St.Joseph's College of Engineering

Department of Computer Science and Engineering & ADS

OCE102- Geographic Information Systems

UNIT I

Introduction to GIS - Basic spatial concepts - Coordinate Systems - GIS and Information Systems – Definitions – History of GIS - Components of a GIS – Hardware, Software, Data, People, Methods – Proprietary and open source Software - Types of data – Spatial, Attribute data- types of attributes – scales/ levels of measurements.

INTRODUCTION TO GIS

What is a GIS?

A Geographic Information System (GIS) is a computer system for capturing, storing, querying, analyzing, and displaying geographic data. 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).

Geographic information systems (GIS) apply computer technology to the tasks of capturing, storing, manipulating, analyzing, modeling, and displaying information about the surface of the Earth, and the phenomena distributed on it. They have emerged over the past three decades as a distinct form of computer use, with its own software industry and array of products, directed at applications ranging from management of the resources of utility companies, to support for global change science. Worldwide sales of GIS software in the late 1990s were in the region of $600 million annually, with much larger investments in associated digital geographic data.

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"

Objectives of GIS

Some of the major objectives of GIS are to

- Maximizing the efficiency of planning and decision making
- Integrating information from multiple sources
- Facilitating complex querying and analysis
- Eliminating redundant data and minimizing duplication

Like any other information technology, GIS can be divided into the following four fundamental parts: computer system, GIS software, brainware, and infrastructure.

Computer System The computer system includes the computer and the operating system to run GIS. Typically the choices are PCs that use the Windows operating system or workstations that use the UNIX operating system. Additional equipment may include monitors for display, digitizers and scanners for spatial data input, and printers and plotters for hard copy data display.

GIS Software The GIS software includes the program and the user interface for driving the hardware. Common user interfaces in GIS are menus, graphical icons, and commands.

Brainware Equally important as the computer hardware and software, the brainware refers to the purpose and objectives, and provides the reason and justification, for using GIS.

Infrastructure The infrastructure refers to the necessary physical, organizational, administrative, and cultural environments for GIS operations. The infrastructure includes requisite skills, data standards, data clearinghouses, and general organizational patterns.

Since the 1970's, GIS has been important in natural resource management, such as land use planning, timber management, wildlife habitat analysis, riparian zone monitoring, and natural hazard assessment. In more recent years, GIS has been used in emergency planning, market analysis, facilities management, transportation planning, and military applications. Integration of GIS with other technologies such as Global Positioning System (GPS) and the Internet has introduced new applications.

The ability of GIS to handle and process geographically referenced data distinguishes GIS from other information systems. Geographically referenced data describe both the location and characteristics of spatial features on the Earth's surface. Roads and land use types are spatial features as are precipitation and elevation. In describing a road, for example, we need to refer to its location (i.e., where it is) and its characteristics (road classification, traffic volume, etc). GIS therefore involves two geographic data components: spatial data relating to the geometry of spatial features, and attribute data giving the information about the spatial features.

It is often helpful to think of a GIS as a computer containing maps. One of the simplest reasons for manipulating maps with computers is to make them easier to construct and draw, and GIS are often used for this purpose. By computerizing the map-making process it is possible to edit easily, manipulate the map's contents without the labor-intensive task of redrafting, communicate maps electronically, and create output in any convenient form. The advent of GIS has made it possible for anyone to be a cartographer who is in possession of the necessary software, a computer to run it on, and a suitable printing device.

FUNCTION OF GIS

The Functions of GIS describe the steps that have to be taken to implement a GIS. These steps have to be followed in order to obtain a systematic and efficient system. The steps involved are:

i. Data Capture.
ii. Data Compilation.
iii. Data Storage (GIS Data Models).
iv. Manipulation.

v. Analysis.

i) Data Capture

Data used in GIS often come from many sources. Data sources are mainly obtained from Manual Digitization and Scanning of aerial photographs, paper maps, and existing digital data sets. Remote sensing satellite imagery and GPS are promising data input sources for GIS.

Digitization; A conversion process which converts paper maps into numerical digits that can be stored in the computer. Digitizing simplifies map data into sets of points, lines, or cells that can be stored in the GIS computer.In this stage Digitization is carried out. There are two basic methods of Digitization: Manual Digitizing & Scanning. Digitization is of two types : Head Up(Digitization tablet) and Head Down(Computer screen).

ii) Data Compilation

Following the digitization of map features, the user completes the compilation phase by relating all spatial features to their respective attributes, and by cleaning up and correcting errors introduced as a result of the data conversion process.The end results of compilation is a set of digital files, each accurately representing all of the spatial and attribute data of interest contained on the original map manuscripts. These digital files contain geographic coordinates for spatial objects (points, line polygons and cells) that represent mapped features.

iii) Data Storage (GIS Data Models)

- Once the data have been digitally compiled, digital map files in the GIS are stored on magnetic or other digital media. Data storage is based on a Generic Data Model that is used to convert map data into a digital form.
- The two most common types of data models are Raster and Vector. Both types are used to simplify the data shown on a map into a more basic form that can be easily and efficiently stored in the computer.

iv) Manipulation

- Once data are stored in a GIS, many manipulation options are available to users. These functions are often available in the form of "Toolkits." A toolkit is a set of generic functions that a GIS user can employ to manipulate and analyze geographic data. Toolkits provide processing functions such as data retrieval measuring area and perimeter, overlaying maps, performing map algebra, and reclassifying map data.
- Data manipulation tools include Coordinate change, Projections, and Edge matching, which allow a GIS to reconcile irregularities between map layers or adjacent map sheets called Tiles.

v) Analysis

The heart of GIS is the analytical capabilities of the system. What distinguish the GIS system from other information system are its spatial analysis functions. Although the data input is, in general, the most time consuming part, it is for data analysis that GIS is used. The analysis functions use the spatial and non-spatial attributes in the database to answer questions about the real world. Geographic analysis facilitates the study of real-world processes by developing and applying models. Such models illuminate the underlying trends in geographic data and thus make new information available. Results of geographic analysis can be communicated with the help of maps, or both.

Functions	Sub-functions
Data Acquisition and prepossessing	Digitizing, Editing , Topology Building, Projection Transformation, Format Conversion etc.
Database Management and Retrieval	Data Archival, Hierarchical Modeling , Network Modeling, Relational Modeling, Attribute Query, Object-oriented Database etc.
Spatial Measurement and Analysis	Measurement operations, Buffering, Overlay operations, connectivity Operations etc.
Graphic output and Visualization	Scale Transformation, Generalization, Topological Map, Statistical Map etc.

GIS APPLICATIONS

Mapping Locations: GIS can be used to map locations. GIS allows the creation of maps through automated mapping, data capture, and surveying analysis tools.

Mapping Quantities: People map quantities, like where the most and least are, to find places that meet their criteria and take action, or to see the relationships between places. This gives an additional level of information beyond simply mapping the locations of features.

Mapping Densities: While you can see concentrations by simply mapping the locations of features, in areas with many features it may be difficult to see which areas have a higher concentration than others. A density map lets you measure the number of features using a uniform areal unit, such as acres or square miles, so you can clearly see the distribution.

Finding Distances: GIS can be used to find out what's occurring within a set distance of a feature. mapping and monitoring change: GIS can be used to map the change in an area to anticipate future conditions, decide on a course of action, or to evaluate the results of an action or policy.

SPATIAL DATA MODELS

GIS uses two basic data models to represent spatial features: vector and raster. The data model determines how the data are structured, stored, processed, and analyzed in a GIS. The vector data model uses points and their x, y coordinates to construct spatial features of points, lines, and areas. Vector-based features are treated as discrete objects over the space. The raster data model uses a grid to represent the spatial variation of a feature. Each cell in the grid has a value that corresponds to the characteristic of the spatial feature at that location. Raster data are well suited to the representation of continuous spatial features like precipitation and elevation. Many GIS functions are either vector-based or raster-based.

1.1. Vector Data Model

The vector data model consists of three types of geometric objects: point, line, and area. A point may represent a gravel pit, a line may represent a stream, and an area may represent a vegetated area. A point has 0 dimension. A point feature occupies a location and is separate from other features.

A line is one-dimensional and has the property of length. A line feature is made of points: a beginning point, an end point, and a series of points marking the shape of the line, which may be a smooth curve or a connection of straight-line segments. Line features may intersect or join with other lines and may form a network.

An area is two-dimensional and has the properties of area and boundary. The boundary of an areal feature separates the interior area from the exterior area. Areal features may be isolated or connected. They may overlap one another, and may form holes within other areas.

Vector data representation using point, line, area, and volume is not always straightforward because it may depend on map scale and, occasionally, criteria established by government mapping agencies. A city on a 1:1,000,000-scale map is represented as a point, but the same city is shown as an area on a 1:24,000-scale map.

A stream is shown as a single line near its headwaters but as an area along its lower reaches. In this case, the width of the stream may determine how it should be represented on a map. The U.S. Geological Survey (USGS) uses single lines to represent streams less than 40 feet wide on 1:24,000-scale topographic maps and double lines for larger streams. When hydrography becomes a layer in Digital Line Graph (DLG) data, streams in single lines are digitized as lines, and streams in double lines are digitized as areas. Therefore, a stream may appear as a line or an area depending on its width and the criterion used by the government agency involved in creating the maps.

Vector data may be topological or non-topological. ARC/INFO coverages are topological and shapefiles are non-topological. Topology expresses explicitly the spatial relationships between geometric objects. ARC/INFO coverages support three basic topological concepts:

- Connectivity: Arcs connect to each other at nodes
- Area definition: An area is defined by a series of connected arcs
- Contiguity: Arcs have directions and left and right polygons

ArcView uses non-topological shapefiles. Shapefiles define the geometry and attributes of map features in three basic files. The .shp file stores the feature geometry, the .shx file maintains the index of the feature geometry, and the .dbf file stores the attributes of map features.

Although the feature geometry file in ArcView saves a point as a pair of X, Y coordinates, a line as a series of points, and a polygon as a series of lines, no files describe the spatial relationship among geometric objects. For example, polygons in a shapefile have duplicate arcs and can overlap one another, thus violating the topology required for a polygon coverage.

Without topology, shapefiles can create problems in some GIS analysis, such as topology-based map overlay and network analysis. Use of shapefiles, however, has two main advantages: (1) they display more rapidly on a view than ARC/INFO coverages, and (2) they are not proprietary and can be used directly in other GIS software packages such as MapInfo and GeoMedia.

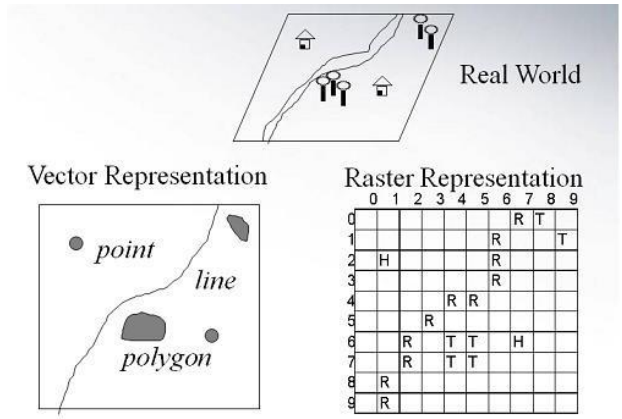
Shapefiles can be converted to ARC/INFO coverages, and vice versa. The conversion from a shapefile to a coverage requires the building of topological relationships and the removal of duplicate arcs. The conversion from a coverage to a shapefile is simpler. But if a coverage has topological errors, such as lines not joined perfectly, the errors can result in missing features in the shapefile.

1.2. Raster Data Model

The raster data model uses a regular grid to cover the space and the value in each grid cell to correspond to the characteristic of a spatial phenomenon at the cell location. Conceptually, the variation of the spatial phenomenon is reflected by the changes in the cell value. Raster data have been described as field-based, as opposed to object-based vector data. A wide variety of data used in GIS are encoded in raster format. They include digital elevation data, satellite images, digital orthophotos, scanned maps, and graphic files. Most GIS packages can display raster and vector data simultaneously, and can convert from raster to vector data or from vector to raster data. Raster data also introduce a large set of data analysis functions to GIS. Integration of both vector and raster data is a common feature in a GIS project.

A grid consists of rows, columns, and cells. The origin of rows and columns is at the upper left corner of the grid. Rows function as Y coordinates and columns as X coordinates in a two-dimensional coordinate system. A cell is defined by its location in terms of row and column. The cell size determines the resolution of the raster data model. A cell size of 30 meters means that each cell measures 30 × 30 meters.

Raster data represent points by single cells, lines by sequences of neighboring cells, and areas by collections of contiguous cells. Each cell in a grid carries a value, either an integer or a floating-point value (a value with decimal digits). Integer cell values typically represent categorical data (i.e., nominal or ordinal data). For example, a land cover model may use 1 for urban land use, 2 for forested land, 3 for water bodies, and so on. Floating-point cell values represent continuous data (i.e., interval or ratio data). For example, a precipitation model may have precipitation values of 20.15 inch, 12.23 inch, and so forth.



MAP PROJECTIONS

A map projection is the transformation of Earth's curved surface (or a portion of) onto a two-dimensional flat surface by means of mathematical equations. During such transformation, the angular geographic coordinates (latitude, longitude) referencing positions on the surface of the Earth are converted to Cartesian coordinates (x, y) representing position of points on a flat map.

Map projection transforms the spatial relationship of map features on the Earth's surface to a flat map. Map projection enables a map user to work with two-dimensional coordinates, rather than spherical or three-dimensional coordinates. But the transformation from the Earth's surface to a flat surface always involves distortion and no map projection is perfect. This is why hundreds of map projections have been developed for mapmaking, each with its own parameters.

A coordinate system is based on a map projection. Plane coordinate systems are typically used in large-scale mapping such as a scale of 1:24,000 or larger. Coordinate systems are designed for detailed calculations and positioning. Therefore, accuracy in a feature's absolute position and its relative position to other features is more important than the preserved property of a map projection.

Map projections are grouped into four classes by their preserved properties: conformal, equal area or equivalent, equidistant, and azimuthal or true direction. A conformal projection preserves local shapes. An equivalent projection represents areas in correct relative size. An equidistant projection maintains consistency of scale for certain distances. An azimuthal projection retains certain accurate directions.

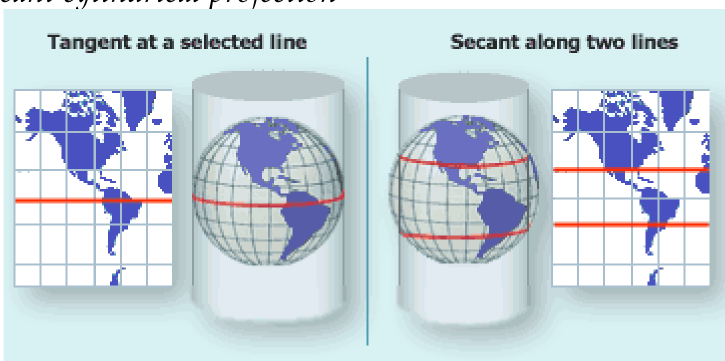
Cartographers often use a geometric object to illustrate how a map projection can be constructed. For example, by placing a cylinder tangent to a lighted globe, a projection can be made by tracing the lines of longitude and latitude onto the cylinder. The cylinder in this case is the projection surface, and the globe is called the reference globe. Other common projection surfaces include a cone and a plane. A map projection is called a cylindrical projection if it can be constructed using a cylinder, a conic projection using a cone, and an azimuthal using a plane.

One way of classifying map projections is by the type of the developable surface onto which the reference sphere is projected. A developable surface is a geometric shape that can be laid out into a flat surface without stretching or tearing. The three types of developable surfaces are cylinder, cone and plane, and their corresponding projections are called cylindrical, conical and planar.

Cylindrical projection

In cylindrical projections, the reference spherical surface is projected onto a cylinder wrapped around the globe. The cylinder is then cut lengthwise and unwrapped to form a flat map.

Tangent vs. secant cylindrical projection

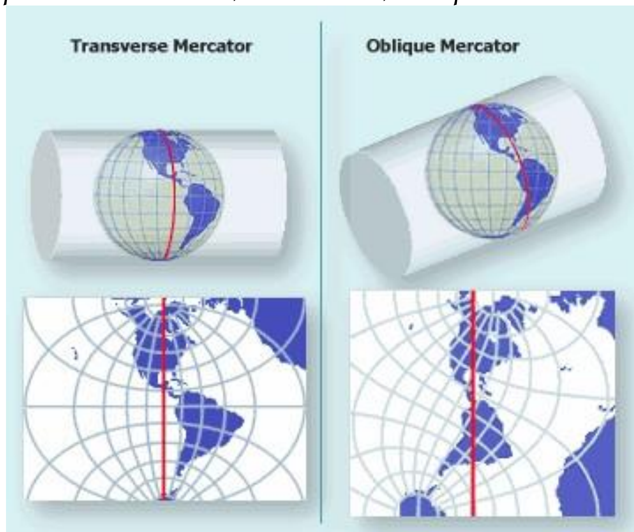


The cylinder may be either tangent or secant to the reference surface of the Earth. In the *tangent* case, the cylinder's circumference touches the reference globe's surface along a great circle (any circle having the same diameter as the sphere and thus dividing it into two equal halves). The diameter of the cylinder is equal to the diameter of the globe. The tangent line is the equator for the equatorial or normal aspect; while in the transverse aspect, the cylinder is tangent along a chosen meridian (i.e. central meridian). In the *secant* case, the cylinder intersects the globe; that is the diameter of the cylinder is smaller than the globe's. At the place where the cylinder cuts through the globe two secant lines are formed.

The tangent and secant lines are important since scale is constant along these lines (equals that of the globe), and therefore there is no distortion (*scale factor* = 1). Such lines of *true scale* are called *standard lines*. These are lines of equidistance. Distortion increases by moving away from standard lines.

In normal aspect of cylindrical projection, the secant or standard lines are along two parallels of latitude equally spaced from equator, and are called *standard parallels*. In transverse aspect, the two standard lines run north-south parallel to meridians. Secant case provides a more even distribution of distortion throughout the map. Features appear smaller between secant lines (scale < 1) and appear larger outside these lines (scale > 1).

Cylindrical aspect - equatorial (normal), transverse, oblique



The aspect of the map projection refers to the orientation of the developable surface relative to the reference globe. The graticule layout is affected by the choice of the aspect.

In *normal* or *equatorial aspect*, the cylinder is oriented (lengthwise) parallel to the Earth's polar axis with its center located along the equator (tangent or secant). The meridians are vertical and equally spaced; the parallels of latitude are horizontal straight lines parallel to the equator with their spacing increasing toward the poles. Therefore the distortion increases towards the poles. Meridians and parallels are perpendicular to each other. The meridian that lies along the projection center is called the central meridian.

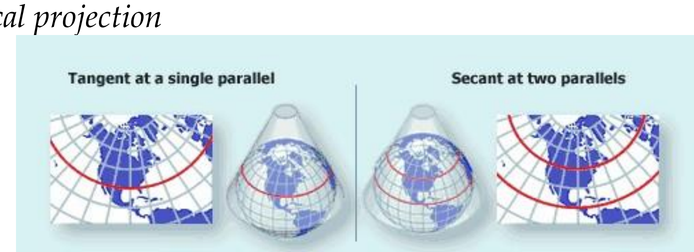
In *transverse aspect*, the cylinder is oriented perpendicular to the Earth's axis with its center located on a chosen meridian (a line going through the poles). And the *oblique aspect* refers to the cylinder being centered along a great circle between the equator and the meridians with its orientation at an angle greater than 0 and less than 90 degrees relative to the Earth's axis.

Examples of cylindrical projections include *Mercator*, *Transverse Mercator*, *Oblique Mercator*, *Plate Carré*, *Miller Cylindrical*, *Cylindrical equal-area*, *Gall-Peters*, *Hobo-Dyer*, *Behrmann*, and *Lambert Cylindrical Equal-Area* projections.

Conical (conic) projection

In *conical* or *conic projections*, the reference spherical surface is projected onto a cone placed over the globe. The cone is cut lengthwise and unwrapped to form a flat map.

Tangent vs. secant conical projection



The cone may be either tangent to the reference surface along a small circle (any circle on the globe with a diameter less than the sphere's diameter) or it may cut through the globe and be secant (intersect) at two small circles.

For the *polar* or *normal aspect*, the cone is tangent along a parallel of latitude or is secant at two parallels. These parallels are called *standard parallels*. This aspect produces a map with meridians radiating out as straight lines from the cone's apex, and parallels drawn as concentric arcs perpendicular to meridians.

Scale is true (scale factor = 1) and there is no distortion along standard parallels. Distortion increases by moving away from standard parallels. Features appear smaller between secant parallels and appear larger outside these parallels. Secant projections lead to less overall map distortion.

Conical aspect - equatorial (normal), transverse, oblique

The *polar aspect* is the *normal aspect* of the conic projection. In this aspect the cone's apex is situated along the polar axis of the Earth, and the cone is tangent along a single parallel of latitude or secant at two parallels. The cone can be situated over the North or South Pole. The polar conic projections are most suitable for maps of mid-latitude (temperate zones) regions with an east-west orientation such as the United States.

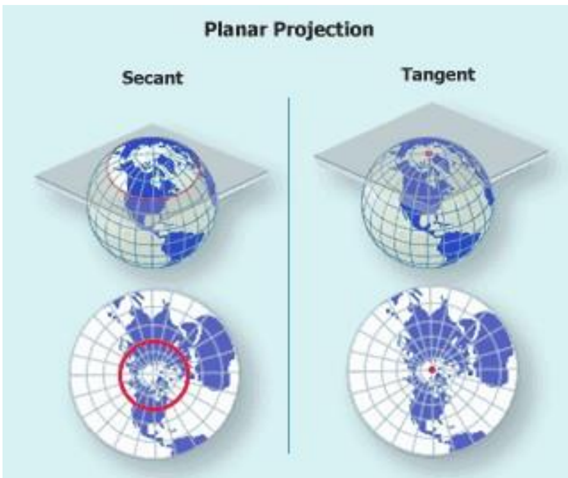
In *transverse aspect* of conical projections, the axis of the cone is along a line through the equatorial plane (perpendicular to Earth's polar axis). *Oblique aspect* has an orientation between transverse and polar aspects. Transverse and oblique aspects are seldom used.

Examples of conic projections include *Lambert Conformal Conic*, *Albers Equal Area Conic*, and *Equidistant Conic* projections.

Planar projection – Azimuthal or Zenithal

In *planar* (also known as *azimuthal* or *zenithal*) projections, the reference spherical surface is projected onto a plane.

Tangent vs. secant planar projection



The plane in planar projections may be tangent to the globe at a single point or may be secant. In the secant case the plane intersects the globe along a small circle forming a *standard parallel* which has true scale. The normal polar aspect yields parallels as concentric circles, and meridians projecting as straight lines from the center of the map.

The distortion is minimal around the point of tangency in the tangent case, and close to the standard parallel in the secant case.

Planar aspect - polar (normal), transverse (equatorial), oblique

The *polar aspect* is the normal aspect of the planar projection. The plane is tangent to North or South Pole at a single point or is secant along a parallel of latitude (standard parallel). The polar aspect yields parallels of latitude as concentric circles around the center of the map, and meridians projecting as straight lines from this center. Azimuthal projections are used often for mapping Polar Regions, the polar aspect of these projections are also referred to as *polar azimuthal* projections.

In transverse aspect of planar projections, the plane is oriented perpendicular to the equatorial plane. And for the oblique aspect, the plane surface has an orientation between polar and transverse aspects.

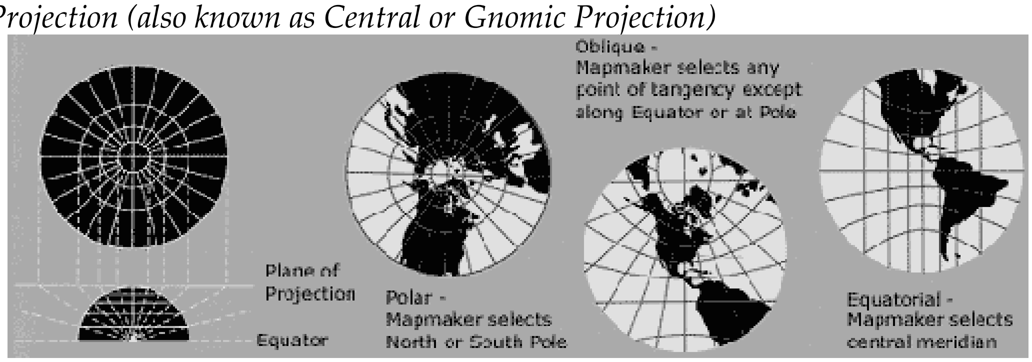
These projections are named *azimuthal* due to the fact that they preserve direction property from the center point of the projection. Great circles passing through the center point are drawn as straight lines.

Examples of azimuthal projections include: *Azimuthal Equidistant*, *Lambert AzimuthalEqual-Area*, *Gnomonic*, *Stereographic*, and *Orthographic* projections.

Azimuthal Perspective Projections

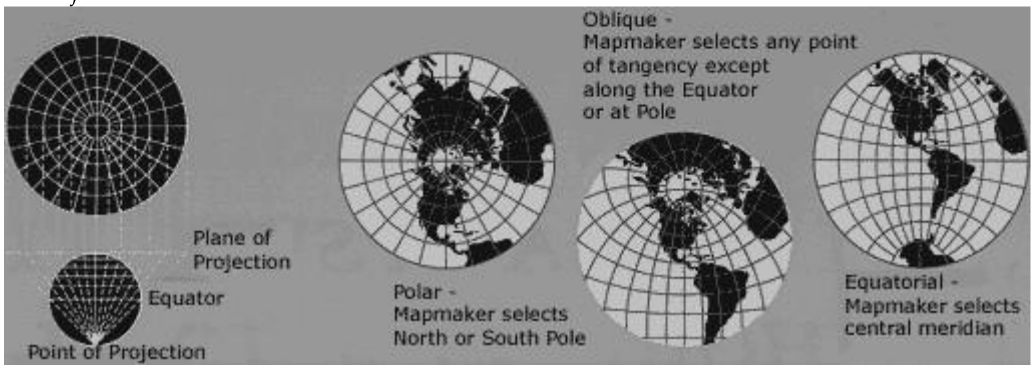
Some classic azimuthal projections are *perspective projections* and can be produced geometrically. They can be visualized as projection of points on the sphere to the plane by shining rays of light from a light source (or point of perspective). Three projections, namely gnomonic, stereographic and orthographic can be defined based on the location of the perspective point or the light source.

Gnomonic Projection (also known as Central or Gnomic Projection)



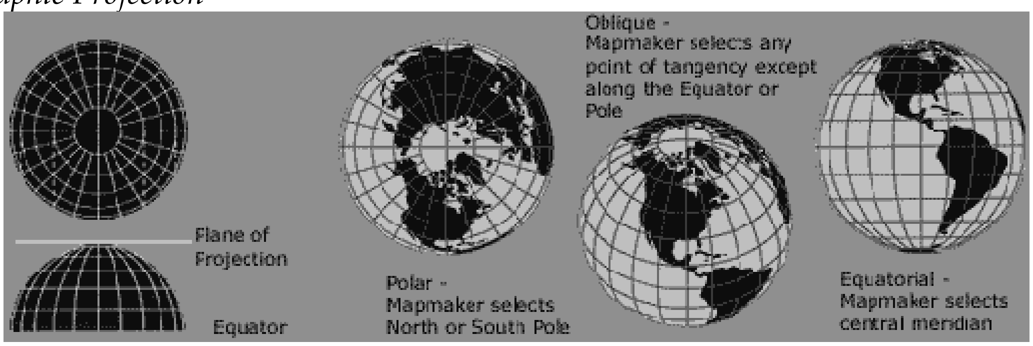
The point of perspective or the light source is located at the center of the globe in gnomonic projections. Great circles are the shortest distance between two points on the surface of the sphere (known as great circle route). Gnomonic projections map all great circles as straight lines, and such property makes these projections suitable for use in navigation charts. Distance and shape distortion increase sharply by moving away from the center of the projection.

Stereographic Projection



In stereographic projections, the perspective point is located on the surface of globe directly opposite from the point of tangency of the plane. Points close to center point show great distortion on the map. Stereographic projection is a *conformal projection*, that is over small areas angles and therefore shapes are preserved. It is often used for mapping Polar Regions (with the source located at the opposite pole).

Orthographic Projection



In orthographic projections, the point of perspective is at infinite distance on the opposite direction from the point of tangency. The light rays travel as parallel lines. The resulting map from this projection looks like a globe (similar to seeing Earth from deep space). There is great distortion towards the borders of the map.

COORDINATE SYSTEM

A coordinate system is a reference system used for locating objects in a two or three dimensional space.

(i) Geographic Coordinate System

A geographic coordinate system, also known as global or spherical coordinate system is a reference system that uses a three-dimensional spherical surface to determine locations on the earth. Any location on earth can be referenced by a point with longitude and latitude.

We must familiarize ourselves with the geographic terms with respect to the Earth coordinate system in order to use the GIS technologies effectively.

Pole: The geographic pole of earth is defined as either of the two points where the axis of rotation of the earth meets its surface. The North Pole lies 90º north of the equator and the South Pole lies 90º south of the equator.

Latitude : Imaginary lines that run horizontally around the globe and are measured from 90º north to 90º south. Also known as parallels, latitudes are equidistant from each other.

Equator : An imaginary line on the earth with zero degree latitude, divides the earth into two halves–Northern and Southern Hemisphere. This parallel has the widest circumference.

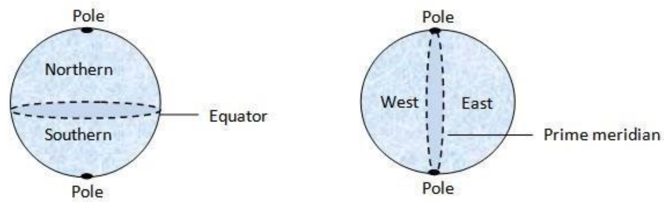


Fig: Division of earth into hemispheres

Longitude : Imaginary lines that run vertically around the globe. Also known as meridians, longitudes are measured from 180º east to 180º west. Longitudes meet at the poles and are widest apart at the equator

Prime meridian : Zero degree longitude which divides the earth into two halves–Eastern and Western hemisphere. As it runs through the Royal Greenwich Observatory in Greenwich, England it is also known as Greenwich meridian

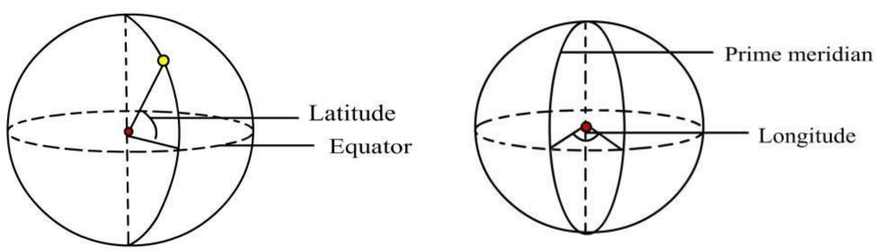


Fig: Latitude and longitude measurements

Equator (0º) is the reference for the measurement of latitude. Latitude is measured north or south of the equator. For measurement of longitude, prime meridian (0º) is used as a reference. Longitude is measured east or west of prime meridian. The grid of latitude and longitude over the globe is known as graticule. The intersection point of the equator and the prime meridian is the origin (0, 0) of the graticule.

Coordinate measurement

The geographic coordinates are measured in angles. The angle measurement can be understood as per following:

A full circle has 360 degrees	1 circle = 360º
A degree is further divided into 60 minutes	1º = 60′
A minute is further divided into 60 seconds	1′ = 60″

An angle is expressed in Degree Minute Second. While writing coordinates of a location, latitude is followed by longitude. For example, coordinates of Delhi is written as 28° 36′ 50″ N, 77° 12′ 32″ E. Decimal Degree is another format of expressing the coordinates of a location. To convert a coordinate pair from degree minute second to decimal degree following method is adopted:

$$
\begin{aligned}
28° 36′ 50″ &= 28 + (36*1/60) + (50 *1/60*1/60) \\
&= 28 + 0.6 + 0.0138 \\
&= 28.6138
\end{aligned}
$$

We have 28 full degrees, 36 minutes - each 1/60 of a degree, and 50 seconds - each 1/60 of 1/60 of a degree. While writing coordinates of a location, latitude is followed by longitude. For example, coordinates of Delhi is written as. Similarly 77° 12′ 32″ can be written as 77.2088. So, we can write coordinates of Delhi in decimal degree format as: 28.6138 N, 77.2088 E.

Local Time and Time Zones

With rotation of earth on its axis, at any moment one of the longitudes faces the Sun (noon meridian), and at that moment, it is noon everywhere on it. After 24 hours the earth completes one full rotation with respect to the Sun, and the same meridian again faces the noon. Thus each hour the Earth rotates by 360/24 = 15 degrees. This implies that with every 15º of longitude change a new time zone is created which is marked by a difference of one hour from the neighboring longitudes specified at 15º gap. The earth's time zones are measured from the prime meridian (0º) and the time at Prime meridian is called Greenwich Mean Time. Thus, there are 24 time zones created around the globe.

Date

The International Date Line is the imaginary line on the Earth that separates two consecutive calendar days. Generally, it is said to be lying exactly opposite to the prime meridian having a measurement of 180º meridian but it is not so. It zigs and zags the 180º meridian following the political jurisdiction of the states but for sake of simplicity it is taken as 180º meridian. Starting at midnight and going east to the International Date Line, the date is one day ahead of the date on the rest of the Earth.

(ii) Projected Coordinate system

A projected coordinate system is defined as two dimensional representation of the Earth. It is based on a spheroid geographic coordinate system, but it uses linear units of measure for coordinates. It is also known as Cartesian coordinate system.

In such a coordinate system the location of a point on the grid is identified by (x, y) coordinate pair and the origin lies at the centre of grid. The x coordinate determines the horizontal position and y coordinate determines the vertical position of the point.

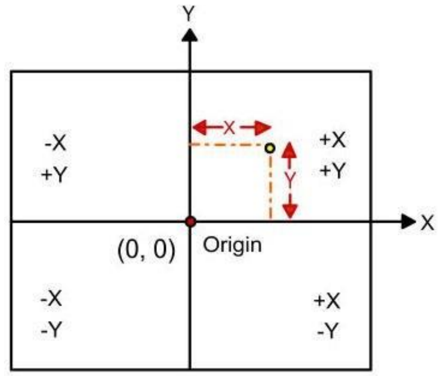


Fig: Cartesian coordinate system

In such a coordinate system the location of a point on the grid is identified by (x, y) coordinate pair and the origin lies at the centre of grid. The x coordinate determines the horizontal position and y coordinate determines the vertical position of the point.

GIS AND INFORMATION SYSTEMS

GIS is only one of a number of new technologies for handling geographic information in digital form. Another is remote sensing, which provides an increasingly important source of data, with the powerful advantage that it is global in scope. The Global Positioning System (GPS) is a constellation of satellites designed to allow position on the Earth's surface to be determined to a known level of accuracy. Each satellite transmits signals that are precisely timed by on-board atomic clocks; a receiver on Earth is able to resolve position in three dimensions if at least four satellite signals are being received. A simple hand-held receiver, available for a few hundred dollars, is capable of determining position to an accuracy of tens of meters, and versions of the technology exist capable of determining relative position to centimeter accuracy, and to meters in vehicles moving at speed. A technically distinct Russian system can be used in conjunction with GPS to improve positioning.

One unexpected consequence of the widespread use of GIS, for ocean and air navigation and for positioning scientific observations, is that it exposes the inaccuracies in much of the world's published mapping, and the inconsistencies between the mathematical figures of the Earth that support mapping. Unfortunately for global change science, mapping remains an activity of strategic importance in many parts of the Earth, and there are very significant gaps in scientific access to good base mapping. GIS makes increasing use of electronic communication. There are now many archives of geographic information of value to global change science that are accessible to anyone connected to the Internet. The EOS (Earth Observing System) Data and Information System (EOSDIS) is one prominent example. With no more than a standard World Wide Web browser, a user is able to access the archive, browse its contents, and in many cases download large and potentially valuable data sets. Such archives of geographic information are being sponsored by national and state governments, non-governmental organizations, universities, and research libraries. It is also increasingly possible to manipulate the data in an archive at its source, allowing full use of GIS functions without the necessity to download what is often a very large set of data.

Definition for GIS

A geographic **information system** (**GIS**) is a **system** designed to capture, store, manipulate, analyze, manage, and present all types of geographical data for decision making.

HISTORY OF GIS DEVELOPMENT

The idea of portraying different layers of data on a series of base maps, and relating things geographically, has been around much older than computers invention. Thousands years ago, the early man used to draw pictures of the animals they hunted on the walls of caves. These animal drawings are track lines and tallies thought to depict migration routes. While simplistic in comparison to modern technologies, these early records mimic the two-element structure of modern geographic information systems, an image associated with attribute information.

Possibly the earliest use of the geographic method, in 1854 John Snow depicted a cholera outbreak in London using points to represent the locations of some individual cases. His study of the distribution of cholera led to the source of the disease, a contaminated water pump within the heart of the cholera outbreak. While the basic elements of topology and theme existed previously in cartography, the John Snow map was unique, using cartographic methods, not only to depict but also to analyze, clusters of geographically dependent phenomena for the first time.

The early 20th century saw the development of "photo lithography" where maps were separated into layers. Computer hardware development spurred by nuclear weapon research led to general-purpose computer "mapping" applications by the early 1960s. In the year 1962, the world's first true operational GIS was developed by the federal Department of Forestry and Rural Development in Ottawa, Canada by Dr. Roger Tomlinson. It was called the "Canada Geographic Information System" (CGIS) and was used to store, analyze, and manipulate data collected for the Canada Land Inventory (CLI). It is an initiative to determine the land capability for rural Canada by mapping information about soils, agriculture, recreation, wildlife, forestry, and land use at a scale of 1:50,000.

CGIS was the world's first "system" and was an improvement over "mapping" applications as it provided capabilities for overlay, measurement, and digitizing or scanning. It supported a national coordinate system that spanned the continent, coded lines as "arcs" having a true embedded topology, and it stored the attribute and location specific information in a separate files. Dr. Tomlinson is known as the "father of GIS," for his use of overlays in promoting the spatial analysis of convergent geographic data.

In 1964, Howard T Fisher formed the Laboratory for Computer Graphics and Spatial Analysis at the Harvard Graduate School of Design, where a number of important theoretical concepts in spatial data handling were developed. This lab had major influence on the development of GIS until early 1980s. Many pioneers of newer GIS "grew up" at the Harvard lab and had distributed seminal software code and systems, such as 'SYMAP', 'GRID', and 'ODYSSEY'.

By the early 1980s, M&S Computing (later Intergraph), Environmental Systems Research Institute (ESRI) and CARIS emerged as commercial vendors of GIS software, successfully incorporating many of the CGIS features, combining the first generation approach to separation of spatial and attribute information with a second generation approach to organizing attribute data into database structures. More functions for user interaction were developed mainly in a graphical way by a user friendly interface (Graphical User Interface), which gave to the user the ability to sort, select, extract, reclassify, reproject and display data on the basis of complex geographical, topological and statistical criteria. During the same time, the development of a public domain GIS begun by the U.S. Army Corp of Engineering Research Laboratory (USA-CERL) in Champaign, Illinois, a branch of the U.S. Army Corps of Engineers to meet the need of the United States military for software for land management and environmental planning.

In the years 1980s and 1990s industry growth were spurred on by the growing use of GIS on Unix workstations and the personal computers. By the end of the 20th century, the rapid growth in various systems had been consolidated and standardized on relatively few platforms and users were beginning to export the concept of viewing GIS 4 data over the Internet, requiring uniform data format and transfer standards. More recently, there is a growing number of free, open source GIS packages, which run on a range of operating systems and can be customized to perform specific tasks. As computing power increased and hardware prices slashed down, the GIS became a viable technology for state development planning. It has become a real Management Information System (MIS), and thus able to support decision making processes.

COMPONENTS OF GIS

GIS enables the user to input, manage, manipulate, analyze, and display geographically referenced data using a computerized system. To perform various operations with GIS, the components of GIS such as software, hardware, data, people and methods are essential.

Software

GIS software provides the functions and tools needed to store, analyze, and display geographic information. Key software components are (a) a database management system (DBMS) (b) tools for the input and manipulation of geographic information (c) tools that support geographic query, analysis, and visualization (d) a graphical user interface (GUI) for easy access to tools. GIS software are either commercial software or software developed on Open Source domain, which are available for free. However, the commercial software is copyright protected, can be expensive and is available in terms number of licensees. Currently available commercial GIS software includes Arc/Info, Intergraph, MapInfo, Gram++ etc. Out of these Arc/Info is the most popular software package. And, the open source software are AMS/MARS etc.

Hardware

Hardware is the computer on which a GIS operates. Today, GIS runs on a wide range of hardware types, from centralized computer servers to desktop computers used in stand-alone or networked configurations. Minimum configuration required to Arc/Info Desktop 9.0 GIS application is as follows:

Product: ArcInfo Desktop 9.0
Platform: PC-Intel
Operating System: Windows XP Professional Edition, Home Edition
Service Packs/Patches: SP 1
SP2 (refer to Limitations)
Shipping/Release Date: May 10, 2004

Hardware Requirements
CPU Speed: 800 MHz minimum, 1.0 GHz recommended or higher
Processor: Pentium or higher
Memory/RAM: 256 MB minumum, 512 MB recommended or higher
Display Properties: Greater than 256 color depth
Swap Space: 300 MB minimum
Disk Space: Typical 605 MB NTFS, Complete 695 MB FAT32 + 50 MB for installation
Browser: Internet Explorer 6.0 Requirement:
(Some features of ArcInfo Desktop 9.0 require a minimum installation of Microsoft Internet Explorer Version 6.0.)

Data

The most important component of a GIS is the data. Geographic data or Spatial data and related tabular data can be collected in-house or bought from a commercial data provider. Spatial data can be in the form of a map/remotely-sensed data such as satellite imagery and aerial photography. These data forms must be properly georeferenced (latitude/longitude). Tabular data can be in the form attribute data that is in some way related to spatial data. Most GIS software comes with inbuilt Database Management Systems (DBMS) to create and maintain a database to help organize and manage data.

Users

GIS technology is of limited value without the users who manage the system and to develop plans for applying it. GIS users range from technical specialists who design and maintain the system to those who use it to help them do their everyday work. 6 These users are largely interested in the results of the analyses and may have no interest or knowledge of the methods of analysis. The user-friendly interface of the GIS software allows the nontechnical users to have easy access to GIS analytical capabilities without needing to know detailed software commands. A simple User Interface (UI) can consist of menus and pull-down graphic windows so that the user can perform required analysis with a few key presses without needing to learn specific commands in detail.

Methods

A successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization.

GIS SOFTWARE

Geographic information can be accessed, transferred, transformed, overlaid, processed and displayed using numerous software applications. Within industry commercial offerings from companies such as ESRI and Mapinfo dominate, offering an entire suite of tools. Government and military departments often use custom software, open source products, such as Gram++, GRASS, or more specialized products that meet a well-defined need. Free tools exist to view GIS datasets and public access to geographic information is dominated by online resources such as Google Earth and interactive web mapping.

Originally up to the late 1990s, when GIS data was mostly based on large computers and used to maintain internal records, software was a stand-alone product. However with increased access to the Internet and networks and demand for distributed geographic data grew, GIS software gradually changed its entire outlook to the delivery of data over a network. GIS software is now usually marketed as combination of various interoperable applications and APIs.

GIS Software Examples

File software for a geographical information system may be split into five functional groups. (a) Data input and verification (b) Data storage and database management (c) Data output and presentation (d) Data transformation (e) Interaction with the user. (f) Environmental Systems Research Institute (ESRI): ArcInfo, ArcView. (g) Autodesk: AutoCAD Map (h) Clark Labs: IDRISI (i) International Institute for Aerospace Survey and Earth Sciences: ILWIS (j) Mapinfo Corporation: Mapinfo. (k) Bentley Systems: Microstation. (l) PCI Geomatics: PAMAP (m)TYDAC Inc. : SPANS (n) Arc View Spatial Analyst (o) Arc View Network Analyst (p) Arc View 3D Analyst (q) GRASS from US Army Corps of Engineers (r) GRAMM++ for CSRE, IIT, Mumbai (s) Atlas GIS (t) CARIS (u) SYCAD.

OPEN-SOURCE SOFTWARE VS. PROPRIETARY SOFTWARE IN GIS

Open Source Software	Proprietary Software
It refers to the software that is developed and tested through open collaboration	It refers to the software that is solely owned by the individual or the organization that developed it.
Anyone with the academic knowledge can access, inspect ,modify and redistribute the source code .	Only the owner or publisher who holds the legal property rights of the source code can access it

The project is managed by an open source community of developer and programmers.	The project is managed by a closed group of individual or team that developed it.
They are not aimed at unskilled users outside of the programming community.	They are focused on a limited market of both skilled and unskilled end users.
It provides better flexibility which means more freedom which encourages innovation.	There is a very limited scope of innovation with the restrictions and all.
It is free of cost	It is expensive
Free Open Source Software (FOSS) is one of the open source organization	Environmental Research System Innovation is one of the commercial organization
More exploration and improvisation can be done	Fewer exploration and improvisation can be done
Example : OpenGeo, Quantum GIS	Examples: ArcGIS, ArcView
QGIS: 1. Quite less documentation for users 2. Supports different Operating System 3. Load time speed is faster 4. Includes more additional plugins 5. Less mapping functionality	ArcGIS: 1. Elaborated documentation for users 2. Only supports Windows 3. Load time speed is slower 4. Includes more additional addins 5. More mapping functionality

DATA TYPES

SPATIAL DATA

Spatial data (mapable data) of geo-referenced data is commonly characterized by the presence of two fundamental components. (i) The physical dimension or class i.e., the phenomena being reported. For example : Height of the forest canopy, demographic class, rock type, regetation type details of a city etc. (ii) The spatial location of the phgenomena For example : Specified with reference to common coordinate system (latitude and longitude etc).

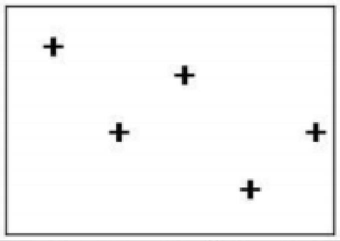
NON SPATIAL / ATTRIBUTE / A SPATIAL OR TABULAR DATA

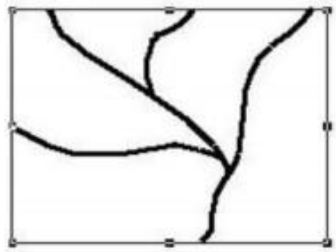
There are usually data tables that contain information about the spatialcomponents of the GIS theme. These can be numeric and/or character data such as timber type, timber volume, road size, well depth etc. The attributes are related back to the spatial features by use of unique identifiers that are stored both with the attribute tables and the features in each spatial data layer. Attributes can be either qualitative (low, medium, high income) or quantitative (actual measurements). The database allows us to manipulate information in many ways : from simple listing of attributes, sorting features by some attributes, grouping by attributes, or selecting and singling out groups by attributes.

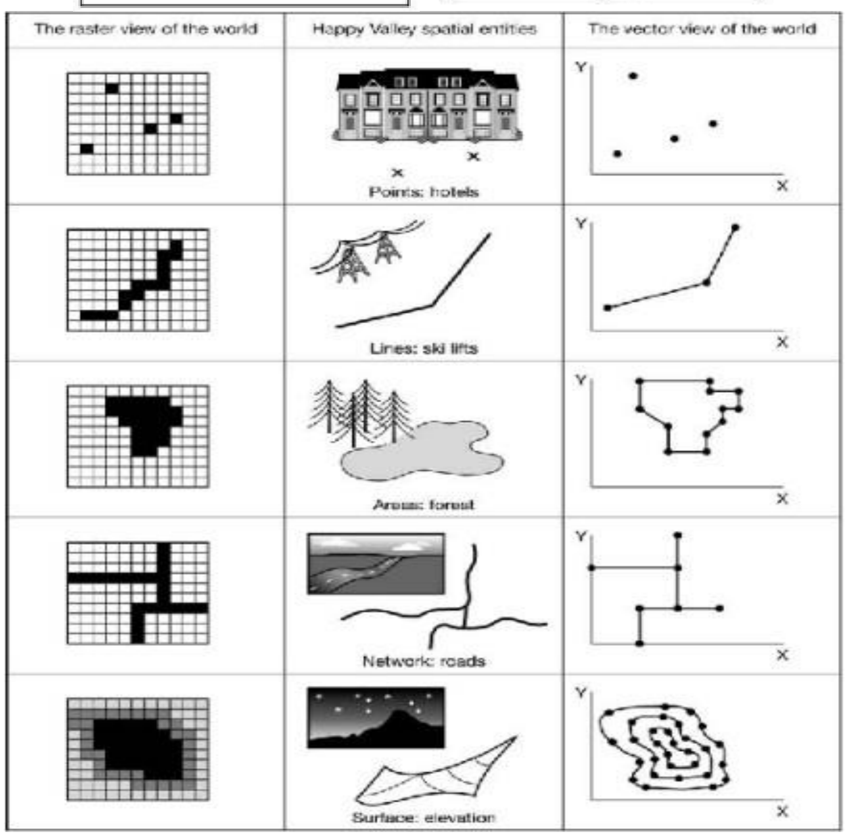
VECTOR DATA
A vector based GIS is defined by the vectorial representation of its geographic data. The most common representation of map is using vector date that is consist of point, line and polygon

A. Vector data

i. Point Data -- layers described by points (or "event") described by x,y (lat,long; east, north)







ii. Line/Polyline Data -- layers that are described by x,y points (nodes, events) and lines (arcs) between points (line segments and polylines)

iii. Polygon Data -- layers of closed line segments enclosing areas that are described by attributes

B. Raster data

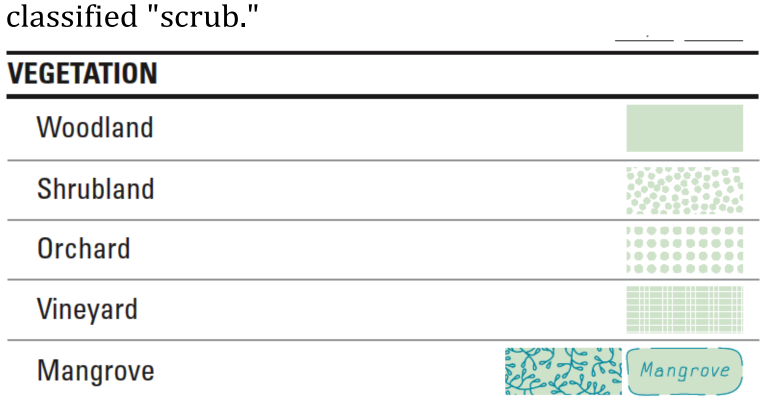
Consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.

LEVELS OF MEASUREMENT

Standardized scales are needed to measure non-spatial attributes as well as spatial features. Unlike positions and distances, however, attributes of locations on the Earth's surface are often not amenable to absolute measurement. In a 1946 article in Science, a psychologist named S. S. Stevens outlined a system of four levels of measurement meant to enable social scientists to systematically measure and analyze phenomena that cannot simply be counted. (In 1997, geographer Nicholas Chrisman pointed out that a total of nine levels of measurement are needed to account for the variety of geographic data.) The levels are important to specialists in geographic information because they provide guidance about the proper use of different statistical, analytical, and cartographic operations. In the following, we consider examples of Stevens' original four levels of measurement: nominal, ordinal, interval, and ratio.

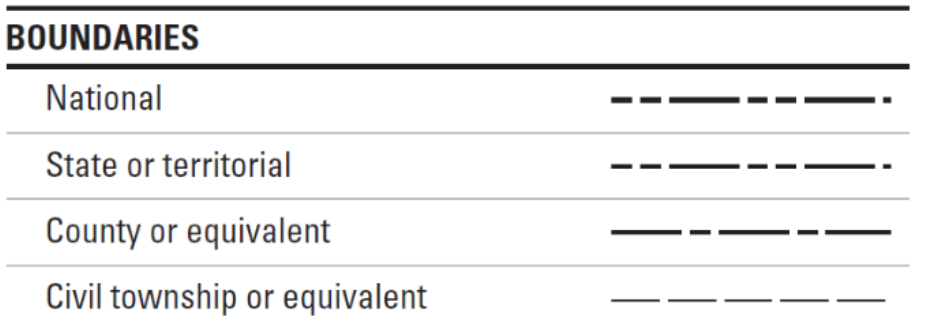
Nominal Level

The term nominal simply means to relate to the word "name." Simply put, nominal level data are data that are denoted with different names (e.g., forest, water, cultivated, wetlands), or categories. Data produced by assigning observations into unranked categories are nominal level measurements. In relation to terminology used in Chapter 1, nominal data are a type of categorical (qualitative) data. Specifically, nominal level data can be differentiated and grouped into categories by "kind," but are not ranked from high to low. For example, one can classify the land cover at a certain location as woods, scrub, orchard, vineyard, or mangrove. There is no implication in this distinction, however, that a location classified as "woods" is twice as vegetated as another location classified "scrub."



Ordinal Level

Like the nominal level of measurement, ordinal scaling assigns observations to discrete categories. Ordinal categories, however, are ranked, or ordered – as the name implies. It was stated in the preceding section that nominal categories such as "woods" and "mangrove" do not take precedence over one another, unless a set of priorities is imposed upon them. This act of prioritizing nominal categories transforms nominal level measurements to the ordinal level. Because the categories are not based upon a numerical value (just an indication of an order or importance), ordinal data are also considered to be categorical (or qualitative).



Interval Level

Unlike nominal- and ordinal-level data, which are categorical (qualitative) in nature, interval level data are numerical (quantitative). Examples of interval level data include temperature and year. With interval level data, the zero point is arbitrary on the measurement scale. For instance, zero degrees Fahrenheit and zero degrees Celsius are different temperatures.

Ratio Level

Similar to interval level data, ratio level data are also numerical (quantitative). Examples of ratio level data include distance and area (e.g., acreage). Unlike the interval level measurement scale, the zero is not arbitrary for ratio level data. For example, zero meters and zero feet mean exactly the same thing, unlike zero degrees Fahrenheit and zero degrees Celsius (both temperatures). Ratio level data also differs from interval level data in the mathematical operations that can be performed with the data. An implication of this difference is that a quantity of 20 measured at the ratio scale is twice the value of 10 (20 meters is twice the distance of 10 meters), a relation that does not hold true for quantities measured at the interval level (20 degrees is not twice as warm as 10 degrees).

Interval and Ratio Level Data

The scales for both interval and ratio level data are similar in so far as units of measurement are arbitrary (Celsius versus Fahrenheit and English versus metric units). These units of measurement are split evenly for each successive value (e.g., 1 meter, 2 meters (add 1 meter), 3 meters (add 1 meter), 4 meters (add 1 meter). Because interval and ratio level data represent positions along continuous number lines, rather than members of discrete categories, they are also amenable to analysis using statistical techniques.

Categorical		Scalar	
Nominal	**Ordinal**	**Interval**	**Ratio**
Presence/absence Counting Diff. in degree or quality Equality of category	Sequence Rel. position < , > , =	Differences Arbitrary Zero + , -	Ratio Real Zero * , /
Classification	**Ordering**	**Measuring**	
name of city type of land use name of highway	large city wettest soil primary highway	angle or bearing in degrees (cycle)	number of people, passengers distance

Advantages of using GIS technology

- It has the ability of improving the organizational integration. GIS would then integrate software, hardware and also data in order to capture, analyse, manage and so display all forms of information being geographically referenced.
- GIS would also allow viewing, questioning, understanding, visualizing and interpreting the data into numbers of ways which will reveal relationships, trends and patterns in the form of globes, maps, charts and reports.
- Geographic Information System is to provide a help in answering questions as well as solve problems through looking at the data in a way which is easily and quickly shared.
- GIS technology could also be integrated into framework of any enterprise information system.
- And there would be numbers of employment opportunities.

Disadvantages of using GIS technology

- GIS technology might be considered as expensive software.
- It as well requires enormous data inputs amount that are needed to be practical for some other tasks and so the more data that is to put in.
- Since the earth is round and so there would be geographic error that will increase as you get in a larger scale.
- GIS layers might lead to some costly mistakes once the property agents are to interpret the GIS map or the design of the engineer around the utility lines of the GIS.
- There might be failures in initiating or initiating additional effort in order to fully implement the GIS but there might be large benefits to anticipate as well.