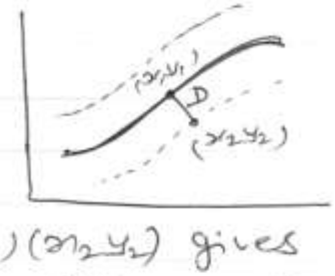
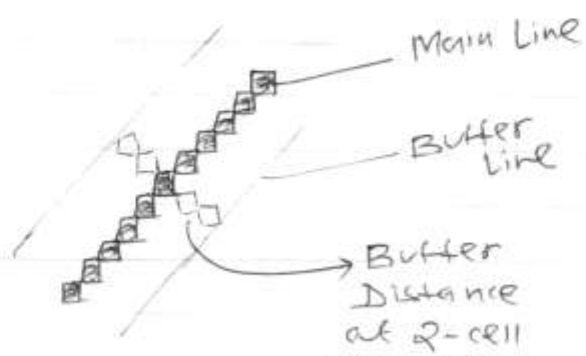
(iv) Used as object for analysis.



we can evaluate riporian habitant of wild life by creating buffer zone of defined riporian zone.

(v) Used as Sampling method with multiple buffering ring.

5.12 Difference Between Vector Based & Raster Based Overlay

Vector Based	Raster Based
(i) More option	(i) Less option
(ii) Option of creating seprate buffer zone for each selected feature  Fig. shows two different width buffer zone of river network	(ii) It would be difficult to create & manipulate seprate buffer zone.
(iii) Uses x- & y- coordinate in measuring distance  $(x_1,y_1)(x_2,y_2)$ gives buffer distance D	(iii) Uses cells in measuring physical distance 
(iv) Creat more accurate buffer zone	(iv) Less.

5.13 Similar Between Vector Based & Raster Based ~~ovr~~ Buffering

* Similar in that, they both measure distance from the selected feature.

UNIT-6

6.1 SDI Concepts & its Current Trend.

Spatial data infrastructure (SDI) can be defined as data series and electronically based services that satisfy common needs of different user group for accurate positioning and georeferenced data. Thechnical development such as internet & GPS have made this type of work very relevent.

6.1.1. National Spatial Data Infrastructure (NSDI)

The defination of NSDI varies from country to country but it normally includes elements such as:

(i) Institutional Framework:

Defines policy, financial arrangement, human resources, needed and legislative and administrative arrangements and cooperation.

(ii) Geodetic Network & positioning Services:

Develops and maintains geodetic network and accurate position the services.

(iii) Standardization:

Develops national standards for geographical data

(iv) Fundamental Data:

Collects and manages fundamental data sets.

(V) Technical Frame works:
Enables users to identify, access and use fundamental data sets.

(Vi) Customer Services:
Distribute data & application services.

Model of NSDI

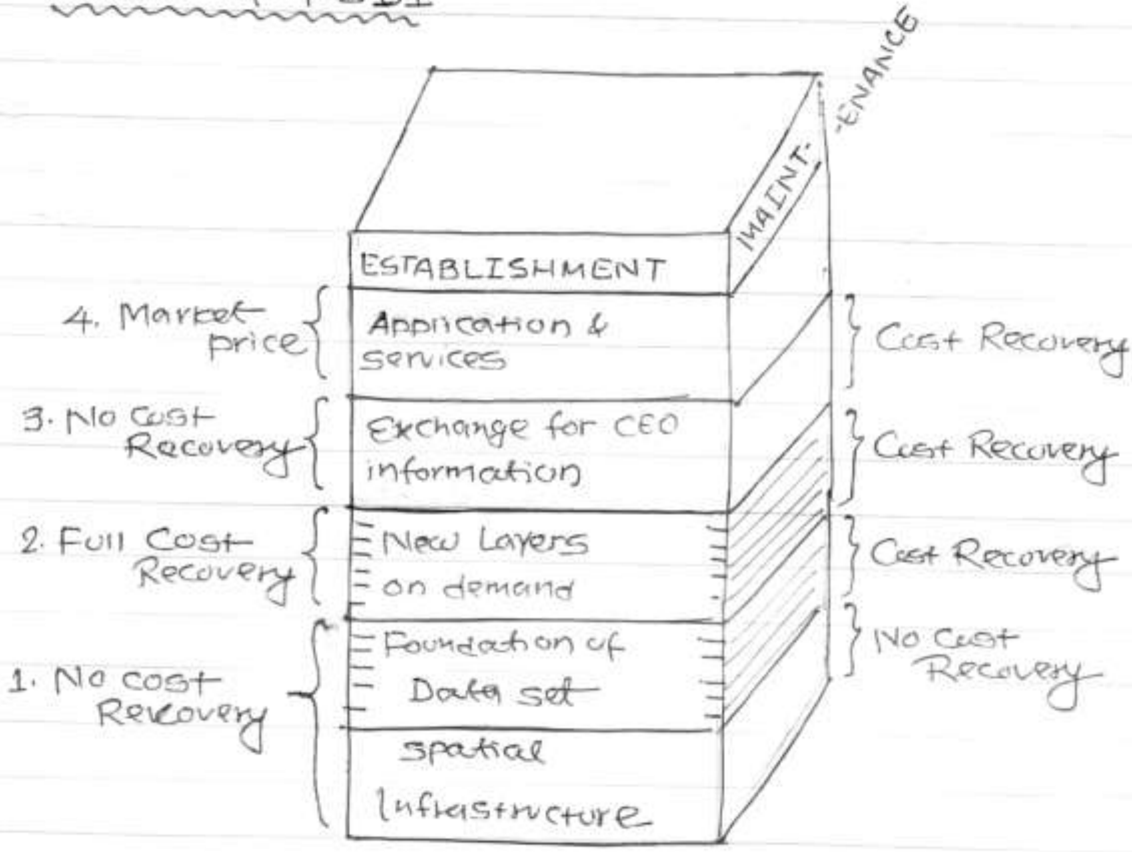


Figure shows possible model for establishment of NSDI, which will encourage the production & use of fundamental data and which will also be user driven. The model is based on "No Cost Recovery" for basic spatial infrastructure and establishment of the foundation data sets, where as maintenance of foundation data sets should be based on "Cost Recovery".

6·1·2 Critical Factor Around SDI's

Geographic data that are collected by different data provider can be exchanged and shared by advance technology of 'data handling' & 'data communication'. This data sharing give rise to problems which is critical factor in SDI.

(i) Data Standard:

Exchange of data between database is difficult if they support different data standard or different query language.

(ii) Heterogeneity:

The inconsistency among data set that exists in variety of location, managed by variety of database, collected by different methods for different purposed, stored in different structure creats many problem when data is shared.

(iii) Communication problems:

Best suit relevant communication technology for transfer of huge amount of spatial data in secure and reliable way is challenging. Efficient tools and communication protocols are important to provide search, browse, delivery mechanism.

(iv) Institutional & Economic problems:

The absence of policy for pricing, copyright, privacy, liability, data quality, data standard is essential to create for data sharing in right environment.

6.2: Metadata

* Data that provides information about geospatial data, is metadata. It is also called "data of data".

* Metadata are integral part of GIS data prepared and entered during data production process.

* Metadata are used for GIS project:
  - (i) It let us know if the data meet our specific needs for area coverage, data quality, data currency
  - (ii) It shows how to transfer, process and interpret geospatial data.
  - (iii) It includes the contact for additional information.

6.2.1. Federal Geographic Data Committee (FGDC)

FGDC has developed Content Standards for metadata and provides detailed information about the standard in following categories:

(i) Identification Information:
Data set, title, geographic data covered, currency

(ii) Data quality Information:
Quality of data set, positional & attribute accuracy

(iii) Spatial Data Organization Information:
Data representation in data set (raster, vector) number of spatial objects.

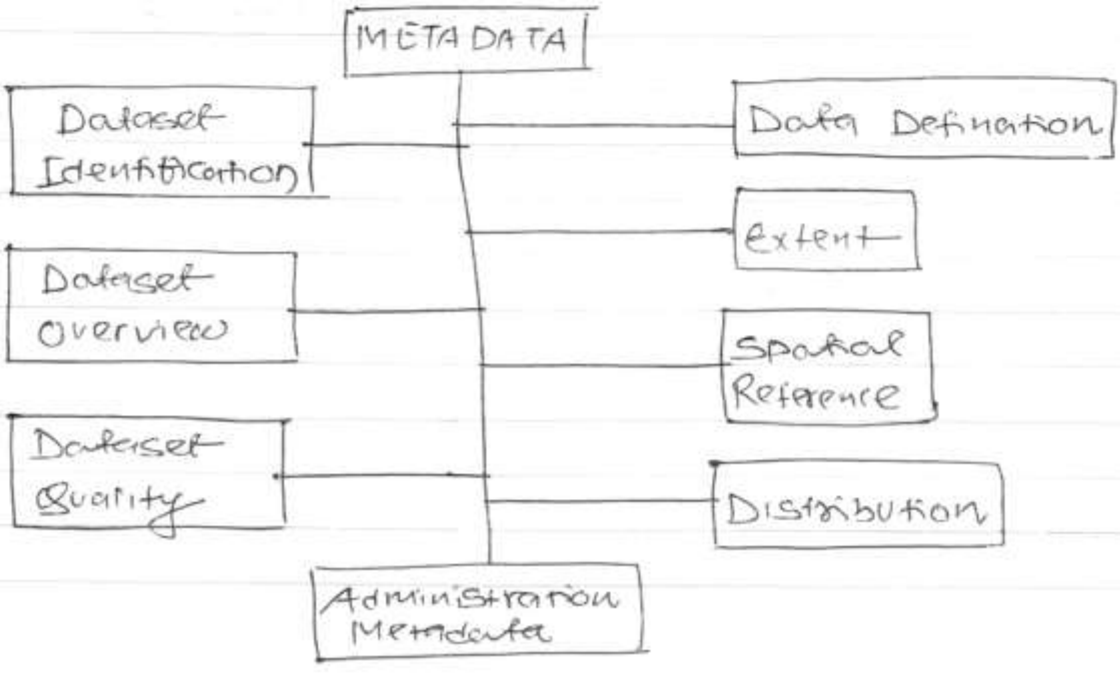
(iv) Spatial Reference Information:
Reference frame, encoding coordinate, coordinate system, datum, map projection.

(v) Entity Attribute Information:
Content of data set, entity type.

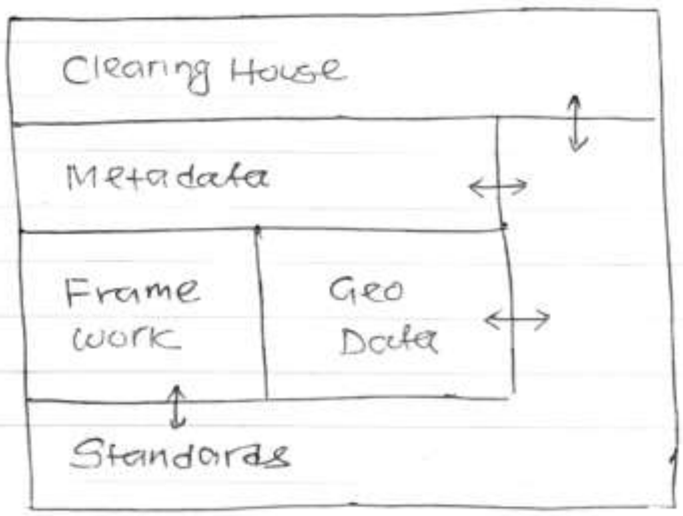
(vi) Distribution Information:
Information about obtaining data set.

(vii) Metadata Reference Information:
Information on the currency of metadata information and responsible party.

6.2.2 Data Model for Metadatabase



6.3 Clearing House



Goal : To provide access to digital spatial data and related online services for data access, visualization or order

Objective : To minimize unnecessary duplication of effort for data capture and maximize the benefit of geographic information sharing.

Function: To detailed Catalog service with support for links to spatial data and browse graphics

Includes: Metadata include hyperlinks to online resources (Map services, data download location, data access services, applications) within their metadata entries.

Advertising : It provides low-cost advertising for spatial data providers via internet.

Band data together : It allows geographically defined individuals or communities to band digital data together, through federated metadata service.

processing : User can query on internet with minimum transactional processing with 'peer' clearing house server within clearing house activity.

Institutional View of ~~Metadata~~ Clearing House :
people and infrastructure to faciliate discovery of who has what geographic information.

Technical view of Clearing House :
A set of information services that uses hardware, software, telecommunication network provide searchable access to information.

6.3.1 Working of Clearing House :

(i) A clearinghouse allows data providers to register their geographic data sets, the quality of these data and also instructions for accessing them.

(ii) Each data provider provides an electronic description of each spatial data set.
In addition access to spatial data set itself.

(iii) Thus, function as detailed catalogue services with support for links to spatial data browsing capabilities

(iv) The data described in the clearinghouse may be located at site of data producers or at sites of designated data disseminators located elsewhere in the country.

(v) Computer network facilates for successful data transmission.

UNIT-7 : OPEN GIS

7.1 Introduction to open concepts in GIS

Open GIS is the full integration of geospatial data into mainstream information technology. What this means is that GIS users would be able to freely exchange data over a range of GIS software systems and networks without having to worry about format conversion or proprietary data types.

Integration

In a true 'open GIS', agencies who operate more than one mapping system can interchange graphic and attribute data with other popular GIS systems. The intent is to move away from the current status quo in which specific GIS applications and capabilities are tightly coupled to their internal data models and structures.

In other words, utilizing a one company based software package also requires same company proprietary data structure in order to utilize all analytical aspects of the software. Currently, a user who wishes to gain access to geo-data developed by another agency is generally faced with a complex data conversion task. The conversion plug-ins commonly found with many of the major software packages help this situation, but do not solve it entirely due the complexities associated with merging vastly different GIS systems and data formats. Thus, even though one GIS software can read and other GIS software files, any editing or analysis would require the conversion of that format to a native data structure.

Open source code and programming language

An open source application software can be freely accessed and modify the source code for. Open source projects typically are worked on by a community of volunteer programmers. Open source GIS programs are based on different base programming languages. Three main groups of open source GIS (outside of web GIS) in terms of programming languages are: "C" languages, Java, and .NET.

(i) "C" language has a long history based on open source GIS software applications include GRASS, Quantum GIS. The capability of coordinate projection has made it popular.

(ii) JAVA as the implementation language, GeoTools, Geoserve, and OpenMap, are among the most popular open source GIS in this group of JAVA tools. This group codes the difficult operator like Union or Buffer to make program appropriate. It also offers geospatial functions that allow to compare objects and return a boolean true/false result indicating the existence (or absence) of any questioned spatial relationship.

(ii) SharpMap and WorldWind are the most popular Open Source GIS that integrates applications that uses ".NET" as the implementation language.

(iv) Open source web mapping is another group that includes OpenLayers and MapBuilder, widely used due to their simplicity and accessibility.

7.1.1 Fundamental Requirements

Interoperable application environment – a user environment that is configurable to utilize the specific tools and data necessary to solve a problem irrespective of the data structure origin or software.

Shared data space – a generic data model supporting a variety of analytical and cartographic applications.

Heterogeneous resource browser – a method for exploring and accessing the information and analytical resources available on a network – this is becoming an especially important goal with the rise of geo-based Internet sites.

7.1.2 Open GIS Consortium (OGC)

The OGC is a consensus-based association of public and private sector organizations to meet the following three objectives. Its purpose is to create and manage an industry-wide architecture for interoperable geo-processing.

1. The first objective is the creation of an interest group to consolidate the Geographic Information System's industry activities and establish a channel to communicate interoperability issues within the Open GIS Consortium.
2. The second focus is the identification and resolution of interoperability issues and their introduction into the global Open GIS specification process.
3. The third focus is the informative role an Open GIS Consortium would perform to inform the GIS industry about the Open GIS process.

7.1.3 Benefits of Open GIS

The establishment of standards for an Open GIS system will benefit all users of georeferenced data. Standardization of data structures and processes will help to optimize data exchange between agencies as well as increase the accessibility of GIS to mainstream users.

7.2 Open Source Software for Spatial Data Analysis

Open source technology is a growing trend in GIS. Open source software is software in which the source code used to create the program is freely available for the public to view, edit, and redistribute. Any type of software program can be open source, including operating systems (e.g., Linux), databases (e.g., PostgreSQL), applications (e.g., OpenOffice.org), games, and even programming languages (e.g., Python).

License
Open source software is identified by the type of license it is released under. These licenses include the Apache 2.0 license, the Microsoft Public License, and the GNU General Public License. While there are some variations, most open source licenses require that the source code be freely available and users are free to modify the source code and redistribute the software and derived works.

Shared community approach
Non-open source software is called *closed source* or *proprietary* software.
The open source license encourages a shared community approach to the development, extension, and patching of open source software. Most open source projects have a dedicated group that moderates and directs the core software development and ensures that needed new features are being developed, bugs are being fixed, and the supporting documentation remains current.

7.2.1 Why Open Source Software?

User demand
The last 20 years have seen dramatic developments in GIS technology and geographical information science. Fierce competition and growing user demand has resulted in a number of high-quality solutions, which are largely responsible for the vast increase in the GIS marketplace. However, the vast majority of the industry solutions are aimed at supporting basic needs of capture, archival and visualization of spatial data.

User-friendly interfaces

Recent technological advances have concentrated in issues such as user-friendly interfaces, interoperability across data repositories and spatial extensions of database technology.

These developments have largely ignored recent advances in GI Science, which include research areas such as spatio-temporal data models, geographical ontologies, spatial statistics and spatial econometrics, dynamic modeling and cellular automata, environmental modeling, and neural networks for spatial data.

Integration of spatial data

Moreover, GIS software development is bound to witness substantial change in the upcoming years, induced by technological advances in spatial databases. Current and expected advances in database technology will enable, in the next few years, the complete integration of spatial data types in data base management systems. This integration is bound to change completely the development of GIS technology, enabling a transition from the monolithic systems of today (that contain hundreds of functions) to a generation of spatial information appliances, small systems tailored to specific user needs. Coupled with the data handling capabilities of new generation of database management systems, rapid application development environments will enable the construction of "vertically-integrated" solutions, directly tailored to the users' needs.

Therefore, an important challenge for the GIS community is finding ways of taking advantage of the new generation of spatially-enabled database systems to build "faster, cheaper, smaller" GIS technology.

Co-operative development network

One of the possible responses to this challenge would be to establish a co-operative development network, based on open source technology. In a similar approach as the Linux-based solutions, the availability of GIS open source software would allow researchers and solution developers access to a wider range of tools than what is currently offered by the commercial companies.

Resolve the "knowledge gap"

A second important reason for developing open-source spatial analysis tools is the need to resolve the "knowledge gap" in the process of deriving information from images and digital maps. This "knowledge gap" has arisen because our capacity to build sophisticated data collecting instruments (such as remote sensing satellites, digital cameras, and GPS) is not matched by our means of producing information from these data sources. To a significant extent, we are failing to exploit the potential of the spatial data we collect. For example, there are currently very few techniques for image data mining in remote sensing archives, and thus we are failing to use the information available in our large earth observation data archives.

General open source GIS library

Therefore, the geographical information community would have much to benefit from the availability of a general open source GIS library. This resource would make a positive impact by allowing researchers and solution developers access to a wider range of tools than what is currently offered by the commercial companies. In a similar approach to the Linux and subsequent open source software efforts, we recognize that such development does not happen by spontaneous growth, but needs a core set of technologies from which further developments may happen.

Research

This co-operative GIS and image processing software environment would allow researchers to share their results with the EO community, thus reducing the "time to market" from academia to society. As an example of such products, a group of R&D institutions in Brazil is currently developing TerraLib, an open-source GIS library that enables quick development of custom-built applications for spatial data analysis.

7.2.2 List of Open Source GIS Software

1. **FlowMap**
   FlowMap is a freeware application designed to analyze and display flow data. This application was developed at the Faculty of Geographical Sciences of the Utrecht University in the Netherlands.
   Platforms: Windows OS

2. **GMT Mapping Tools**
   GMT is a free, public-domain collection of ~60 UNIX tools that allow users to manipulate (x,y) and (x,y,z) data sets (including filtering, trend fitting, gridding, projecting, etc.) and produce Encapsulated PostScript File (EPS) illustrations ranging from simple x-y plots through contour maps to artificially illuminated surfaces and 3-D perspective views in black and white, gray tone, hachure patterns, and 24-bit color.
   Platforms: UNIX, Macintosh

3. **GRASS**
   Geographic Resources Analysis Support System (GRASS) is the public domain GIS software application originally developed by the US Government. GRASS is probably the most well-known open source and original GIS software applications. GRASS is a raster-based GIS, vector GIS, image processing system, graphics production system, data management system, and spatial modeling system. GRASS can be downloaded for free.
   Platforms: Linux, Macintosh, Sun Solaris, Silicon Graphics Irix, HP-UX, DEC-Alpha, and Windows OS

4. **gvSIG**
   gvSIG is an open source GIS application written in Java.
   Platforms: Windows, Macintosh, Linux, UNIX

5. **MapWindow GIS**
   MapWindow GIS is open source GIS application that can be extended through plugins. The application is built using Microsoft's .NET
   Platforms: Windows

6. **OpenJUMP GIS**
   OpenJUMP GIS is an open source GIS written in Java through a collaborative effort by volunteers. Formerly known as JUMP GIS, the application can read shapefiles and GML format files.
   Platforms: Windows, Macintosh, Linux, UNIX

7. **Quantum GIS**
   Also referred to as QGIS, Quantum GIS is an Open Source Geographic Information System (GIS).
   More: Getting Started With QGIS: Open Source GIS
   Platforms: Linux, Unix, Mac OSX, and Windows.

8. **SPRING**
   SPRING is a GIS and Remote Sensing Image Processing system with an object-oriented data model which provides for the integration of raster and vector data representations in a single environment.
   Platform: Windows, Linux, UNIX, Macintosh

9. **TNTLite**
   TNTLite MicroImages, Inc. provides TNTlite as a free version of TNTmips , the professional software for geospatial data analysis. The free TNTlite product has all the features of the

professional version, except TNTlite limits the size of Project File objects, and TNTlite enables data sharing only with other copies of TNTlite (export processes are disabled). Can either be downloaded or ordered on CD.
Platforms: Windows

10. **uDig GIS**
uDig GIS is a free, open source GIS desktop application that runs on Windows, Linux and MacOS. uDig was designed to use OGC's OpenGIS standards such as WMS, WFS and more. One-click install allows you to view local shapefiles, remote WMS services and even directly edit your own spatial database geometries.
Platforms: Windows, Linux, Macintosh

11. **GeoMajas**
Written in java, GeoMajas is an open source GIS framework for the web.

12. **GeoServer**
Java based open source server software that allows users to edit and share geospatial data and uses open standards to spublish GIS data.

13. **MapGuide Open Source**
First introduced as open source by Autodesk in 2005, MapGuide Open Source allows for the development of web based mapping.

14. **MapFish**
An open source mapping development framework for web mapping applications based on the Pylon Pythons web framework.

15. **MapServer**
MapServer is an Open Source development environment for building spatially enabled Internet applications. The software builds upon other popular Open Source or freeware systems like Shapelib, FreeType, Proj.4, libTIFF, Perl and others.

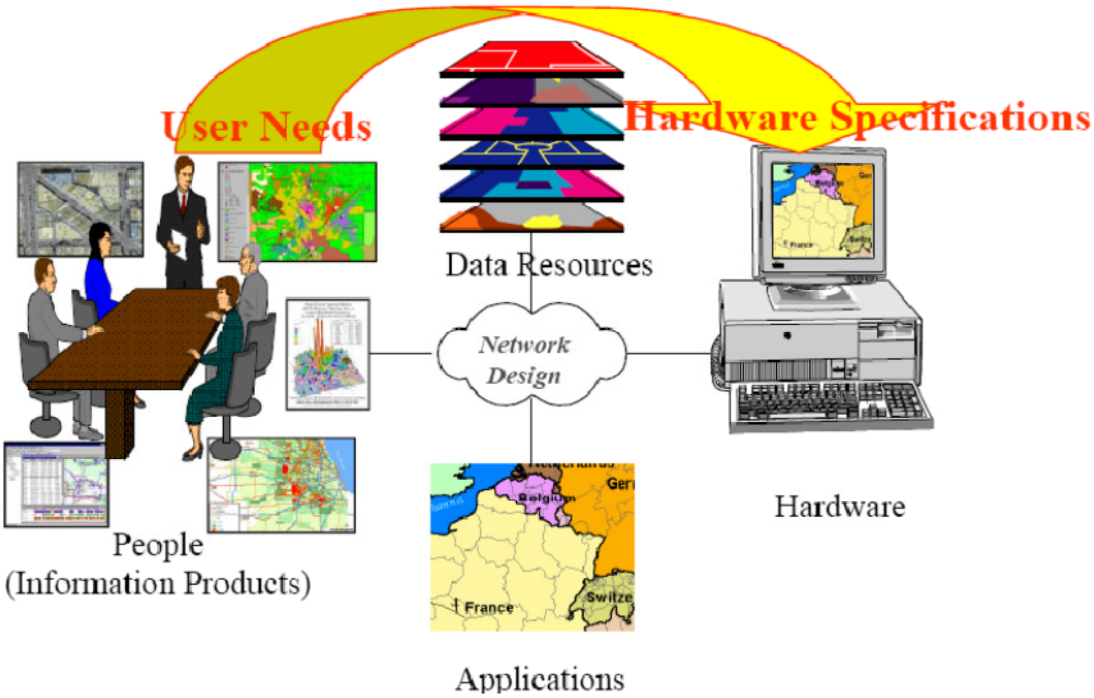
16. **OpenLayers**
Javascript library that is open source for displaying GIS data within a browser environment. OpenStreetMap uses OpenLayers for its main map display (aka the "Slippy Map").

17. **TileMill**
Built on open source libraries (Mapnik, node.js, backbone.js,express and CodeMirror). The Chicago Tribune included TileMill in a series entitled Making Maps using PostGIS, Mapnik, TileMill, and Google Maps.

7.3 System Analysis and Design in GIS

7.3.1 System Architecture Design

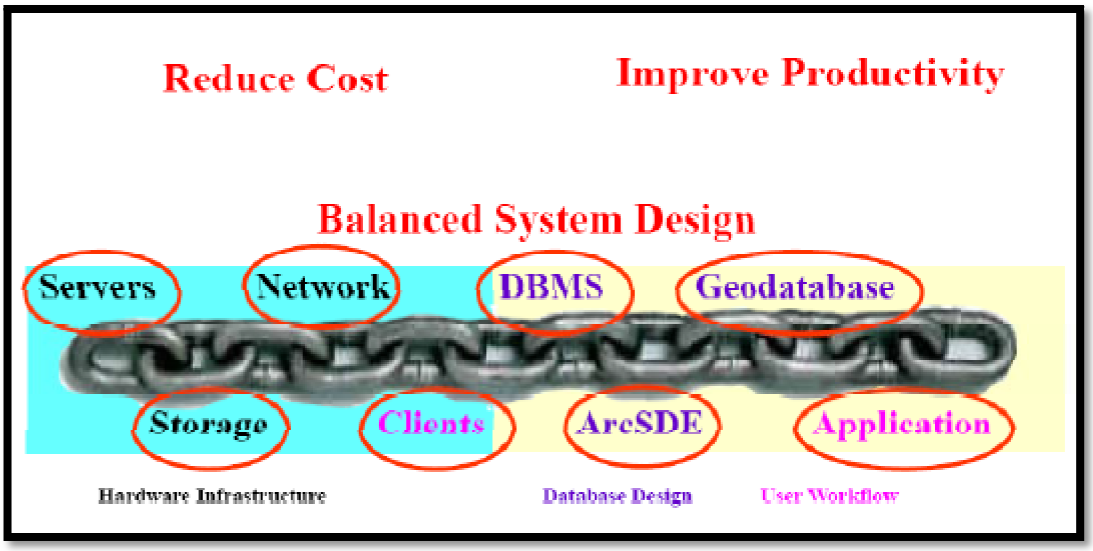
System architecture design is a process developed by ESRI to promote successful GIS implementations. This process supports existing infrastructure requirements and provides specific recommendations for hardware and network solutions based on existing and projected user needs. Application requirements, data resources, andpeople within an organization are all important in determining the optimum hardware solution as shown in figure 1-1.



The ESRI system architecture design process provides specific deployment strategies and associated hardware specifications based on identified operational workflow requirements.

7.3.2 Important of System Architecture Design

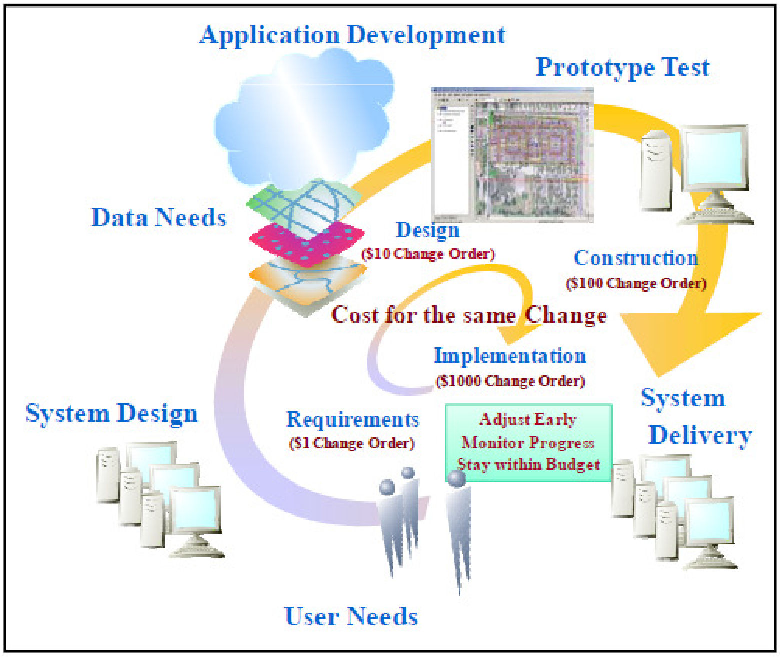
A distributed computer environment must be designed properly to support user performance requirements. The weakest "link" in the system will limit performance. The system architecture design process develops specifications for a balanced hardware solution. Investment in hardware and network components based on a balanced system load model provides the highest possible system performance at the lowest overall cost as shown in figure below.



System architecture design provides a framework for supporting the implementation of a successful enterprise GIS. User workflows must be designed to optimize interactive client productivity and efficiently manage heavier geoprocessing loads. The geodatabase design and database selection should be optimized to support performance requirements. The selected system platform components (servers, client workstations, storage systems) must perform adequately and have the capacity to support peak user workflow requirements. The system architecture design strategy must address performance needs and bandwidth constraints over distributed communication networks—technology and configuration must be selected to conserve shared infrastructure resources. System architecture design provides a solid foundation for building a productive operational environment.

7..3.3 What Does It Take to Support Successful GIS Operations?

There are several critical deployment stages that support a successful implementation. Understanding the importance of each stage and the key objectives that support success leads to more effective enterprise implementations. Figure 1-3 shows the different stages of GIS deployment.



Requirements Stage: Understanding GIS technology alternatives, quantifying GIS user requirements, and establishing an appropriate system architecture design deployment strategy are critical during the requirements stage. Capacity planning during this phase can establish preliminary software performance specifications. This is a planning stage where "getting it right" can save considerable effort and money throughout the implementation.

Design Stage

System development and prototype functional testing build the components and confidence to support the follow-on deployment. This is where time and money are invested to build and test the selected environment. Initial prototype testing demonstrates functionality and reduces implementation risk. Preliminary software performance testing can validate initial capacity planning assumptions.

Construction Stage

A successful initial system deployment can set the stage for success. This is where the solution comes together and final operational support needs are validated. This is an important time to demonstrate performance and the capacity of the deployed system and validate that the selected hardware and infrastructure will support full production deployment.

Implementation Stage

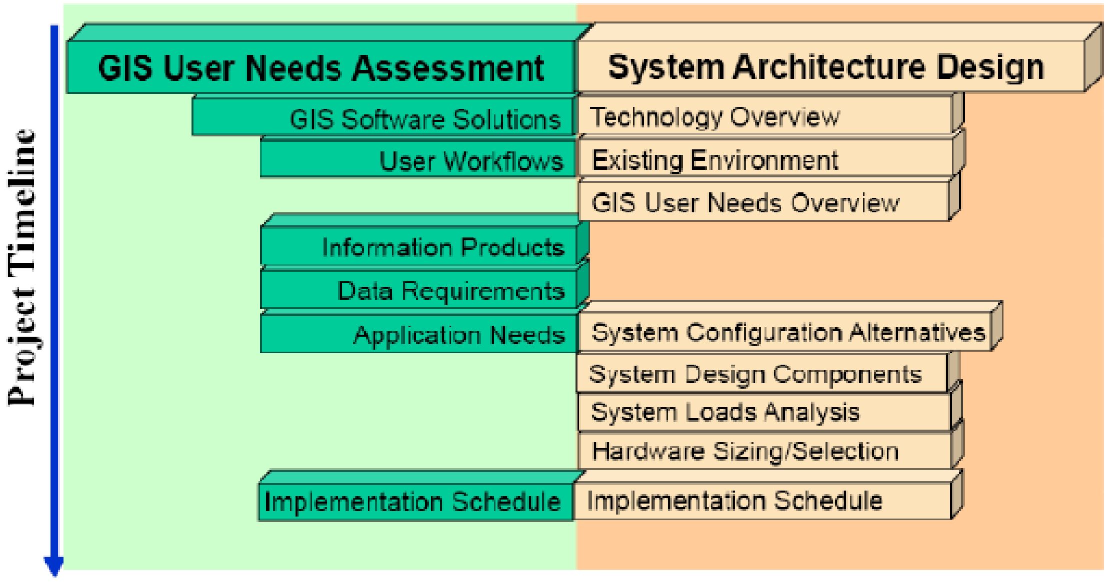
Final system procurement and deployment demonstrate operational success. Capacity planning metrics can be used to monitor and maintain system performance objectives. Good planning, development, and testing will support a smooth deployment, productive operations, and satisfied users.

Getting it right from the start is best done by taking the time to understand the technology, quantify user requirements, select the right software technology, and deploy the right hardware. Not getting it right from the start will cost money to make it right later. The cost of change increases exponentially as the project implementation proceeds.

Establishing workflow performance target milestones and managing software performance to achieve performance goals throughout deployment is a positive recipe for success. Building systems without regard to performance and scalability can lead to disappointing results and costly recovery.

7.3.4 System Design Process

The traditional system design process includes a GIS needs assessment and a system architecture design. The system architecture design is based on user workflow requirements identified in the GIS needs assessment. The most effective system design approach considers user needs and system architecture constraints throughout the design process. Figure 1-4 provides an overview of the system design process.



GIS System Architect
(Customer Business Processes + Capacity Planning Framework)
Integrated Business Needs Assessment

GIS Needs Assessment

The GIS needs assessment includes a review of user workflow requirements and identifies where GIS applications can improve user productivity. This assessment identifies GIS application and data requirements and an implementation strategy for supporting GIS user needs. The user requirements analysis is a process that must be accomplished by the user organization. A GIS professional consultant familiar with current GIS solutions and customer business practices can help facilitate this planning effort.

System Architecture Design

The system architecture design is based on user requirements identified by the GIS needs assessment. Customers must have a clear understanding of their GIS application and data requirements before they are ready to develop system design specifications. System implementation strategies should identify hardware purchase requirements "just in time" to support user deployment needs.

The system design begins with technology exchange. Technology exchange provides the foundation for client support throughout the design process. Client participation is a key ingredient in the design process. The design process includes a review of the existing computer environment, GIS user requirements, and system design alternatives. The system design capacity planning tools provided by ESRI translate projected peak user workflow requirements to specific platform specifications. An integrated implementation strategy is developed to support GIS deployment milestones.

Traditionally, the user needs assessment and the system architecture design were two separate efforts. There are some key advantages in completing these efforts together. GIS Software solutions should include a discussion of architecture options and system deployment strategies for each technology option. The existing hardware environment and information on peak user workflows and user locations can be identified during the user workflow interviews. Technology selection should consider configuration options, required platforms, peak system loads for each technology option, and overall system design costs. And finally the system implementation schedule must consider delivery milestones. A primary goal of developing the new capacity planning tools presented later in this document is to automate the system architecture design analysis in such a way that GIS professional consultants will be able to use the capacity planning tools to support an integrated business needs assessment.

7.4 Web Based GIS System

7.4.1 Definition

- Web GIS started off as GIS running in Web browsers and has evolved into Web GIS serving desktop and mobile clients.
- Web GIS is any GIS that uses Web technology to communicate between components: server(identified by URL) and client (a browser, a desktop application, or a mobile application). The communication is via HTTP. The format of the response can be an HTML, binary image, XML(Extensible Markup Language), or JSON(JavaScript Object Notation).
- The simplest architecture: 2-tier client-server (C-S) system. Server program runs on the Web or in the cloud. C-S can be on one computer.
- Multi-tier system: 3 tier (including a data tier), >3 tiers in mashup Web GIS.
- GeoWeb is not identical to WebGIS. GeoWeb is the merging of geospatial information with non-geospatial information (e.g., Webpages, photos, videos, and news). GeoWeb is related to the geotagging and geoparsing research area of WebGIS.

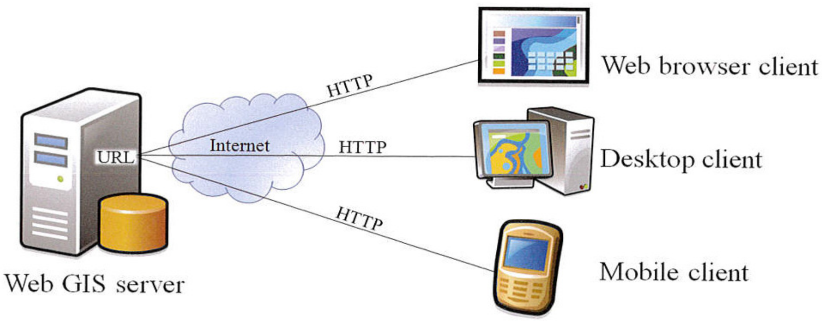


Figure 1.9 The simplest architecture of Web GIS should have at least a Web application server and a client, which can be a Web browser, desktop client, or mobile client. The server and the client communicate via HTTP.

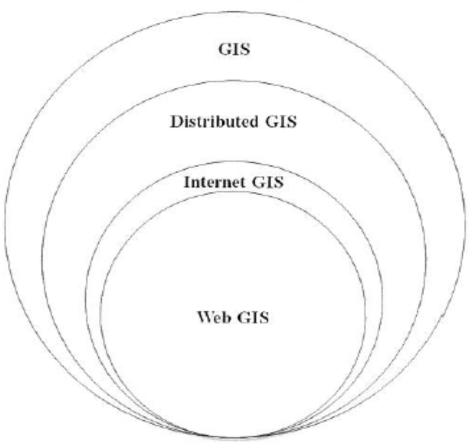
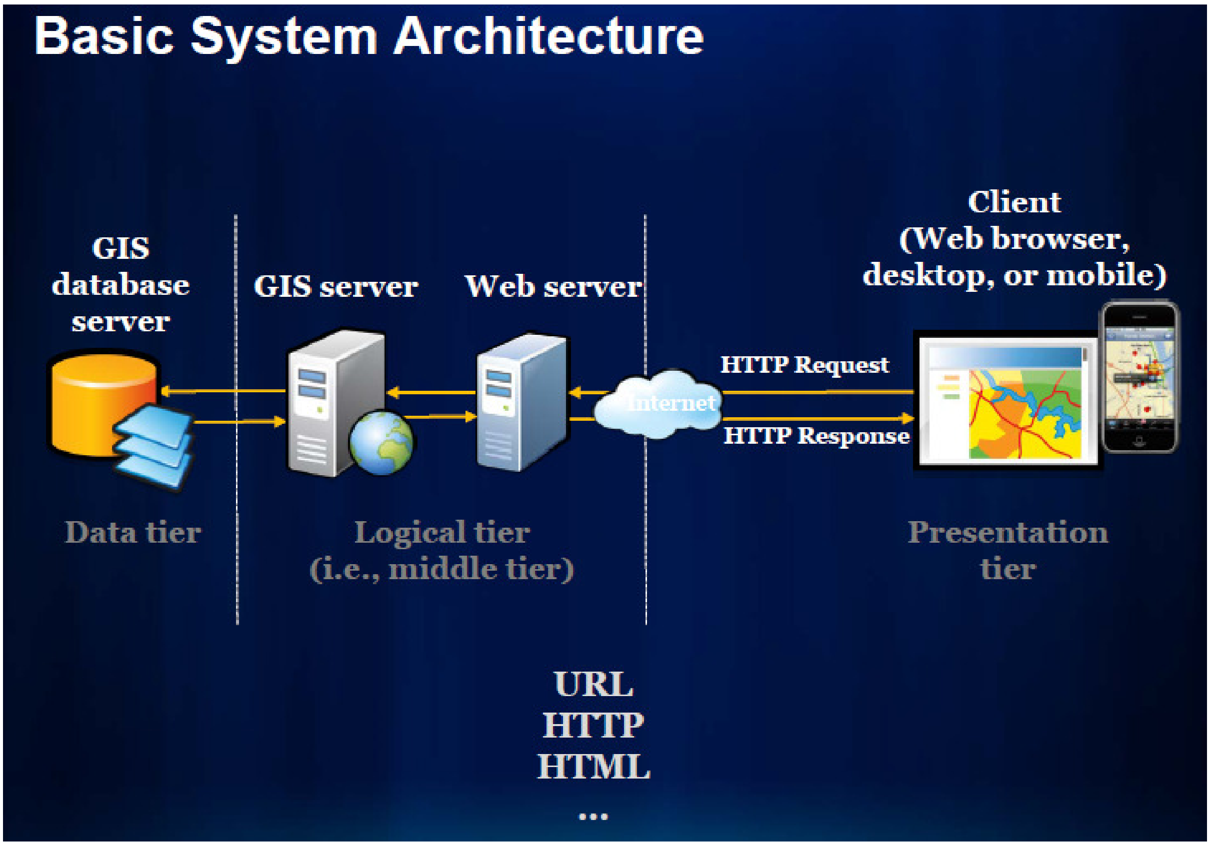


Figure 1.10 Web GIS is shown in relation to other related GIS terms. While Internet GIS has a slightly broader coverage, Web GIS is the most widely used form of Internet GIS. Thus, many people use the terms synonymously.



7.4.2 Characteristics of Web GIS

- Global reach by HTTP.
- Support a large number of users simultanuously: requires high performance and scalability.
- Better cross-platform capability:
  - -Different Web browsers: IE, Firefox, G. Chrome for diverse OSs (Win, Linux, Mac OS, iOS).
  - -Web GIS relying on HTML clients supports different operating systems(OSs).
  - -Web GIS relying in Java, .Net, and Flex can run on multiple platforms.
  - -However, Web GIS for mobile clients is far from being cross-platform b/c of the diversity in mobile Oss and the incompatibility of mobile Web browsers.
- Easy to use for end users. "If I do not know how to use your site, it is your fault".
- Unified system update.
- Diverse applications. Neogeopgarphy,("new geography"), is commonly applied to the usage of geographical techniques and tools used for personal and community activities or for utilization by a non-expert group of users

7.4.3 Functions

- Mapping/visualization and query (attribute or spatial).
- Collaborative collection of geospatial information. E.g., wikimapia, OpenStreetMap.
  - - VGI (volunteered geographic information).
- Geospatial analysis: measurement, optimal driving path, routing, pollution dispersion modeling, retail site selection,…

7.4.4 Uses

- Web GIS as a new business model and a new type of commodity:
  - Location-specific advertising based on map mapping, e.g., Google Map.
  - SaaS business model: Web GIS can also be provided as a commodity. E.g., ESRI Business Analyst Online (BAO).
- Web GIS as an engaging and powerful tool for e-government.

- A new infrastructure for e-science: **E-Science** (or **eScience**) is computationally intensive science that is carried out in highly distributed network environments, or science that uses immense data sets that require grid computing (the federation of computer resources from multiple administrative domains to reach a common goal); Web GIS provides an infrastructure for geo-science research collaboration.
- Web GIS in daily life: location-based service (LBS) supported by mobile Web, smart phones and tablets. LBS include services to identify a location of a person or object, such as discovering the nearest banking cash machine or the whereabouts of a friend or employee. LBS include parcel tracking and vehicle tracking services. LBS can include mobile commerce when taking the form of coupons or advertising directed at customers based on their current location. They include personalized weather services and even location-based games.