3️⃣

Unit - 3

9
Introduction to GIS
Elements of GIS
cartography
Maps and types
Coordinate system
Projection
Datum
GIS - data types
Spatial and non-spatial data
Data input - Methods
Digitization
Errors in digitization
Data output - Methods
Software modules
Vector data structure
Topology
Raster data structure
Merits and demerits

PYQ →

28. a. Discuss on
(i) Components of GIS 7
(ii) Universal Transverse Mercator System 3

(OR)

b. Describe the raster data structure with neat sketches. 10

Notes →

GIS →

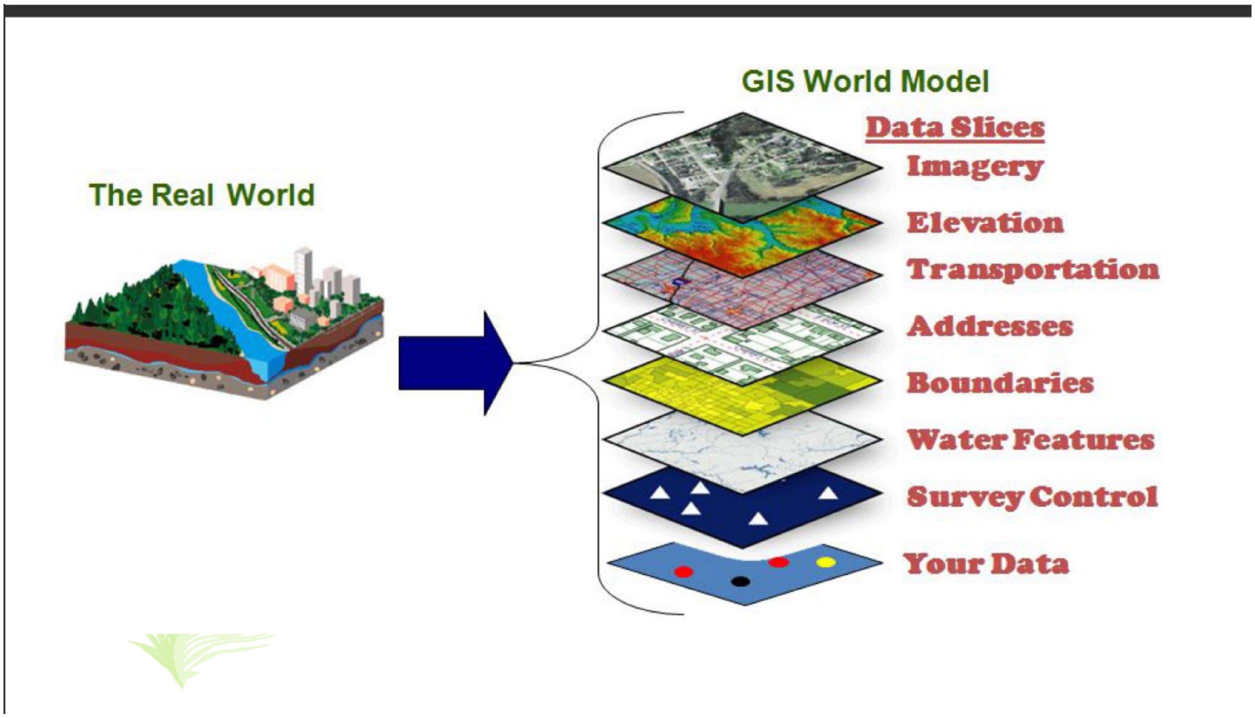
GIS stands for Geographic Information System. It is a technology that allows users to capture, analyze, interpret, visualize, and present data related to specific geographic locations on the Earth's surface. GIS combines hardware, software, data, and people to work with various types of geographic information. Here's a more detailed explanation of GIS:

1. **Geographic Information**: GIS deals with data that has a geographic or spatial component. This data can include information about locations, such as latitude and longitude coordinates, addresses, or even the boundaries of countries, states, and cities.
2. **Data Collection**: GIS involves the collection of various types of geographic data. This can be done through GPS devices, remote sensing (e.g., satellite imagery, aerial photography), surveys, and other methods. Data can also come from existing sources, such as government databases, weather records, or demographic information.
3. **Data Storage**: GIS systems store geographic data in a structured manner. This data can be stored in databases, files, or distributed across servers. It's organized in a way that makes it easy to retrieve and analyze.
4. **Data Analysis**: One of the primary functions of GIS is to analyze geographic data. This can involve spatial analysis, where relationships between different geographic features are explored. For example, you could use GIS to determine the proximity of a school to a residential area or analyze the spread of a disease in a region.
5. **Data Visualization**: GIS tools provide powerful visualization capabilities. You can create maps, charts, and graphs to represent geographic data. This helps in

understanding and communicating the information effectively. Visualization is essential for decision-making and planning.

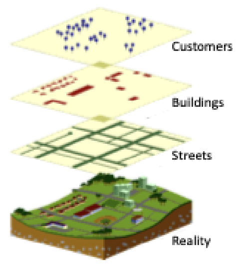
6. **Data Interpretation**: GIS allows users to interpret the data in a spatial context. By overlaying different layers of data, you can identify patterns and trends that might not be evident in tabular data. This can be crucial in making informed decisions.
7. **Data Presentation**: GIS enables the creation of informative and visually appealing maps and reports. These can be used for presentations, reports, and publications. It's a valuable tool for conveying information to a wide range of audiences.
8. **Decision Support**: GIS is used in a wide range of applications, including urban planning, environmental management, disaster response, logistics, and more. It provides decision-makers with valuable insights into geographic aspects of their work, helping them make better decisions.
9. **Geospatial Software**: A variety of software tools are available for GIS, ranging from open-source solutions like QGIS to commercial options like ArcGIS. These tools offer various features for data manipulation, analysis, and visualization.
10. **Interdisciplinary Field**: GIS is not limited to a single discipline. It's used in geography, urban planning, environmental science, geology, transportation, agriculture, and many other fields. It's an interdisciplinary technology that has applications in numerous domains.

In summary, GIS is a technology that enables the handling and analysis of geographic data, allowing for better decision-making, planning, and understanding of the world around us. It has become an indispensable tool in various industries and research fields.

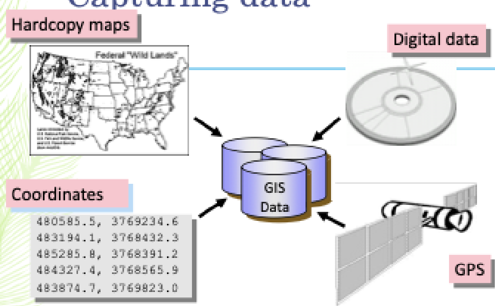

GIS World Model
Data Slices
The Real World
Imagery
Elevation
Transportation
Addresses
Boundaries
Water Features
Survey Control
Your Data

GIS functions

- Capture
- Store
- Query
- Analyze
- Display
- Output

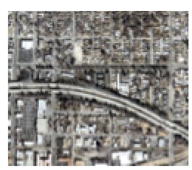


Capturing data



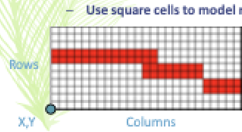
Storing data

- Vector formats
  - Discrete representations of reality



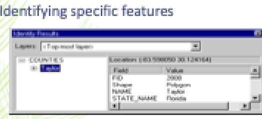
Reality
(A highway)

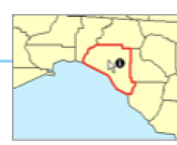
- Raster formats
  - Use square cells to model reality



Query

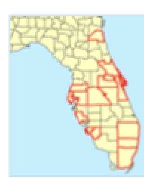
- Identifying specific features

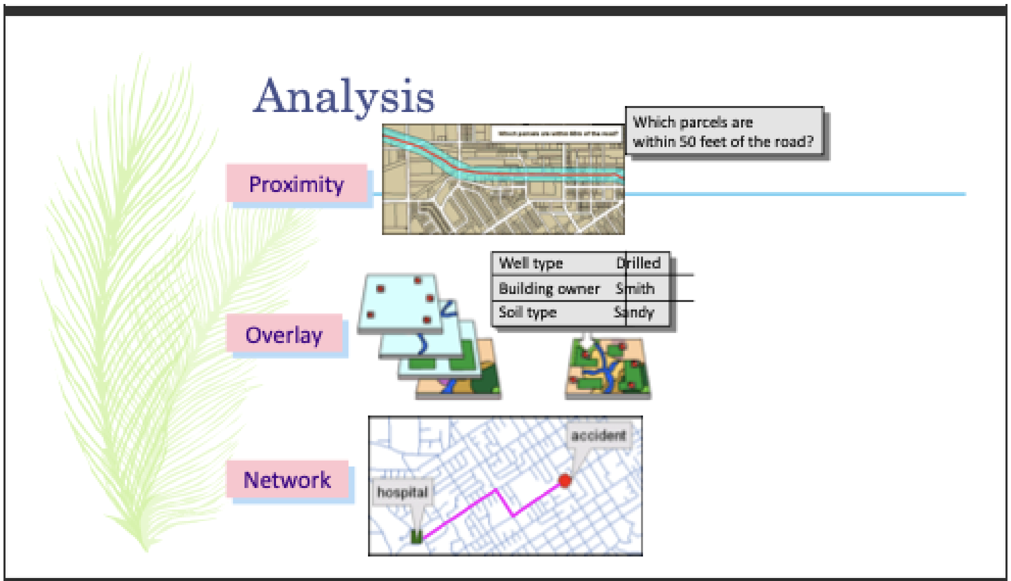


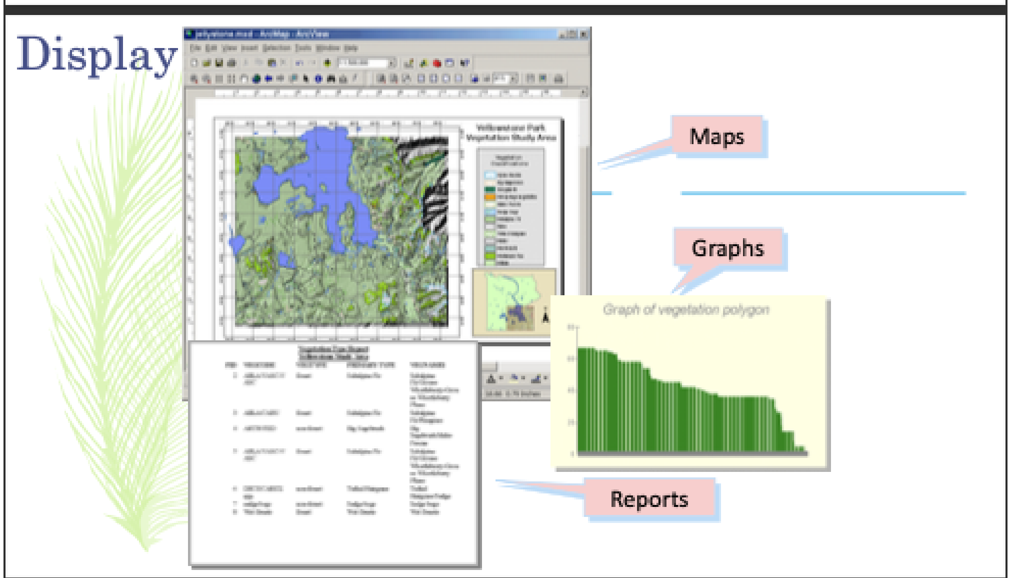


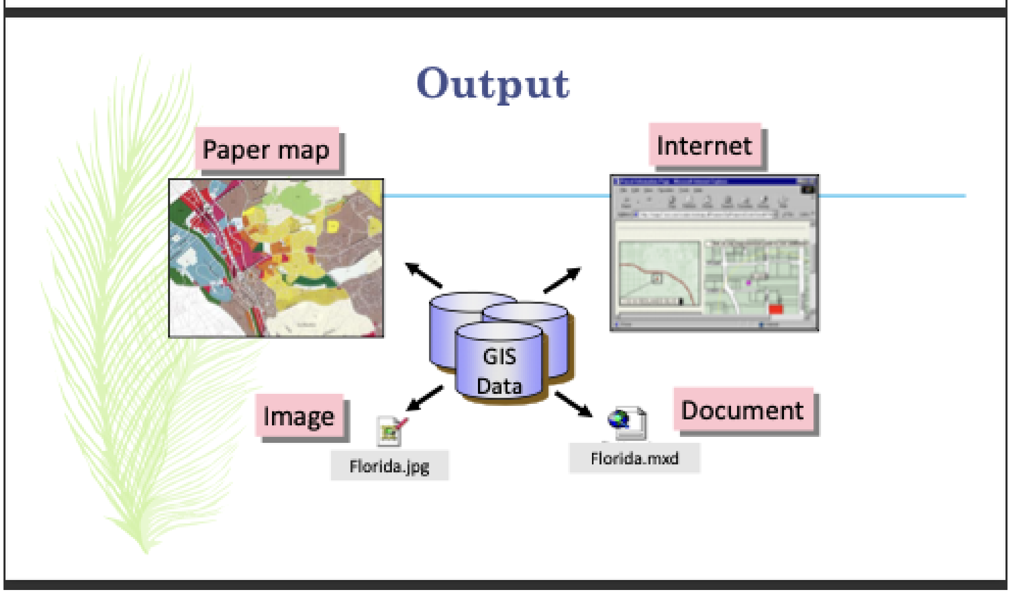
- Identifying features based on conditions

Florida counties with a population greater than 300,000

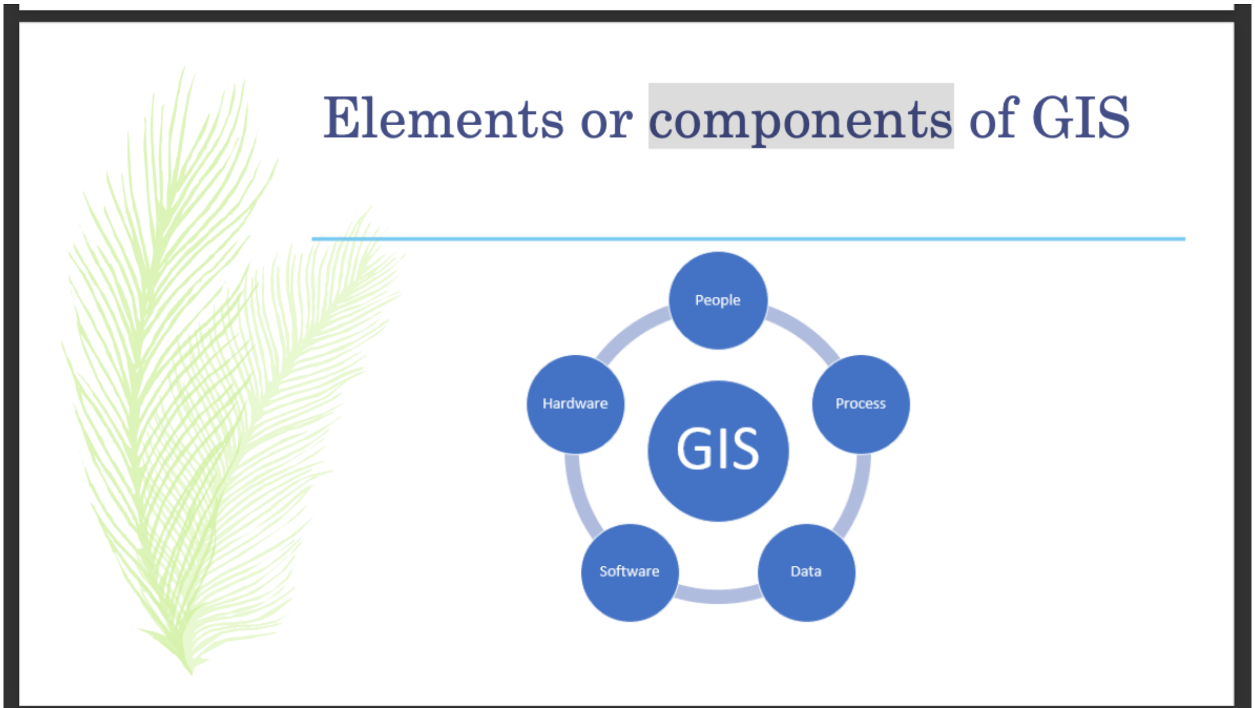


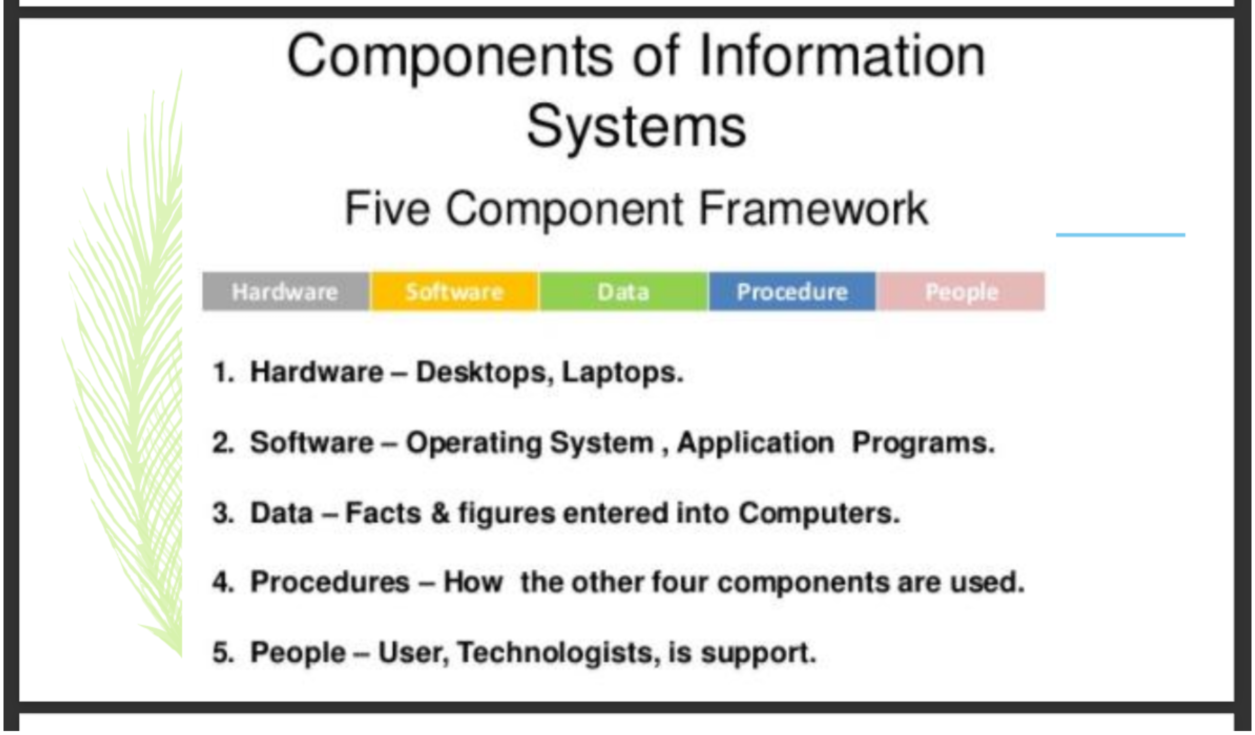

Analysis
Proximity
Which parcels are within 50 feet of the road?
Overlay
Well type Drilled
Building owner Smith
Soil type Sandy
Network
hospital
accident


Display
Maps
Graphs
Graph of vegetation polygon
Reports


Output
Paper map
Internet
GIS Data
Image
Florida.jpg
Document
Florida.mxd

Components of GIS →





Geographic Information Systems (GIS) consist of several key components that work together to manage and analyze geographic data. These components include:

1. **Hardware**: The hardware component of GIS refers to the physical equipment and devices used to capture, store, process, and display geographic data. This can include computers, servers, GPS receivers, tablets, smartphones, scanners, and specialized devices for remote sensing.
2. **Software**: GIS software is the heart of any GIS system. It provides the tools and capabilities to create, edit, analyze, and visualize geographic data. Popular GIS software includes ArcGIS, QGIS, MapInfo, and various open-source options. GIS software often includes functions for data management, mapping, spatial analysis, and cartography.
3. **Data**: Data is a critical component of GIS. Geographic data can be categorized into two types:
    - **Spatial Data**: This represents the geographic locations and shapes of features on the Earth's surface. Spatial data includes points, lines, polygons, and raster images. Examples of spatial data include road networks, land parcels, and satellite imagery.
    - **Attribute Data**: This data describes the characteristics or attributes of geographic features. For example, attribute data for a set of cities might include population, elevation, and average annual temperature.

    High-quality and accurate data is essential for GIS applications. Data can be collected through surveys, remote sensing, and existing sources, such as government databases and satellite imagery.
4. **People**: GIS relies on skilled professionals who use the software and data to perform tasks like data collection, analysis, and map creation. These professionals include GIS analysts, technicians, cartographers, and database administrators. Training and expertise are crucial for making the most of GIS technology.
5. **Methods and Procedures**: GIS involves various methods and procedures for data collection, analysis, and visualization. These methods can include geospatial analysis techniques, data modeling, and cartographic principles. Standard operating procedures are often established to ensure consistency and quality in GIS work.

Cartography →

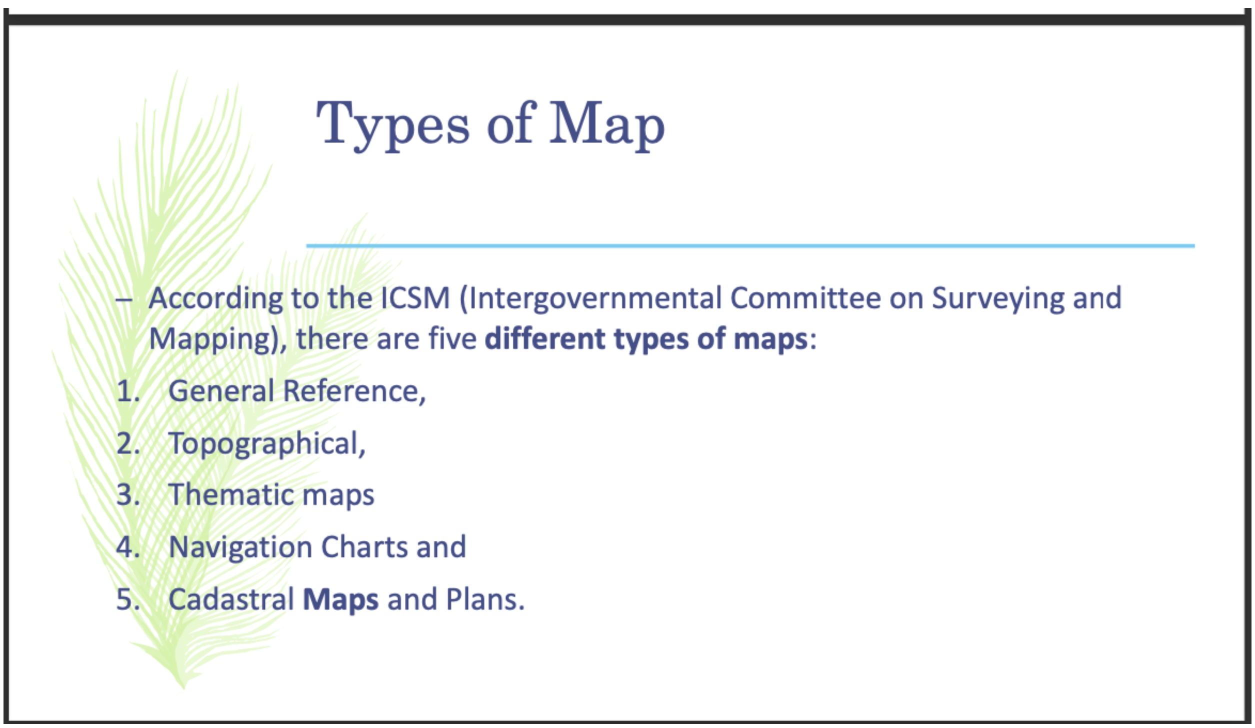
The art and science of graphically representing a geographical area, usually on a flat surface

such as a map or chart. It may involve the superimposition of political, cultural, or other non
geographical divisions onto the representation of a geographical area.

Map →

A map is a visual representation of an area, showing the spatial relationships between various features, objects, and phenomena. Maps are essential tools for understanding and navigating the physical world. There are several types of maps, each designed for specific purposes. Here are some common types of maps:

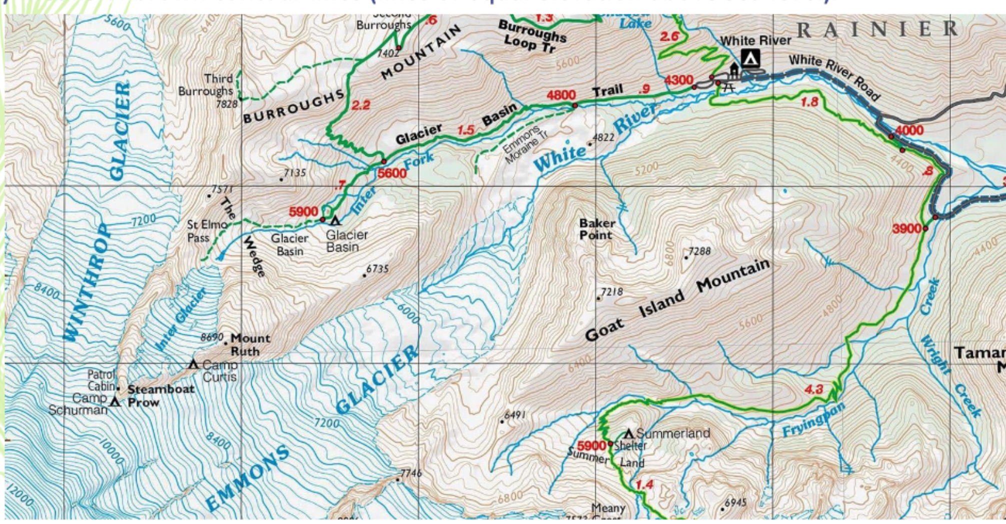
1.



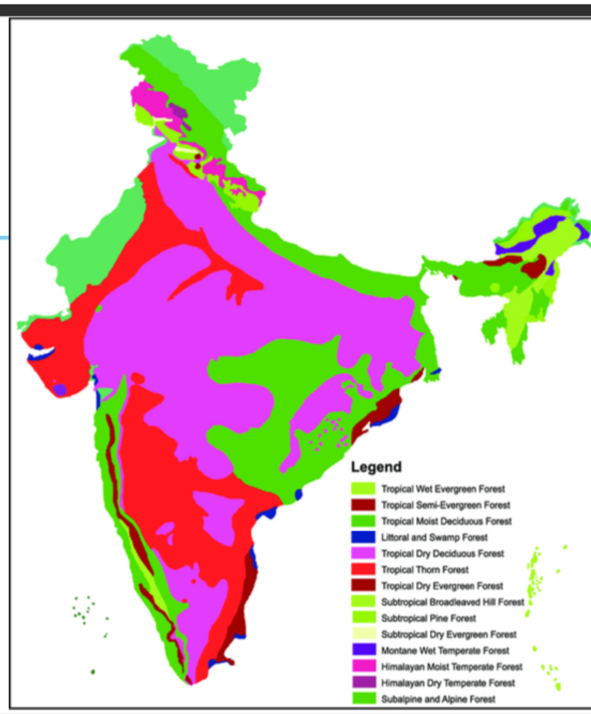
General Reference

– Think of a regular map, where cities and towns are named, major transport routes are included along with natural features like lakes and rivers, and you'll be thinking of a general reference map. These are the maps that are ideal for helping you to get to your destination – they tend to be easy to read, and include street and tourist maps, and we can't think of many better examples than HERE maps.

– **Topographic maps** are a detailed record of a land area, giving geographic positions and elevations for both natural and man-made features. They show the shape of the land the mountains, valleys, and plains by **means** of brown contour lines (lines of equal elevation above sea level).

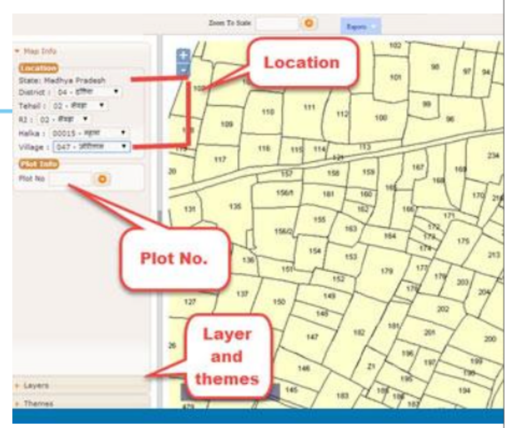


– A thematic map is a type of map specifically designed to show a particular theme connected with a specific geographic area, such as temperature variation, rainfall distribution or population density.



– A cadastre is a comprehensive land recording of the real estate or real property's metes-and-bounds of a country. In most countries, legal systems have developed around the original administrative systems and use the cadastre to define the dimensions and location of land parcels described in legal documentation.

– **A cadastral map** is a map which provides detailed information about **real property** within a specific area. A simple example of a cadastral map might be a map of a village which shows the boundaries of all of the parcels or lots within the village, although cadastral maps can show other types of areas as well. These maps are usually maintained by the government, and they are a matter of public record; anyone who wishes to go to the office which maintains the records can ask to see them.



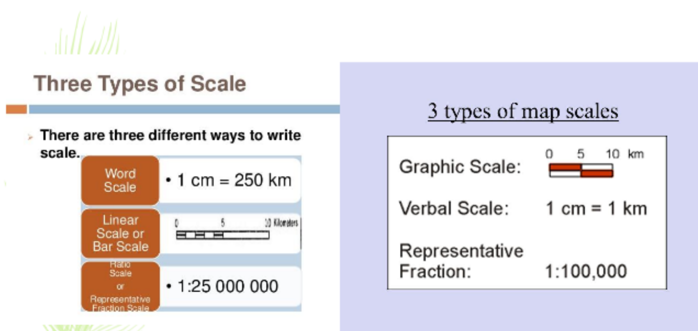
Map Components →

Map components/Elements

- Maps contain lots of information. Most maps will have the five following elements
- **Title**,
- **Legend**,
- Grid,
- Compass Rose to indicate **direction**, and
- **Scale**.

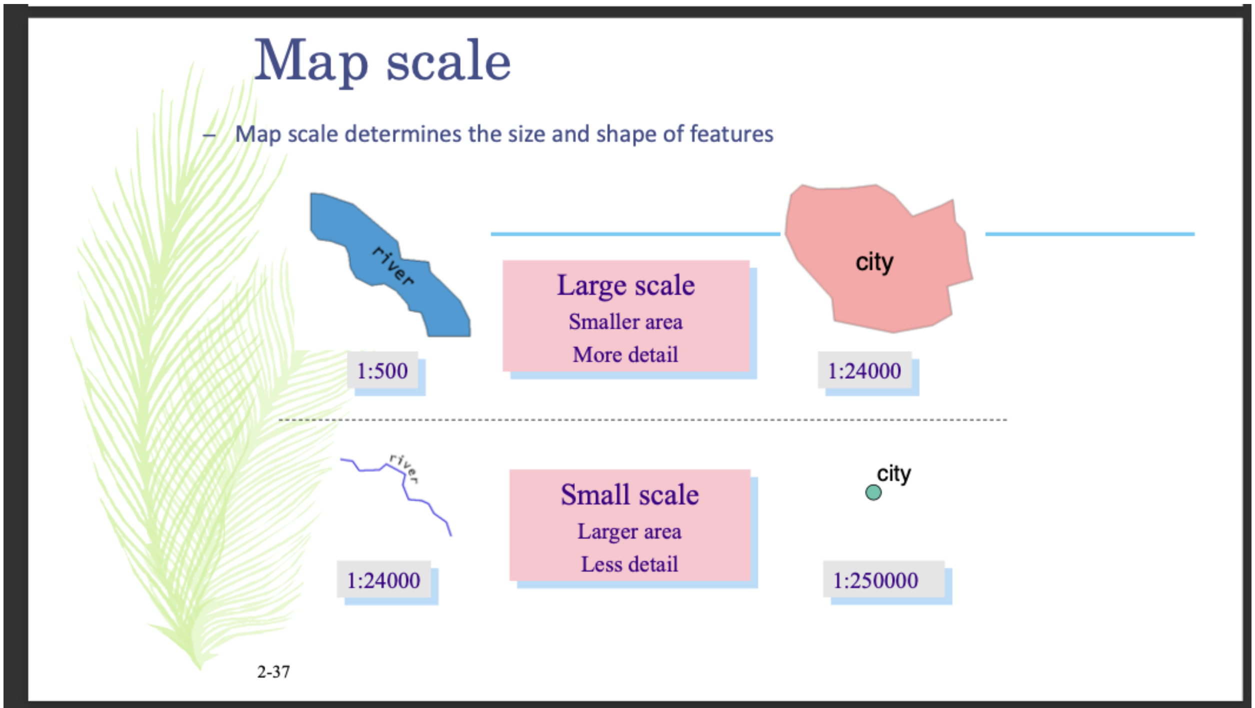
- Scale is the relationship that the depicted feature on map has to its actual size in the real word (more: *map scale*).
- All maps are modeled representations of the real world and therefore the features are reduced in size when mapped. In other words, scale is the measurement of the amount of reduction a mapped feature has to its actual counterpart on the ground.
- There are **three** main ways that **scale** is indicated on a **map**:

1. graphic (or bar),
2. verbal, and
3. representative fraction (RF).



Large scale map and small scale map

- Large scale maps show a smaller amount of area with a greater amount of detail. The geographic extent shown on a large scale map is small. A large scaled map expressed as a representative scale would have a smaller number to the right of the ratio. For example, a large scale map could have a RF scale of 1 : 1,000. Large scale maps are typically used to show neighborhoods, a localize area, small towns, etc.
- Small scale maps show a larger geographic area with few details on them. The RF scale of a small scale map would have a much larger number to the right of the colon such as 1 : 1,000,000. Small scale maps are used to show the extent of an entire country, region, or continent.



Based on scale: Large , Medium and small
Ways of expressing scale of a map: Representative Fraction (RF), Statement /Verbal,Graphical/Bar

Typical RF	1:1000 1:5,000 1:10,000	1:20,000 1:50,000 1:100,000	1:1,000,000 1:2,500,000
Description	LARGE-SCALE	MEDIUM-SCALE	SMALL-SCALE
Characteristics	• Depict small features • Show geometric shapes	• Small features disappear • Generalize geometric shapes • Good compromise between map detail and extent of map coverage	• Symbolize features, e.g., areas represented by point or line symbols • Show macro features, e.g., climatic zones

Coordinate System →

A coordinate system is a mathematical framework used to specify the precise location of points in space or on a plane. It allows you to describe the position of objects, features, or events in a standardized way, typically using numerical values or coordinates. There are various types of coordinate systems, and the choice of system depends on the context and application.

COORDINATE SYSTEM

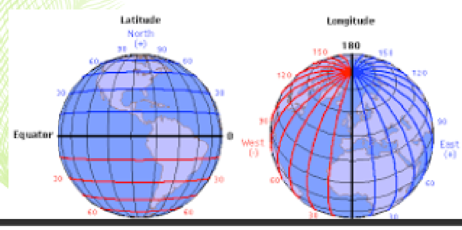
A coordinate system is a reference system used to represent the locations of geographic features, imagery, and observations such as GPS locations within a common geographic framework.

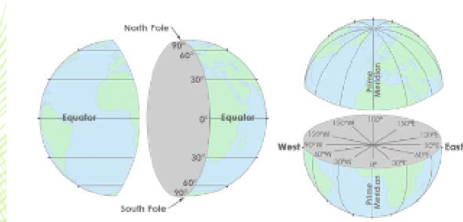
Coordinate systems (either geographic or projected) provide a framework for defining real-world locations.

Coordinate system

- Each coordinate system is defined by the following:
- Its measurement framework, which is either geographic (in which spherical coordinates are measured from the earth's center) or planimetric (in which the earth's coordinates are projected onto a two-dimensional planar surface)
- Units of measurement (typically feet or meters for projected coordinate systems or decimal degrees for latitude-longitude)
- The definition of the map projection for projected coordinate systems
- Other measurement system properties such as a spheroid of reference, a datum, one or more standard parallels, a central meridian, and possible shifts in the x- and y-directions

- **Latitude, Longitude**
- **Latitude** lines run east-west and are parallel to each other. If you go north, latitude values increase. Finally, latitude values (Y-values) range between -90 and +90 degrees
- But **longitude** lines run north-south. They converge at the poles. And its X-coordinates are between -180 and +180 degrees.
- Latitude and longitude coordinates make up our geographic coordinate system.



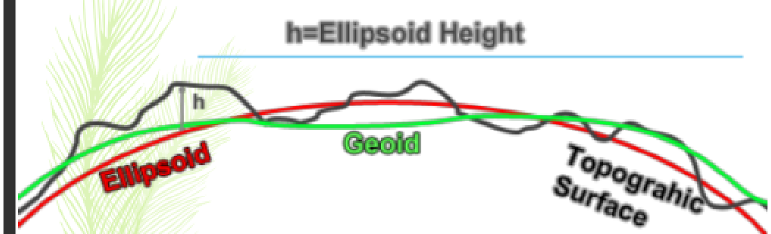


20.5937° N, 78.9629° E

Types of coordinate systems

- Horizontal **coordinate systems** locate data across the surface of the earth, and vertical **coordinate systems** locate the relative height or depth of data. Horizontal **coordinate systems** can be of three **types**: geographic, projected, or local.
- Geographic coordinate systems
- A geographic coordinate system (GCS) uses a three-dimensional spherical surface to define locations on the earth.
- Projected coordinate systems
- A projected coordinate system (PCS) is defined on a flat, two-dimensional surface. Unlike a GCS, a PCS has constant lengths, angles, and areas across the two dimensions. A PCS is always based on a GCS that is based on a sphere or spheroid. In addition to the GCS, a PCS includes a map projection, a set of projection parameters that customize the map projection for a particular location, and a linear unit of measure.

- **Vertical coordinate systems** are either gravity-based or ellipsoidal. Gravity-based vertical coordinate systems reference a mean sea level calculation. Ellipsoidal coordinate systems reference a mathematically derived spheroidal or ellipsoidal volumetric surface.



A **geographic coordinate** system (GCS) uses a three-dimensional spherical surface to define locations on the earth. Geographic coordinates based on a spheroid is **geodetic coordinates**

A projected coordinate system based on a map projection to project features of the earth's spherical surface onto a two dimensional Cartesian coordinate plane.

DATUM →

DATUM

Mathematical model of the earth which serves as the reference or base for calculating the geographic coordinates of a location.

It consists of a origin, parameter of the spheroid, and separation of spheroid and earth at the origin.

Projections →

A **map projection** is a systematic transformation of the latitudes and longitudes / all or part of surface of a sphere into locations on a plane.

Perspective	Non perspective
Geometric in nature	Perspective with modification to maintain area, distance, direction and shape

Many properties can be measured on the Earth's surface independent of its geography. Some of these properties are:

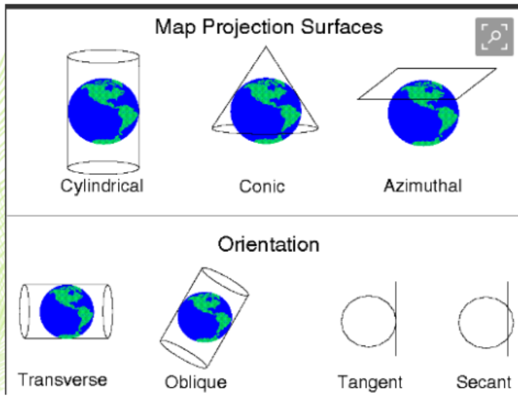
Area, Shape, Direction, Bearing, **Distance,** Scale

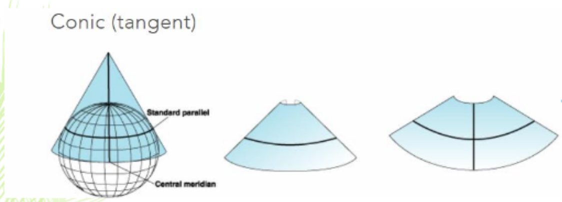
A map projection is a systematic method for representing the three-dimensional surface of the Earth on a two-dimensional plane, such as a map. Since the Earth is a three-dimensional object and maps are flat, some form of projection is necessary to accurately depict the Earth's surface. Map projections can introduce distortions in properties like area, shape, distance, and direction, and different projections are chosen based on the specific needs of a map and the region it represents. Here are some key concepts and types of map projections:

Key Concepts:

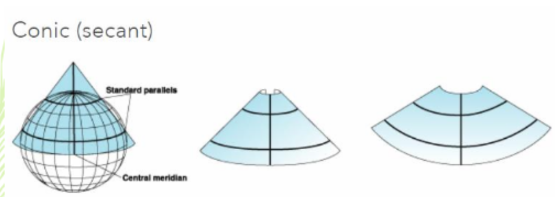
1. **Projection Surface**: The Earth's surface is projected onto a mathematical surface. Common projection surfaces include cones, cylinders, and planes. The choice of surface affects the properties of the projection.
2. **Secant and Tangent Lines**: Projections may have secant lines, where the projection surface intersects the Earth, or tangent lines, where it touches the Earth at a single point.
3. **Projection Parameters**: Map projections are defined by various parameters, including the central meridian, standard parallels, and false easting/northing. These parameters are used to customize a projection to fit a specific region.
4. **Distortion**: All map projections introduce some form of distortion. The type and extent of distortion depend on the projection method and the region being represented. Common types of distortion include area distortion, shape distortion, distance distortion, and direction distortion.

Types of Map Projections:

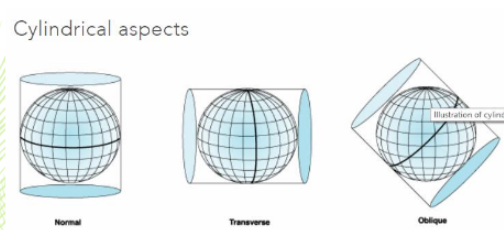




A cone is placed over a globe. The cone and globe meet along a latitude line. This is the standard parallel. The cone is cut along the line of longitude that is opposite the central meridian and flattened into a plane



A cone is placed over a globe but cuts through the surface. The cone and globe meet along two latitude lines. These are the standard parallels. The cone is cut along the line of longitude that is opposite the central meridian and flattened into a plane.

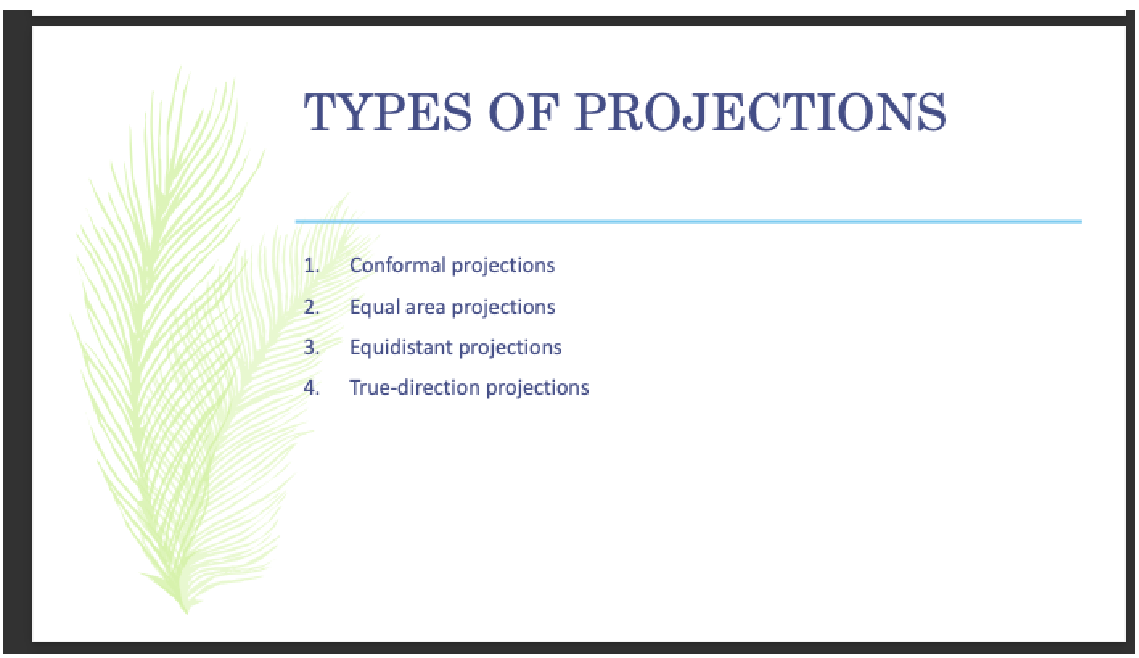


A cylinder is placed over a globe. The cylinder

1. **Cylindrical Projections**:

- These projections use a cylindrical surface to project the Earth onto a flat map.
- Examples include the Mercator projection (conformal), the Transverse Mercator projection (used in UTM), and the Miller projection.

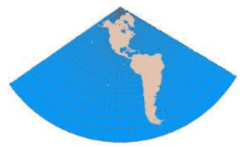
2. **Conic Projections**:
   - These projections use a cone to project the Earth's surface.
   - Examples include the Albers Equal Area Conic projection (equal area) and the Lambert Conformal Conic projection (conformal).
3. **Planar (Azimuthal) Projections**:
   - These projections project the Earth onto a flat plane.
   - Examples include the stereographic projection and the Lambert Azimuthal Equal Area projection.
4. **Pseudocylindrical Projections**:
   - These projections balance some distortions across the map.
   - Examples include the Robinson projection and the Mollweide projection.



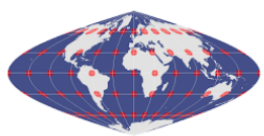
TYPES OF PROJECTIONS

1. Conformal projections
2. Equal area projections
3. Equidistant projections
4. True-direction projections

– A **conformal projection** is a map **projection** that favors **preserving** the shape of features on the map but may greatly **distort** the size of features.
– reserve Shape (only for small areas)
– Preserve Angles
– Used for Large Scale Mapping
– Distortion increases outwards from the central meridian and standard parallel Fig. Lambert conformal conic projection



– An **equal area projection** is a map projection that shows regions that are the same size on the Earth the same size on the map but may distort the shape, angle.

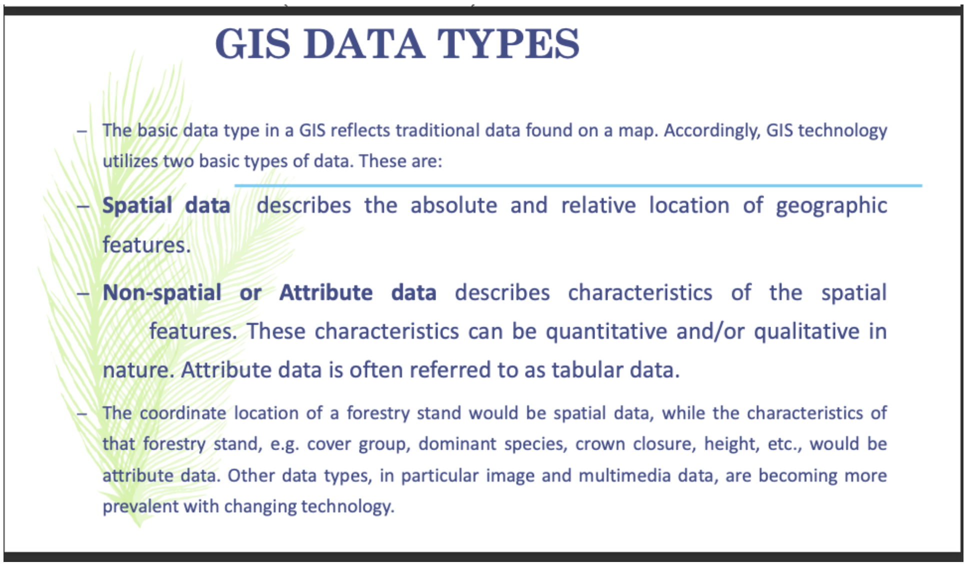


– Equidistance projections A **projection** that maintains scale along one or more lines, or from one or two points to all other points on the **map**. Lines along which scale (distance) is correct are the same proportional length as the lines they reference on the globe.

True directional projections

– Directions from a central point to all other points are maintained accurately in *azimuthal projections* (also known as *zenithal or true-direction projections*). These projections can also be equal area, conformal or equidistant.

GIS Data Types →



Vector Data Format →

VECTOR DATA format

Vector features (geographic objects with vector geometry) are a versatile and frequently used geographic data representation, well suited for representing features with discrete boundaries, such as wells, streets, rivers, states, and parcels.

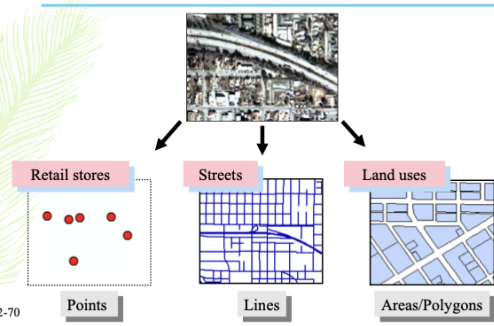
A feature is simply an object that has a location stored as one of its properties (or fields) in the row.

Features are spatially represented as points, lines, polygons, or annotation and are organized into feature classes.

Feature classes are collections of features of the same type with a common spatial representation and set of attributes (Eg. Line feature class for Roads).

Representing features in vector data

– Real-world entities are abstracted into three basic shapes



2-70

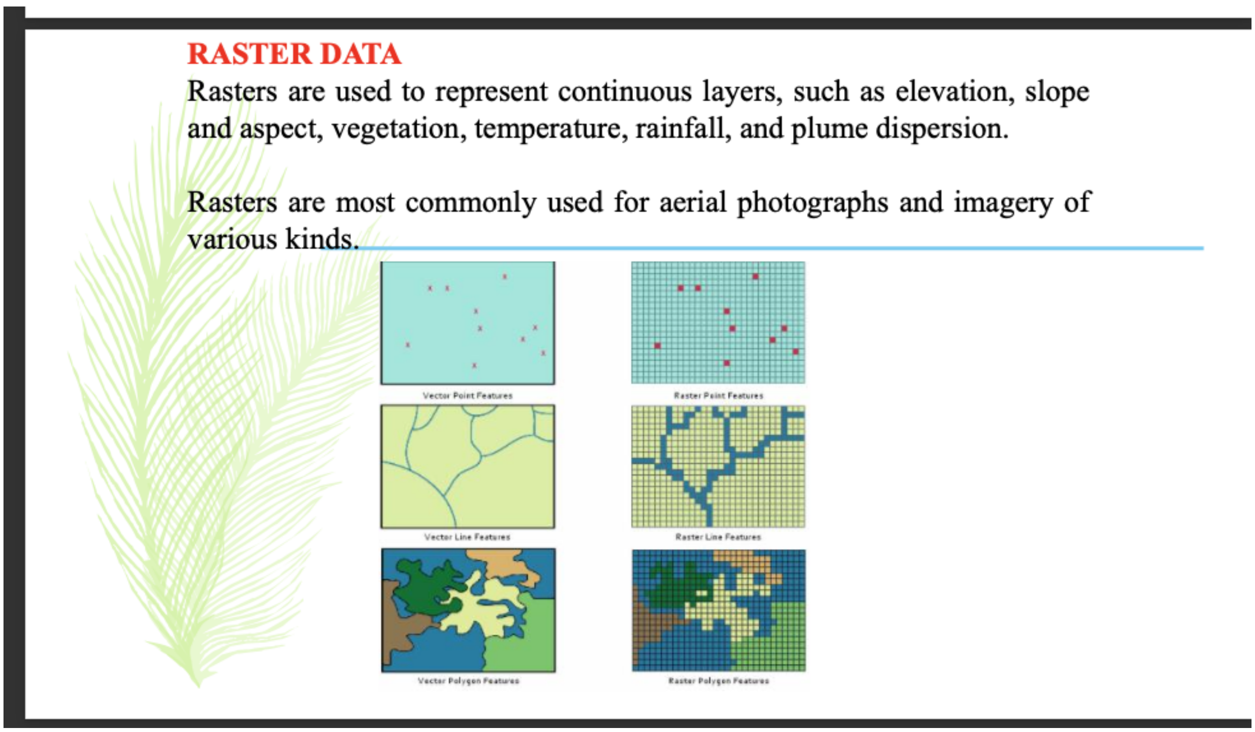
Vector data format is a way of representing geographic or spatial information using vectors, which are typically composed of points, lines, and polygons. This format is commonly used in Geographic Information Systems (GIS) and computer-aided design (CAD) software to store and manipulate spatial data. Vector data formats are more versatile and precise than raster data formats, which represent data as a grid of pixels.

Key characteristics of vector data formats include:

1. **Points**: Points are individual, discrete locations in space represented by their x, y (and sometimes z) coordinates. They are used to represent features like cities, wells, or any other specific point location.
2. **Lines**: Lines are used to represent linear features such as roads, rivers, and boundaries. They are composed of a series of connected points and are defined by their vertices (points) and attributes such as length or road type.

3. **Polygons**: Polygons are used to represent areas or regions. They are defined by a series of connected lines and enclosed by a boundary. Common examples include land parcels, administrative boundaries, and lakes.
4. **Attributes**: In vector data, each point, line, or polygon can have associated attributes. These attributes provide additional information about the feature, such as its name, population, or any other relevant data.

Raster Data →



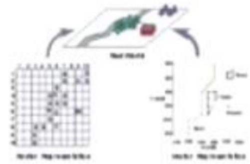
ATTRIBUTE DATA VERSUS SPATIAL DATA

ATTRIBUTE DATA	SPATIAL DATA
Characteristics of geographical features that are quantitative and/or qualitative in nature	All types of data objects or elements that are present in a geographical space or horizon
Town planning and management departments, fire departments, environmental groups and online media help to obtain attribute data	Satellite images and scanned maps help to obtain spatial data
Describes the characteristics of a geographical feature	Describes the absolute and relative location of a geographic feature

Visit www.PEDIAA.com

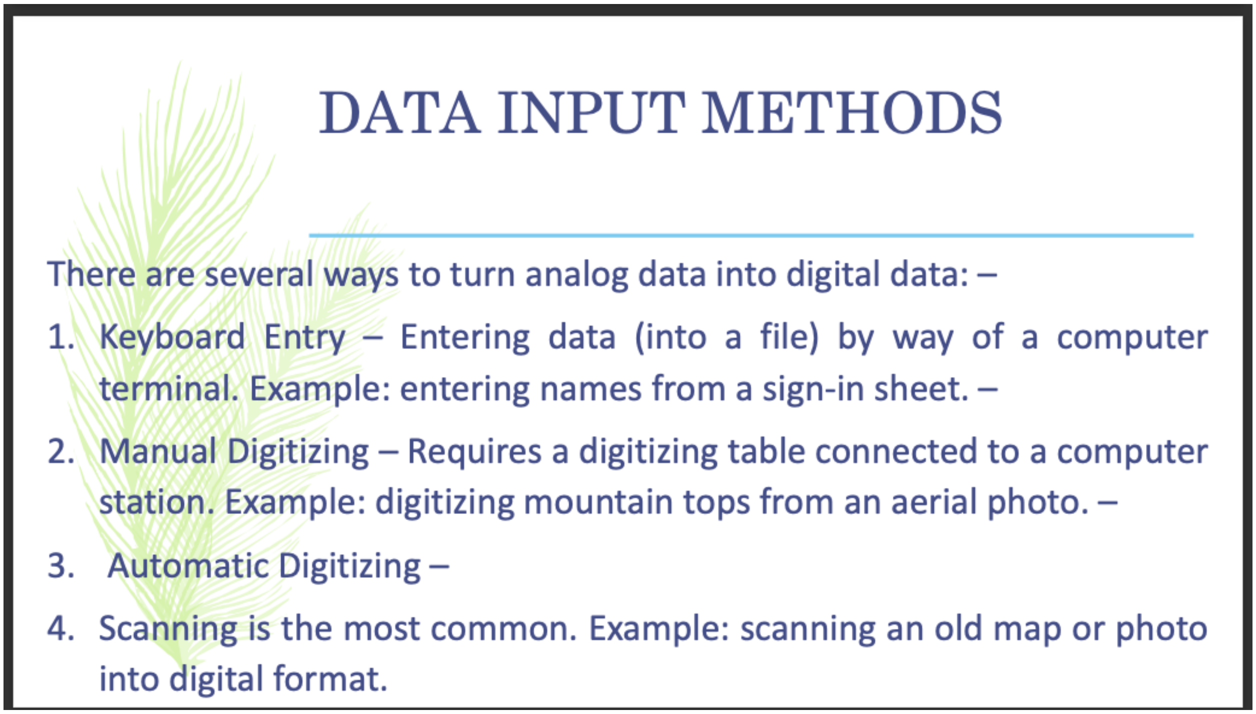
SPATIAL DATA SOURCES

- **Primary Data Sources** (first-hand collection)
  - Digitizing
    - Tablet digitizing
    - Heads up digitizing
    - Automatic digitizing



  - Scanning
  - Other point measurements
  - Census data
  - GPS collections
  - Aerial photographs
  - Remote sensing data

- **Secondary Data Sources** (from others)
  - Published or released data (originally primary data)
  - All primary data from others are secondary data for you and me
  - Large amount of data is now available
  - Several groups of data exist
    - Free data from the government
    - Government data available for a fee
    - Internet map servers
    - Commercial data
    - Data from other GIS users



In Geographic Information Systems (GIS), data input and output methods are essential for acquiring, creating, and sharing spatial data. These methods facilitate the flow of data into and out of GIS systems, allowing users to work with geographic information effectively. Here are some common data input and output methods in GIS:

Data Input Methods:

1. **Digitizing**: Digitizing involves converting hardcopy maps, drawings, or aerial photographs into digital format. This is typically done using specialized digitizing tablets or software that allows the manual tracing of features to capture their spatial information.
2. **Global Positioning System (GPS)**: GPS receivers are used to collect precise location data in the field. This data can be directly input into a GIS system for creating or updating spatial data.

Types of Errors in Digitization →

Types of Errors in Digitization

- 1. **Geodetic Errors**
- Geodetic errors are due to the odd choice of a projection system. Generally, earth features are in 3 Dimensions. But the features on the map are in 2 Dimensions. So the projection system leads to inaccuracy. Improper projection leads to inaccurate placement of elements on the map. Therefore making the map and the digitized features do not overlap each other appropriately.

- **2. Machine Error**
- Machine error occurs due to the digitizing tablet or the software used to digitizing the elements. It is an inherent error that cannot be removed but can only be minimized. Sometimes it may occur when converting the maps from analog to the digital formats.
- **3. Cartographic Errors**
- Cartographic errors arise due to existing mistakes that are present in the source map itself, and it can be transferred into the digital map.
- Incorrect interpretations or drafting of the elements in the maps are also one of the reasons for these errors.

- **4. Manuscript Errors**
- Manuscript errors occur based on the quality of the source maps. Hard copy maps shrink with time. Any stretching, warping, wrinkling, or traces of folding of the original map might affect the digitization process. It may lead to irregular shape, area & coordinates of the digitized features. It can't be completely rectified.
- **5. Positional Errors**
- Positional Error happens when an element is not captured correctly or carelessness of the digitizer, and it can be completely rectified.
- Positional Error is categorized as Dangling Nodes, Switchbacks, knots, and loops, Overshoots, and Undershoots, Silvers, and Overlaps.

- Dangling Nodes
- Dangling nodes occur in polygon & polyline. In digitized polyline, which hasn't met, or there is any gap between the nodes. In a digitized polygon, it happens when a polygon doesn't connect back to it.
- Switchbacks, Knots & Loops
- These errors occur due to unpractised digitizer. With the wrong movement of the cursor/ puck, the line being digitized ends up with extra vertices/nodes. In the case of additional vertices, switchbacks are formed in line with a bend. With knots and loops, the line folds onto itself, creating a polygon. Also known as a weird polygon. It also occurs in both polygon & polyline.

- Overshoots and Undershoots
- When a digitized line does not connect properly, overshoots and undershoots errors occur. During Digitization, a snap tolerance or snap distance (snap tolerance or the snap distance is the measurement of the diameter from the point of the cursor) is set by any digitizer.

Topology →

Topology, in the context of Geographic Information Systems (GIS) and spatial data, refers to the spatial relationships and connectivity between geographic features and their attributes. It defines the rules and constraints that govern how features are related to one another and how they interact in a geographic dataset. Topology plays a crucial role in ensuring data integrity, accuracy, and consistency in GIS. Here are some key aspects of topology in GIS:

1. **Spatial Relationships**: Topology defines relationships between geographic features, such as adjacency, containment, intersection, and connectivity. For example, it can describe how a road network is connected, how administrative boundaries relate to one another, or how rivers intersect with other water bodies.

Coverage Data Structure →

A "coverage" in the context of geographic information systems (GIS) refers to a specific data structure used to store and manage spatial data. The concept of coverages was originally popularized by ESRI in its ArcInfo software. Coverages are now considered somewhat outdated and have been largely replaced by more versatile and flexible data models, such as the Geodatabase, in modern GIS systems. Nevertheless, understanding the coverage data structure is still relevant, especially when dealing with legacy GIS data or older software systems.

Raster data model uses **grid and grid cells** to represent spatial variation of a feature.

A raster represents a continuous surface, but for data storage and analysis, a raster is divided into rows, columns, and cells.

Raster data represent points by single cells, lines by sequences of neighboring cells, and areas by collections of contiguous cells.

Raster Data Structure

Refers to storage of raster data so that it can be processed by the computer.

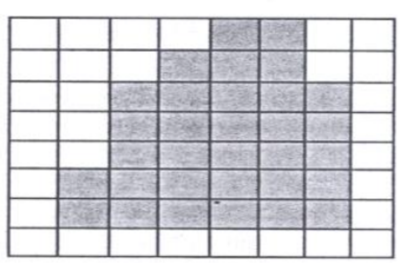
Cell-by Cell Encoding

A raster model is stored as a matrix. Its cell values are written into a file by row and column. Ideal to store the cell values that change continuously, e.g.,DEM.

Run-length Encoding

Records the cells by row and by group. Each group includes a cell value and the number of cells with that value. If all cells in a row contain the same value, only one group is recorded, hence save computer memory.

The run length encoding method records the cell values in runs. Row 1, for example, has two adjacent cells in columns 5 and 6 that are gray or have the value of 1. Row 1 is therefore encoded with one run, beginning in column 5 and ending in column 6. The same method is used to record other rows.



Row 1: 5 6
Row 2: 4 6

Raster Model	Vector Model
Advantages: • Simple data structure • Easy and efficient overlaying of grids • Compatibility with satellite imagery • High spatial variability which helps in efficient representation • Simple structure for own programming.	**Advantages:** • Compact data structure that is efficient for network analysis and projection transformation • Accurate map output.
Disadvantages: • Inefficient use of computer storage • Errors in perimeter and shape • Difficult network analysis • Inefficient projection transformations • Loss of information when using large cells which tend to give out less accurate maps.	**Disadvantages:** • Complex data structure • Difficult overlay operations • High spatial variability is inefficiently represented • Not compatible with satellite imagery.

Software Modules

GIS Software Producers and their main products

AUTODESK Inc: Autodesk Map
Baylor University: GRASS (Geographic Resources Analysis System),Open Source
Bentley Systems: Microstation
Caliper Cooperation: TransCad, Maptitude
Clark Labs: IDRISI
ESRI (Environmental System Research Institute): ArcGIS, Arc View 3x
Intergraph Corperation: MGE, GeoMedia
International Institute for Aerospace Survey and Earth Sciences: ILWIS
Keigan Systems: Mfworks, Keigan Grid
Manifold.net: Manifold Systems
Map Info Corporation: MapInfo
PCI Geomatics: Geomatica
QuantumGIS (Open Source)