LEARNING MATERIAL

GIS & GPS

LEARNING MATERIAL
UNIT-I

Introduction to Maps

Cadastral Map: A large-scale map drawn at a scale of 1: 500 to 1: 4000 to show property boundaries, designating each parcel of land with a number.
Cardinal Points: North (N), South (S), East (E) and West (W).

Cartography: Art, science and technology of making maps, charts, plans and other modes of graphical expression as well as their study and use.
Generalisation-Map: A simplified representation of the features on the map, appropriate to its scale or purpose, without affecting their visual form.
Geoid: An oblate spheroid whose shape resembles the actual shape of the Earth.

Map: A selective, symbolised and generalised representation of the whole or part of the earth at a reduced scale.
Map series: A group of maps produced at same scale, style and specifications for a country or a region.
Projection-Map: The system of the transformation of the spherical surface onto a plane surface.
Scale: The ratio between the distances of two points on the map, plan or photograph and the actual distance between the same two points on the ground. ***Sketch Map:*** A simplified map drawn freehand which fails to preserve the true scale or orientation.

We may be familiar with maps that you have seen in most of your books of social sciences representing the earth or any of its parts. We may also know that the shape of the earth is geoid (three-dimensional) and a globe can best represent it. A map, on the other hand, is a simplified depiction of whole or part of the earth on a piece of paper. In other words, it is a two-dimensional form of the three-dimensional earth. Hence, a map can be drawn using a system of map projections. As it is impossible to represent all features of the earth's surface in their true size and form, a map is drawn at a reduced scale. Imagine your school campus. If a plan/map of our school is to be drawn in its actual size, it will be as large as the campus itself. Hence, maps are drawn at a scale and projection so that each point on the paper corresponds to the actual ground position. Besides, the representation of different features is also simplified using symbols, colours and shades. A map is, therefore, defined as selective, symbolised and generalised representation of whole or a part of the earth's surface on a plane surface at a reduced scale. It may also be understood that a simple network of lines and polygons without a scale shall not be called a map. It is only referred to as "the sketch". In the present chapter, we will study the essential requirements of maps, their types and the uses.

Essentials of Map Making

In view of the variety of maps, we may find it difficult to summarise what they all have in common. Cartography, being an art and science of map-making, does include a series of processes that are common to all the maps. These processes that may also be referred to as essentials of maps are:

- Scale
- Map Projection
- Map Generalisation
- Map Design
- Map Construction and Production

Scale: We know that all maps are reductions. The first decision that a map-maker has to take is about the scale of the map. The choice of scale is of utmost importance. The scale of a map sets limits of information contents and the degree of reality with which it can be delineated on the map.

Projection: We also know that maps are a simplified representation of the three- dimensional surface of the earth on a plane sheet of paper. The transformation of all- side-curved-geoidal surface into a plane surface is another important aspect of the cartographic process. We should know that such a radical transformation introduces some unavoidable changes in directions, distances, areas and shapes from the way they appear on a geoid. A system of transformation of the spherical surface to the plane surface is called a map projection. Hence, the choice, utilisation and construction of projections is of prime importance in map-making.

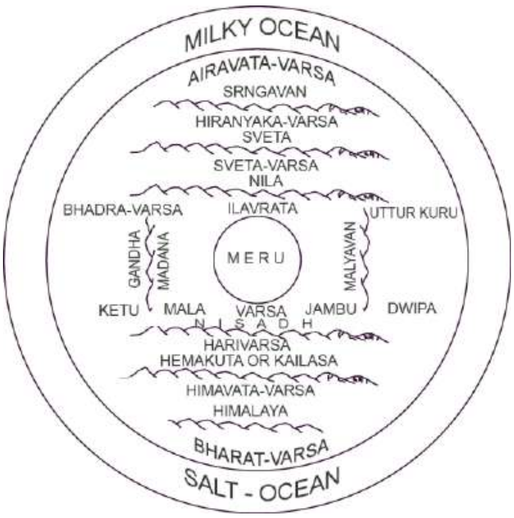
Generalisation: Every map is drawn with a definite objective. For example, a general purpose map is drawn to show information of a general nature such as relief, drainage, vegetation, settlements, means of transportation, etc. Similarly, a special purpose map exhibits information pertaining to one or more selected themes like population density, soil types or location of industries. It is, therefore, necessary to carefully plan the map contents while the purpose of the map must be kept in the forefront. As maps are drawn at a reduced scale to serve a definite purpose, the third task of a cartographer is to generalise the map contents. In doing so, a cartographer must select the information (data) relevant to the selected theme and simplify it as per the needs.

Map Design: The fourth important task of a cartographer is the map design. It involves the planning of graphic characteristics of maps including the selection of appropriate symbols, their size and form, style of lettering, specifying the width of lines, selection of colours and shades, arrangement of various elements of map design within a map and design for map legend. The map design is, therefore, a complex aspect of map- making and requires thorough understanding of the principles that govern the effectiveness of graphic communication.

Map Construction and Production: The drawing of maps and their reproduction is the fifth major task in the cartographic process. In earlier times, much of the map construction and reproduction work used to be carried out manually. Maps were drawn with pen and ink and printed mechanically. However, the map construction and reproduction has been revolutionised with the addition of computer assisted mapping and photo-printing techniques in the recent past.

History of Map Making

The history of map making is as old as the history of mankind itself. The oldest map was found in Mesopotamia drawn on a clay tablet that belongs to 2,500 B.C. Ptolemy's Map of the World Greek and the Arab geographers laid the foundation of modern cartography. The measurement of the circumference of the Earth and the use of the system of geographical coordinates in map-making are some of the significant contributions of the Greeks and the Arabs. The art and science of map making was revitalised in early modern period, with extensive efforts made to minimise the effects of the transformation of the geoid onto a plane surface. The maps were drawn on different projections to obtain true directions, correct distances and to measure area accurately. The aerial photography supplemented the ground method of survey and the uses of aerial photographs stimulated map-making in the nineteenth and twentieth centuries.



Round World surrounded by water as conceived in Mahabharata

The foundation of map-making in India was laid during the Vedic period when the expressions of astronomical truths and cosmological revelations were made. The expressions were crystallised into ‘sidhantas' or laws in classical treaties of Arya Bhatta, Varahamihira and Bhaskara, and others. Ancient Indian scholars divided the known world into seven ‘dwipas’ . Mahabharata conceived a round world surrounded by water.

Seven Dwipas of the World as conceived in Ancient India

Surveying and map-making as an integral part of the revenue collection procedure. Besides, Sher Shah Suri’s revenue maps further enriched the mapping techniques during the medieval period. The intensive topographical surveys for the preparation of up–to–date maps of the entire country, were taken up with the setting up of the Survey of India in 1767, which culminated with the map of Hindustan in 1785. Today, the Survey of India produces maps at different scales for the entire country.

Types of Maps Based on Scale:

On the basis of scale, maps may be classified into large-scale and small-scale. Large scale maps are drawn to show smal areas at a relatively large-scale. For example, the topographical maps drawn at a scale of 1: 250,000, 1:50,000 or 1:25,000 and the village maps, the zonal plans of the cities and house plans prepared on a scale of 1:4,000, 1:2,000 and 1:500 are large scale maps. On the other hand, small-scale maps are drawn to show large areas. For example, atlas maps, wall maps, etc.

1. **Large-scale Maps:** Large-scale maps are further divided into the following types :
   - Cadastral maps
   - Topographical maps

- **Cadastral Maps:** The term ‘cadastral’ is derived from the French word ‘cadastre’ meaning ‘register of territorial property’. These maps are drawn to show the ownership of landed property by demarcating field boundaries of agricultural land and the plan of individual houses in urban areas. The cadastral maps are prepared by the government agencies to realise revenue and taxes, along with keeping a record of ownership. These maps are drawn on a very large scale, such as the cadastral maps of villages at 1 : 4,000 scale and the city plans at a scale of 1 : 2,000 and larger.

- **Topographical Maps:** These maps are also prepared on a fairly large scale. The topographical maps are based on precise surveys and are prepared in the form of series of maps made by the national mapping agencies of almost all countries of the world. For example, the Survey of India undertakes the topographical mapping of the entire country at 1: 250,000, 1: 50,000 and 1: 25,000 scale. These maps follow uniform colours and symbols to show topographic details such as relief, drainage, agricultural land, forest, settlements, and means of communication, location of schools, post offices and other services and facilities.

2. **Small-scale Maps:** Small-scale maps are further divided into the following types:
   1. Wall Maps
   2. Atlas Maps

   1. **Wall Maps:** These maps are generally drawn on large size paper or on plastic base for use in classrooms or lecture halls. The scale of wall maps is generally smaller than the scale of topographical maps but larger than atlas maps.
   2. **Atlas Maps:** Atlas maps are very small-scale maps. These maps represent fairly large areas and present highly generalised picture of the physical or cultural features. Even so, an atlas map serves as a graphic encyclopaedia of the geographical information about the world, continents, countries or regions. When consulted properly, these maps provide a wealth of generalised information regarding location, relief, drainage, climate, vegetation, distribution of cities and towns, population, location of industries, transport-network system, tourism and heritage sites, etc.

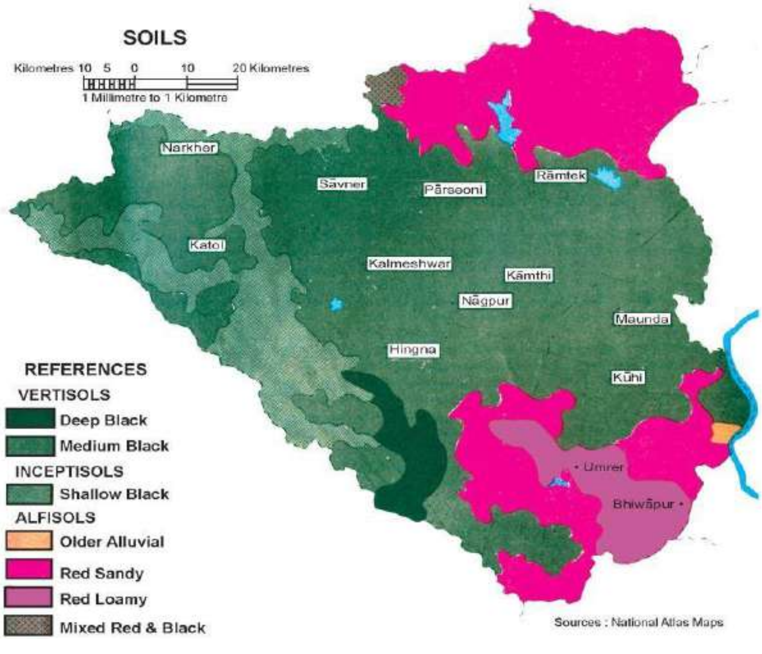
Types of Maps Based on Function

The maps may also be classified on the basis of their functions. For example, a political map serves the function of providing administrative divisions of a continent or a country and a soil map shows the distribution of different types of soils. Broadly, maps based on their functions may be classified into physical maps and cultural maps.

- **Physical Maps:** Physical maps show natural features such as relief, geology, soils, drainage, elements of weather, climate and vegetation, etc.
- **Relief Maps:** Relief maps show general topography of an area like mountains and valleys, plains, plateaus and drainage.
- **Geological Maps:** These maps are drawn to show geological structures, rock types, etc. Figure 1.8 shows the distribution of rocks and minerals in Nagpur district.

- **Climatic Maps:** These maps depict climatic regions of an area. Besides, maps are also drawn to show the distribution of temperature, rainfall, cloudiness, relative humidity, direction and velocity of winds and other elements of weather.

Distribution of Rocks and Minerals in Nagpur District

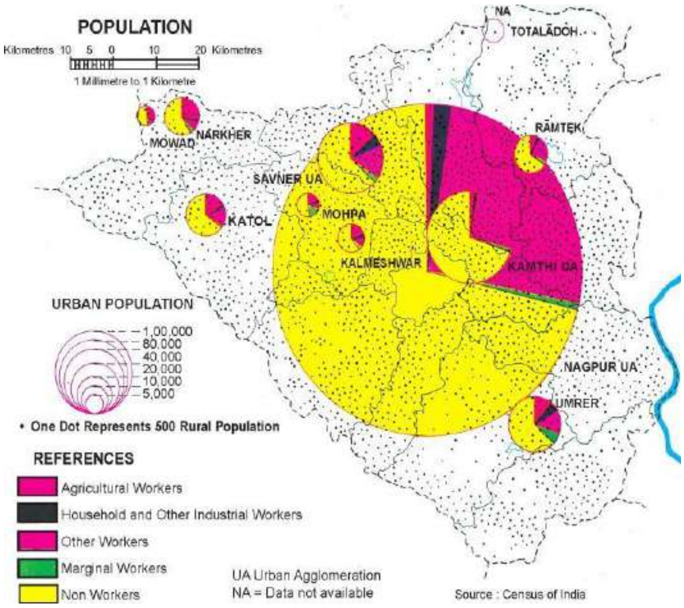


Soils of Nagpur District

- **Soil Maps *:*** Maps are also drawn to show the distribution of differentypes of soil(s) and their properties.

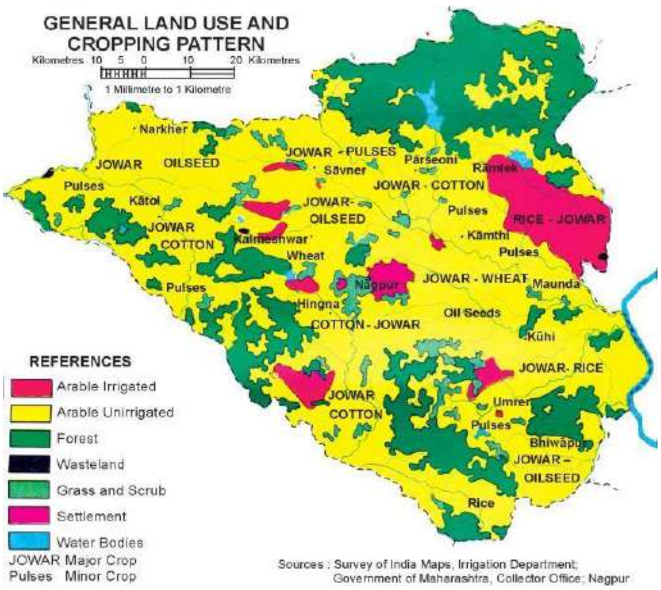
- **Cultural Maps:** Cultural maps show man-made features. These include a variety of maps showing population distribution and growth, sex and age, social and religious composition, literacy, levels of educational attainment, occupational structure, location of settlements, facilities and services, transportation lines and production, distribution and flow of different commodities.
- **Political Maps:** These maps show the administrative divisions of an area such as country, state or district. These maps facilitate the administrative machinery in planning and management of the concerned administrative unit.

Population Maps: The population maps are drawn to show the distribution, density and growth of population, age and sex composition, distribution of religious, linguistic and social groups, occupational structure of the population, etc. Population maps serve the most significant role in the planning and development of an area.



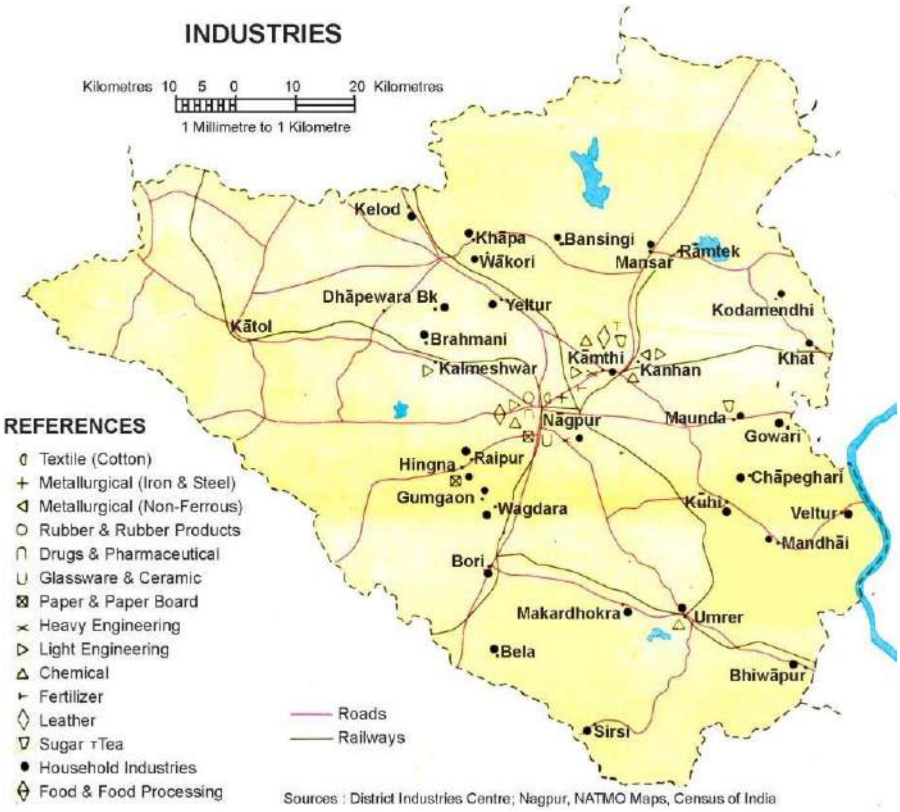
Nagpur District : Distribution of Population

Economic Maps: Economic maps depict production and distribution of different types of crops and minerals, location of industries and markets, routes for trade and flow of commodities.



Land use and Cropping Patterns in Nagpur District

Transportation Maps: These maps show roads, railway lines and the location of railway stations and airports.



Location of Industries in Nagpur District

What is Scale ?

You must have seen maps with a scale bar indicating equal divisions, each marked with readings in kilometres or miles. These divisions are used to find out the ground distance on the map. In other words, a map scale provides the relationship between the map and the whole or a part of the earth's surface shown on it. We can also express this relationship as a ratio of distances between two points on the map and the corresponding distance between the same two points on the ground.

There are at least three ways in which this relationship can be expressed. These are:

1. Statement of Scale
2. Representative Fraction (R. F.)
3. Graphical Scale

Each of these methods of scale has advantages and limitations. But before taking up these issues, let us understand that the scale is normally expressed in one or the other system of measurement. You must have read and/or used kilometre, metre, centimetre etc. to measure the linear distances between two points on the ground. You might have also heard of miles, furlongs, yards, feet, etc. These are two different systems of measurement of the distances used in different countries of the world. Whereas the former system is referred to as the Metric System of Measurement and presently used in India and many other countries of the world, the latter system is known as the English System of Measurement and is prevalent in both the United States and the United Kingdom. India also used this system for measuring/showing linear distances before 1957.

METHODS OF SCALE

As mentioned above, the scale of the map may be expressed using one or a combination of more than one methods of scale. Let us see how these methods are used and what are their advantages and limitations.

1. **Statement of Scale**: The scale of a map may be indicated in the form of a written statement. For example, if on a map a written statement appears stating 1 cm represents 10 km, it means that on that map a distance of 1 cm is representing 10 km of the corresponding ground distance. It may also be expressed in any other system of measurement, i.e. 1 inch represents 10 miles. It is the simplest of the three methods. However, it may be noted that the people who are familiar with one system may not understand the statement of scale given in another system of measurement. Another limitation of this method is that if the map is

reduced or enlarged, the scale will become redundant and a new scale is to be worked out.

2. **Graphical or Bar Scale:** The second type of scale shows map distances and the corresponding ground distances using a line bar with primary and secondary divisions marked on it. This is referred to as the graphical scale or bar scale (Fig. 2.1). It may be noted that the scale readings as shown on the bar scale in Figure
2.1 reads only in kilometres and metres. In yet another bar scale the readings may be shown in miles and furlongs. Hence, like the statement of scale method, this method also finds restricted use for only those who can understand it. However, unlike the statement of the scale method, the graphical scale stands valid even when the map is reduced or enlarged. This is the unique advantage of the graphical method of the map scale.

3. **Representative Fraction (R. F.):** The third type of scale is R. F. It shows the relationship between the map distance and the corresponding ground distance in units of length. The use of units to express the scale makes it the most versatile method. R. F. is generally shown in fraction because it shows how much the real world is reduced to fit on the map.

For example, a fraction of 1 : 24,000 shows that one unit of length on the map represents 24,000 of the same units on the ground i.e. one mm, one cm or one inch on the map representing 24,000 mm, 24,000 cm and 24,000 inches, respectively of the ground. It may, however, be noted that while converting the fraction of units into Metric or English systems, units in centimetre or inch are normally used by convention. This quality of expressing scale in units in R. F. makes it a universally acceptable and usable method.

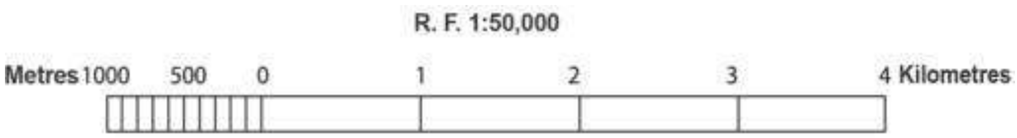
Let us take R. F. of 1 : 36,000 to elaborate the universal nature of R. F. If the given scale is 1: 36,000, a person acquainted with the Metric System will read the given units by converting them into cm, i.e. the distance of 1 unit on the map as 1 cm and the distance of 36,000 units on the ground distance as 36,000 cm. These values may subsequently be converted into a statement of scale, i.e. 1 cm represents 360 metres. (by dividing values in denominator by the number of centimetres in a metre, i.e. 100).

Yet another user of the map familiar with the English system of measurement will understand the map scale by converting it into a statement of scale convenient to him/her and read the map scale as 1 inch represents 1,000 yards. The said statement of scale will be obtained by dividing 36,000 units in the denominator by 36 (number of inches in a yard). R. F. into Statement of Scale Problem Convert R. F. 1: 253, 440 into Statement of Scale (In Metric System) Solution the given R. F. of 1: 253, 440 may be converted into Statement of Scale using the following steps: 1: 253, 440 means that 1 unit on the map represents

253, 440 units on the ground. or 1 cm represents 253, 440/100,000 (1 km = 100,000 cm) or 1 cm represents 2.5344 km After rounding of up to 2 decimals, the answer will be : Answer 1 cm represents 2.53 km Construction of the Graphical/Bar Scale.

Problem 1 Construct a graphical scale for a map drawn at a scale of 1: 50,000 and read the distances in kilometre and metre.
NOTE: By convention, a length of nearly 15 cm is taken to draw a graphical scale. **Calculations:** To get the length of line for the graphical scale, these steps may be followed: 1: 50,000 means that 1 unit of the map represents 50,000 units on the ground or 1 cm represents 50,000 cm or 15 cm represents 50,000 × 15/100,000 km or 15 cm represents 7.5 km Since the value of 7.5 (km) is not a round number, we can choose 5 or 10 (km) as the round number. In the present case, we choose 5 as the round number. To determine the length of the line to show 5 km, the following calculations are to be carried out: 7.5 km is represented by a line of 15 cm 5 km will be represented by a line of 15 × 5/7.5 or 5 km will be represented by a line of 10 cm.

Construction: The graphical scale may be constructed by following these steps: Draw a straight line of 10 cm and divide it into 5 equal parts and assign a value of 1 km each for 4 right side divisions from the 0 mark. Also divide the extreme left side division into 10 equal parts and mark each division by a value of 100 metres, beginning from 0. (You may also divide it into 2, 4, or 5 parts and assign a value of 500, 250, or 200 metres to each of the subdivisions respectively from 0.



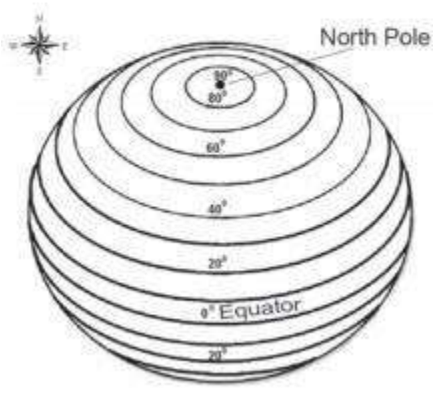
Latitude & Longitude

THE EARTH is nearly a sphere. It is because of the fact that the equatorial radius and the polar radius of the earth is not the same. The rotation of the earth over its axis produces bulging at the equator. Hence, the actual shape resembles that of an oblate spheroid. The shape of the earth presents some difficulties in positioning its surface features, as there is no point of reference from which to measure the relative positions of other points. Hence, a network of imaginary lines is drawn on a globe or a map to locate various places. Let us find out what are these lines and how are they drawn. The spinning of the earth on its axis from west to east provides two natural points of reference, i.e. North and South Poles. They form the basis for the geographical grid. A network of intersecting lines is drawn for the purpose of fixing the locations of different features. The grid consists of two sets of horizontal and vertical lines, which are called parallels of latitudes and the meridians of longitudes.

Horizontal lines are drawn parallel to each other in east-west direction. The line drawn midway between the North Pole and the South Pole is called the equator. It is the largest circle and divides the globe into two equal halves. It is also called a great circle. All the other parallels get smaller in size, in proportion to their distance from the equator towards the poles and divide the earth into two unequal halves, also referred to as the small circles. These imaginary lines running east-west are commonly known as the parallels of latitude. The vertical lines running north-south, join the two poles. They are called the meridians of longitude. They are spaced farthest apart at the equator and converge at a point at each pole.

PARALLELS OF LATITUDES

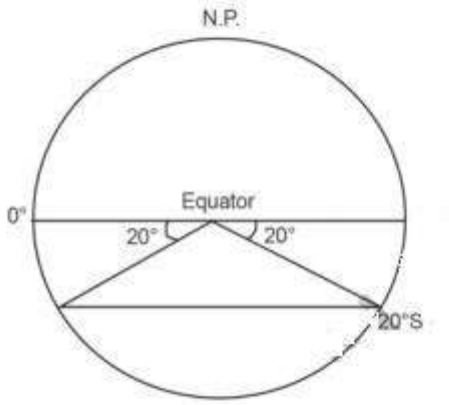
The latitude of a place on the earth's surface is its distance north or south of the equator, measured along the meridian of that place as an angle from the centre of the earth. Lines joining places with the same latitudes are called parallels. The value of equator is 0° and the latitude of the poles are 90°N and 90°S. If parallels of latitude are drawn at an interval of one degree, there will be 89 parallels in the northern and the southern hemispheres each. The total number of parallels thus drawn, including the equator, will be 179. Depending upon the location of a feature or a place north or south of the equator, the letter N or S is written along with the value of the latitude. If the earth were a perfect sphere, the length of 10 of latitude (a one degree arc of a meridian) would be a constant value, i.e. 111 km everywhere on the earth. This length is almost the same as that of a degree of longitude at the equator. But to be precise, a degree of latitude changes slightly in length from the equator to the poles. While at the equator, it is 110.6 km at the poles, it is 111.7 km. Latitude of a place may be determined with the help of the altitude of the sun or the Pole Star.



Parallels of Latitudes

DRAWING THE PARALLELS OF LATITUDES

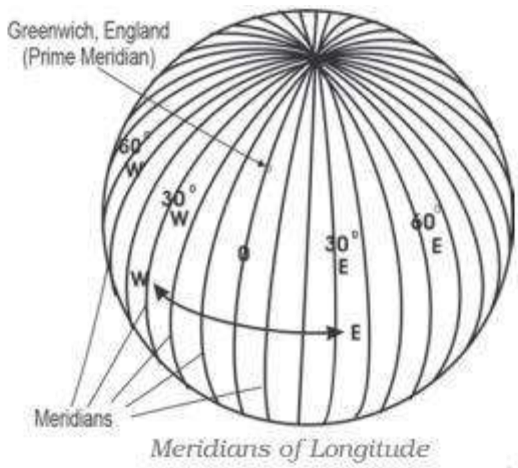
How to draw the parallels of latitudes? Draw a circle and divide it into two equal halves by drawing a horizontal line in the centre. This represents the equator. Place a protractor on this circle in a way that 0° and 180° line on the protractor coincide with the equator on the paper. Now to draw 20°S, mark two points at an angle of 20° from the equator, east and west in the lower half of the circle. The arms of the angle cut the circle at two points. Join these two points by a line parallel to the equator. It will be 20^{0}S.



Drawing of Parallels of Latitudes

MERIDIANS OF LONGITUDE

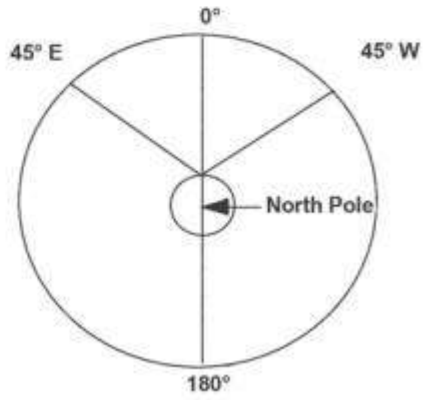
Unlike the parallels of latitude which are circles, the meridians of longitude are semi- circles that converge at the poles. If opposite meridians are taken together, they complete a circle, but, they are valued separately as two meridians. The meridians intersect the equator at right angles. Unlike the parallels of latitude, they are all equal in length. For convenience of numbering, the meridian of longitude passing through the Greenwich observatory (near London) has been adopted as the Prime Meridian by an international agreement and has been given the value of 0°. The longitude of a place is its angular distance east or west of the Prime Meridian. It is also measured in degrees. The longitudes vary from 0° to 180° eastward and westward of the Prime Meridian. The part of the earth east of the Prime Meridian is called the eastern hemisphere and in its west referred to as the western hemisphere.



Meridians of Longitude

Drawing the Meridians of Longitude

How to draw the lines of longitude? Draw a circle whose centre represents the North Pole. The circumference will represent the equator. Draw a vertical line through the centre of the circle, i.e. crossing the North Pole. This represents the 0°and 180°meridians, which meet at the North Pole. When you look at a map, the east is towards your right and the west is towards your left. However, to draw a longitude, imagine that you are on the North Pole, i.e. at the centre of the circle. Observe now that the relative directions of east and west would reverse in this case and east would be towards your left while west would be towards your right. Now, draw 45° E and W For this, place your protractor along the vertical line, coinciding with the 0° and 180° meridians and then measure 45° on both the sides, which will denote 45° E meridian and 45° W meridian on your left and right, respectively. The diagram will represent the appearance of the earth if we look at it from directly above the North Pole.



Drawing of Meridians of Longitude

Map Projection

Map projection is a mathematical expression using which the three-dimensional surface of earth is represented in a two dimensional plane. The process of projection results in distortion of one or more map properties such as shape, size, area or direction.

A single projection system can never account for the correct representation of all map properties for all the regions of the world. Therefore, hundreds of projection systems have been defined for accurate representation of a particular map element for a particular region of the world.

Classification of Map Projections

Map projections are classified on the following criteria:

1. Method of construction
2. Development surface used
3. Projection properties
4. Position of light source
5. Method of Construction

The term map projection implies projecting the graticule of the earth onto a flat surface with the help of shadow cast. However, not all of the map projections are developed in this manner. Some projections are developed using mathematical calculations only. Given below are the projections that are based on the method of construction:

Perspective Projections : These projections are made with the help of shadow cast from an illuminated globe on to a developable surface

Non Perspective Projections : These projections do not use shadow cast from an illuminated globe on to a developable surface. A developable surface is only assumed to be covering the globe and the construction of projections is done using mathematical calculations.

Development Surface

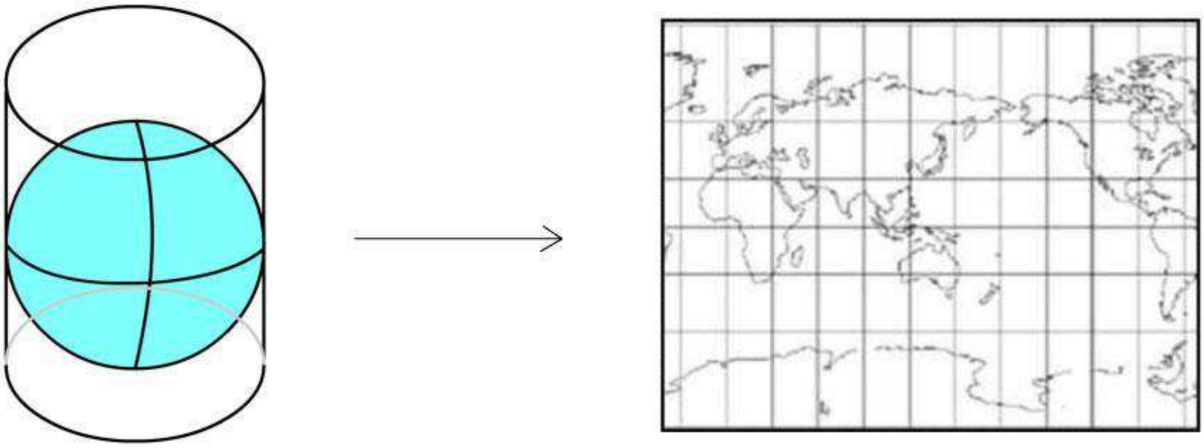
Projection transforms the coordinates of earth on to a surface that can be flattened to a plane without distortion (shearing or stretching). Such a surface is called a developable surface. The three basic projections are based on the types of developable surface and are introduced below:

1. Cylindrical Projection

It can be visualized as a cylinder wrapped around the globe. Once the graticule is projected onto the cylinder, the cylinder is opened to get a grid like pattern of latitudes and longitudes.

The longitudes (meridians) and latitudes (parallels) appear as straight lines

Length of equator on the cylinder is equal to the length of the equator therefore is suitable for showing equatorial regions.

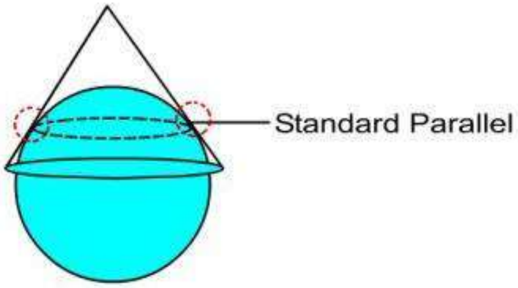


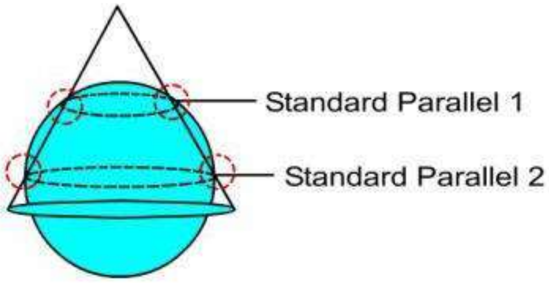
2. Conic Projection

It can be visualized as a cone placed on the globe, tangent to it at some parallel.

After projecting the graticule on to the cone, the cone is cut along one of the meridian and unfolded. Parallels appear as arcs with a pole and meridians as straight lines that converge to the same point.

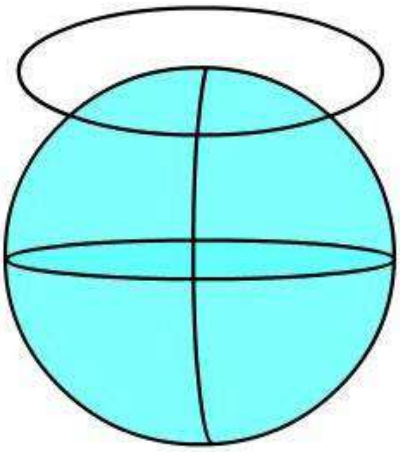
It can represent only one hemisphere, at a time, northern or southern. Suitable for representing middle latitudes.





3. Azimuthal/Zenithal Projection

It can be visualized as a flat sheet of paper tangent to any point on the globe
The sheet will have the tangent point as the centre of the circular map, where meridians passing through the centre are straight line and the parallels are seen as concentric circle. Suitable for showing polar areas



Projection Properties

According to properties map projections can be classified as:

Equal area projection: Also known as homolographic projections. The areas of different parts of earth are correctly represented by such projections.

True shape projection: Also known as orthomorphic projections. The shapes of different parts of earth are correctly represented on these projections.

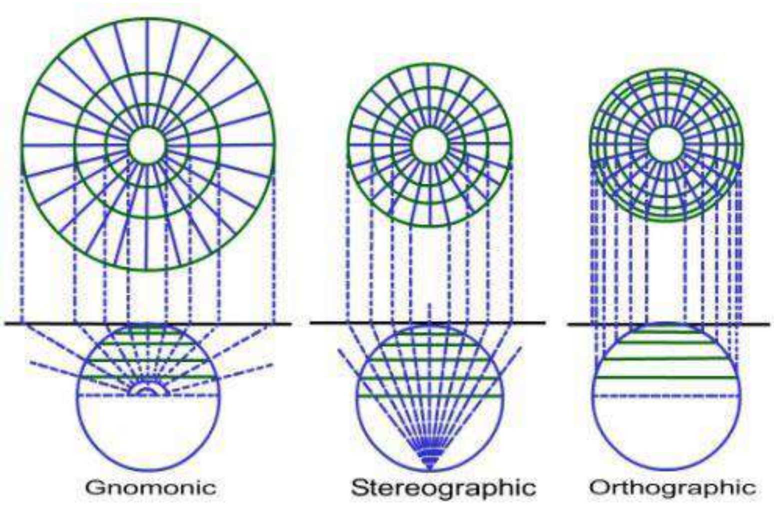
True scale or equidistant projections: Projections that maintain correct scale are called true scale projections. However, no projection can maintain the correct scale throughout. Correct scale can only be maintained along some parallel or meridian.

Position of light source

Placing light source illuminating the globe at different positions results in the development of different projections. These projections are:

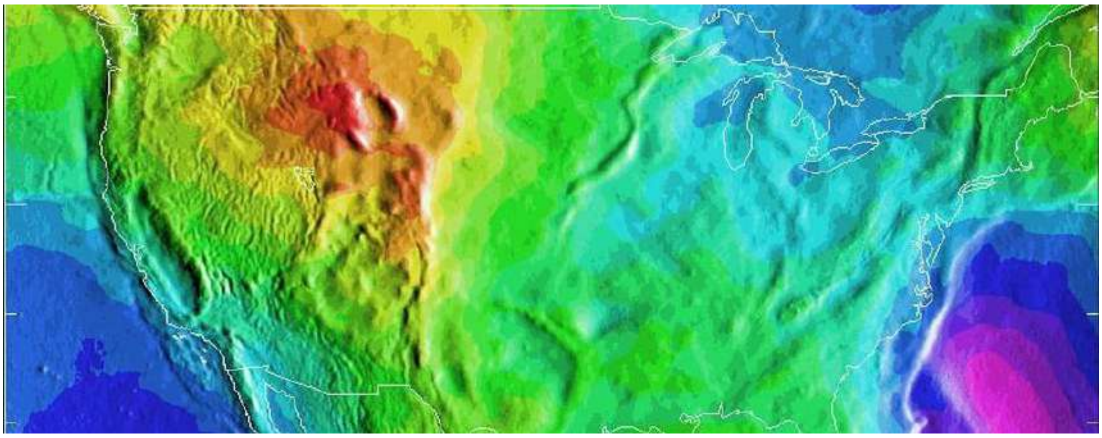
Gnomonic projection: when the source of light is placed at the centre of the globe **Stereographic Projection:** when the source of light is placed at the periphery of the globe, diametrically opposite to the point at which developable surface touches the globe.

Orthographic Projection: when the source of light is placed at infinity from the globe opposite to the point at which developable surface touches the globe.



Geoids and their representation.

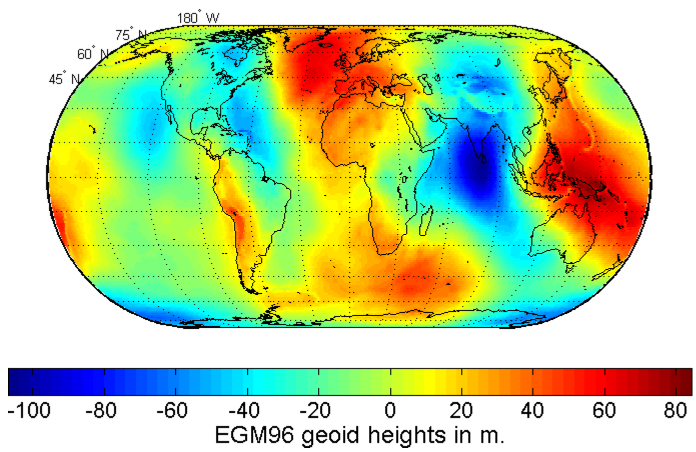
The geoid is a model of global mean sea level that is used to measure precise surface elevations.

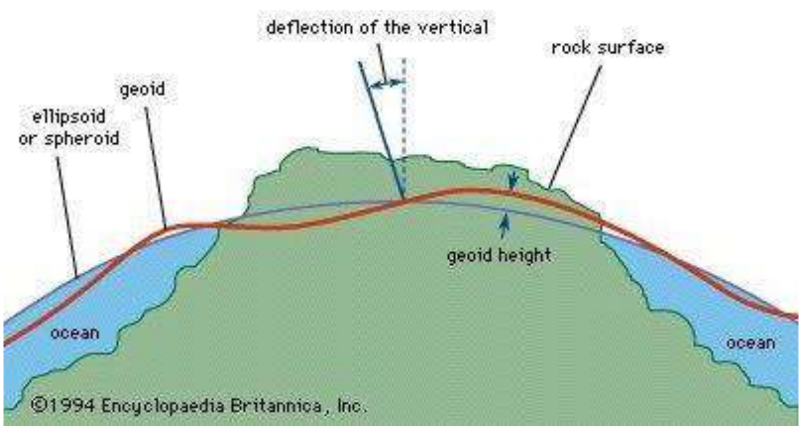


A depiction of the United States geoid. Areas in yellow and orange have a slightly stronger gravity field as a result of the Rocky Mountains.

While we often think of the earth as a sphere, our planet is actually very bumpy and irregular. The radius at the equator is larger than at the poles due to the long-term effects of the earth's rotation. And, at a smaller scale, there is topography—mountains have more mass than a valley and thus the pull of gravity is regionally stronger near mountains. All of these large and small variations to the size, shape, and mass distribution of the earth cause slight variations in the acceleration of gravity (or the "strength" of gravity's pull). These variations determine the shape of the planet's liquid environment.

If one were to remove the tides and currents from the ocean, it would settle onto a smoothly undulating shape (rising where gravity is high, sinking where gravity is low). This irregular shape is called "the geoid," a surface which defines zero elevation. Using complex math and gravity readings on land, surveyors extend this imaginary line through the continents. This model is used to measure surface elevations with a high degree of accuracy.





UNIT –II

Learning Material

Introduction

GIS stands for Geographical Information System. It is defined as an integrated tool, capable of mapping, analyzing, manipulating and storing geographical data in order to provide solutions to real world problems and help in planning for the future. GIS deals with what and where components of occurrences. For example, to regulate rapid transportation, government decides to build fly-over (what component) in those areas of the city where traffic jams are common (where component).

GIS means differently to different people and therefore has different definitions. For example, Burrough (1998) defined GIS as " a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes"

Definitions

GIS is defined as an information system that is used to input, store, retrieve, manipulate, analyze and output geographically referenced data or geospatial data, in order to support decision making for planning and management of land use, natural resources, environment, transportation, urban facilities, health services so on.

GIS is a set of tool that allows for the processing of spatial data into information.

Components of a GIS

A GIS can be divided into five components: People, Data, Hardware, Software, and Procedures. All of these components need to be in balance for the system to be successful. No one part can run without the other.

People

The people are the component who actually makes the GIS work. They include a plethora of positions including GIS managers, database administrators, application specialists, systems analysts, and programmers. They are responsible for maintenance of the geographic database and provide technical support. People also need to be educated to make decisions on what type of system to use. People associated with a GIS can be categorized into: viewers, general users, and GIS specialists.

- Viewers are the public at large whose only need is to browse a geographic database for referential material. These constitute the largest class of users.
- General Users are people who use GIS to conducting business, performing professional services, and making decisions. They include facility managers, resource managers, planners, scientists, engineers, lawyers, business entrepreneurs, etc.
- GIS specialists are the people who make the GIS work. They include GIS managers, database administrators, application specialists, systems analysts, and programmers. They are responsible for the maintenance of the geographic database and the provision of technical support to the other two classes of users. (Lo, 2002)

Procedures

Procedures include how the data will be retrieved, input into the system, stored, managed, transformed, analyzed, and finally presented in a final output. The procedures are the steps taken to answer the question needs to be resolved. The ability of a GIS to perform spatial analysis and answer these questions is what differentiates this type of system from any other information systems.

The transformation processes includes such tasks as adjusting the coordinate system, setting a projection, correcting any digitized errors in a data set, and converting data from vector to raster or raster to vector. (Carver, 1998)

Hardware

Hardware consists of the technical equipment needed to run a GIS including a computer system with enough power to run the software, enough memory to store large amounts of data, and input and output devices such as scanners, digitizers, GPS data loggers, media disks, and printers. (Carver, 1998)

Software

There are many different GIS software packages available today. All packages must be capable of data input, storage, management, transformation, analysis, and output, but the appearance, methods, resources, and ease of use of the various systems may be very different. Today's software packages are capable of allowing both graphical and descriptive data to be stored in a single database, known as the object-relational model. Before this innovation, the geo-relational model was used. In this model, graphical and descriptive data sets were handled separately. The modern packages usually come with a set of tools that can be customized to the users needs (Lo, 2002).

Data

Perhaps the most time consuming and costly aspect of initiating a GIS is creating a database. There are several things to consider before acquiring geographic data. It is crucial to check the quality of the data before obtaining it. Errors in the data set can add many unpleasant and costly hours to implementing a GIS and the results and conclusions of the GIS analysis most likely will be wrong.

Fundamental operations of GIS

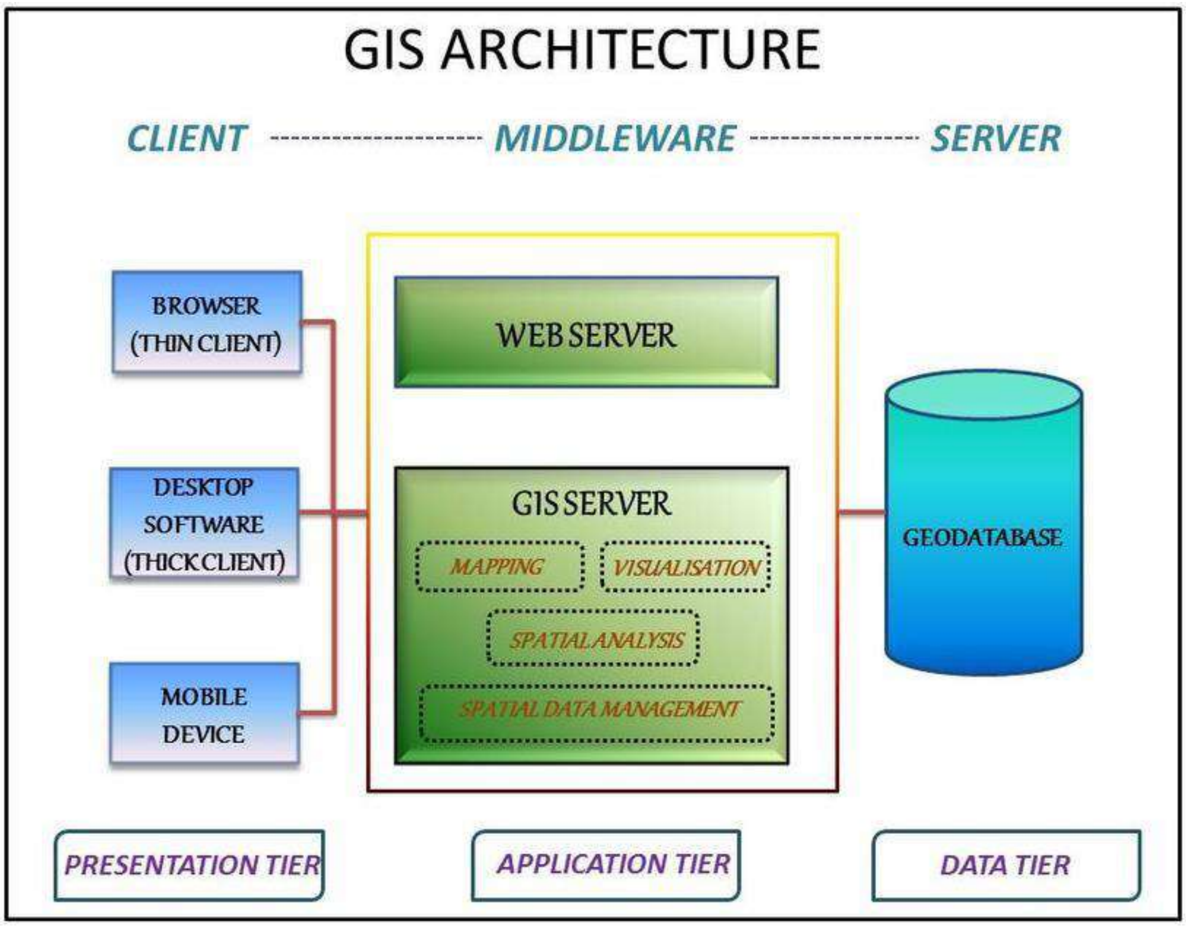
1. Reclassification operations transform the attribute information associated with a single map coverage.
2. Overlay operations involve the combination of two or more maps according to boolean conditions and may result in the delineation of new boundaries.
3. Distance and connectivity measurement include both simple measure of interpoint distance and more complex operations such as the construction of zones of increasing transport cost away from specified locations, and
4. Neighbourhood characterisation involves the values to a location both summary and mean measures of avariable, and include smoothing and enhancement filters. Sequences or such manipulation operations have become known as 'cartographic modelling'.

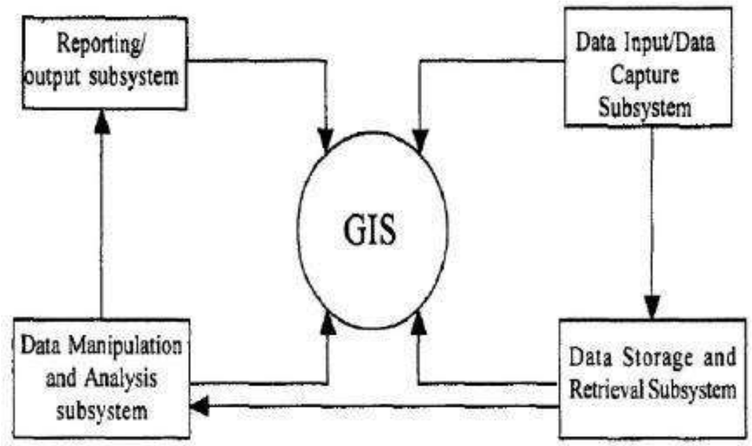
Theoretical framework of GIS

Based on the way in which the data is transformed:

1. Traditional Cartographic process
2. Based on GIS operation.

GIS Architecture





GIS Workflow 5 elements

1. Data Acquisition
2. Pre-processing
    a. Format Conversion
    b. Data Reduction & Generalization
    c. Error Detection & Editing
    d. Merging the points into lines and lines into Polygons
    e. Edge-matching & Tiling
    f. Rectification & Registration
    g. Interpolation
    h. Interpretation
3. Data Management
    a. Insert
    b. Update
    c. Delete
    d. Retrieve
4. Manipulation & Analysis
    a. Reclassification & Aggregation
    b. Geometric Operations: Rotation, Scaling, Rectification
    c. Controlled Determination
    d. Data Structure Conversion
    e. Spatial Operation of Connectivity &Neighbourhood Operations
    f. Measurement of Distance & Direction
    g. Statistical Analysis
    h. Modelling
5. Product Generation (Final Outputs from GIS are created)

Data entry & preparation – Spatial data input

Collecting data and creating a GIS database is a time consuming but an important task. There are many sources of geographic data and many ways to enter that data into a GIS. A data pool can be generated by either data capture or data transfer. The data sources are divided into following two main classes:

Primary data

It involves direct measurement of objects and phenomena. Given below is the partial list of primary data:

Remote sensing data capture: Remote sensing refers to the technique of deriving the information about the objects without getting in physical contact with them. The information is derived from the measurements of the amount of electromagnetic (EM) radiations reflected, emitted or scattered from the objects under observation. The response is measured /captured by the sensors deployed in air or in space. The remote sensing data is often talked in terms of spatial, spectral and temporal resolutions.

Aerial photographic data is as important as remote sensing data for a GIS project. Though both aerial photographs and remote sensing images are technically similar, they have few differences as well. The most notable difference is that aerial photographs are captured using analog optical cameras and are then rasterized by scanning a film negative. Now a days digital cameras are being used for aerial photography. The aerial photographs are suitable for surveying and mapping projects.

Both satellite images and aerial photographs can provide stereo imagery from overlapping pairs of images i.e. they can generate a three dimensional model of the earth's surface. The other advantages include global coverage and repetitive monitoring that make these datasets useful for large area projects and short time events.

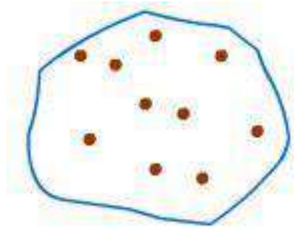
Surveying: Ground surveying is based on the principle of determining the 3D location of a point with the help of angles and distance measured from other known points. Survey starts from a benchmark position. The location of all surveyed points is relative to other points. The traditional surveying involves the use of transits, theodolites, chains and tapes for angle and distance measurement. These days, electro-optical devices called total stations measure both angles as well distance to an accuracy of 1mm. Surveying is a time and resource consuming activity but is the best way of obtaining accurate geographical data.

Sampling

Since it is not practically possible as well as worthwhile to observe the value of a variable at every point throughout the study area we adopt the strategy of sampling. Using sampling we measure subsets of the features in the area that best capture the spatial variation of the concerned attribute over the study area. The following five patterns options may be considered for sampling:

a. Simple random

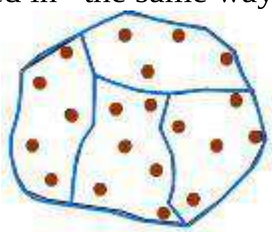
This method ensures that all parts of the project area have an equal chance of being sampled. Project area is divided into a grid with numbered coordinates. A random site is picked by selecting coordinate pairs from a number table and plotting those on the project area map. Each random site is a sample point.



b. Stratified random

Simple random pattern

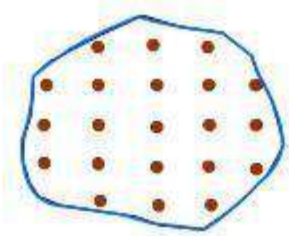
It maintains randomness and at the same time overcomes the chance of an uneven distribution of points among the map classes. Specific numbers of sample points are assigned to each class with respect to its size and significance for the project. Within a class the random sites are generated in the same way as in simple random pattern.



Stratified random pattern

c. Systematic

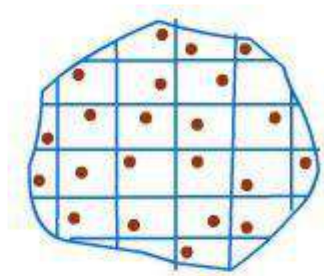
It arranges sample points at equidistant intervals thus forming a grid. Orientation of the grid is chosen randomly.



d. Systematic unaligned

Systematic pattern

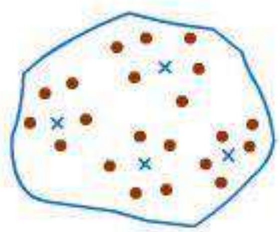
It distributes the project area into a grid and assigns the positions of sample points randomly within the grid cells.



Systematic unaligned pattern

e. Clustered

In this method, nodal points are the centers for clusters of sample points. The nodal locations are selected randomly, stratified by classes, or by identification of accessible sites.



Clustered pattern

Spatial Data Models

Spatial data structures provide the information that the computer requires to reconstruct the spatial data model in digital form. Although some lines act alone and contain specific attribute information that describes their character, other more complex collections of lines called networks add a dimension of attribute characters. Thus not only does a road network contain information about the type of road or similar variables, but it will also indicate, that travel is possible only in a particular direction. This information must be extended to each connecting line segment to advise the user that movement can continue along each segment until the attributes change-perhaps until a one-way street becomes a two-way street. For example, one node might indicate the existence of a stop sign, a traffic signal, or a sign prohibiting U-turns. All these attributes must be connected throughout the network so that the computer knows the inherent real-world relationships that are being modelled within the network. Such explicit information about connectivity and relative spatial relationships is called topology.

Vector data model: A representation of the world using points, lines, and polygons. Vector models are useful for storing data that has discrete boundaries, such as country borders, land parcels, and streets.

Raster data model: A representation of the world as a surface divided into a regular grid of cells. Raster models are useful for storing data that varies continuously, as in an aerial photograph, a satellite image, a surface of chemical concentrations, or an elevation surface

Types of Raster GIS Models

The grid based GIS spatial data can be stored, manipulated, analysed, and referenced basically in anyone of the three methods/models. These three models (Burrough, 1983) are: GRID/LUNAR/MAGI model, IMGRID model and MAP model. All of these models use the grid cell values, their attributes, coverages and corresponding legends. These models are developed depending upon the requirements from time to time. Based on the applications of interest, availability of software's and other related information, anyone of the above models can be selected for the execution of a particular GIS project. There are a number of ways of forcing a computer to store and reference the individual grid cell values, their attributes, coverage names and legends.

1. GRID Model

The first and foremost model for the representation of raster data is the GIRD model. The method of storing, manipulating, and analysing the grid based data was first conceptualised by an attempt to deve'lop GRID model. Burrough (1983) used this approach, because each of those early GIS systems used this model. Fig. 8.9 (a) illustrates the GRID model. In this method, each grid cell is referenced and addressed individually and is associated with identically positioned grid cells in all other coverages, rather like a vertical column of grid cells, each dealing with a separate theme. Comparisons between coverages are therefore performed on a single column at a time. For example, to compare soil attributes in one coverage with vegetation attributes in a second coverage, land use/land cover attributes in a third coverage, each X and Y location must be examined individually. So a soil grid cell at location must be examined individually. So a soil grid cell at location X10-Y10 will be compared to its vegetation counterpart and third layer land use/land cover at location X 10-Y1
O. You might be able to envision this by imagining a geological core in which each rock type is lying directly on top of the next, and to get a picture of the entire study area, it will be necessary to put a large number of cores together. The advantage of this model is that computational comparison of multiple themes or coverages for each grid cell location is relatively easy. This is a reasonable approach and has proven successful. The main disadvantage is that it limits the efficient examination of relationships of themes to one-to-one relationships within the spatial framework. In other words, it is more inconvenient to compare groups in one coverage to groups in another coverage because each grid cell location must be addressed individually. Second disadvantage is more storage space for the cell data and the representation is vertical rather than horizontal, which would more closely resemble our notion of maps.

2. IMGRID Model

With a slight modification of the checkerboard analog, the second basic raster data model, that is the IMGRID data model, can be illustrated (Fig. 8.9 (b». This model is also used in the early GIS system (Burrough, 1983). Let us assume that the red squares on checkerboard map serve to contain a single attribute, rather than just a theme. Instead, we can use the number 1 (red squares) to repre·sent water and 0 (black squares) to indicate the absence of water. How can we represent a thematic map of land use that contains, say four categories, namely, recreation, agriculture, industry, and residences? Each of these four attributes would have to be separated out as an individual layer. One layer would stand for agriculture only, with 1 's and O's representing the presence or absence of this activity for each grid cell. Recreation, industry, and residences would be represented in the same way, with each variable referenced directly, rather than referencing the grid cell as we did in the GRID/LUNAR/ MAGI data model. Finally, the coverages would be combined vertically, or in column fashion, to produce a single theme or coverage, much as red, yellow, green, and blue printing plates are combined to create a single colour image.

IMGRID system has two major advantages. First, we have a contiguous object that more closely resembles how we think about a map. That is, our primary storage object is a two-dimensional array of numbers, rather than a column of numbers for different themes. Second, we reduce the numbers that must be contained in each coverage to O's and 1 'so This will certainly simplify our computations and will eliminate the need for map legends. Since each variable is uniquely identified, assigning a single attribute value to a single grid cell is possible, and this is a third advantage. Let us assume that a given grid cell partly occupies agriculture and partly recreation and each of these attributes of land use theme is separated out. In such a case, we may encounter difficulties when creating our final thematic coverage if multiple values occur in individual cells. To avoid such problems, we must be able to ensure that each grid cell has only a single value for each variable.

3. MAP Model

The third raster GIS model Map Analysis Package (MAP) model developed by C. Dana Tomlin (Burrough, 1983) formally integrates the advantages of the above two raster data structure methods. In this data model each thematic coverage is recorded and accessed separately by map name or title. This is accomplished by recording each variable, or mapping unit, of the coverage's theme as a separate number code or label, which can be accessed individually when the coverage is retrieved. The label corresponds to a portion of the legend and has its own symbol assigned to it. In this way, it is easy to perform operation on individual grid cells and groups of similar grid cells, and the resolution changes in value require rewriting only a single number per mapping unit, thus simplifying the computations. The overall major improvement is that the MAP method allows ready manipulation of the data in a many-to-one relationship of the attribute values and the sets of grid cells.

The MAP data model is compatible to almost all computer systems from its original mainframe version to Macintosh and PC versions and modern UNIX- based workstation versions. It can be used as a teaching version of GIS as it is very flexible and also becomes a major module in commercial GIS packages like ARC/INFO.

Vector GIS Models

Vector data structures allow the representation of geographic space in an intuitive way reminiscent of the familiar analog map. The geographic space can be represented by the spatial location of items or attributes which are stored in another file for later access. Fig. 8.5 shows how the different entity, namely, points, lines, and areas can be defined by coordinate geometry. Like the raster spatial data model, there are many potential vector data models that can be used to store the geometric representation of entities in the computer.

The two basic types of vector data models are (i) spaghetti model, and (ii) topological model.

1. Spaghetti Model

The simplest vector data structure that can be used to reproduce a geographical image in the computer is a file containing (x, y) coordinate pairs that represent the location of individual point features. The shortest spaghetti can be represented as a point, collection of a number of point spaghettis for a line entity and collections of line segments that come together at the beginning and ending of surrounding areas form an area entity. Each entity is a single, logical record in the computer, coded as variable length strings of (x, y) coordinate pairs. Let us assume that two polygons lie adjacent to each other in a thematic coverage. These two adjacent polygons must have separate pieces of spaghetti for adjacent sides. That is, no two adjacent polygons share the same string of spaghetti. Each side of polygon is uniquely defined by its own set of lines and coordinate pairs. In this model of representing vector data, all the spaghetties are recorded separately for polygons. But in the computer they should have the same coordinates.

Topological Models

In order to use the data manipulation and analysis subsystem more efficiently and obtain the desired results, to allow advanced analytical techniques on GIS data and its systematic study in any project area, much explicit spatial information is to be created. The topological data model incorporates solutions to some of the frequently used operations in advanced GIS analytical techniques. This is done by explicitly recording adjacency information into the basic logical entity in topological data structures, beginning and ending when it contacts or intersects another line, or when there is a change in the direction of the line. Each line then has two sets of numbers: a pair of coordinates. and an associated node number. The node is the intersection of two or more lines, and its number is used to refer to any line to which it is connected. In addition, each line segment, called a link, has its own identification number that is used as a pointer to indicate the set of nodes that represent its beginning and ending polygon. These links also have identification codes that relate polygon numbers to see which two polygons are adjacent to each other along its length. In fact, the left and right polygon are also stored explicitly, so that even this tedious step is eliminated.

There are a number of topological vector data models. Out of the available models, three models are very common in use. These three models are: (a) GBFI DIME model created by US Department of Commerce, Bureau of the Census, 1969 (b) TIGER model (Marx, 1986) and (c) POLYVERT (Peuquet, 1984).

2. GBF/DIME Topological Vector Model

The best-known topological data model is the GBF/DIME (Geographical Base File/Dual independent Map Encoding) model created by the US Bureau of the Census to automate the storage of street map data for the decennial census (US Department of Commerce, Bureau of the Census, 1969). GBF/DIME models were designed to incorporate topological information about urban areas for use in demographic analyses (Cooke, 1987) and were created by graph theory. In this case the straight-line segment ends when it either changes direction or intersects another line, and the nodes are identified with codes. In addition to the basic topological model, the GBF/DIME model assigns a directional code in'the form of a 'From node and a To node,' that is, a low-value node to a high-value node in the sequence.

TIGER Topological Vector Model

TIGER stands for Topologically Integrated Geographic Encoding and Referencing system. This model does not depend upon the graph theory designed for use in the 1990 US census. In this system, points, lines, and areas can be explicitly addressed, and therefore census blocks can be retrieved directly by block number rather than by relying on the adjacency information contained in the links. Real-world features such as meandering streams and irregular coastlines are given a graphic portrayal more representative of their true geographic shape. Thus TIGER files are more generally used in research which is not related to census.

3. POL YVRT Topological Vector Model

POLYVRT developed by Peucker and Chrisman (1975) and later implemented at the Harvard Laboratory for Computer Graphics was called the POL YVRT (POLYgon con VERT) model. In this method of representing vector data, each type of geographic entity is stored separately. These separate objects are then linked in a hierarchical data structure with pOints relating to lines, which in turn are related to polygons through the use of pOinters. Each collection of line segments, is collectively called chains in this explicit directional information in the form of To-From nodes as well as left-right polygons.

Raster and Vector data

Raster data is made up of pixels (or cells), and each pixel has an associated value. Simplifying slightly, a digital photograph is an example of a raster dataset where each pixel value corresponds to a particular colour. In GIS, the pixel values may represent elevation above sea level, or chemical concentrations, or rainfall etc. The key point is that all of this data is represented as a grid of (usually square) cells. The difference between a digital elevation model (DEM) in GIS and a digital photograph is that the DEM includes additional information describing where the edges of the image are located in the real world, together with how big each cell is on the ground. This means that your GIS can position your raster images (DEM, hillshade, slope map etc.) correctly relative to one another, and this allows you to build up your map.

Vector data consists of individual points, which (for 2D data) are stored as pairs of (x, y) co-ordinates. The points may be joined in a particular order to create lines, or joined into closed rings to create polygons, but all vector data fundamentally consists of lists of co-ordinates that define vertices, together with rules to determine whether and how those vertices are joined.

Advantages : Data can be represented at its original resolution and form without generalization. Graphic output is usually more aesthetically pleasing (traditional cartographic representation); Since most data, e.g. hard copy maps, is in vector form no data conversion is required. Accurate geographic location of data is maintained. Allows for efficient encoding of topology, and as a result more efficient operations that require topological information, e.g. proximity, network analysis.

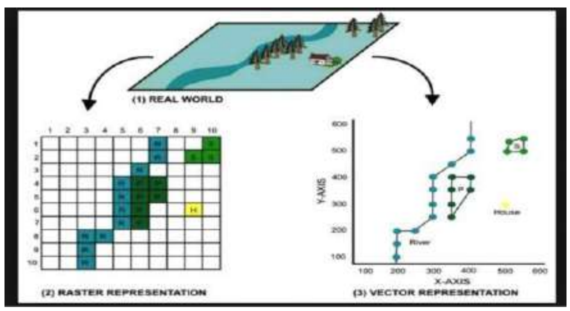
Disadvantages: The location of each vertex needs to be stored explicitly. For effective analysis, vector data must be converted into a topological structure. This is often processing intensive and usually requires extensive data cleaning. As well, topology is static, and any updating or editing of the vector data requires re-building of the topology. Algorithms for manipulative and analysis functions are complex and may be processing intensive. Often, this inherently limits the functionality for large data sets, e.g. a large number of features. Continuous data, such as elevation data, is not effectively represented in vector form. Usually substantial data generalization or interpolation is required for these data layers. Spatial analysis and filtering within polygons is impossible.

Raster Data

Advantages : The geographic location of each cell is implied by its position in the cell matrix. Accordingly, other than an origin point, e.g. bottom left corner, no geographic coordinates are stored. Due to the nature of the data storage technique data analysis is usually easy to program and quick to perform. The inherent nature of raster maps, e.g. one attribute maps, is ideally suited for mathematical modeling and quantitative analysis.

Discrete data, e.g. forestry stands, is accommodated equally well as continuous data, e.g. elevation data, and facilitates the integrating of the two data types. Grid-cell systems are very compatible with raster-based output devices, e.g. electrostatic plotters, graphic terminals.

Disadvantages: The cell size determines the resolution at which the data is represented.; It is especially difficult to adequately represent linear features depending on the cell resolution. Accordingly, network linkages are difficult to establish. Processing of associated attribute data may be cumbersome if large amounts of data exists. Raster maps inherently reflect only one attribute or characteristic for an area. Since most input data is in vector form, data must undergo vector-to-raster conversion. Besides increased processing requirements this may introduce data integrity concerns due to generalization and choice of inappropriate cell size. Most output maps from grid-cell systems do not conform to high-quality cartographic needs.

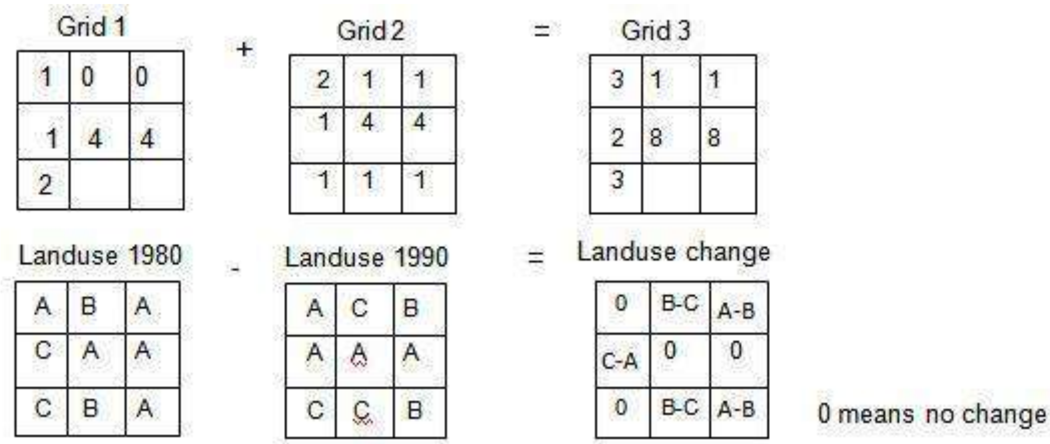


Local Operations

Local functions process a grid on a cell-by-cell basis, that is, the output value of each cell depends on the values of corresponding cells in the rasters input for the analysis. The following are the examples of the local operations.

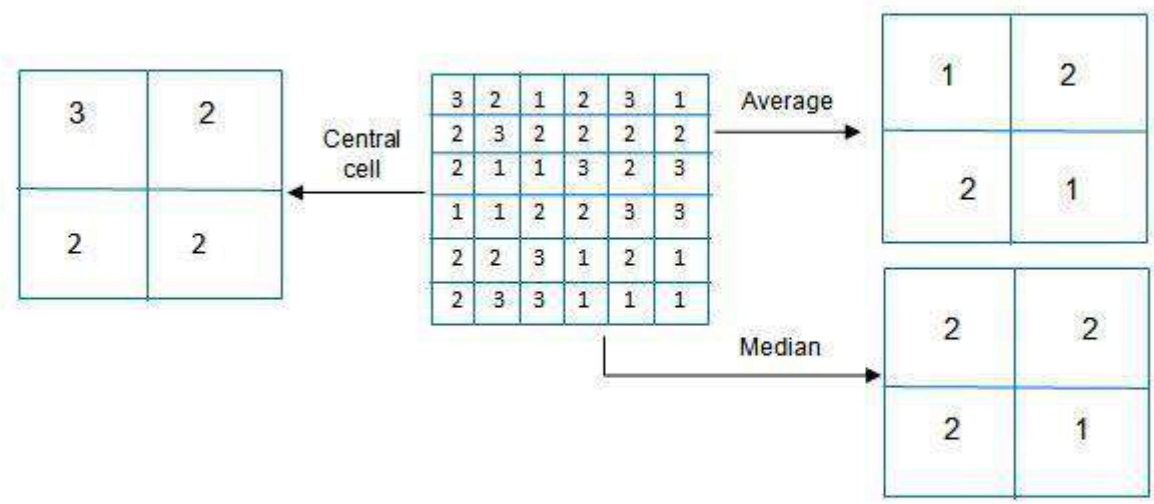
Arithmetic Operation

Grids can undergo a range of arithmetic operations such as addition, subtraction, multiplication, and division. If the data in grids (operands) is in the form of integer then the data in the resultant grid after any mathematical operation would also be integer.
Only in one case, when any integer is divided by zero the corresponding resultant cell will be undefined and are assigned to no data. No data cells always remain No data in arithmetic operations.



Focal Operations (neighborhood analysis)

The value of a cell in the output raster depends upon the value of the corresponding cells and their neighbouring cells in the input rasters. The neighbourhood for a cell is generally taken as a 3×3 matrix (window) in which the cell itself occupies the centre and is surrounded by the others eight cells. With each cell in the input getting processed, the neighbourhood window keeps moving.



Zonal Operations

Zonal functions process grid in such a manner that cells of same zone are analyzed together. A zone may or may not be contiguous. The output value for each location depends upon the value of cell at that location and the association the location has within a zone.

Global Operations

The value of each cell in the output raster is a function of the entire grid.

UNIT-III

GIS Concepts

Editing can update existing feature classes or create new ones. If a housing subdivision is added to a city, the new roads, parcels, sewer lines, and other infrastructure need to be added to the city database to ensure that it is up-to-date. Entirely new feature classes can be created, for example, if the city planning department decides to create a map of garbage collection zones where none existed before. Parcel ownership attributes must be updated when parcels are sold. Topology refers to the spatial relationships between features in terms of adjacency, connectivity, intersection, or overlap. When editing, care must be taken to create and maintain topological integrity between features, so that the relationship in the database matches the relationship in the real world. If two parcels share a common boundary, then the boundaries should match exactly. Line features, such as streets or water lines, should connect to each other in the feature class. Lines that cross each other should intersect at a node. Lines and polygon boundaries should not cross over themselves. These basic rules must be observed to ensure the logical consistency of features so that they properly represent the relationships of their real-world counterparts. Topological data models permit the user to test, locate, and fix topological errors. However, topology is even more important when editing spaghetti models because the user must manage it without help. This chapter introduces two capabilities that aid in creating and maintaining topological integrity: snapping and coincident boundary creation.

Snapping features

When creating line features that connect to each other, such as roads, one must take care that the features connect properly . A line that fails to connect is called a dangle. Although you may not be able to see the gap between the lines, the gap will exist unless the endpoints of each line (nodes) have exactly the same coordinate values. Even though the map may look correct, certain functions, such as tracing networks or locating intersections, will not work properly. It is impossible to intersect lines properly by simple digitizing. Snapping ensures that the nodes of lines and the vertices of polygons match. When snapping is turned on, it affects features being added or modified. If you place the cursor within a specified distance of an existing node or vertex , then the new feature is snapped to the existing one—that is, the coordinates are matched at that one point. This distance is called the snap tolerance. Care must be taken in specifying the snap tolerance. If it is too small, then features snap won't snap. If it is too large, then features may snap when it isn't appropriate. Snap tolerances are set in either pixels on the screen or meters in the map units. A snap tolerance of 10 pixels indicates that features will be snapped if the cursor moves within 10 screen pixels of an existing feature. When set in pixels, the snap tolerance remains the same as the user zooms in and out, which is convenient. Setting the snap tolerance in map units is useful if the user is trying to maintain a particular level of geometric accuracy independent of zoom scale.

Four types of snapping can be used. Point snapping is only used for point feature classes and snaps to an existing point. End snapping only allows a new vertex to be snapped to the endpoints of an existing line. End snapping can ensure that new streams connect to the ends of existing streams, and only to their ends. End snapping only applies to line features. Vertex snapping allows the endpoints of the new line to be snapped to any vertex in an existing line or polygon. It can ensure that adjacent parcels connect only at existing corners. Edge snapping constrains the feature being added to meet the edge of an existing line or polygon feature. In this case, the vertex being added could be placed anywhere on or between vertices. Edge snapping can ensure that a street ends exactly on another street.

Adjacent polygons

Another type of topology to consider is the relationship between two adjacent polygons. A polygon is stored as a series of x-y vertices that completely enclose a space. If two polygons share a boundary, then that boundary gets stored twice. If the shared edge contains exactly the same x-y pairs for both polygons, it is called a coincident boundary. If the pairs do not match exactly, then there will be gaps where the polygons fail to touch, or overlaps where they cross each other, or both. Both types of relationships are possible in the real world. If the two polygons represented fires that burned in two different years, then it is possible that the second fire might have overlapped the first, or that some space existed between them; in which case the presence of gaps and overlaps is real and necessary. However, most polygons should have coincident boundaries—soil units, land use areas, school districts, counties, states all represent features for which gaps and overlaps are errors, usually caused by careless data entry. Imagine the legal headaches that would ensue if the two polygons represent parcels; both overlaps and gaps would likely be in dispute as to who owned what. When editing polygons, it is important to ensure that the right relationship is incorporated into the database, and that adjacent polygons have coincident boundaries, except for the rare instances when gaps or overlaps are justified.

What can you edit?

ArcGIS offers different levels of editing capability depending on the type of license. ArcGIS Basic can edit shapefiles and personal or file geodatabases. ArcGIS Standard and ArcGIS Advanced can also edit SDE databases, geometric networks, and planar topology. All of these levels are accessed through the same ArcMap interface. ArcMap can edit several layers at once, as long as they are all in the same folder or geodatabase (workspace). This capability makes it easier to view and edit related layers simultaneously or to copy features from one layer to another.

How editing works

An editing session must be initiated before any changes to a file can be made. This requirement protects the user from accidentally making changes to a file without realizing it. Also, because ArcMap can edit within only one directory or one geodatabase at a time, opening the session establishes the workspace being edited. Basic editing uses three main components: the Edit tool, the feature templates, and the construction tools. The

Edit tool selects existing features when they need to be moved, rotated, deleted, and so on. It is analogous to the Select Features tool on the Standard toolbar, but it should always be used for editing. The templates control the features being added and in which layer they go. The construction tools control the characteristics of the feature being created.

GIS Errors, Accuracy, and Precision

Errors can be injected at many points in a GIS analysis, and one of the largest sources of error is the data collected. Each time a new dataset is used in a GIS analysis, new error possibilities are also introduced. One of the feature benefits of GIS is the ability to use information from many sources, so the need to have an understanding of the quality of the data is extremely important.

Accuracy in GIS is the degree to which information on a map matches real-world values. It is an issue that pertains both to the quality of the data collected and the number of errors contained in a dataset or a map. One everyday example of this sort of error would be if an online advertisement showed a sweater of a certain color and pattern, yet when you received it, the color was slightly off.

Precision refers to the level of measurement and exactness of description in a GIS database. Map precision is similar to decimal precision. Precise location data may measure position to a fraction of a unit (meters, feet, inches, etc.). Precision attribute information may specify the characteristics of features in great detail. As an example of precision, say you try on two pairs of shoes of the same size but different colors. One pair fits as you would expect, but the other pair is too short. Do you suspect a quality issue with the shoes or do you buy the shoes that fit? Would you do the same when selecting GIS data for a project?

The more accurate and precise the data, the higher cost to obtain and store it because it can be very difficult to obtain and will require larger data files. For example, a 1-meter-resolution aerial photograph will cost more to collect (increased equipment resolution) and cost more to store (greater pixel volume) than a 30-meter-resolution aerial photograph.

Highly precise data does not necessarily correlate to highly accurate data nor does highly accurate data imply high precision data. They are two separate and distinct measurements. Relative accuracy and precision, and the inherent error of both precision and accuracy of GIS data determine data quality.

Types of Error

Positional error is often of great concern in GIS, but error can actually affect many different characteristics of the information stored in a database.

Positional accuracy and precision

This applies to both horizontal and vertical positions.

Accuracy and precision are a function of the scale at which a map (paper or digital) was created. The mapping standards employed by the United States Geological Survey specify that:

"requirements for meeting horizontal accuracy as 90 percent of all measurable points must be within 1/30th of an inch for maps at a scale of 1:20,000 or larger, and 1/50th of an inch for maps at scales smaller than 1:20,000."

Accuracy Standards for Various Scale Maps

1:2,400 ± 6.67 feet

1:4,800 ± 13.33 feet

1:10,000 ± 27.78 feet

1:12,000 ± 33.33 feet

1:24,000 ± 40.00 feet

1:63,360 ± 105.60 feet

1:100,000 ± 166.67 feet

1:1,200 ± 3.33 feet

This means that when we see a point on a map we have its "probable" location within a certain area. The same applies to lines.

Beware of the dangers of false accuracy and false precision, that is reading locational information from map to levels of accuracy and precision beyond which they were created. This is a very great danger in computer systems that allow users to pan and zoom at will to an infinite number of scales. Accuracy and precision are tied to the original map scale and do not change even if the user zooms in and out. Zooming in and out can, however, mislead the user into believing – falsely – that the accuracy and precision have improved.

Attribute accuracy and precision

The non-spatial data linked to location may also be inaccurate or imprecise. Inaccuracies may result from mistakes of many sorts. Non-spatial data can also vary greatly in precision. Precise attribute information describes phenomena in great detail. For example, a precise description of a person living at a particular address might include gender, age, income, occupation, level of education, and many other characteristics. An imprecise description might include just income, or just gender.

Conceptual accuracy and precision

GIS depend upon the abstraction and classification of real-world phenomena. The users determines what amount of information is used and how it is classified into appropriate categories. Sometimes users may use inappropriate categories or misclassify information. For example, classifying cities by voting behavior would probably be an ineffective way to study fertility patterns. Failing to classify power lines by voltage would limit the effectiveness of a GIS designed to manage an electric utilities infrastructure. Even if the correct categories are employed, data may be misclassified. A study of drainage systems may involve classifying streams and rivers by "order," that is where a particular drainage channel fits within the overall tributary network. Individual channels may be misclassified if tributaries are miscounted. Yet, some studies might not require such a precise categorization of stream order at all. All they may need is the location and names of all stream and rivers, regardless of order.

Logical accuracy and precision

Information stored in a database can be employed illogically. For example, permission might be given to build a residential subdivision on a floodplain unless the user compares the proposed plan with floodplain maps. Then again, building may be possible on some portions of a floodplain but the user will not know unless variations in flood potential have also been recorded and are used in the comparison. The point is that information stored in a GIS database must be used and compared carefully if it is to yield useful results. GIS systems are typically unable to warn the user if inappropriate comparisons are being made or if data are being used incorrectly. Some rules for use can be incorporated in GIS designed as "expert systems," but developers still need to make sure that the rules employed match the characteristics of the real-world phenomena they are modeling.

Finally, It would be a mistake to believe that highly accurate and highly precision information is needed for every GIS application.

Edgematch End Points

When you have two counties with disconnected lines at the borders, you should use the edge matching tools to connect them.

In the case below, there are disconnected lines at the border. This is a case when you'll need to use some of the conflation tools.

In order to conflate these two data sets, you should use a two-step combo. First, you'll have to generate edge match links. Secondly, you'll actually move those endpoints connecting the two data sets.

In this step, you generate edge match links and see where those connections are made geographically.

Rubbersheet Two Data Sets

While edge matching is good for endpoints, rubber sheeting conflation matches a whole load of vertices.

As you can see in the example below, these two data sets are not aligned.

The first step to take is to generate rubber sheeting links as displayed with arrows.

Again, make a copy of the data set you want to conflate. When you rubber sheet feature, you are physically moving all those vertices from one data set to another.

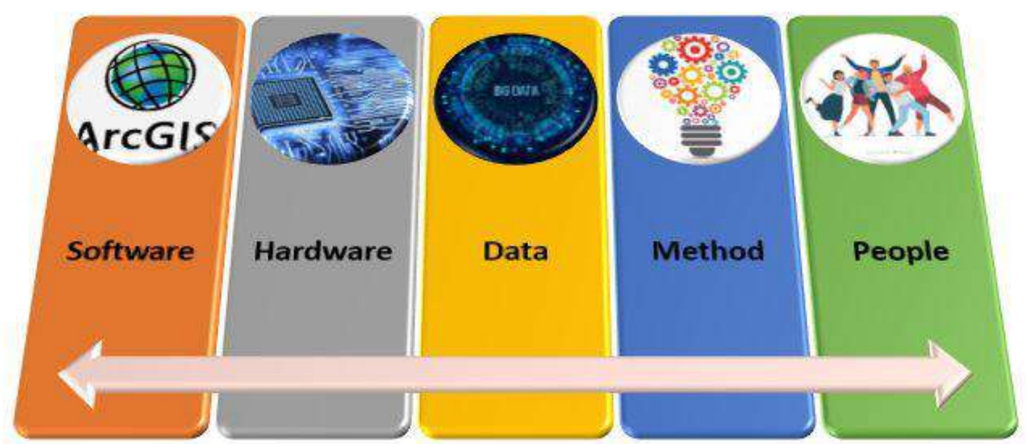
Depending on the rubber sheeting links, you should get similar-looking features using either one of the linear and natural neighbor methods.

UNIT – IV

Introduction to GIS Components

Like any other System, Geographic Information Systems is also an integration of various components. Software, Hardware, People, Method and Data are the 5 components. This 5 crucial components are brought together to build a robust and powerful system. Every System integration requires a powerful and synchronous amalgamation between all the primary and crucial components. Software and Hardware are important to handle a large amount of geospatial data, databases, visualizations and even complex process inputs or outputs. The rest of the things are completed by People, Method and Data. In a nutshell, GIS Components are the crucial factors for forming or building a system that can handle all kinds of GIS-related tasks.

Components of GIS



1. Software

- Software is the primary focus while setting up any of the systems. There are many GIS software available that are readily available to start the work, but only the right ones suffice the need for tackling business problems. The software can be classified into two main types, Licensed and Freeware.
- Licensed software requires heavy investments and have business subscriptions attached to it, while Freeware is easily available on the internet marketplace with minimum or no fees.

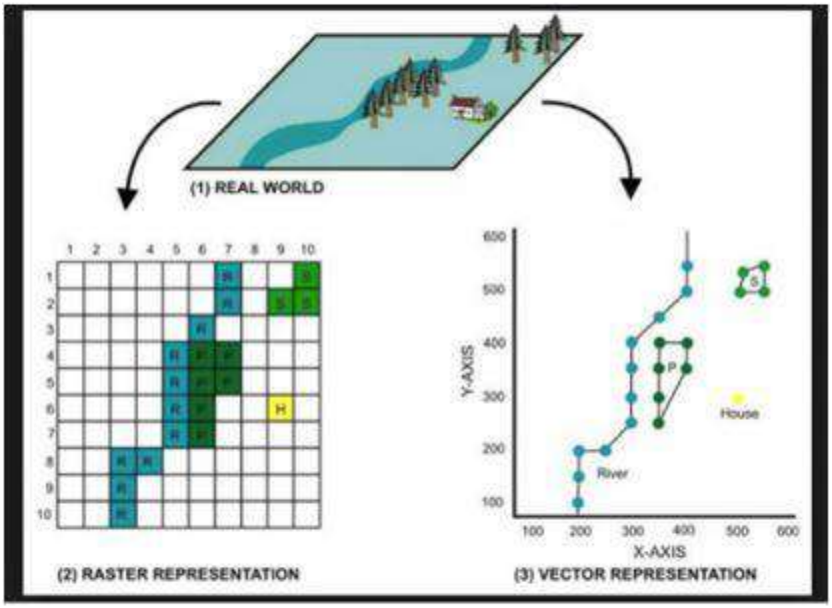
- Good software that handles a large amount of geospatial data, GUI for manipulating data and querying environment for analyzing and visualizing large data sets is a perfect fit for GIS.

2. Hardware

- Hardware is the second most important part of any GIS Components. Software and Hardware complement each other when they are deployed correctly looking at the compatibility. If there is any mismatch in any of the two components, then the functionality effects and results are not approximate.
- Some organizations have moved over to cloud services like AWS and Azure for creating a virtual environment and balancing the load on physical servers.It requires huge server stations and command centres to handle a large amount of geospatial data and even to keep everything ongoing in a live environment
- Hardware should be robust and should have future potential to deal with heavy software patches and updates. Latest high chip and AI-based processors, Motherboards and even GPUs are needed in today’s world to handle GIS software and data.

3. Data

- Geospatial data is like the blood of any GIS Components. Field workers, Drones, Satellites and SONAR – LIDAR Technology are used to collect geospatial data. The format of this data varies from tool to tool and depends upon the source from where the data is extracted.Primarily the geospatial data is classified into Raster data and Vector data. Raster Data is the imagery files from different camera-enabled sources. They form like a sheet covering of different layers that portray longitudinal, latitudinal and even topographical visual of the maps.
- Vector Data**,** on the other hand, deals with address points, Graphs and Datascience and Machine Learning models are further used to analyze and work on the data sets. With the analysis of past data, organizations can perform analytics and showcase various future trends.
- Geospatial RDBMS is used to handle these data sets. Analysts and Database administrators work together to handle the databases and even sanitizing the irrelevant parts of imported data.



4. People

- People is an important catalyst in doing a GIS Components setup. With the help of proper management and technical expertise, all the known-unknown problem areas can be addressed. Project-Program Management is then used to understand any scope of a GIS project.
- People with the right level of geology, information systems and statistics knowledge participate in the technical aspects of the project setup, while the ones with strong management and business knowledge concentrate on handling the projects and the business. GIS projects require strong workforce as well as inventory management and hence people also concentrate more on the overall project development lifecycle techniques.
- GIS Analysts and Technicians play along with the GIS data to analyze and monitor various forms of data sets. GIS developers and database administrators look after the frontend and the backend part of the setup. Project Managers and Architects deal with architecture and project planning by keeping the actionable scope in the picture.
- Organizations are also taking the help of ML/AI engineers to build strong models for solving business issues. Data scientists with strong analytical and programming skills are also targeted by GIS organization to work on complex geospatial data sets and trends.

5. Method and Processes

- For any system to function efficiently, there should be a defined business process set so that the desired results are approximate. Organizations nowadays use various standardized process models to build a system that is still in a transition phase.
- Total Quality Management, LEAN, SIX SIGMA and KAIZEN are some of the standardized models followed by organizations to make sure the business process doesn't become an unsolved puzzle.Audits are performed internally and externally to understand if the setting process is being followed accurately without any anomalies.

- ISO Audits and certifications give an organization a certain benchmark to portray their work at a wider audience. Due to these certifications and audit trails, organizations trust the authenticity and integrity of the system that is used. Methods are not only used until the process is set up perfectly but also to maintain it. Some organizations keep on evolving ambitiously by deploying new processes.
- Process reengineering is followed in understanding the AS-IS part of the business process and to define the TO-BE part of the process.This allows organizations and LEAN experts to remove nonproductive parts of the process so that further time and cost of the company can be saved.

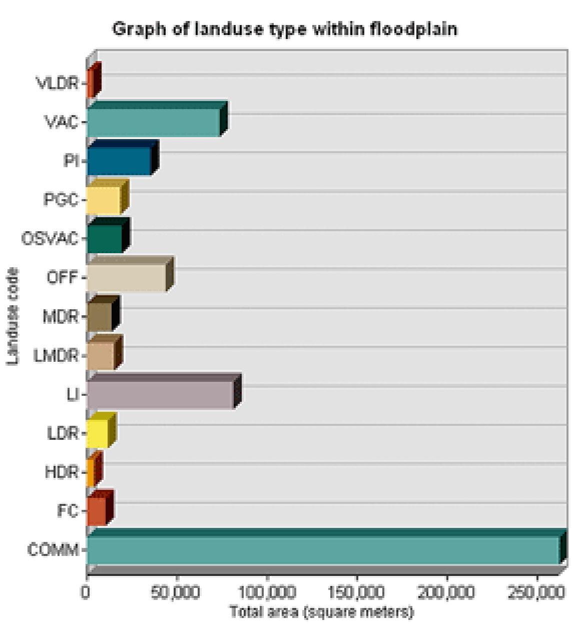
Overlay analysis

Overlay analysis is one of the spatial GIS operations. **Overlay analysis** integrates spatial data with attribute data. **Overlay analysis** does this by combining information from one GIS layer with another GIS layer to derive or infer an attribute for one of the layers.

Vector overlay

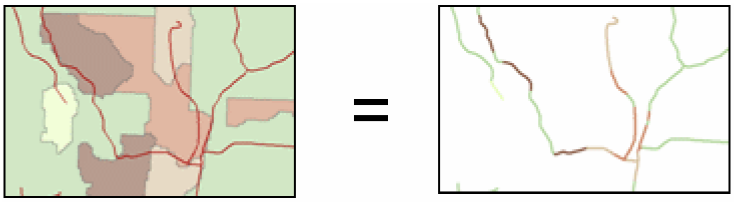
A **vector overlay** involves combining point, line, or polygon geometry and their associated attributes. All overly operations create new geometry and a new output geospatial data set. The clip function defines the area for which features **will** be output based on a "clipping" polygon.

An overlay operation is much more than a simple merging of line work; all the attributes of the features taking part in the overlay are carried through, as shown in the example below, where parcels (polygons) and flood zones (polygons) are overlaid (using the Union tool) to create a new polygon dataset. The parcels are split where they are crossed by the flood zone boundary, and new polygons created. The FID_flood value indicates whether polygons are outside (-1) or inside the flood zone, and all polygons retain their original land-use category values. The total area of each land-use type in the flood zone can be calculated by selecting all polygons within the flood zone (using the Select Layer By Attribute tool, for example) and summarizing the area by land-use type (using the Frequency tool). Following is a chart illustrating the result of this calculation.



Similarly, you'd overlay watershed boundaries with a vegetation layer to calculate the amount of each vegetation type in each watershed.

In the illustration below, logging roads (lines) and vegetation types (polygons) are overlaid to create a new line feature class. The lines have been split where they were intersected by polygons, and each line feature has been assigned the attributes of both original layers. The lines are shown symbolized by the vegetation type associated with each.



FID	Shape*	LOCALID	RD_TYPE
6	Polyline	222192	1500
7	Polyline	220893	1500

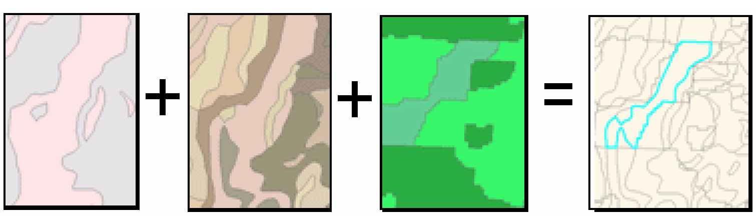
+

FID	Shape*	VEG_TYPE
6	Polygon	CC
7	Polygon	SO
8	Polygon	SS

FID	Shape*	LOCALID	RD_TYPE	VEG_TYPE
6	Polyline	219378	1500	FC
7	Polyline	219384	1500	FC
8	Polyline	219380	1500	FC
9	Polyline	219380	1500	SO
10	Polyline	224631	1500	FC

You can use overlay analysis to combine the characteristics of several datasets into one. You can then find specific locations or areas that have a certain set of attribute values—that is, match the criteria you specify. This approach is often used to find locations that are suitable for a particular use or are susceptible to some risk. For example, you'd overlay layers of vegetation type, slope, aspect, soil moisture, and so on, to find areas susceptible to wildfire.

Below is an example of an overlay of steep slopes, soils, and vegetation. New polygons are created by the intersection of the input polygon boundaries. The resulting polygons have all the attributes of the original polygons.



FID	Shape*	FID_soils	CODE	CLASS	FID_sl	SLOPE	FID_veg	DET_TYPE
3039	Polygon	508	38F	6	0	60	117	A
3040	Polygon	508	38F	6	0	60	119	SS
3041	Polygon	508	38F	6	0	60	157	U
3042	Polygon	508	38F	6	0	60	158	A
3043	Polygon	508	38F	6	0	60	160	FC

Overlay analysis is often used in conjunction with other types of analysis. For example, you might include datasets derived from proximity analysis (such as the Buffer tool) or surface analysis (the Slope or Aspect tool). Similarly, you'll likely perform additional analysis on the results of the overlay, such as extraction to select a subset of features, or generalization (to dissolve polygons, for example). Often, overlay is one step in an analysis process or model and may occur at various points in the process.

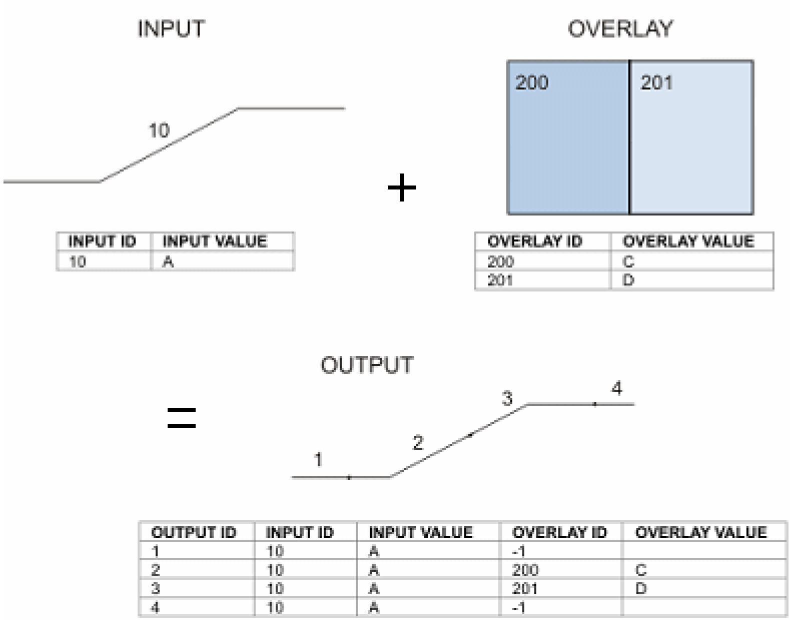
Overlay methods

In general, there are two methods for performing overlay analysis—feature overlay (overlaying points, lines, or polygons) and raster overlay. Some types of overlay analysis lend themselves to one or the other of these methods. Overlay analysis to find locations meeting certain criteria is often best done using raster overlay (although you can do it with feature data). Of course, this also depends on whether your data is already stored as features or rasters. It may be worthwhile to convert the data from one format to the other to perform the analysis.

Feature overlay (Vector overlay)

The key elements in feature overlay are the input layer, the overlay layer, and the output layer. The overlay function splits features in the input layer where they are overlapped by features in the overlay layer. New areas are created where polygons intersect. If the input layer contains lines, the lines are split where polygons cross them. These new features are stored in the output layer—the original input layer is not modified. The attributes of features in the overlay layer are assigned to the appropriate new features in the output layer, along with the original attributes from the input layer.

Below is an example of line-on-polygon overlay. The line is split at the polygon boundaries, and each of the resulting line features has the original line attributes plus the attributes of the polygon it fell within.



INPUT ID	INPUT VALUE
10	A

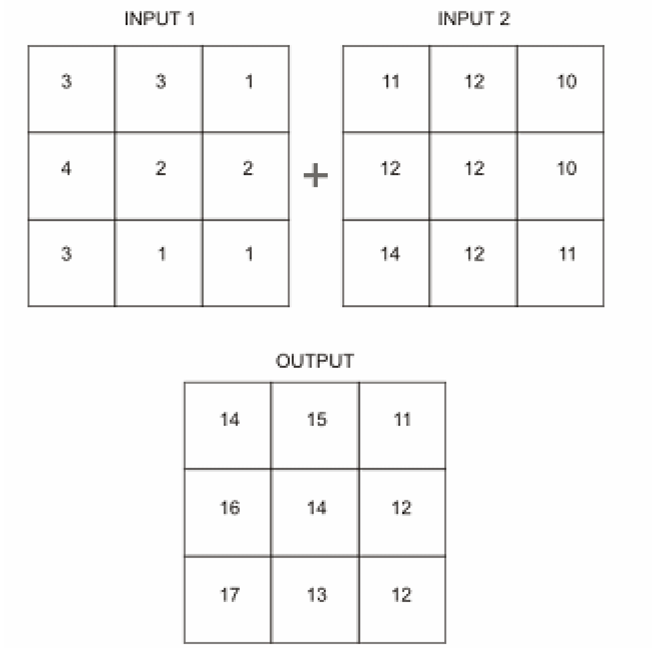
OVERLAY ID	OVERLAY VALUE
200	C
201	D

OUTPUT ID	INPUT ID	INPUT VALUE	OVERLAY ID	OVERLAY VALUE
1	10	A	-1	
2	10	A	200	C
3	10	A	201	D
4	10	A	-1	

Raster overlay

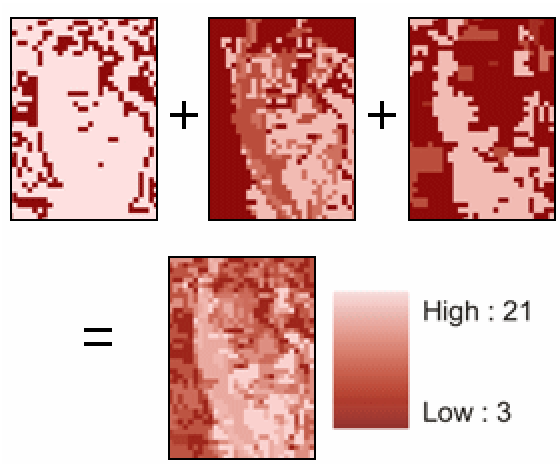
In raster overlay, each cell of each layer references the same geographic location. That makes it well suited to combining characteristics for numerous layers into a single layer. Usually, numeric values are assigned to each characteristic, allowing you to mathematically combine the layers and assign a new value to each cell in the output layer.

Below is an example of raster overlay by addition. Two input rasters are added together to create an output raster with the values for each cell summed.



This approach is often used to rank attribute values by suitability or risk, then add them to produce an overall rank for each cell. The various layers can also be assigned a relative importance to create a weighted ranking (the ranks in each layer are multiplied by that layer's weight value before being summed with the other layers).

Below is an example of raster overlay by addition for suitability modeling. Three raster layers (steep slopes, soils, and vegetation) are ranked for development suitability on a scale of 1 to 7. When the layers are added (bottom), each cell is ranked on a scale of 3 to 21.



Alternatively, you can assign a value to each cell in the output layer based on unique combinations of values from several input layers.

Overlay tools

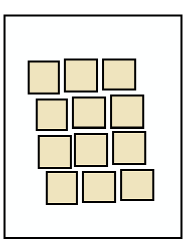
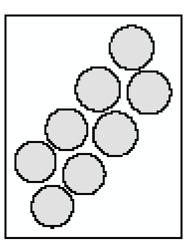
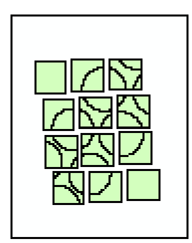
Vector overlay tools

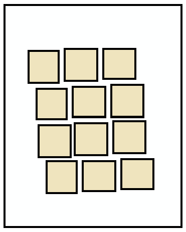
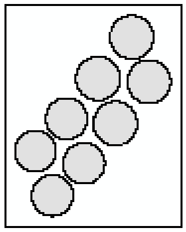
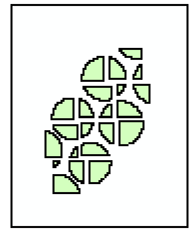
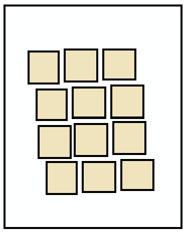
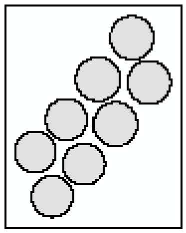
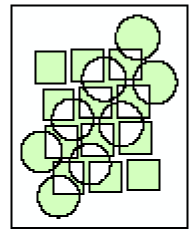
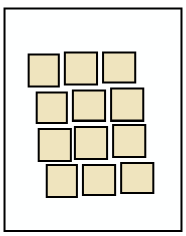
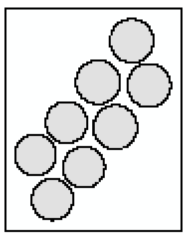
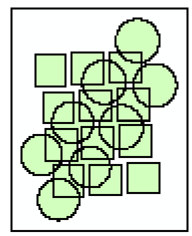
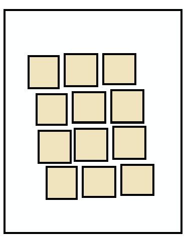
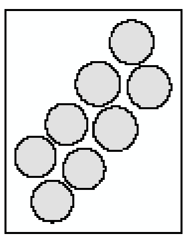
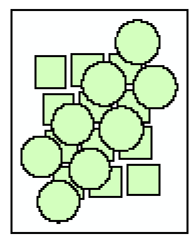
Feature overlay tools are located in the Analysis toolbox in the Overlay toolset. Conceptually, the tools are similar—they differ by the feature types they allow you to overlay, by whether you can overlay multiple layers at one time, and by which input and overlay features are maintained in the output layer.

Tool	Binary or multiple overlay	Input data type	Overlay data type	Output
Identity	Binary	Any	Polygon or same as input	Input features, split by overlay features
Intersect	Multiple	Any	N/A	Only features common to all input layers
Symmetrical difference	Binary	Any	Same as input	Features common to either input layer or overlay layer but not both
Union	Multiple	Polygon	N/A	All input features
Update	Binary	Any	Polygon	Input feature geometry replaced by update layer

Overlay operations summary table

The table below shows the results of overlaying an input dataset and an overlay dataset using each tool.

Input features	Overlay features	Operation	Result
		Identity	

Input features	Overlay features	Operation	Result
		Intersect	
		Symmetrical difference	
		Union	
		Update	

Overlay results visualization

Raster overlay tools

Raster overlay tools are located in several toolsets in the Spatial Analyst toolbox. Spatial Analyst is an ArcGIS extension that is licensed separately. If your site has a Spatial Analyst license and the Spatial Analyst extension has been installed, you will have access to the Spatial Analyst toolbox in ArcToolbox.

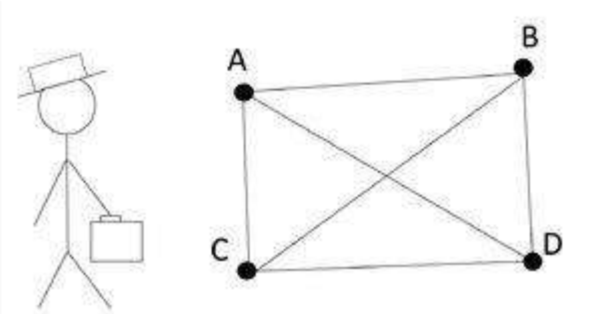
Tool	Location	What it does
Zonal Statistics	Zonal toolset	Summarizes values in a raster layer by zones (categories) in another layer—for example, calculate the mean elevation for each vegetation category.

Tool	Location	What it does
Combine	Local toolset	Assigns a value to each cell in the output layer based on unique combinations of values from several input layers.
Weighted Overlay	Overlay toolset	Automates the raster overlay process and lets you assign weights to each layer before adding (you can also specify equal influence to create an unweighted overlay).
Weighted Sum	Overlay toolset	Overlays several rasters, multiplying each by their given weight and summing them together.

GIS Network Analyst provides network-based spatial analysis tools for solving complex routing problems. It uses a configurable transportation network data model, allowing organizations to accurately represent their unique network requirements. You can plan routes for an entire fleet, calculate drive-times, locate facilities and solve other network related problems.

Network Analysis in GIS is based on the mathematical sub-disciplines of graph theory and topology. Any network consists of a set of connected vertices and edges. Graph theory describes, measures, and compares graphs or networks. Topological properties of networks are: connectivity, adjacency, and incidence. These properties serve as a basis for analysis. A simple example of a network in GIS can be streets, power lines, or city centreline.

Types of networks that can be modeled in GIS



This shows a graphic of how the traveling salesman problem is displayed. The salesperson must find the shortest route that leads to each of the four points.

It's possible to perform analyses of movement within networks on GIS. These networks include:

- Utility networks: including water mains, sewage lines, and electrical circuits. These networks are generally directed.
- Transportation networks: including roads, railroads, and flight paths. These networks are generally undirected.

- Networks based on social connections.

The streets in this map were partitioned into zones based on the driving time to the nearest service point. No matter where you are in any of the zones, the point that is the shortest drive-time away is the one located within that zone.

Shortest Path

One common type of network analysis is finding the shortest path between two points. In a network of streets, the "shortest" route can either refer to different variables, such as: distance, time, and monetary cost (such as purchasing a plane ticket). An ambulance driver looking for the shortest path to his destination will travel the route that will get him or her from point A to point B in the least amount of time.

Traveling Salesman

The traveling salesman problem is defined as reaching every point in a network in the most efficient way possible. It is derived from the idea of a salesperson trying to reach a planned set of cities to sell his or her product in the quickest, most efficient way possible, either through money made, or time. UPS uses a traveling salesman algorithm to efficiently deliver as many packages as possible to their customers every day.

Network Partition

Network partition is a divvying up of regions in a network to zones or sub categories. These regions are sized based on proximity to specific points in a network. This is common for fire stations in metropolitan areas.

Transportation Modelling

Basic functions already existing in GIS including buffer, overlay, query, etc. are useful in Transportation Planning. However, deeper analysis of network data is available for planning applications. Examples of such higher uses include network flow equilibrium models, travel demand models, trip generation and distribution, as well as activity-based models and transportation/land-use interaction models. The latter use is particularly useful as demand for transportation influences land use, and reciprocally, the changed land-use's influence on transportation. Limited commercial software exists to perform such tasks, nevertheless, skilled programmers should be able design programs to perform these tasks where software is inaccessible or non-existent. See link #1 below for more information on Transportation and GIS.

Digital Terrain Models (**DTM**) sometimes called **Digital Elevation Models** (**DEM**) is a **topographic model** of the bare Earth that can be manipulated by computer programs. ... Vegetation, buildings and other cultural features are removed digitally - leaving just the underlying **terrain**.

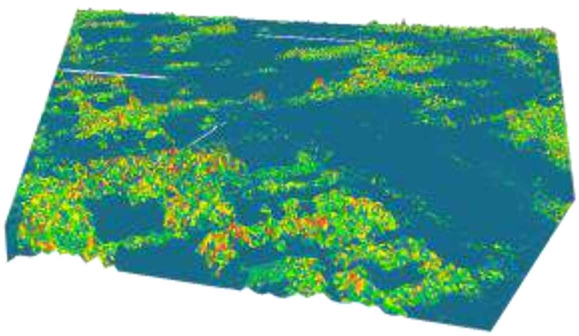
What is a Digital Surface Model (DSM)?

Airborne Light Detection and Ranging (LiDAR)

In a **LiDAR system**, pulses of light travel to the ground. When the pulse of light bounces off its target and returns to the sensor, it gives the range (a variable distance) to the Earth. Hence, how this system earned its name of Light Detection and Ranging.

In the end, LiDAR delivers a massive point cloud with elevation values. But height can come from the top of buildings, tree canopy, powerlines, and other features. A DSM captures the **natural and built features** on the Earth's surface.

A DSM is useful in 3D modeling for telecommunications, urban planning and aviation. Because objects extrude from the Earth, this is particularly useful in these examples:



Digital Surface Model (DSM) – Extruding features are tree canopy

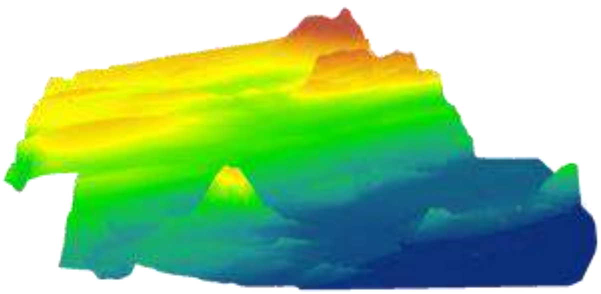
RUNWAY APPROACH ZONE ENCROACHMENT: In aviation, DSMs can determine runway obstructions in the approach zone.

VEGETATION MANAGEMENT: Along a transmission line, DSMs can see where and how much vegetation is encroaching.

VIEW OBSTRUCTION: Urban planners use DSM to check how a proposed building would affect the viewshed of residents and businesses.

What is a Digital Elevation Model (DEM)?

A digital elevation model is a **bare-earth raster grid** referenced to a **vertical datum**. When you filter out non-ground points such as bridges and roads, you get a smooth digital elevation model. The built (power lines, buildings, and towers) and natural (trees and other types of vegetation) aren't included in a DEM.



Digital Elevation Model (DEM)

When you void vegetation and man-made features from elevation data, you generate a DEM. A bare-earth elevation model is particularly useful in hydrology, soils, and land use planning

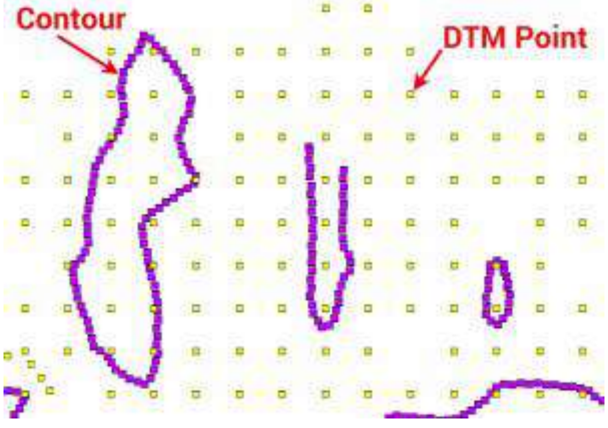
HYDROLOGIC MODELLING: Hydrologists use DEMs to delineate watersheds, calculate flow accumulation and **flow direction**.

TERRAIN STABILITY: Areas prone to avalanches are high slope areas with sparse vegetation. This is useful when planning a highway or residential subdivision.

SOIL MAPPING: DEMs assist in mapping soils which is a function of elevation (as well as geology, time, and climate).

What is a Digital Terrain Model (DTM)?

When you refer to the **USGS LiDAR Base Specification** a digital terrain model (DTM) actually has two definitions depending on where you live.



Digital Terrain Model (DTM)

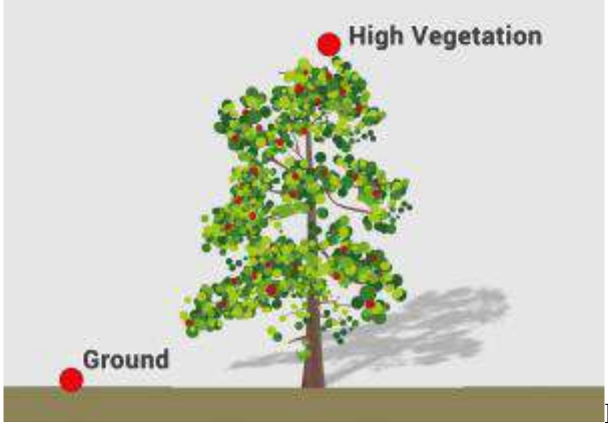
- In some countries, a DTM is actually synonymous with a DEM. This means that a DTM is simply an elevation surface representing the bare earth referenced to a common vertical datum.
- In the United States and other countries, a DTM has a slightly different meaning. A DTM is a vector data set composed of regularly spaced points and natural features such as ridges and breaklines. A DTM augments a DEM by including linear features of the bare-earth terrain.

DTMs are typically created through stereo photogrammetry like in the example above. For example, **contour lines** are in purple. The DTM points are regularly-spaced and characterize the shape of the bare-earth terrain.

In the image above, you can see how the DTM is not continuous and that it's not a surface model. From these regularly-spaced and contour lines, you can interpolate a DTM into a DEM. A DTM represents distinctive terrain features much better because of its 3D breaklines and regularly spaced 3D mass points.

How to capture Digital Elevation Models?

Some of the remote sensing methods for obtaining DEM surfaces are:



LiDAR High Vegetation

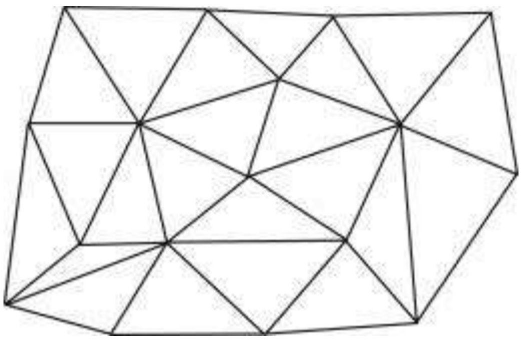
SATELLITE INTERFEROMETRY: **Synthetic aperture radar** such as **Shuttle Radar Topography Mission** uses two radar images from antennas captured at the same time to create a DEM.

PHOTOGRAMMETRY: In aerial photography, **photogrammetry** uses photographs from at least two different vantage points. Similar to how your vision works, it's able to obtain depth and perspective because of the separate vantage points.

LiDAR: Using light, LiDAR measures reflected light that bounces off the ground and back to the sensor to obtain the elevation of the Earth's surface.

The triangulated irregular network

The TIN utilizes the original sample points to constitute many nonoverlapping triangles that cover the entire region according to a set of rules. The ground surface is described approximately with these triangles.



Because of the irregularity of the TIN, the organization, storage, and application of its data are more complicated than that of the regular grid DEM. In addition to storing the elevation of the points, the planimetric position and the topological relationship between adjacent triangles are recorded.

The construction of the TIN is also an important step, and the criterion for triangulation division is often used to construct the nonoverlapping triangles based on the discrete sampling points. Delaunay is the most common triangulation algorithm. However, the radiation scanning algorithm, the simulated annealing algorithm, and algorithms based on mathematical morphology are also used.

TIN models are less widely available than raster surface models and tend to be more expensive to build and process. The cost of obtaining good source data can be high, and processing TINs tends to be less efficient than processing raster data because of the complex data structure.

TINs are typically used for high-precision modeling of smaller areas, such as in engineering applications, where they are useful because they allow calculations of planimetric area, surface area, and volume.

The maximum allowable size of a TIN varies relative to free, contiguous memory resources. Ten to 15 million nodes represents the largest size achievable under normal operating conditions with Win32. Regardless, it's strongly recommended to cap the size at a few million for the sake of usability and performance. Anything larger than this is best represented using a terrain dataset.

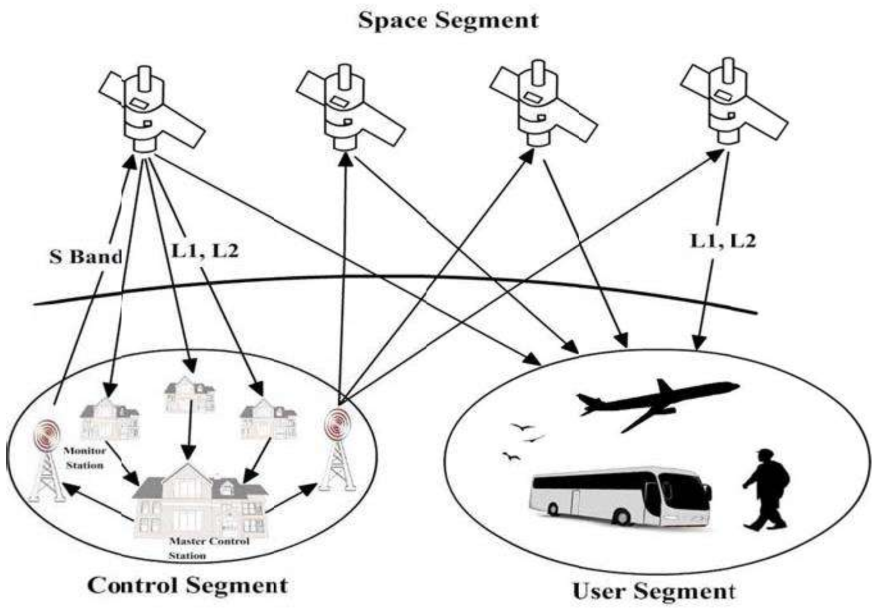
Because nodes can be placed irregularly over a surface, TINs can have a higher resolution in areas where a surface is highly variable or where more detail is desired and a lower resolution in areas that are less variable.

UNIT-IV

Details of GPS Segments

The GPS configuration comprised of 3 segments, which are the operational elements of the GPS

- Space Segment
- Control Segment
- User Segment



Segments of GPS

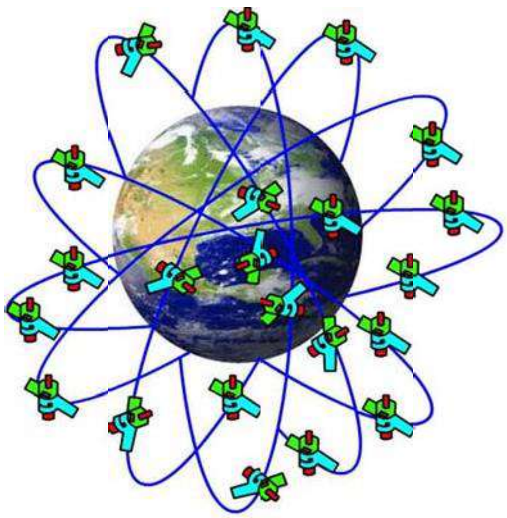
Space Segment (GPS Satellite Constellation or GPS Satellites orbiting the Earth)

- U.S Air Force has launched first GPS satellite in 1978. Later on more satellites were launched to complete the GPS satellite constellation to total 24 satellites orbiting the earth at an altitude of about 20,200 km above the surface of Earth. The high altitude insures that the satellite orbits are stable, precise and predictable, and that the satellites' motion through space is not affected by atmospheric drag.

- The PS satellites comprise of sun seeking solar panels having NiCad batteries providing secondary power. The system consists of 24 satellites (21 + 3 active spares) nominally orbiting the earth in MEO i.e. Medium Earth Orbit at an altitude of 20,200 Km approximately **a**lso named as GPS Operational Constellation. Each satellite takes 12 hours in completing one full orbit and repeat the same ground track each day. The satellites are arranged in 6 orbits with 4 satellites in each orbit, as shown in figure 2.7A and 2.7B. At present there are 27 operational GPS satellites orbiting the earth as new ones are replacing older one.

- The GPS satellite orbits are designed in such a manner that they ensure the availability of minimum 4 satellites whose visibility is ab ve a 15° cut off angle anywhere on the earth's surface irrespective of day and night. The satellites send radio signals from spa**c**e, which are received by the GPS receivers. Data from minimum four satellites are required for po**s**itioning computations. 15° cut-off angle is taken to compensate for ground undulations. Normally for an open ground, with fewer obstructions (undulating topography, high rise buildings tc.) there are 6 or 7 satellites visible quite often.

- A very accurate atomic clock having a fundamental frequency of 10.23 MHZ is a very special characteristic of each GPS satellite. On board each GPS satellite are four atomic clocks, only one of which is in use at a time. These highly accurate atomic clocks having accuracy of better than 10^{-10} seconds enable GPS to provide the most accurate timing system that exists. These clocks are generating the signals via broadcasting from the satellite.



S satellite constellation

GPS satellite

Control Segment (U.S. DOD Monitoring or The control and monitoring stations)

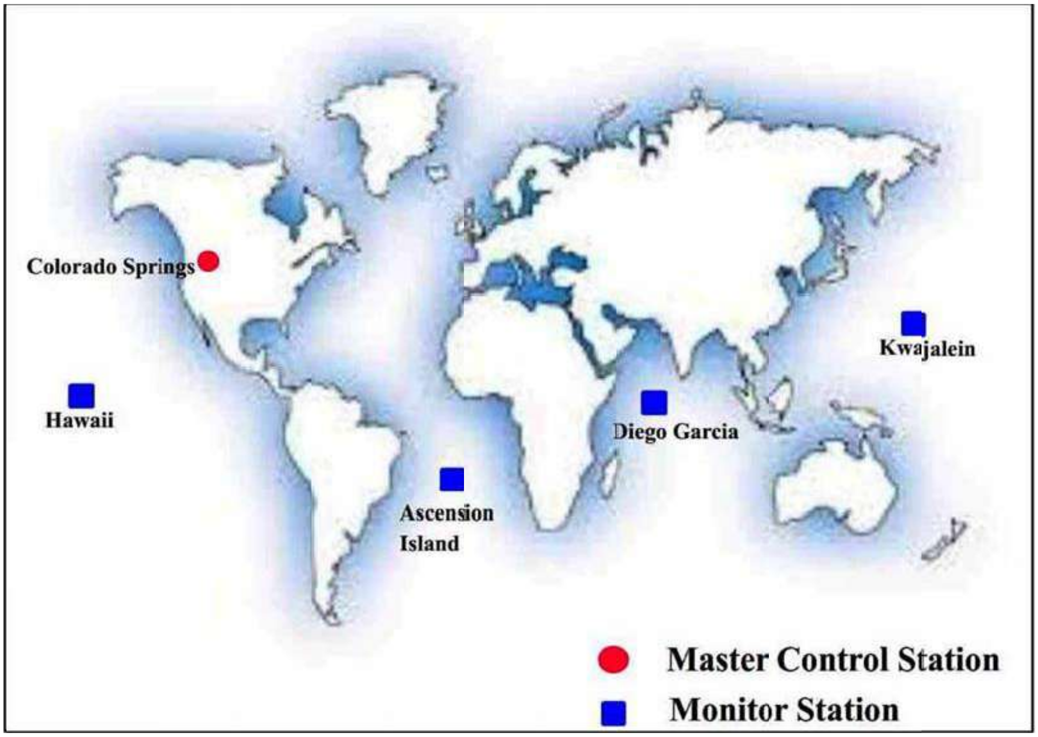
- The U.S. Department of Defense manages a master control station at Falcon Air Force Base in Colorado Springs, CO. There are four other monitor stations located in Hawaii, Ascension Island, Diego Garcia and Kwajalein. Figure 2.8 shows the locations of Control Segment stations. The DOD control stations measure the satellite orbits precisely. These are classified according to 5 locations approx. on the earth's equator and used to measure signals from SVs (Satellite Vehicles) incorporation with orbital model which enables the computation of orbital data i.e. ephemeris & SV clock correction for each satellite.

- The main function of Master Control Stations is to upload ephemeris and clock data into SVs which then send their subsets to GPS receivers via radio signals.

- The control segment is used in tracking stations, updating GPS satellite position located around the world with calibration and synchronization process of their clocks.

- It monitors and predicts the orbital path of satellite for the next 24 hrs. It also works to successfully locate the expected position of each satellite via GPS receiver. Monitor stations easily observe the satellite signals. Any discrepancies between predicted orbits and actual orbits are subsequently

uploaded and broadcasted to each satellite. The satellites can then broadcast these corrections, along with the other position and timing data, so that a GPS receiver on the earth can precisely establish the location of each satellite it is tracking.



Locations of Control Segment stations

User Segment (Military and Civilian GPS Users)

- It comprises of anyone who wish to determine his position and/or time. The user should be equipped with a GPS receiver to receive the GPS signal. Various applications which can be performed in the user segment are surveying and navigation including marine, aerial, machine control, vehicle etc.

- GPS has been used by U.S. Military for the purpose of reconnaissance, navigation & missile

  guidance. Civilian use of GPS developed at the same time as military uses were being established, and has expanded far beyond original expectations. There are civilian applications for GPS in almost every field, from surveying to transportation to natural resource management to agriculture. Most civilian uses of GPS, however, fall into one of four categories: navigation, surveying, mapping and timing. Figure 2.9 shows various types of GPS receivers **a**s well as their uses in various fields.

User segment

- User Segment comprises of the user group equipped with GPS receivers. The GPS receiver receives the signals from SV and converts these into position, velocity, and time estimates. Minimum four satellites are required to compute the positional dimensions of X, receivers are mainly used for navigation and precise positioning.

GPS Signal Structure

- The satellites broadcast two carrier waves constantly in L-Band (used for radio). These waves travel towards Earth with the speed of light. These carrier waves generated with precise atomic clock are derived from the fundamental frequency.

- **Carrier phase measurements** are based on the principle of EDM (electronic distance measurement) where the phase measurement is done. In GPS, the measured quantity is the difference between the phase of the internal receiver oscillator and the received satellite carrier phase (as sensed by the receiver antenna). Phase measurement has high accuracy of upto 3 - 10 mm.

- GPS receivers on the basis of different codes are used to differentiate between satellites. These codes are defined on the pseudo range measurements and positions are computed on the basis of that.

GPS Codes

- The L1 carrier having two codes modulated i.e. C/**A (Coarse/Acquisition) code at 1.23 MHz & P**

(Precision) code at 10.23 MHz. This carrier is broadcast at 1575.42 MHz.

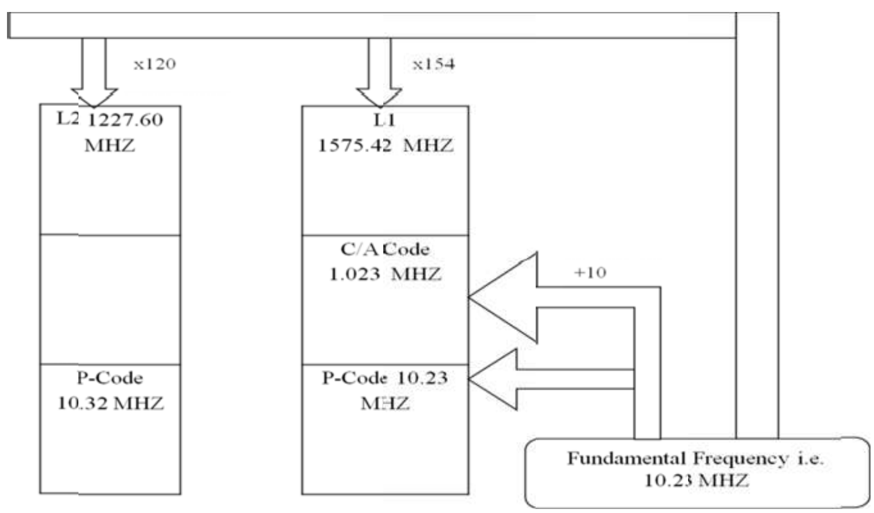
- The L2 carrier having one code modulated i.e. P-code at 10.23 MHz. This carrier is broadcast at 1227.60 MHz.

- The advantages of P-Code are as follows:- (http://www.sage.unsw.edu.au/)

  - P-code ranging enables fixing of most accurate position because of higher chipping rate and measurement precision.
  - Helps in overcoming ionospheric signal delay via modulating it on both L1 and L2 carriers.
  - More suitable for highly dynamic environments. Signal jamming resistance capability is better compared to C/A code receivers. Multipath can generate to both P & C/A code ranges simultaneously.
  - Multiple reflections from nearby buildings, hills & vegetation provide the cause of Multipath that provides the solution in signal measurement process to provide noisy signal.
  - Multipath is the reason for "jumps" in the signal measurement to provide its effective wavelength. This error will be of tens to hundreds of meters in case of pseudo-ranges whereas it is of only centimeters in case of carrier phase measurements.
  - Multipath depends on receiver-satellite position geometry which causes due to permanent features i.e. metallic fences, chimneys, water surfaces etc. and the effect of this will repeat continuously on the daily basis.
  - Receiver-satellite geometry depends upon the variation in angle of incidence or reflection on the basis of reflective surface. On the basis of this, static GPS positioning is better in accuracy and reliability in comparison to kinematic GPS positioning.

- Multipath helps in improving consistency of the original signal by interference via reflected signals at antenna.
- Magnitude of 15 cm approximately on L1 carrier and 15 to 20 m on pseudo range.
- Thus precaution should be taken that there should not be any reflecting surface around the antenna.

Figure 2.10 show the GPS signal structure and GPS codes.



GPS Receivers

- A GPS receiver is an L-band radio processor. It processes the signal broadcast by GPS satellites, solves the equations for navigation so that user can easily compute their position, precise time & velocity.

Types of GPS Receivers

1) On the basis of features
2) On the basis of level of accuracy

- Types of GPS Receivers on the basis of features-

  - **Not-self-contained receivers**: also known as 'GPS mice'. These are without screen and are need to be connected to a computer for the purpose of visualization of real position of GPS receiver. Bluetooth (wireless) can be the link of connection between the GPS and computer. This type is best used in car-navigation systems.
  - **Self contained receivers**: have a screen and is integrated with the computer itself. Sometimes, additional features e.g. electronic compass, barometer etc. are found in this type. It is primarily used in boating and aviation.
  - **Sophisticated receivers**: are meant for professional use, e.g. in the field of mapping & GIS, transportation safety, crop & agriculture etc. Though the working principle remains the same as others, the only important difference is its storage capacity and higher accuracy, which helps to store a larger amount of data that can be treated later in the office.

- Types of GPS Receivers on the basis of different levels of accuracy-

  - **C/A Code receivers:** These receivers have the accuracy of 1 to 5 m related to position and differential correction so that getting an occupation time of 5 seconds. The recent advancement in the GPS receiver design now enables it to provide sub-meter accuracy down to 30 cm.
  - **Carrier Phase receivers:** These receivers provide 10-30 cm GPS position accuracy with differential correction. The distance from the receiver to the satellite is measured by determining the total number of waves which supports the C/A code signal, which is more accurate and takes about 5 minutes of the occupation time.
  - **Dual-Frequency receivers:** provide GPS position accuracy according to differential correction within sub centimeter & accuracies according to survey grade. These receivers are presented with the signals from satellites on the basis of two frequencies at the same time. The use of two frequencies will help in omission of atmospheric and other errors and thus improving the accuracy.

Structure of GPS Receivers

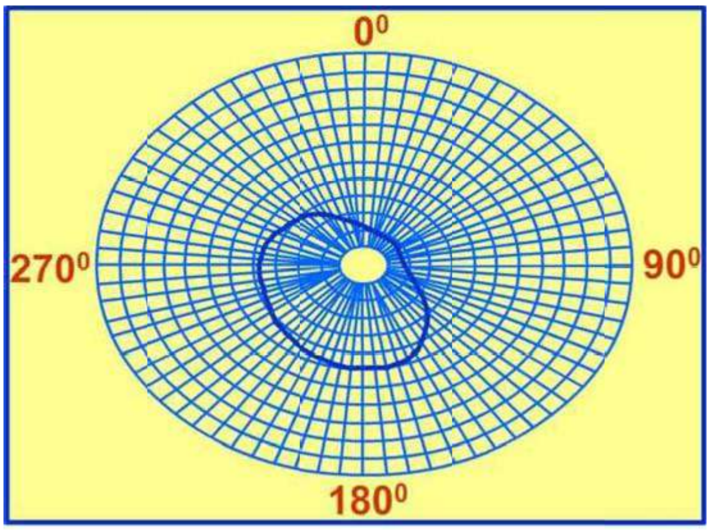
- **Antenna**: A GPS antenna is designed to collect maximum number of signals. It must have coverage with a wide spatial angle. The important thing that is needed for GPS antenna is to receive signals via all GPS satellites above the horizon with an approx 5° elevation angle.

  - The 3-D geometry of different GPS satellites in the sky, i.e. the spatial arrangement of the satellites (which are used for positioning) in the space also plays an important role in positioning accuracy.

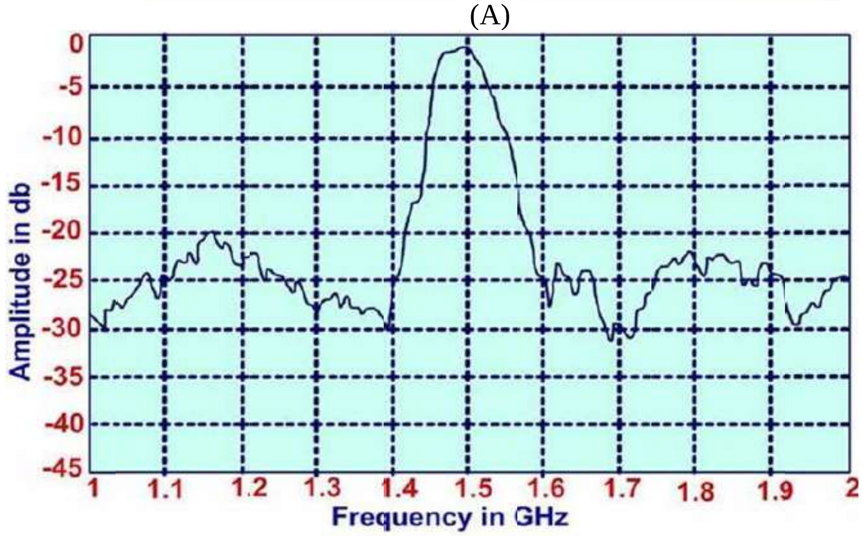
- Combination of satellites at low and high elevation angles can output a low value of GDOP (Geometric Dilution of Precision), a measure of positioning accuracy.
- The chances of interfering signals are present via low elevation angle. An antenna having

  comparatively narrow spatial angle is used sometimes for avoiding signals via low elevation angle, in order to minimize the interference. Therefore, a GPS a**n**tenna receiving higher number of satellites will tend to have more interference. This factor should be carefully evaluated while making the choice for GPS antenna.
- When the antenna is capable to receive both L1 & L2 signals having frequency 1575.42 MHz & 1227.6 MHz respectively, then the antenna is supposed to have a wide bandwidth or two narrow bands to cover entire frequency range or desired frequency range respectively.
- The antenna is considered as an integral part of receiver unit in some GPS receivers. Some GPS posses separate antennas with integration with an amplifier. The connection between those

  antennas & receiver is done via a long cable. The cable loss is compensated by the amplifier gain. The result is computed via antenna pattern in a chamber. It is shown in the fig. 2.11(A). The frequency response of the antenna is shown in fig. 2.11(B).



(A)



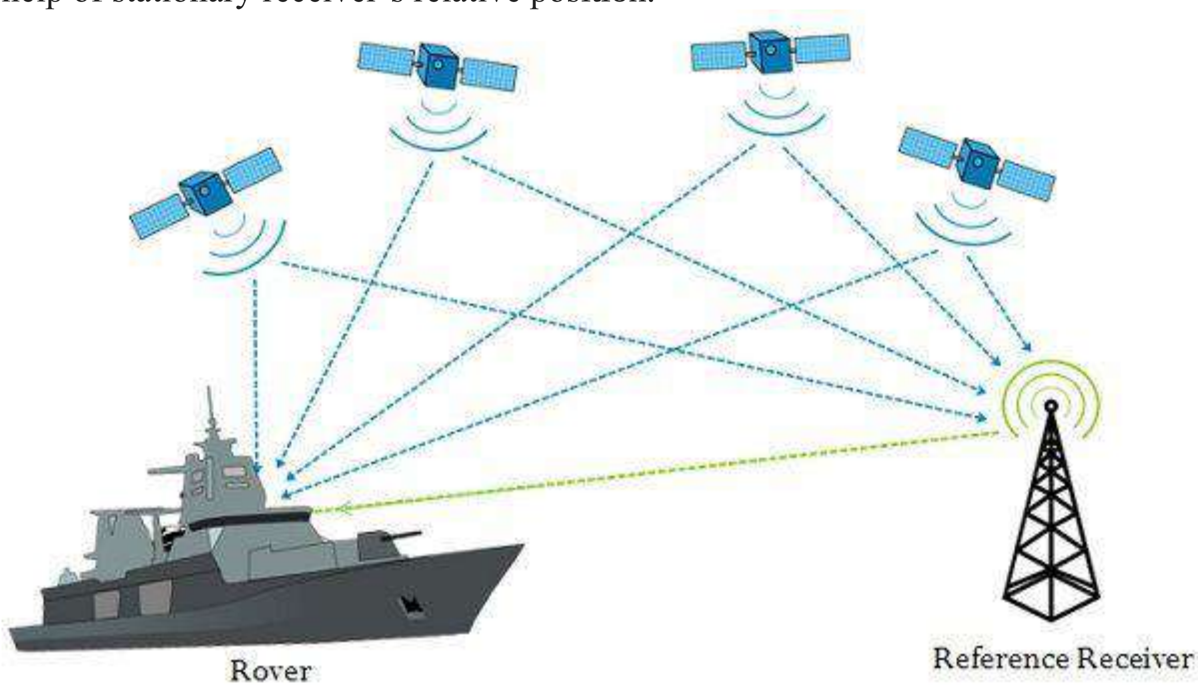
(A): Spatial pattern and (B): Frequency response of GPS antenna (Source: Tsui (2000))

The GPS and DGPS are the satellite-based navigation systems. The basic difference between GPS and DGPS lies on their accuracy, DGPS is more accurate than GPS. DGPS was intentionally designed to reduce the signal degradation. GPS provides the accuracy about 10 meters, but DGPS can provide accuracy around 1 meter, even beyond that 10 cm.

Definition of DGPS

Differential Global Positioning System (DGPS) is an improvement to GPS. DGPS technology can achieve accuracy up to 10 cm. It reduces or eliminates the signal degradation, resulting in improving the accuracy. The goal of differential GPS is not to go directly for the location; rather it finds the location relative to a fixed reference point. DGPS relies on two receivers rover and reference receiver, rover is the user, and reference receiver is also known as the stationary receiver.

A stationary receiver is fixed, and its position is known to the system. The satellite information is continuously beamed towards the rover and the base station tower. Base station tower uses its known position to calculate the accurate timing. The stationary receiver sends the information to the rover receiver to rectify the measurements with the help of stationary receiver's relative position.



Comparison Chart

BASIS FOR COMPARISON	**GPS**	**DGPS**
Number of	Only one, i.e., Stand-alone	Two, Rover and stationary

BASIS FOR COMPARISON	GPS	DGPS
receivers used	GPS receiver	receivers
Accuracy	15-10 m	10 cm
Range of the instruments	Global	Local (within 100 km)
Cost	Affordable as compared to DGPS	Expensive
Frequency range	1.1 - 1.5 GHz	Varies according to agency
Factors affecting the Accuracy	Selective availability, satellite timing, atmospheric conditions, ionosphere, troposphere and multipath.	Distance between the transmitter and rover, ionosphere, troposphere and multipath.
Time coordinate system used	WGS84	Local coordinate system

UNIT-VI

Preparation of GPS surveys

A GPS receiver computes its satellite position via satellite ranging that enables the measurement of GPs receiver and the satellites that is being tracked. The range is basically defined as an estimate or pseudo range as not being in contact with true range or distance and termed as measurement of elapsed transit time. Satellites broadcast their position as a part of message via radio waves. Position. The initial step is to measure the distance between GPS receiver and satellite via measuring the time taken by signal from satellite to receiver. A 3-dimensional position with latitude, longitude and altitude has been computed via distance measurements to four satellites.

Before start of the GPS survey, some points must be considered as listed below:

- Accuracy must be considered in survey work.
- Hardware and software available for GPS survey, if GPS data used by different types of manufacturer, then supplied software should be able to convert it into a desired format or compatible format, (RINEX : Receiver Independent Exchange format it is used in different types of receiver for data interchange).
- How many personnel requirement.
- Survey control, horizontal, vertical or both.
- How many survey controls required etc.

Desired accuracy will determine following:

- Type of GPS operation
- Type of GPS receiver
- Duration of observation
- Type of network adjustments required

Required Resources: First step

- How many personnel
- Receivers with accessories
- Transportation facility
- Images or Maps
- Satellite and weather forecast information
- accommodation
- availability of equipments

Reconnaissance of field survey: Second step

The following steps needs to be consider for the operation of reconnaissance

- Existing control and new station must be visited
- documentation must be completed
- obstruction must be removed
- Stations must be easily accessible
- orientation must be noted if there is presence of obstruction

Establishing control station: Third step

In order to establish the control station, the following points must be kept in mind:

- Control points should be easily accessible
- No physical or electromagnetic surfaces in control stations
- No reflecting surfaces
- Safe area and should be free from vandalism and theft
- Shelter against weather
- Quiet area for the control station

An Observation plan setting up: Fourth step

For finalizing the observation plan, following points must be consider:

- Number of satellites
- satellite observation window
- GDOP
- Visibility of satellites
- Recording time
- common baseline or station
- Session interval

Cost and quality considerations: Fifth step

It is important to minimize the cost of survey work. Hence, the following expenses need to be evaluated carefully when survey work needs to be done.

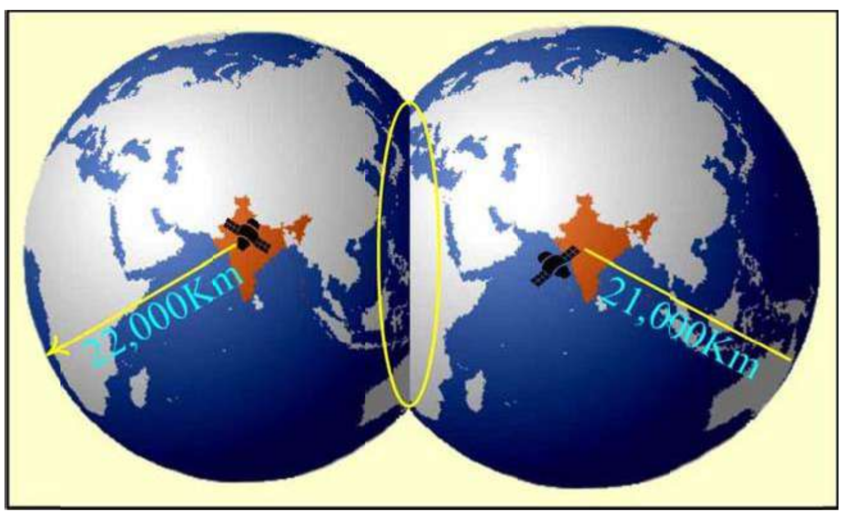
- mobilization and demobilization
- equipment, personnel, shipping expenses for survey
- vehicle or helicopter cost used in survey
- final processing, adjustment and transformation of results
- project report after finalization
- contingency costs
- stand-by rates
- re-observation of survey
- daily rate versus fixed price per point at control station

Position Calculation: Sixth step

Travel time is measured via satellite transmitted the signal and received by receiver. All GPs receivers checks internal lock and synchronized with the satellites for generating same digital code at the same time. Fig. 6.5 shows the measurement of signal by receiver from first satellite having sphere of radius 12,000 miles.

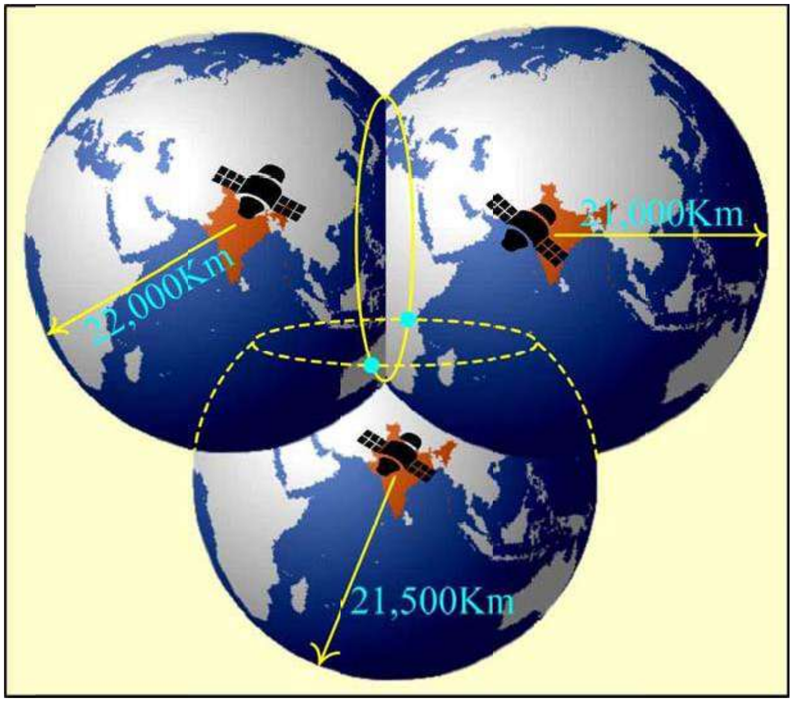
Measurement of signal by receiver from first satellite (http://www.montana.edu/gps/understd.html)

If we assume the receiver picking up a signal from a second satellite, the range between receiver and satellite i considered as 11,000 miles radius via intersecting of two spheres and forming a circle. Fig. 6.6 shows the measurement of signal by receiver from second satellite having sphere of radius 11000 miles.



Measurement of signal by receiver from second satellite (http://www.montana.edu/gps/understd.html).

Fig. shows the measurement of signal by receiver from third satellite having sphere of radius 11,500 miles.



Measurement of signal by receiver from third satellite

Preparation of GPS surveys

Setting up an observation plan:

As long as the GPS system was not yet complete, a pre-computation of coverage was an indispensable preparatory step in project planning. With the system completely deployed in 1995, sufficient satellites are visible above the horizon at any time; hence field campaigns can be planned independently of the constellation. For analysis purposes, and for kinematic observations, a pre-computation of the satellite constellation can still be of importance.

These so-called ALERT-lists can be computed with data from the satellite almanac. Almanac data, that is, low accuracy orbit data for all available satellites, are transmitted in the fourth and fifth sub frames of the navigation message. These sub frames have 25 “pages” each 30 seconds long, so almanac information can be read in 12.5 minutes.

With the aid of the almanac data, satellite positions can be precompiled over several months with sufficient accuracy for planning purposes. One must, however, occasionally expect larger orbit maneuvers, so that a regular check of the almanac data is recommended. With the almanac data, visibility diagrams and PDOP values can be generated. Most manufacturers provide suitable software packages (mission planning software) on a PC basis. The almanac data are available from various internet sources.

Practical GPS survey field procedures

There is major improvement in modern GPS surveying compared to conventional GPS surveying. Both have strength and weakness but conventional GPS surveying is more accurate and proves an ideal solution.

- Conventional GPS Surveying:-
  Advantages:-
  - Highest accuracy and robust technique.
  - Non- critical Ambiguity resolution and less impact of orbital error via multipath.

  Disadvantages:-
  - Long time observation sessions that is not effective for engineering applications.
- Modern GPS Surveying:-
  Advantages:-
  - Highest accuracy compared to pseudo range and High productivity.
  - Effective for engineering applications.

  Disadvantages:-
  - Higher capital costs with special hardware and software.
  - Susceptible to orbit, atmospheric multi-path disturbances.

Absolute positioning:

A single passive receiver is used for collection of data from multiple of satellites at a one station to compute the station location. It is not useful in precise GPS surveying due to less accurate data received, however it is most widely used in military and commercial GPS positioning system for real time based navigation and position determination. The accuracies of poisoning are manly depends on the authorization of users. GPS point positioning is also known as stand-alone or autonomous type of positioning which involves a single GPS receiver. It can be determined by the carrier-phase range measurements or code range measurements. GPS receiver tracks at a time more than 4 satellites to determine its own position coordinates.

A standard Positioning Services (SPS) can achieve a real time positional accuracy of 25m without selective availability. The low level accuracies provided by SPS are due to the degradation of GPS signal by the selective availability. The Precise Positioning Services (PPS) user with a receiver capable of tracking P-code can use a device to decrypt to attain a point positional accuracy of range 10-12 m by receiving single frequency. To get accuracies less than and equal to 1m, special equipment are required with post processing techniques.
Absolute positioning can be sub-divided into following categories;

- Absolute positioning using carrier phase.
- Pseudo range or C/A code based Absolute Positioning.

A GPS receiver which is capable of receiving both the C/A-code and carrier-phase is used to collect the positional information. Broadcast ephemeris enables user to use pseudo range values via real time to compute absolute point positions by achieving an accuracy of 3 m and 25 m in best and worst conditions respectively. Post processing technique can be used to enhance the accuracy level which can be raise up to sub-meter level in best condition and 15m in worst conditions.

Pseudo range or C/A code based Absolute Positioning

It is used for navigation purpose in which reference system must be defined and maintained with no direct access to origin. Absolute positioning enables the position vector of the satellite, range vector from ground tracking station to satellite being tracked and determine the position vector of ground station. When a GPS user performs a navigation solution using C/A-code, and then an approximate pseudo range is measured. Satellite position and range are very important parameters which should be known when determining the precise location. Application of pseudo range is to compute the distance between GPS antenna & satellite approximately via correlation between transmitted code by satellite and reference code by receiver as synchronization between clock signal between transmitter and receiver is not affected by an error correction. The traveled distance by a signal can be measured by multiplying elapsed time and velocity of transmission of satellite, with the tropospheric and ionospheric effects are accounted. The accuracy of positioning is defined in terms of range measurement and geometry of satellite. The geometrical magnification of uncertainty in a GPS point positioning can be described by Dilution of Precision (DOP). For improvement of GPS range accuracy repeated and redundant range observation must be taken, however DOP remains same.

In a static mode, range measurement may be continuously measured again and again over the variation of orbital locations of satellites. Different positional geometry of intersection is determined by different satellite orbits.

At least four observations on the pseudo range must be considered to determine a solution of 3D GPS position while only three observations on the pseudo range are needed for 2D GPs position. To resolve the problem related to clock biases received by satellite and ground receiver, more pseudo ranges are needed.

Relative Positioning

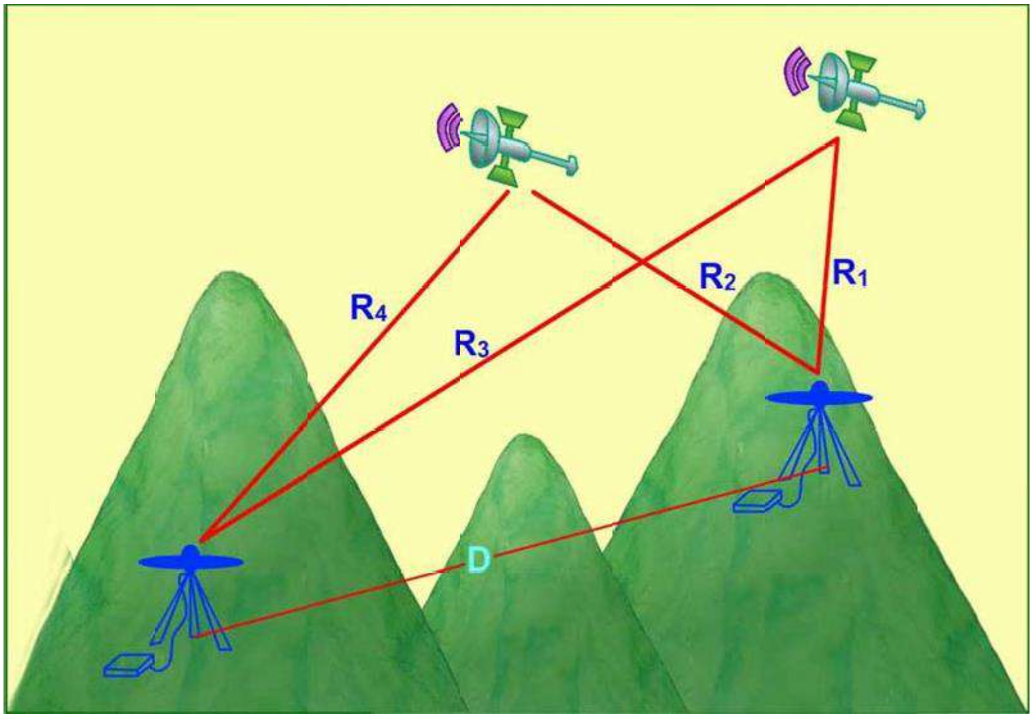
In this positioning system, point with respect to another point is taken as the origin of local coordinate system. Absolute positing is poorly defined as compared to relative positioning which can be performed to high precision. Conventional positioning techniques are used to determine intersection vectors which indicates link between adjacent network points which restricts station Intervisibility. It is beneficial for differentiate between horizontal geodetic network i.e. Latitudes & Longitudes and geodetic leveling i.e. points whose heights is known. Here, coordinates are considered as a three global reference system coordinates that derived from nearby control points observation.

A network has been constructed in this system which tends to efficient for propagating position information and provide many possible pathways from one station to another station. After that network adjustment has computed the best set of coordinates for all control points. In this system, coordinates of another station has been determined more accurate to acquire high precision geodetic survey operations.

- It consists of two GPS receivers (reference or base and rover or remote) which are able to track four or more satellite to compute their relative coordinates on the basis of center of the earth as shown in Figure 2.17. It is also known as differential positioning. It provides different parameter for receiver coordinates and clock error in WGS 84 system and transformation parameter into local datum. Reference receiver having known coordinates remain stationary while rover receiver having unknown coordinates may vary.

  - Known : X,Y,Z (satellites)
: R_1, R_2, R_3, R_4
: X, Y, Z (base)

  - Unknown : X,Y,Z (rover or remote location)



Principle of GPS relative positioning

- Minimum two GPS receivers receive signals at the same time from **s**ame set of satellites. One GPS unit, known as the reference or base station, is always positioned on a known point. The observations are processed with respect to the base station to obtain th**e** position of other station known as the rover station. Figure 2.17 shows a typical arrangement for differential positioning. Accuracy achieved by this method is much higher than that in point positioning because erro**r**s common to both receivers get cancelled. The DGPS method is classified as :

  - **Static Positioning:** All receivers remain stationary and collect carrier phase over a period of time. Most accurate positioning technique defines Static Positioning due to some changes in satellite geometry. The estimated accuracy is in root means square i.e. 5 mm + 1ppm from geodetic receiver depends on baseline
  - **Fast (rapid) static: -** It is somewhat similar to static Positioning. The difference is that in this case only base receiver kept stationary for whole obs**e**rvation.
  - **Kinematic Positioning:** Reference receiver remains fixed while rovers vary from point to point.
  - **Stop-and-go GPS surveying:-** It is si ilar to other Kinematic Ps surveying. It is used where l rge number of unknown point is to be compute within 10- 15 km of known point. Positional accuracy is higher in comparison to Kinematic surveying

Introduction to GLONASS and GALILEO system

GLONASS

GLONASS refers to Global Navigation System operated for Russian government. So, it is also termed as in Russia i.e. Global'naya Navigatsionnaya Sputnikovaya Sistema. It creates an alternative to GPS which is operated for U.S government. GLONASS have the benefits of global or wide coverage and same accuracy or precision. The beginning of development of GLONASS has started in the Soviet Union in 1976 by launching 43 GLONASS satellites. After that in 1982, satellites with aided functionality have been launched by number of rockets to form constellation. In 2000's, on the basis of government priority, restoration of the system has been increased. It is most expensive program as seen in third budget of Russia in 2010. GLONASS proves very beneficial for Russia's territory by 2010. In 2011, restoration of system is improved to enabling full global coverage. Many upgrades of GLONASS have been launched
i.e. GLONASS-K.

Following features are:

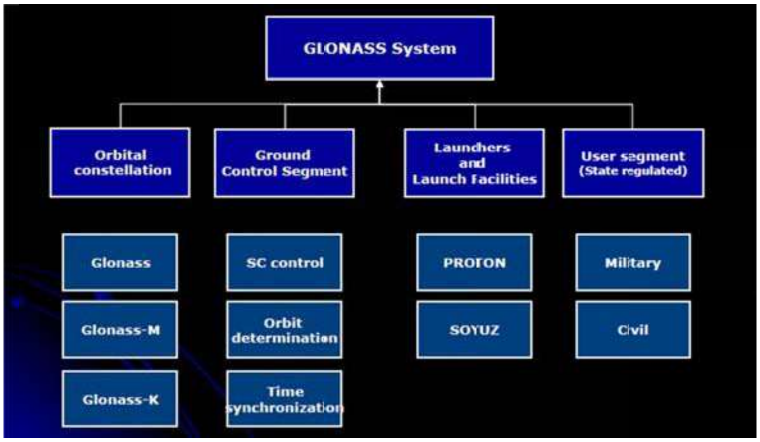
- Developed by Soviet Union, first launch: 1982.
- Declined under Russia, but now revived.
- Have launched 81 satellites so far Constellation.
- 24 satellites in 3 orbital planes, 64.8o inclination.
- 19,100 km altitude, 11 1⁄4 hour period Signals.
- 3 allocated bands: G1 (1602 MHz), G2: (1245 MHz), G3 (1202 MHz).
- C/A-like code: 511 chips, 1 ms code period, 50 bps.
- All SVs use same PRN with frequency division multiple access (FDMA) using 16 frequency channels, reused for antipodal SVs.

Importance of GLONASS to INDIA

Network centric warfare is one component basically depend on the navigation system (GLONASS) for precision while many variations and future weapons have been already developed. As earlier plans, alternative for GLONASS is GPS operated for U.S. but GPS dependent device would not be strategically correct. For that reason, India has to depend on autonomous choice in communications. India becomes a partner for Galileo but now days; it is used for civilian purpose in Russia.

GLONASS Architecture

The GLONASS architecture has been shown in figure



GLONASS Architecture

GLONASS Orbit

- Following Orbit Constellation are used in GLONASS:-
  - Total 24 satellites divided in 3 orbital planes consisting of 8 satellites each.
  - 120° orbit shift along the equator.
- Different parameters of orbit are:-
  - Circular
  - 19100 km height
  - 64.8° inclination
  - 11 h 15 min revolution time

GLONASS-M spacecraft

- Main specifications are given below:-
  - 580 W Power consumption.
  - Clock stability $1x10^{-13}$.
  - 0.5 deg accuracy for attitude control.
  - Mass 250 kg.
  - Solar panel pointing accuracy 2 deg.
  - Frequency band.
  - L1, 1600 MHz.

The GLONASS development cycles as well as the characteristics of various satellite constellations are given in table

GLONASS Development cycle and characteristics of various satellite constellations

Specifications	**GLONASS**	**GLONASS-M**	**GLONASS-K1**	**GLONASS-K2**
Commencement	1982	2003	2011	2014
Year				
Design life	3 years	7 years	10 years	10 years
Unpressurized	No	No	Yes	Yes

Clock stability	5 x 10^{-13}	1 x 10^{-13}	5 x 10^{-14}	1 x 10^{-14}
Signals	L1SF, L2SF, L1OF, (FDMA)	GLONASS + L2OF (FDMA)	GLONASS-M + L3OC (CDMA)	GLONASS-M + L1OC, L3OC, LISC, L2SC (CDMA)
Total Launched Satellites	81	39	SAR	SAR

Galileo

Galileo is a €20 billion project developed by collaboration of European Union and European Space Agency (ESA). Apart from Russian GLONASS, US GPS, high precision has been achieved in this positioning system.

Applications of GPS

GPS is defined as satellite navigation and positioning system formed by satellites moving at an altitude of 22,200 km about the surface of Earth, for all civilian and military users which may be land, sea water air-borne providing location, velocity and time information irrespective of weather conditions. The location is used to determine ground position and velocity even when there is obstruction in direct line of sight between the two observation stations. This system has enormous applications in various fields. Some of those are:

Geodetic control surveys

A control survey represents a class of survey for establishing point with high accuracy enabling support of activities i.e. mapping, construction, boundary surveys etc. A unified coordinate base system can be established for survey and other activities by addition of established control nets with a monumented control point network. Range of a control survey can vary by establishing few points to a network that may consist of numerous points or may cover a large extent of geographic area. For high order control surveys, high precision total stations are used whereas in most of the cases time and resources is very much important compared to accuracy. GPS surveys are now a better alternative to those needs. Static method is used in high order geodetic control surveys, but for low order control surveys such as in photogrammetric and other types of mapping, fast static techniques are used. For achieving the desired results and proper completion proper planning is must. It is necessary to plan the whole geodetic survey, considering the factors e.g. geometry and availability of the satellites.

Cadastral Survey

Cadastral survey is the discipline of land surveying which considers the definition of property boundaries and their ownership. It is the most important of all type of surveys, as the major dealing of land is done in real estate and cadastral surveys provide accurate results.

It is common in most of the cases of real estate dealing where the conflict arises because of improper records of land sizes. To resolve issues a cadastral survey has to be performed.

With the introduction of GPS in surveying, cadastral surveys also share its benefits. Whether it is for large or small areas GPS receivers proved to be faster alternatives without compromising the accuracy of the measurements.

RTK mode of Differential GPS is preferred in cadastral surveys to attain high accuracy. To achieve maximum accuracy in real-time Dual frequency (L1 & L2) is necessary; most of the professional receivers available today are dual frequency receivers. But second frequency is locked until a separate license is purchased. To attain same accuracy using single frequency, Baseline Processing of acquired data is to be done in the post processing.

Photogrammetry, Remote sensing and Surveying

Along with enhancement of ease and versatility of spatial data acquisition by GPS Technology, it is integrated with Photogrammetry, Remote Sensing and Surveying with a much diversified approach. GPS can be integrated with Remote Sensing to yield applications in various fields like precision farming & environmental modeling; Disaster mitigation, Emergency response, mobile mapping, etc.

GPS receivers now days are widely used in surveying everywhere, hence providing very accurate digital data. For any application of surveying, this data can be directly utilized. For example, surveying of roads, terrain, lakes, etc. is done mostly by GPS these days, providing a cluster of accurate control points. Geodetic GPS with post processing corrections can provide an accuracy of the order of sub-meter, therefore can be effectively used for any surveying project. It can provide very accurate controls required for Satellite Photogrammtery for mapping and creation of stereo-model. It incredibly boosts the process like creation of a new map, updating of existing map, etc.

Engineering and monitoring

GPS proves to be invaluable in development of maps as the military HQs keeps on changing by instantly providing accurate location. It tremendously boosts the updating rate of the maps. GPS also proves very efficient for the grid control locations establishment for various weapons and other gadgets and also for targeting location. For registration of images into absolute geo-coordinates, modern mapping techniques e.g. remote sensing and GIS consistently prefers DGPS technology.

Military Applications

Navigation

One of the most difficult tasks for soldiers in the unknown enemy territory is to navigate the unfamiliar areas. It becomes really challenging when they have to navigate in the dark. GPS plays an important role in giving the soldiers their precise location with respect to the surroundings. Soldiers equipped with GPS have clear advantage against the enemies, who are already familiar with the surroundings. Advanced GPS receivers are used by specialized forces with crack teams to achieve goals and diffuse enemy installations. Gun positions in modern warfare can be identified using GPS for tracking and to avoid counter fire hit via enemies and their installations. Navigation supports major application for military peoples.

Tracking

In a military usage before declaring a target hostile and engaged by various weapon systems, it needs to be tracked for suspicious activities. These modern weapon systems of missiles and smart bombs are fed with the tracking data as input. For example, Truth Data Acquisition, Recording, and Display System (TDARDS) are developed on GPS by US Army which comprises of many features i.e. lightweight, easily affordable etc. or GPS based tracking system on mobile that provides up to date data with radio link & high computer technology enabling highly accurate and real time position information system on the basisof various objects e.g. ground vehicles, helicopters, aircrafts etc. which enables effective tracking.

Bomb and Missile guidance

GPS broadly provides designs of modern day weapon system for guidance and targeting. While in flight US Cruise Missiles use multichannel GPS receivers to precisely ascertain their position to hit the target accurately from repulsion distance The Multiple Launched Rocket System (MLRS) for vehicle positions aims the launch box towards the targets instantly on the basis of GPS, reducing the counter bombardment & detection chance. A 2000 lb glide bomb developed by exploitation of EDGE (DGPS for Guidance Enhancement) program uses a GPS sewer for guidance for US army instead of a Laser. Even an 11 miles away target from the drop point can be destroyed by this bomb under the guidance of four DGPS base stations 1000 nautical miles far away.

Rescue

GPS always proves very worth in case of rescue and emergency response services. Emergency response team members can make the benefits of GPS for reducing response time, by determining the location of a casualty during operations.

Map Updation

GPS proves to be invaluable in development of maps as the military HQs keeps on changing by instantly providing accurate location. It tremendously boosts the updating rate of the maps. GPS also proves very efficient for the grid control locations establishment for various weapons and other gadgets and also for targeting location. For registration of images into absolute geo-coordinates, modern mapping techniques e.g. remote sensing and GIS consistently prefers DGPS technology.