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Unit - 4

9
Spatial data analysis
Non spatial data analysis
Spatial interpolation
Data retrieval – Reclassification techniques
Buffer analysis
Vector and topological overlay analysis
Raster overlay analysis
Measurement -
Spatial and non-spatial query
Expert system
Digital elevation model
Generation- parameters
Modeling surface
DEM application
Digital terrain model and visualization
TIN-Generation
Cost-Path analysis

DEM and DTM –Merits and demerits

Endsem →

29. a.	Elaborate on vector overlay operations with figures.	10	3	4	1,2,5
	(OR)				
b.	Detail on DEM and the parameters which can be derived from DEM.	10	3	4	1,2,5

IMP topics →

DEM generation and it's parameters

2. Raster overlay
3. Vector overlay
5. Buffer analysis
6. Reclassification
7. Data retrieval
8. Spatial interpolation

Notes →

SPATIAL DATA ANALYSIS

Spatial analysis is the process by which turn raw data into useful information.

The study of the locations, shapes of geographic features and the relationships between them.

Spatial analysis generally requires both non-spatial (attributes) and spatial information (location of objects).

The principal objective of spatial data analysis is to transform and combine data from diverse sources/disciplines into useful information, to improve one's understanding or to satisfy the requirements of objectives of decision makers.

Spatial analysis is how we understand our world mapping where things are, how they relate, what it all means, and what actions to take.

Spatial data analysis is a field of study and a set of techniques used to examine, interpret, and draw insights from data that have a spatial or geographic component. It involves the exploration and manipulation of data that is associated with specific locations or regions on the Earth's surface. Spatial data analysis is widely used in various disciplines, including geography, environmental science, urban planning, epidemiology, and more. Here are some key aspects and methods related to spatial data analysis:

1. Geographic Information Systems (GIS): GIS is a powerful tool in spatial data analysis, allowing for the creation, visualization, and analysis of spatial data. It involves the use of maps and spatial data layers to understand relationships and patterns within geographic space.
2. Spatial Data Visualization: Creating maps, charts, and visualizations is a fundamental aspect of spatial data analysis. These visuals help convey complex spatial information in a more understandable and accessible manner.
3. Spatial Statistics: Spatial statistics involves the application of statistical methods to spatial data. It helps in identifying patterns, clusters, trends, and relationships within spatial datasets. Common techniques include spatial autocorrelation, spatial regression, and hotspot analysis.
4. Spatial Interpolation: This method is used to estimate values at unobserved locations based on data available at sampled locations. Techniques like kriging and

inverse distance weighting are often employed for this purpose.

5. Spatial Clustering: Identifying clusters of similar data points in space is essential for various applications, such as disease outbreak detection or urban planning. Cluster analysis methods help to locate and characterize these spatial groupings.
6. Point Pattern Analysis: Point pattern analysis focuses on the distribution of individual data points in space. It is often used in ecological studies and urban planning to understand the spatial arrangement of events or objects.
7. Network Analysis: Spatial data analysis often involves the analysis of networks, such as transportation networks, social networks, or utility networks. Methods like shortest path analysis and network flow analysis are applied to study these systems.
8. Remote Sensing: Remote sensing technologies, including satellite and aerial imagery, provide valuable spatial data sources for monitoring and analyzing changes in the Earth's surface, such as land use, vegetation, and environmental conditions.
9. Spatial Data Modeling: Building spatial models involves creating mathematical or computational representations of spatial processes. These models help in simulating and predicting various spatial phenomena, such as urban growth, climate patterns, or wildlife habitat suitability.
10. Geostatistics: Geostatistics is a branch of statistics focused on the analysis of spatially correlated data. It is particularly valuable for applications like mineral resource assessment, pollution mapping, and groundwater modeling.

Spatial data analysis plays a crucial role in understanding the world around us, making informed decisions, and solving complex problems that involve geographic aspects. It is used in a wide range of fields and industries to gain insights from spatial data and improve decision-making processes.

Spatial Interpolation →

What is spatial interpolation?

Spatial interpolation is the process of using points with known values to estimate values at other points.

These points with known values are called **known points, control points, sampled points, or observations.**

Spatial interpolation is a process of intelligent guesswork in which the investigator attempt to make a reasonable estimate of the value of a continuous field at places where the field has not actually been measured.

Spatial interpolation is therefore a means of creating surface data from sample points so that the surface data can be displayed as a 3-D surface or an isoline map and used for analysis and modeling.

Applications

In estimating rainfall, temperature and other attributes at places where no direct measurements of these variable are available

In estimating the elevation of the surface between the measured locations of DEM

In contouring when it is necessary to guess where to place contours between measured locations

In resampling raster, the operation that must take place whenever raster data must be transformed to another grid

Sure, let me explain spatial interpolation in simpler terms.

Imagine you have a map with a few weather stations that measure temperatures. These stations are like dots on the map, and they give you temperature readings at their locations.

Now, what if you want to know the temperature at a point on the map that doesn't have a weather station? Spatial interpolation helps you estimate the temperature at that point based on the information from the nearby weather stations.

It's like guessing what the temperature might be at your home when you only have data from your neighbor's weather station and another one down the street. Spatial interpolation uses math to make an educated guess about what the temperature could be in between those stations.

So, in simple terms, spatial interpolation fills in the gaps on a map by making an educated guess about what's happening in places where you don't have direct measurements. It's like connecting the dots, but with some math to help you guess the values in between.

Spatial interpolation is a technique used in spatial data analysis and geographic information systems (GIS) to estimate values at unobserved or unmeasured locations within a geographic area based on data available at sampled or observed locations. It is a valuable tool for filling in data gaps and creating continuous surfaces from discrete data points. Spatial interpolation is used in a variety of applications, including environmental modeling, geostatistics, weather forecasting, and more.

Type of spatial interpolation

1. Global interpolation and local interpolation
2. Exact interpolation and inexact interpolation
3. Deterministic interpolation and stochastic interpolation
4. Abrupt *vs* Smooth

Global interpolation:

Use every point available to estimate an unknown value.

Global interpolators determine a single function which is mapped across the whole region

- e.g. Trend surface

Local interpolation:

Uses sample of known points to estimate an unknown values.

Local interpolators apply an algorithm repeatedly to a small portion of the total set of points

- e.g. Inverse distance weighted

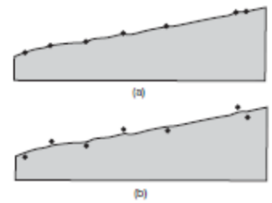
Global interpolation:	Local interpolation:
More number of control points are considered	Less number of control points are considered
Designed to capture general trend of surface	Designed to find short range variation
Less accuracy	More accuracy

Exact interpolation:

Predicts a value at the point location that is same as its known value.

Exact interpolators honor all data points

- e.g. Inverse distance weighted



Inexact interpolation:

Predicts a value at the point location that differs from its known value.

Approximate interpolators try to approach all data points

- e.g. Trend surface

Exact interpolation	Inexact interpolation
Generates a surface that passes through the control points	Generates a surface that slightly differs from the control points

Deterministic interpolation:

A deterministic interpolation method provides no assessment of errors with predicted values.

Stochastic interpolation:

A stochastic interpolation method, offers assessment of prediction errors with estimated variances.

Gradual/Abrupt Interpolators

Gradual/smooth interpolators assume continuous and smooth behavior of data everywhere.

Abrupt interpolators allow for sudden changes in data due to boundaries or undefined derivatives.

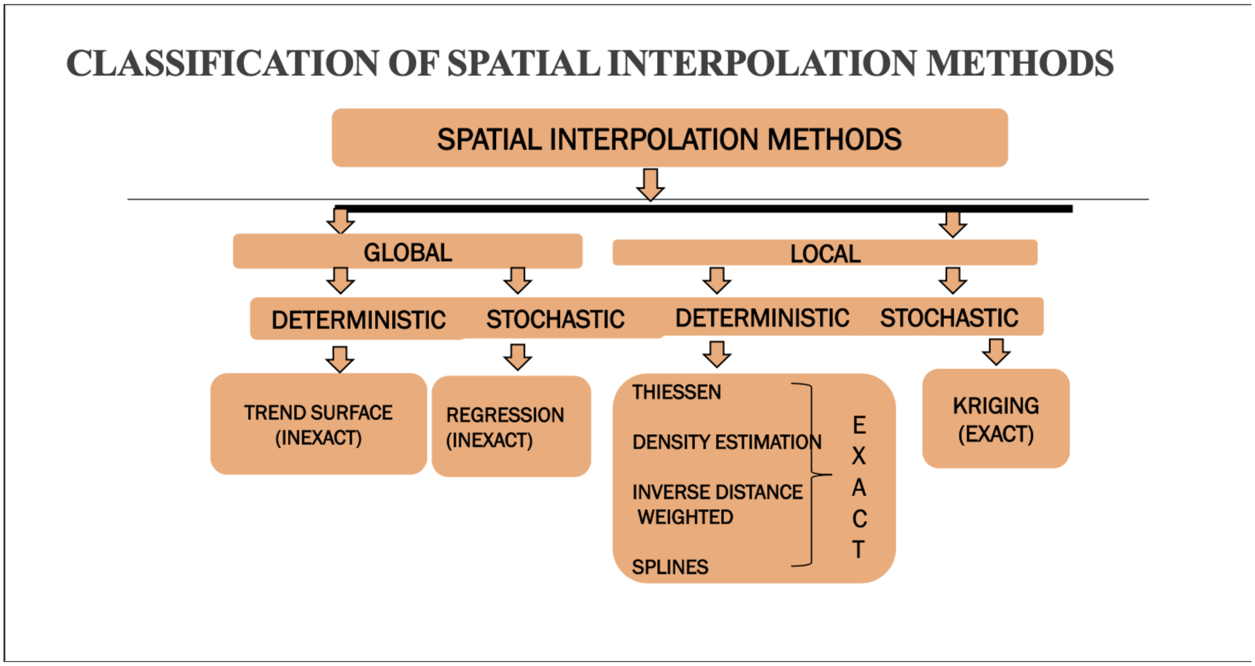
The categorization you provided touches upon different aspects of spatial interpolation methods. Here's an explanation of each type:

1. **Global Interpolation and Local Interpolation:**
   - **Global Interpolation:** Global interpolation methods aim to create a single, continuous surface over the entire study area, often by considering all available data points. They provide a global representation of the spatial phenomenon being interpolated.
   - **Local Interpolation:** Local interpolation methods focus on smaller, localized regions of the study area. They create separate interpolations for different parts of the area, considering only nearby data points. Local interpolations can capture small-scale variations within a larger study area.
2. **Exact Interpolation and Inexact Interpolation:**
   - **Exact Interpolation:** Exact interpolation methods ensure that the interpolated values exactly match the observed values at the measured locations. These methods may not provide estimates between data points but instead preserve the data points' values exactly.
   - **Inexact Interpolation:** Inexact interpolation methods allow for some deviation between the estimated values and the observed values at the measured

locations. They provide estimated values that are close to the observed values but not necessarily equal.

3. **Deterministic Interpolation and Stochastic Interpolation:**
    - **Deterministic Interpolation:** Deterministic interpolation methods are based on known mathematical relationships or rules. They assume that the spatial phenomenon being interpolated follows a predictable pattern, and they do not consider random variability.
    - **Stochastic Interpolation:** Stochastic interpolation methods account for randomness and uncertainty in the spatial data. They take into consideration the probabilistic nature of the data and often involve statistical techniques to provide estimated values with associated uncertainty measures.
4. **Abrupt vs. Smooth Stochastic:**
    - **Abrupt Stochastic Interpolation:** In this context, abrupt stochastic interpolation typically refers to methods that model abrupt changes or discontinuities in the spatial data. These methods are suitable for situations where the spatial phenomenon changes abruptly from one area to another.
    - **Smooth Stochastic Interpolation:** Smooth stochastic interpolation methods aim to model the spatial phenomenon as a continuous and smooth process. They assume that changes in the data values occur gradually and smoothly across space.

These categorizations highlight the diversity of spatial interpolation methods, each of which may be more suitable for specific applications and datasets depending on the nature of the spatial phenomenon and the available data.



It appears that you've listed several spatial interpolation methods along with their categorizations as "exact" or "inexact." Let me provide a brief description of each method and its categorization:

- Global Methods →

1. **Trend Surface (Inexact):**
    - Trend surface interpolation is an inexact method used to estimate values at unobserved locations. It fits a mathematical surface to the observed data points and uses this surface to estimate values at other locations. The estimation may not exactly match the observed values.

GLOBAL METHODS

I. TREND SURFACE:

Trend surface analysis approximates points with known values with a polynomial equation.

A linear or first order trend surface uses the equation :

$$\mathbf{Z_{x,y} = b_o + b_1x + b_2y}$$

Where, Z is a attribute value with function x and y coordinates

b_o , b_1 and b_2 are the coefficients estimated from known points

Example: precipitation

2. **Regression (Inexact):**

- Regression-based interpolation uses statistical regression models to predict values at unobserved locations based on the relationships between the dependent variable (e.g., the variable of interest) and one or more independent variables (predictors). The predictions may not be exact but are based on statistical relationships.

II. **REGRESSION MODEL:**

A regression model relates a dependent variable to a number of independent variables in a linear equation (an interpolator) which can be then used for prediction and estimation.

This model uses both spatial and nonspatial attributes for the interpolation.

$$\mathbf{Z = b_o + b_1x + b_2y + b_3e + b_4p}$$

Where, Z is a dependent variable

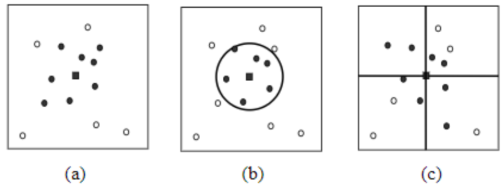
b_o,b_1,b_2,$b_3$and b_4 are coefficients and

x, y, e and p are the independent variables

Example: snow water equivalent

- Local Methods →

Local methods



Find the closest point to the point to be estimated

Points within the radius

Points within each quadrant

3. **Thiessen (Inexact):**

   - Thiessen polygon (Voronoi diagram) interpolation divides the study area into polygons around each observed point, and the value at an unobserved location is estimated based on the value of the nearest observed point. The estimation can be inexact because it depends on the nearest neighbor.

I. THIESSEN POLYGON:

Thiessen polygon interpolation also known as **Nearest neighbor interpolation.**

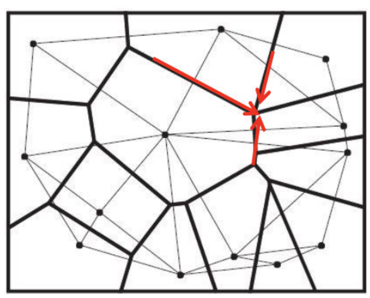
This is conceptually the simplest interpolation method, in the sense that the mathematical function used is the simple equality function, and only one point, the nearest point, is used to assign a value to an unknown location.

Thiessen polygon interpolation do not use an interpolator but require initial triangulation for connecting known points can form different set of triangles (Delauney triangulation).

After triangulation, Thiessen polygon can be easily constructed by connecting lines drawn perpendicular to the sides of each triangle at their mid points.

Example: Average areal precipitation

Thiessen polygon (thick) are interpolated from known points and Delaunay triangulation (thinner).



4. **Density Estimation (Inexact):**

- Density estimation is a technique that models the density of data points within a geographic area. It provides estimates of the likelihood of finding data points at unobserved locations. These estimates are probabilistic and therefore inexact.

II. DENSITY ESTIMATION:

Density estimation measures cell densities in a raster by using a sample of known points.

There are two types of Density Estimation Methods:

1. **Simple density estimation method**
2. **Kernel density estimation method**

5. **Inverse Distance Weighted (Inexact):**

- Inverse Distance Weighted (IDW) interpolation assigns values to unobserved locations based on a weighted average of nearby observed values, with closer points receiving more weight. The estimated values are based on the distances to the observed points and are therefore inexact.

III. **INVERSE DISTANCE WEIGHTED INTERPOLATION:**

The IDW is simple and intuitive deterministic interpolation method based on principle that sample values closer to the prediction location have more influence on prediction value than sample values farther apart. Using higher power assigns more weight to closer points resulting in less smoother surface.

On the other hand, lower power assigns low weight to closer points resulting in smoother surface. Major disadvantage of IDW is "bull's eye" effect (higher values near observed location) and edgy surface.

Inverse distance weighting results in smooth interpolated surfaces. The values do not jump discontinuously at edges, as occurs with Thiessen polygons, and sometimes with fixed radius interpolation.

6. **Splines (Inexact):**

- Spline interpolation uses mathematical curves or functions to create a smooth and continuous surface that passes through or near the observed data points.

While splines provide smooth estimates, they are inexact because they are based on a mathematical model.

IV. Splines

- The mathematical equivalent of using a flexible ruler (called a spline)
- Can be used as an exact or approximate interpolator, depending upon the degrees of freedom granted (e.g. polynomial order)
- Best for smooth datasets, can cause wild fluctuations otherwise

7. **Kriging (Exact):**

- Kriging is an exact spatial interpolation method that employs geostatistical techniques. It estimates values at unobserved locations while providing measures of uncertainty. Kriging aims to provide the best linear unbiased predictions, making it exact in the sense that it optimally honors the spatial data and their correlations.

Kriging

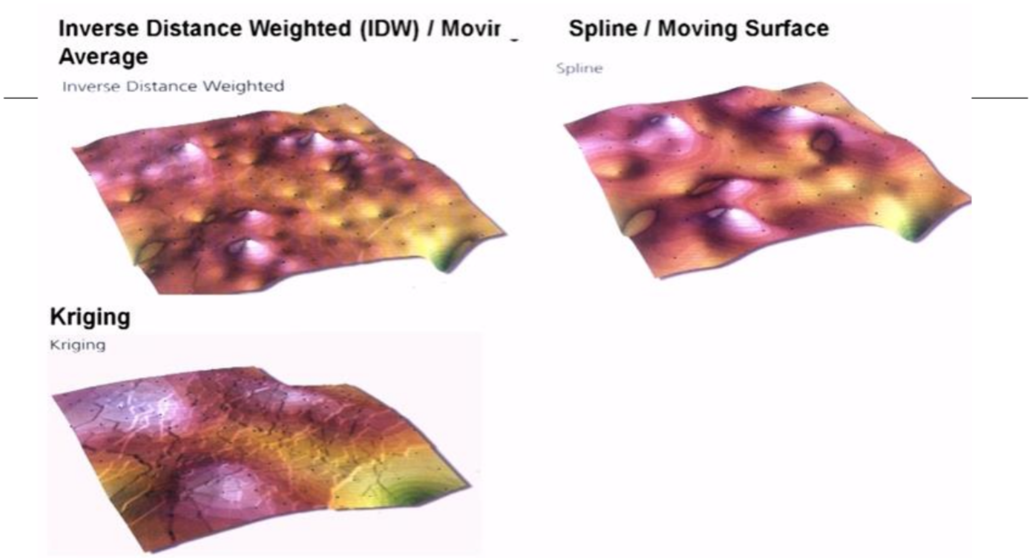
Developed by Georges Matheron, as the "theory of regionalized variables", and D.G. Krige as an optimal method of interpolation for use in the mining industry.

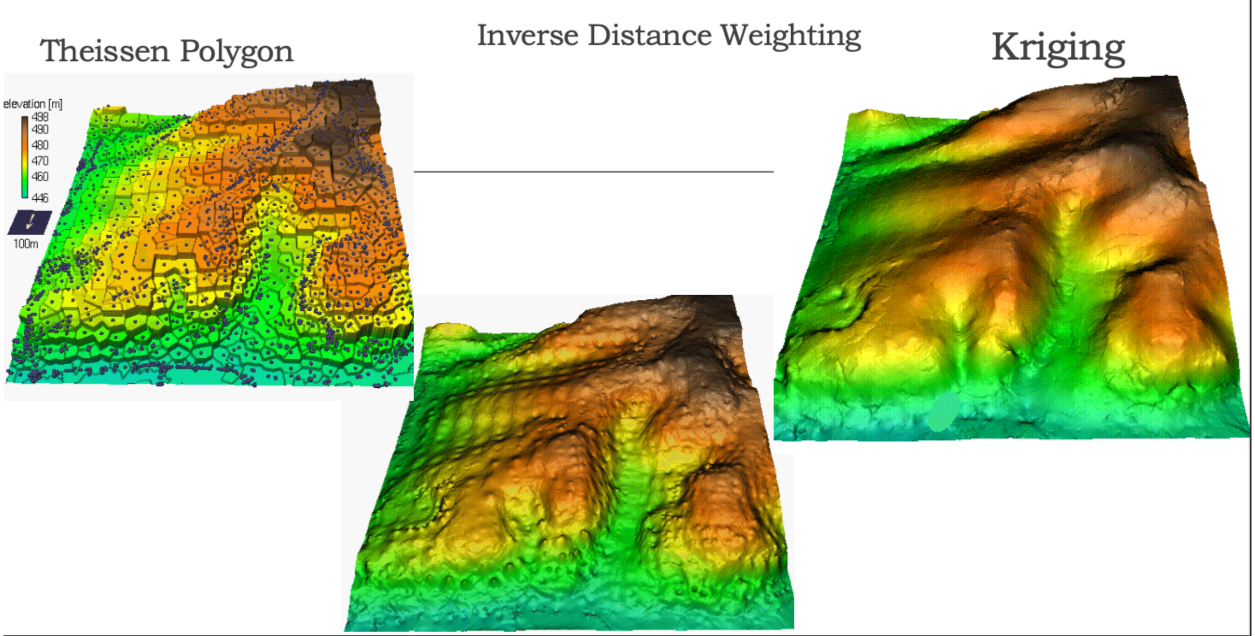
Kriging is the geostatistical method for spatial interpolation.

Basis of technique is the rate at which the variance between points changes over space

This is expressed in the variogram which shows how the average difference between values at points changes with distance between points

In the context of your list, the terms "exact" and "inexact" refer to the degree of exactness or precision of the interpolation method. Exact methods aim to produce estimates that closely match observed values, whereas inexact methods may provide estimates that deviate from observed values to some extent, taking into account various factors and assumptions. The choice of method depends on the specific requirements and characteristics of the spatial data and the intended application.





- Interpolation method depends upon
  - Character of data
  - Your assumptions of data behavior
- When possible, best way to compare methods is to
  1. try several methods
  2. make sure you understand theory
  3. refine best method

Reclassification Technique →

Reclassification Technique

The process of taking input cell values and replacing them with new output cell values

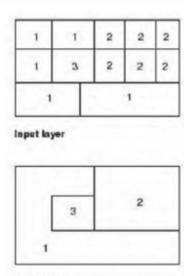
Reclassification is often used to simplify or change the interpretation of raster data by changing a single value to a new value, or grouping ranges of values into single values—for example, assigning a value of 1 to cells that have values of 1 to 50, 2 to cells that range from 51 to 100, and so on.

Reclassification serves three main purpose

- Creating a simplified raster: eg 1 for slopes 0-10%, 2 for 10-20%
- Creating new raster that contains a unique category or values: eg slopes of 10-20%, irrigated croplands
- Creating a new raster that shows the ranking of cell values in the input raster: eg 1 to 5, with 1 being the least suitable and 5 being the most suitable

RECLASSIFICATION

- Reclassification of attribute data by dissolving a part of the boundaries and merging into new reclassified polygons.
- Example: Population densities classified into classes such as "Sparsely populated" or "Over crowde



Reclassification is a spatial analysis technique used in geographic information systems (GIS) and remote sensing to reassign or transform the values of data within a raster or grid dataset. This technique is particularly useful for data simplification, reorganizing data categories, or creating new datasets with modified values. Reclassification can be applied to various types of data, such as land use, elevation, vegetation, and more. Here's how it works:

1. **Input Data:** Reclassification begins with an input raster dataset, where each cell or pixel has an assigned value or category. These values could represent land cover types, elevation ranges, temperature values, or any other geospatial information.
2. **Reclassification Rules:** To perform reclassification, you define a set of rules or criteria that specify how the original values in the input dataset should be transformed into new values or categories. These rules typically involve specifying value ranges or conditions for reassignment.
3. **Reassignment:** The reclassification process involves scanning the entire input dataset and applying the reclassification rules to each cell or pixel. When a cell meets the criteria defined in the rules, its value is updated according to the reclassification rules.
4. **Output Dataset:** The result of the reclassification process is a new raster dataset, often referred to as the "reclassified" or "output" dataset. This dataset has values that have been transformed or reorganized based on the defined rules.

Reclassification can serve several purposes, including:

- Simplifying data: Reclassification can reduce the complexity of a dataset by aggregating similar categories or values into broader classes. For example, combining multiple land cover types into a smaller number of land use classes.
- Creating thematic maps: Reclassification is often used to generate thematic maps with simplified, categorical data that are easier to interpret and analyze.
- Change detection: Reclassification can be used to detect changes over time by comparing reclassified datasets from different time periods and identifying areas where values have shifted from one category to another.
- Customizing data: Analysts can tailor raster datasets to their specific research needs by reclassifying them to match the criteria relevant to their study.

Reclassification is a fundamental tool in spatial analysis and GIS, and it is commonly used to preprocess and transform data for various applications, including environmental assessment, urban planning, natural resource management, and more.

DATA RETRIEVAL →

DATA RETRIEVAL

Data retrieval is the process of identifying and extracting data from database.

Data retrieval is feasible and easy if there is no ambiguity in the data and it should be presented in standard structure.

Data retrieval: 1. Locating, 2. Selecting by attributes 3. Buffering 4, Map overlay 5. Map algebra.

Data retrieval is done by applying the rules of Boolean logic to operate on the attributes.

DATA RETRIEVAL – SOURCES (Example)

Digital Library (Books, Journals)

Web Search engine (Flight ticket, Movie, Education)

USGS Data Library (Satellite image – Free of cost)

NRSC Data Center (Purchasing Indian satellite)

Etc..

Data retrieval in the context of spatial data refers to the process of acquiring and accessing geospatial information from various sources, databases, or repositories for analysis, visualization, and other purposes. Spatial data retrieval can involve a range of data types, including maps, satellite imagery, GPS data, geospatial databases, and more. Here's an overview of the key steps and methods involved in spatial data retrieval:

1. **Data Sources:** Spatial data can be obtained from a variety of sources, including government agencies, research institutions, commercial providers, and user-generated data. Common sources include:
   - **Government Agencies:** Government organizations often provide valuable spatial data, such as topographic maps, census data, and land use information.
   - **Satellite and Aerial Imagery:** Remote sensing data from satellites and aerial platforms offer high-resolution imagery for various applications.
   - **GPS and Sensor Data:** Global Positioning System (GPS) receivers and sensors on devices like smartphones generate location data.
   - **Geospatial Databases:** Spatial databases and Geographic Information Systems (GIS) repositories store and manage spatial data.
2. **Data Formats:** Spatial data can be stored in various formats, including vector and raster data. Vector data represent geographic features as points, lines, or polygons, while raster data use grids or pixels to represent continuous or disc

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Buffer Analysis →

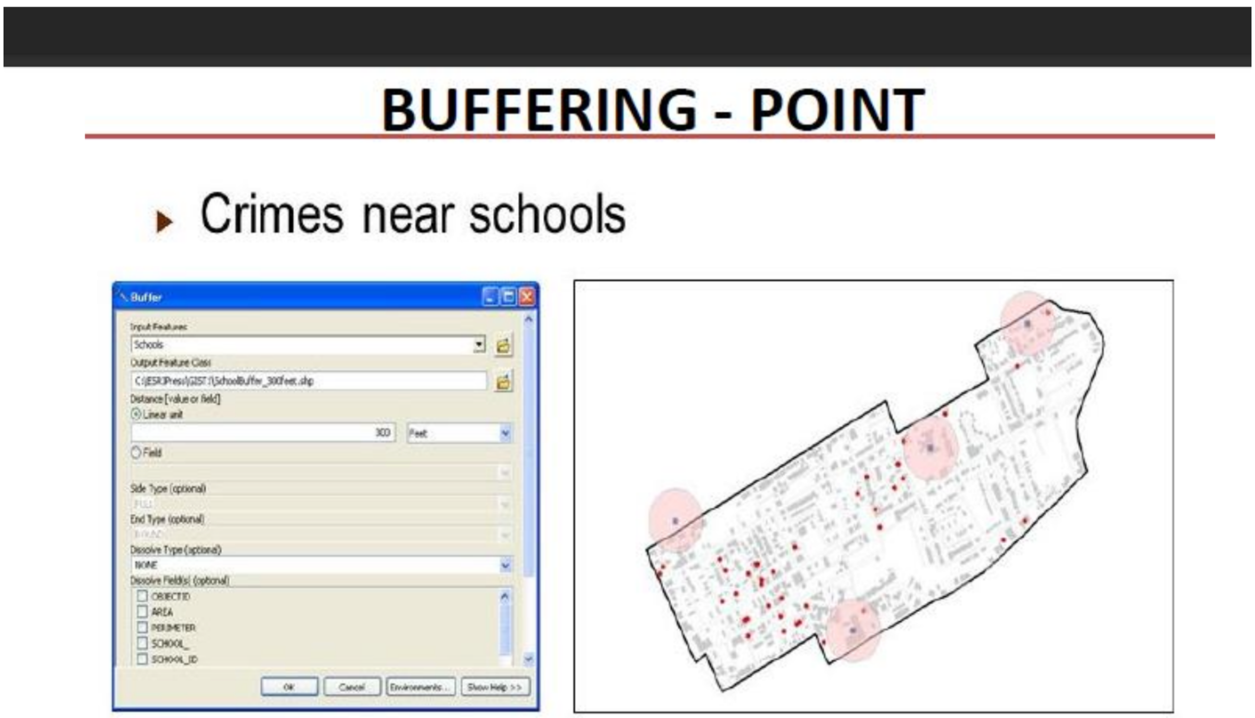
BUFFER

A buffer is a zone with a width created around a spatial feature and is measured in units of distance from the feature.

Buffering is used for neighborhood analysis which aims to evaluate the characteristics of the area surrounding the spatial feature.

Common examples of buffering include the identification of properties within a certain distance of an object,

Delineation of areas around natural features where human activities are restricted, determination of areas affected by location etc



Buffer analysis is a fundamental spatial analysis technique used in geographic information systems (GIS) and geospatial data analysis. It involves creating a zone or area around a specific geographic feature or point by defining a distance or radius from that feature. This zone is known as a "buffer," and buffer analysis serves various purposes in spatial analysis and planning. Here are the key aspects of buffer analysis:

1. **Buffer Creation:** Buffer analysis starts by defining a central point, line, or polygon feature on a map. Then, a buffer is created around that feature by specifying a buffer distance, typically in units such as meters or miles. The buffer can be a circular area (for points) or a band (for lines) with a defined width.
2. **Applications:**
   - **Proximity Analysis:** Buffer analysis is often used to assess the proximity or accessibility of various geographic features to the central feature. For example, it can be used to identify all the schools within a 1-mile radius of a park.
   - **Environmental Impact Assessment:** Buffer analysis can help determine the environmental impact or protection zones around sensitive features like wetlands, rivers, or archaeological sites.
   - **Safety and Emergency Planning:** Emergency services use buffer analysis to identify response zones based on response time, such as locating fire stations within a 5-minute drive of residential areas.
   - **Land Use Planning:** Urban planners use buffers to assess the impact of proposed developments on surrounding neighborhoods.
   - **Wildlife Conservation:** Buffer analysis helps create habitat protection areas around wildlife reserves or nesting sites.
   - **Retail Site Selection:** Businesses may use buffer analysis to find suitable locations for new stores based on the proximity to their target customer base.
3. **Buffer Types:**
   - **Fixed Buffer:** A fixed buffer uses a consistent distance or radius from the central feature. For example, you may create a fixed 2-mile buffer around a park.
   - **Variable Buffer:** A variable buffer uses different distances based on specific criteria. For instance, you might create a buffer of 1 mile around a school but a 0.5-mile buffer around a hospital.
4. **Overlay Analysis:** Buffer analysis often involves overlaying buffer zones with other spatial data layers, such as land use, population density, or transportation networks. This helps in understanding spatial relationships and making informed decisions.

5. **Multiple Buffers:** In some cases, multiple buffers can be created around a central feature at different distances or with different criteria to assess varying impacts or opportunities.

Buffer analysis is a versatile tool for visualizing and quantifying spatial relationships, and it is widely used in urban planning, environmental management, transportation planning, real estate, and many other fields where proximity and spatial interaction are important factors. It helps in making informed decisions, managing resources, and evaluating the impact of various factors on specific geographic features.

Query

Query is a request to select features or records from a database is known as a Query.

Query is often written as a statement or logical expression. Analysing the data by querying it is Known as the Query Analysis. This is an immensely powerful feature that allows you to view a subset of the layer without selecting & exporting those features to a new layer each time. Three types of Queries are there (a) Interactive (b) Selection (SQL) (c) Spatial (Location) and Graphical

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Spatial Measurement Methods →

Spatial Measurement Methods

- Measurements allow to produce ratios of lengths to widths and of perimeters to areas
- The GIS user need to describe not only what objects are, how many objects exist and where they are, but also how large they are, how far apart and what the distance between them is like
- Method of measurements depend upon the type of data, data model and availability of software

Spatial measurement methods are techniques used to quantify and analyze various spatial attributes and characteristics in geographic data and the physical world. These methods are crucial for understanding spatial relationships, patterns, and processes. Here are some key spatial measurement methods:

1. **Distance Measurement:**
    - Euclidean Distance: This is the straight-line or "as-the-crow-flies" distance between two points in a two-dimensional space.
    - Manhattan Distance: Also known as the city block distance, it measures the distance between two points by summing the horizontal and vertical distances, like walking along city streets.
2. **Area Measurement:**
    - Planimetric Measurement: This method calculates the area of a polygon on a flat plane, assuming a 2D surface.
    - Spherical Measurement: For measuring areas on the Earth's surface, various techniques account for the curvature of the Earth.
3. **Perimeter Measurement:**
    - Perimeter measurement calculates the length of the boundary of a geographic feature, such as the perimeter of a polygon.

In raster, measurements are done using Pythagorean geometry

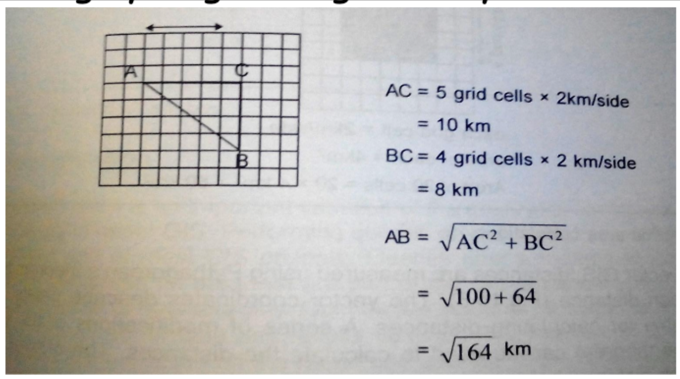


Fig 1: Length Calculation

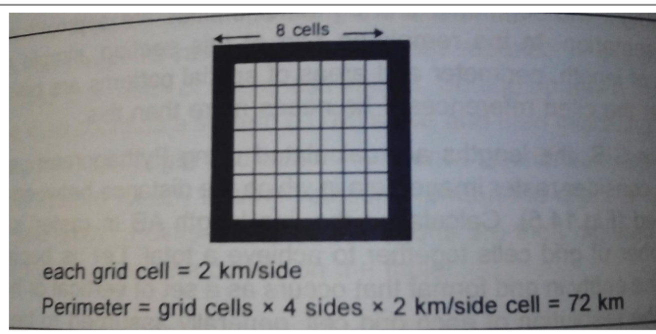


Fig 2: Perimeter Calculation

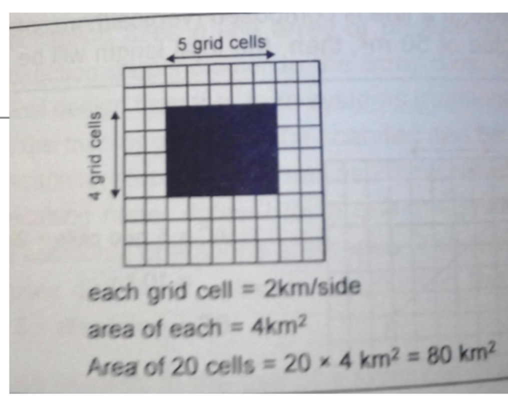


Fig 3: Area Calculation

In vector, measurements are also done using Pythagorean geometry

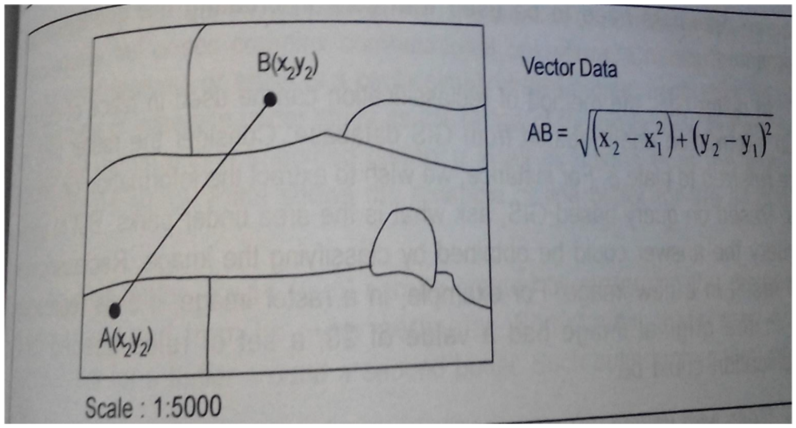


Fig 4: Vector Distance Calculation

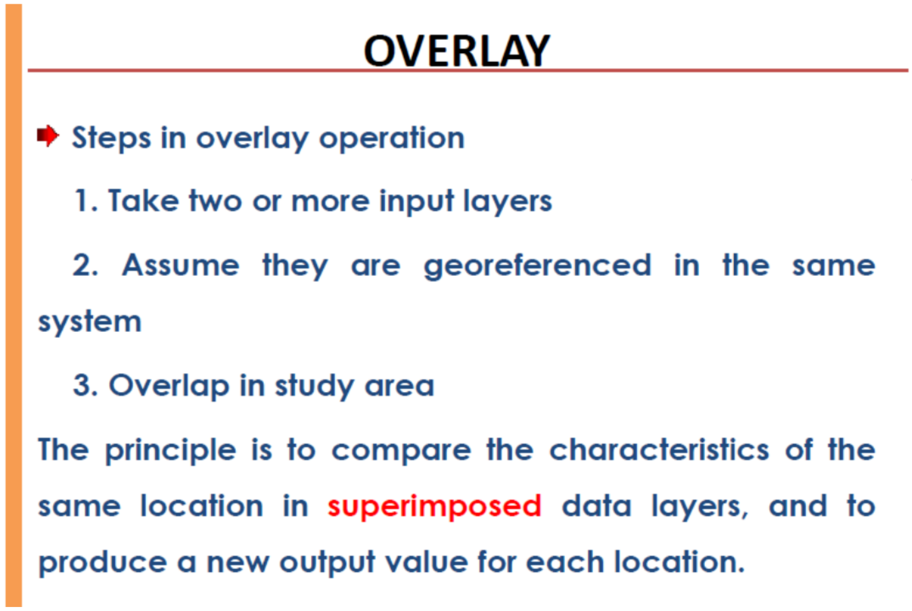
Overlay →

OVERLAY

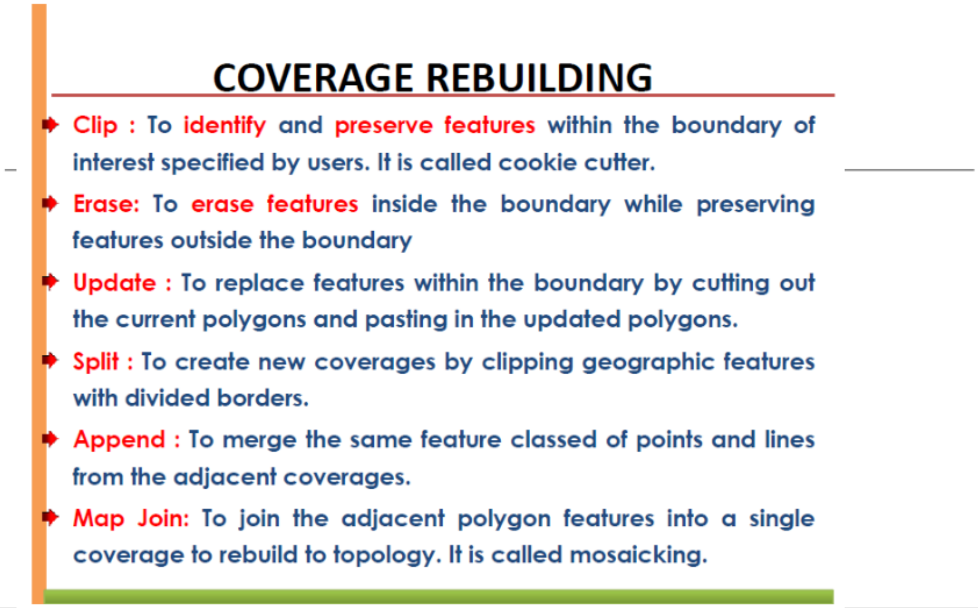
- Overlay that superimposes multiple data sets together for the purpose of identifying relationships between them.
- An overlay operation combines features and attributes from the input layers.

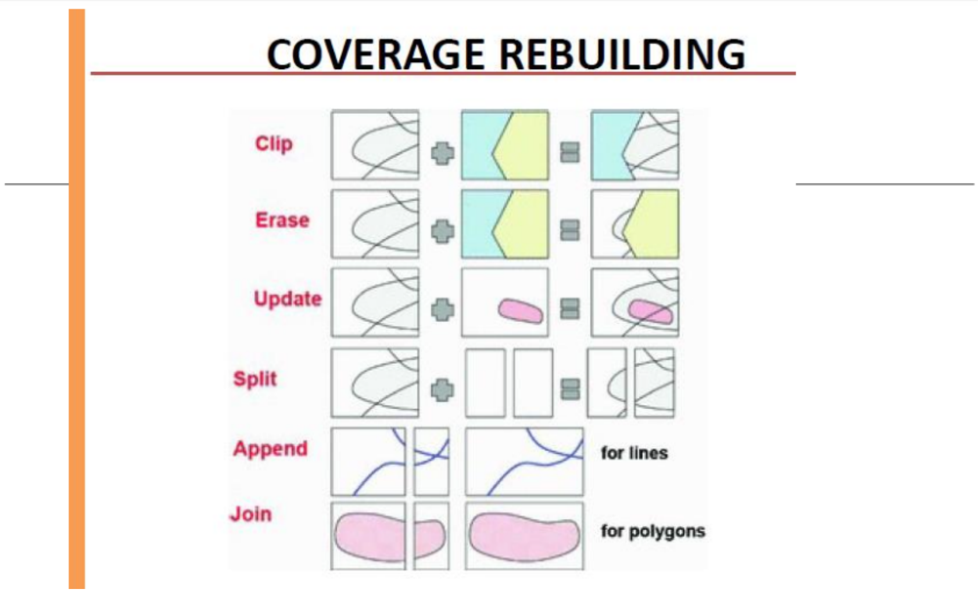
OVERLAY

- Overlaying of more than two layers, including rebuilding topology of the merged points, lines and polygons and operations on the merged attributes for suitability study, risk management and potential evaluation.



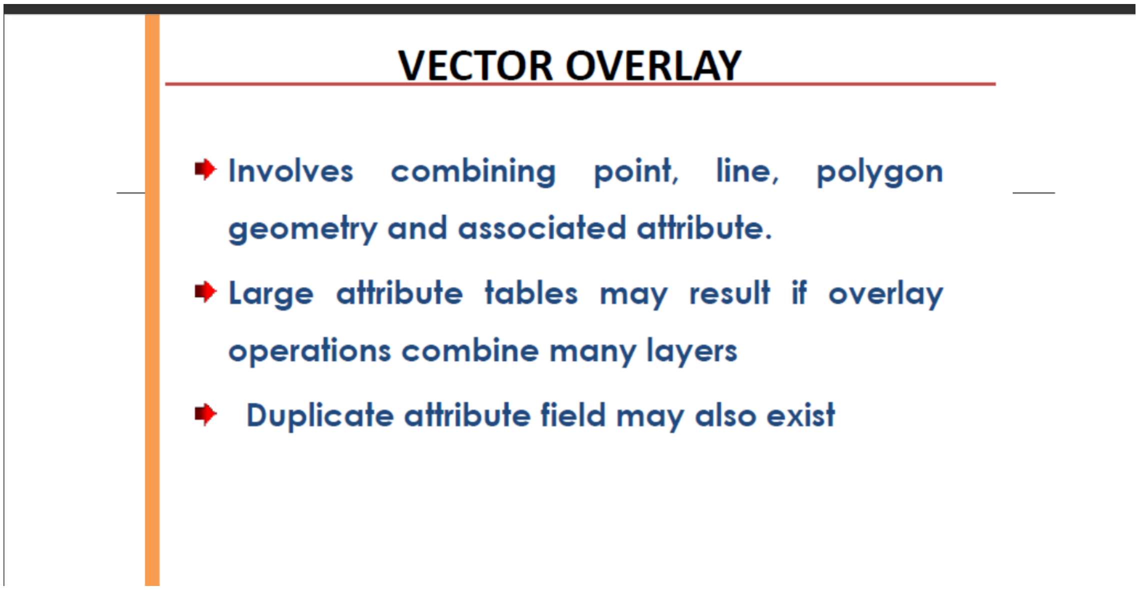
Overlay, in the context of geographic information systems (GIS) and spatial analysis, refers to the process of combining or merging multiple spatial datasets, often in the form of vector or raster layers, to create a new composite dataset that contains information from all the input layers. Overlay is a fundamental operation in GIS that allows for the examination of spatial relationships, the identification of areas of interest, and the generation of new datasets for further analysis. There are different overlay techniques for vector and raster data:



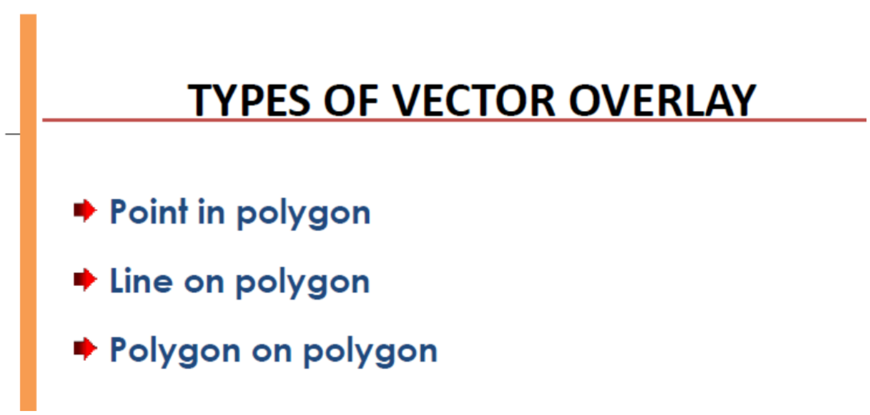


Vector Overlay:

Vector overlay involves combining vector-based geographic features, such as points, lines, and polygons. Common vector overlay operations include:



1. **Union:** The union operation combines two or more vector layers, creating a new layer that includes all the features from the input layers. Overlapping features are merged, and non-overlapping features are retained.
2. **Intersection:** Intersection identifies the common areas where features from two or more layers overlap. The result contains only the parts of features that intersect with each other.
3. **Difference:** The difference operation identifies the areas in one layer that do not overlap with features in another layer. It creates a new layer with the non-overlapping parts.
4. **Symmetrical Difference:** Symmetrical difference combines the non-overlapping parts of two layers, excluding their common areas. It creates a new layer with features unique to each input layer.

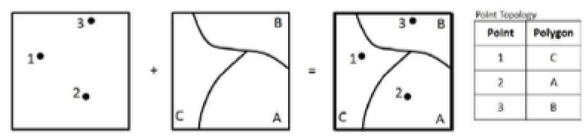


Vector overlay operations in Geographic Information Systems (GIS) are used to analyze the spatial relationships between different geographic features in vector data (e.g., points, lines, polygons). The specific operations you mentioned—point in polygon, line on polygon, and polygon on polygon—are important components of vector overlay analysis. Here's how these operations work in vector overlay:

1. **Point in Polygon:**
    - This operation is used to determine whether points are located within the boundaries of polygons. It helps answer questions like "Which city district does each address belong to?" or "Are there any trees within a park boundary?"
    - Result: Each point is associated with the polygon it falls within.
2. **Line on Polygon:**
    - This operation assesses the spatial relationship between lines (linear features) and polygons. It is used to identify which parts of a line intersect, cross, or lie within the boundaries of polygons.
    - Result: Segments of the line are associated with the polygons they intersect, allowing for the identification of where lines interact with polygon features.
3. **Polygon on Polygon:**
    - In this operation, you evaluate how polygons relate to other polygons. It helps determine if one polygon is entirely contained within another polygon, if they overlap, or if they have no spatial relationship.
    - Result: Polygons are associated with other polygons, indicating relationships like containment, intersection, or disjointedness.

POINT IN POLYGON OVERLAY

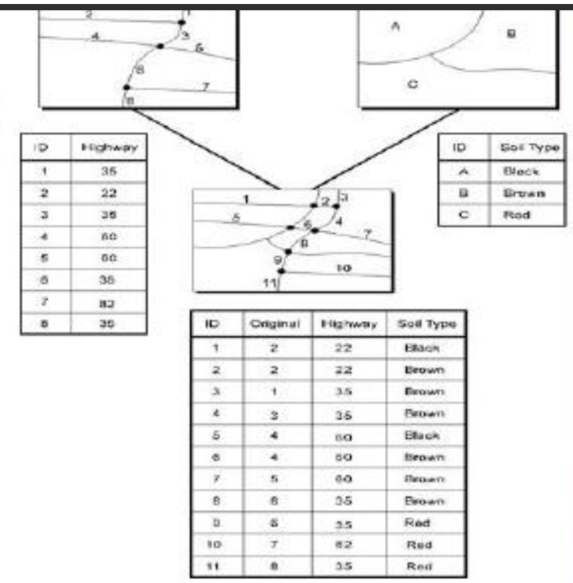
- Points are overlaid on polygon. Topology of point in polygon is " contained in" relationship.
- Point topology in the new data layer is a new attribute of polygon for each point.



POINT IN POLYGON OVERLAY

LINE – ON – POLYGON OVERLAY

- Line – on – polygon algorithm overlays line objects on area objects and compute " is contained in" relationship.
- Lines are broken at each area object boundary to form line segments and new attributes created for each output line specifying the area it belongs to.



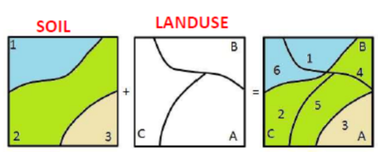
ID	Highway
1	35
2	22
3	35
4	60
5	60
6	35
7	82
8	35

ID	Soil Type
A	Black
B	Brown
C	Red

ID	Original	Highway	Soil Type
1	2	22	Black
2	2	22	Brown
3	1	35	Brown
4	3	35	Brown
5	4	60	Black
6	4	60	Brown
7	5	60	Brown
8	6	35	Brown
9	6	35	Red
10	7	82	Red
11	8	35	Red

POLYGON-ON-POLYGON OVERLAY

- Two layers of area objectives are overlaid. The number of new polygons is usually larger than that of the original polygons.

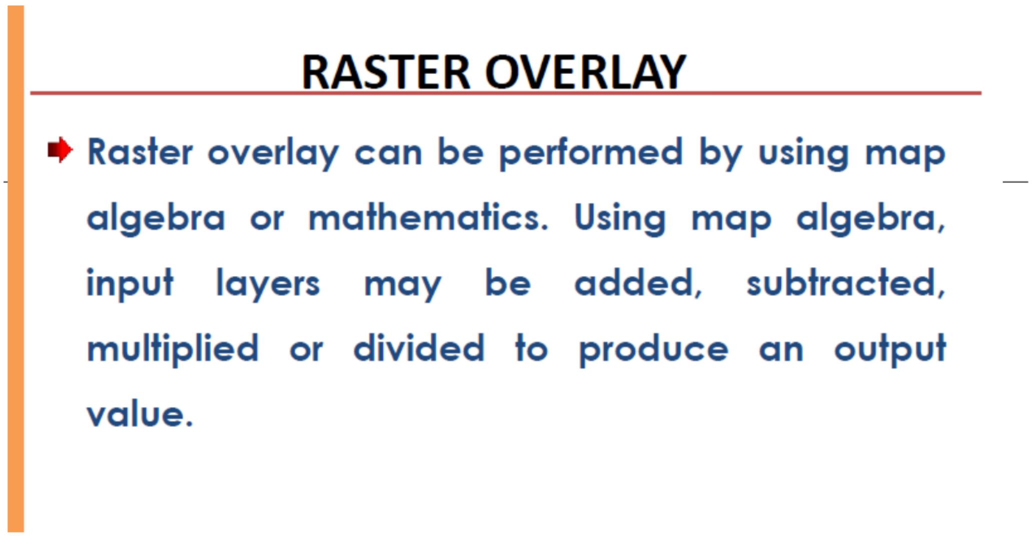


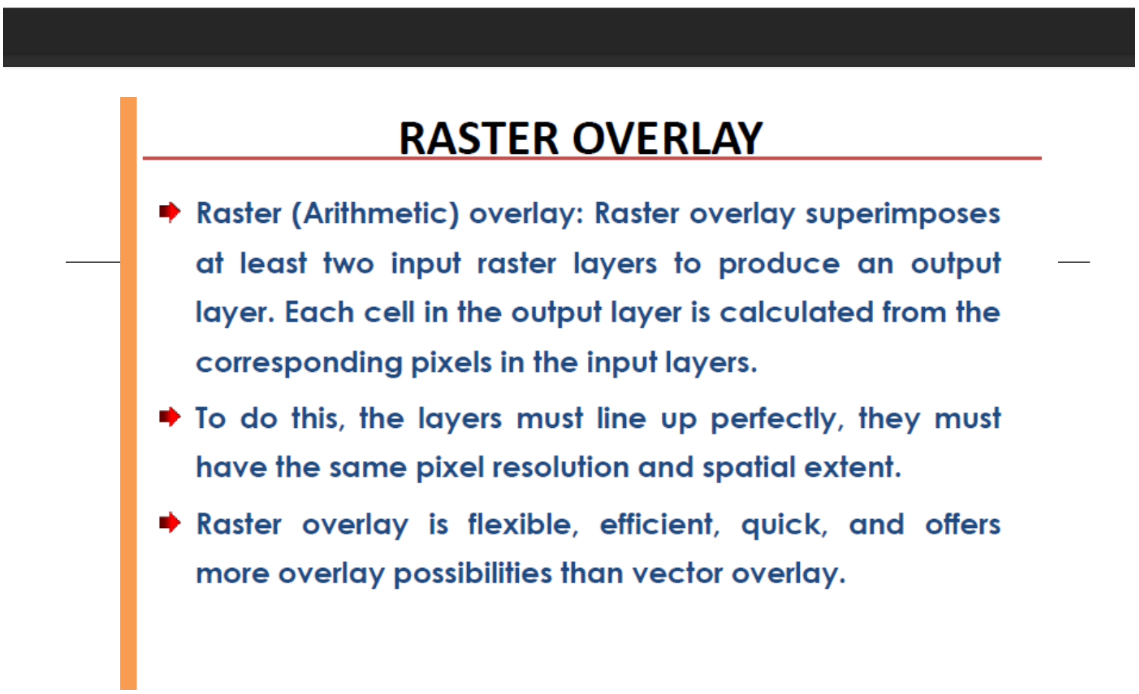
Polygon Topology

ID	Polygon (A)	Polygon (B)
1	1	B
2	2	C
3	3	A
4	2	B
5	2	A
6	1	C

Raster Overlay:

Raster overlay involves combining pixel-based raster layers, which are often used for continuous data. Common raster overlay operations include:





1. **Map Algebra:** Map algebra allows for various mathematical operations on raster layers, such as addition, subtraction, multiplication, division, and more. It is useful for creating composite datasets or performing spatial modeling.
2. **Boolean Overlay:** Boolean operations combine two or more raster layers based on logical conditions (AND, OR, NOT). For example, the AND operation combines layers where both conditions are met.

3. **Local Operations:** Local operations are applied to each cell individually and are often used for calculations, such as neighborhood statistics or filtering.
4. **Zonal Statistics:** Zonal statistics aggregate data within specific zones defined by a second raster layer. This is useful for analyzing data within predefined areas, such as watersheds or administrative boundaries.

RASTER-WEIGHTED OVERLAY ANALYSIS →

Raster-weighted overlay analysis is a spatial analysis technique used in Geographic Information Systems (GIS) to combine and analyze multiple raster layers or grids to make decisions or derive new information. This method assigns a weight to each raster layer, indicating its relative importance in a decision-making process. The weighted raster layers are then combined to create a composite output raster that represents the overall suitability or fitness of locations based on the assigned weights and individual layer values. This is particularly useful for multi-criteria decision-making in land use planning, environmental assessment, site selection, and more.

Here are the key steps involved in raster-weighted overlay analysis:

1. **Data Preparation:**
   - Collect and preprocess raster datasets that represent different factors or criteria relevant to the decision-making process. Each raster layer should have values that reflect the suitability, cost, risk, or any other attribute for each cell or pixel in the study area.
2. **Assign Weights:**
   - Assign a weight to each raster layer to indicate its relative importance compared to other layers. Weights can be numeric values, often between 0 and 1, with a higher weight indicating higher importance.
3. **Normalization:**
   - Normalize the values within each raster layer to ensure they are on a consistent scale. Common normalization methods include rescaling the values to a common range (e.g., 0 to 1) or converting them to suitability scores.

4. **Overlay and Weighting:**
    - Multiply each normalized raster layer by its corresponding weight. This is done to emphasize the importance of each layer in the final decision. The result is a set of weighted raster layers.
5. **Aggregate and Sum:**
    - Sum the weighted raster layers pixel-wise to create a composite raster that represents the overall suitability or desirability of each cell in the study area. The higher the value, the more suitable the location is according to the assigned weights and criteria.
6. **Final Analysis:**
    - Interpret the results of the weighted overlay analysis. The output raster can be used to identify the most suitable or optimal locations based on the combination of criteria and their assigned weights. It helps in decision-making and spatial planning.

Raster-weighted overlay analysis is widely used in applications such as land use planning, site selection, environmental impact assessment, natural resource management, and more. It allows decision-makers to consider multiple factors simultaneously and derive a comprehensive suitability or fitness map that can guide planning and decision processes.

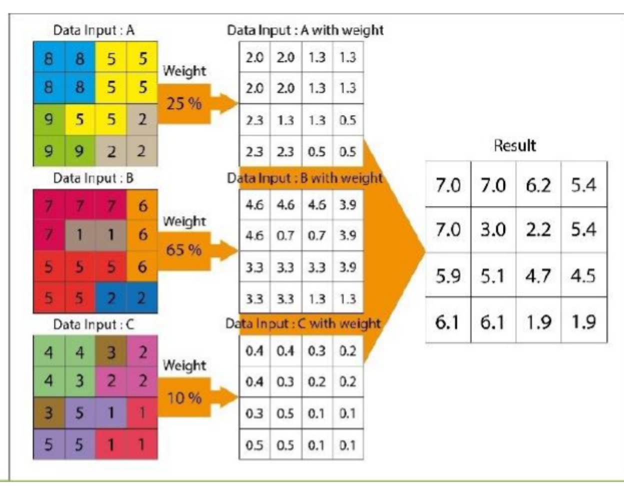
RASTER- WEIGHTED OVERLAY ANALYSIS

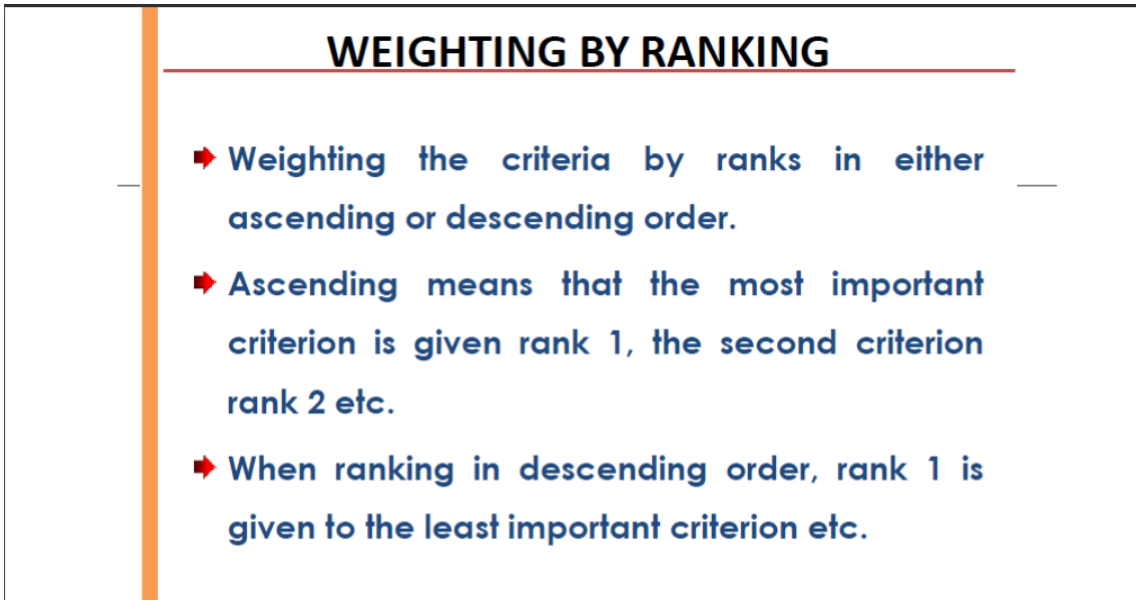
- Assigning a weight to each raster in the overlay process allows you to control the influence of different criteria in the suitability model.

RASTER-WEIGHTED OVERLAY ANALYSIS

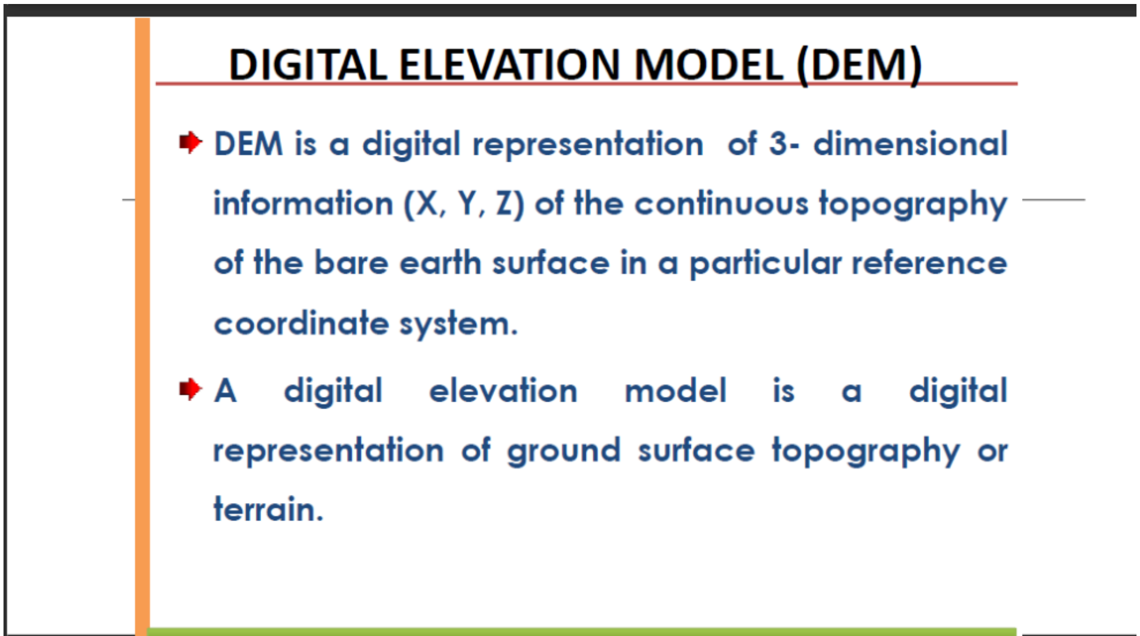
- Steps: 1. Each raster layer is assigned a weight in the suitability analysis.
- 2. Values in the rasters are reclassified to a common suitability scale.
- 3. Raster layers are overlaid, multiplying each raster cell's suitability value by its layer weight and totaling the values to derive a suitability value.
- 4. These values are written to new cells in an output layer.

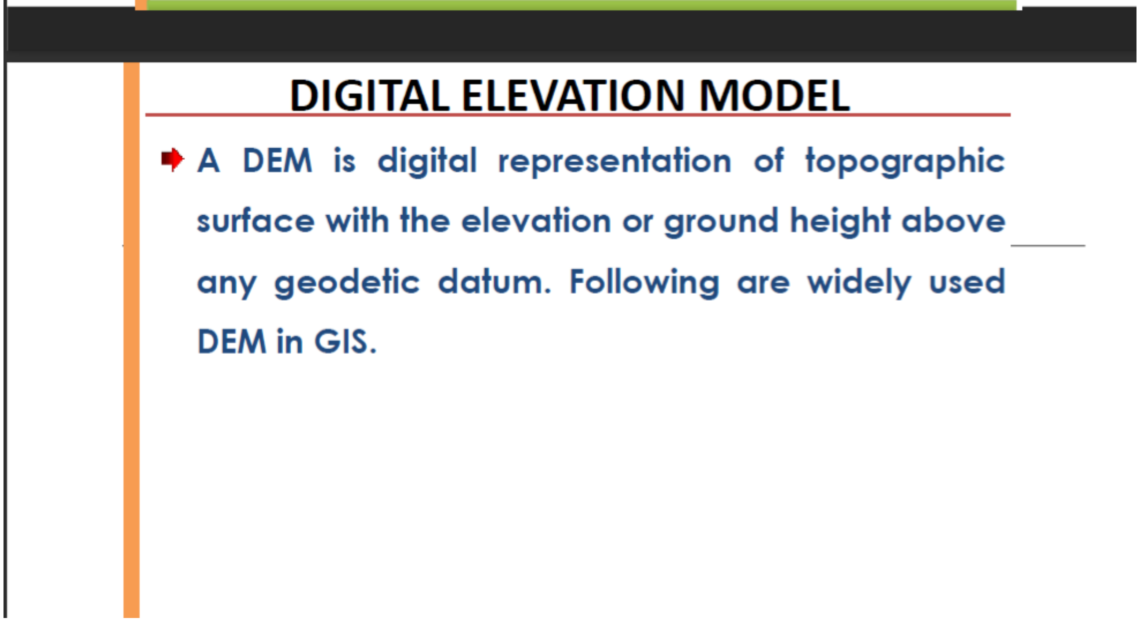
RASTER - WEIGHTED OVERLAY ANALYSIS





Digital Elevation Model (DEM) →



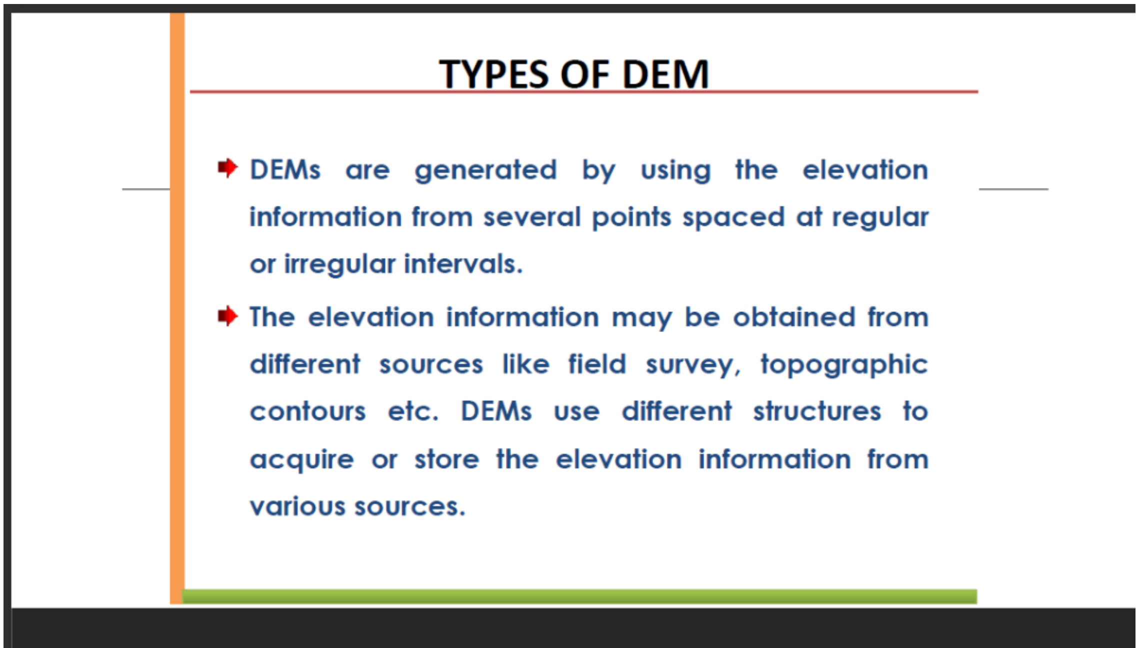


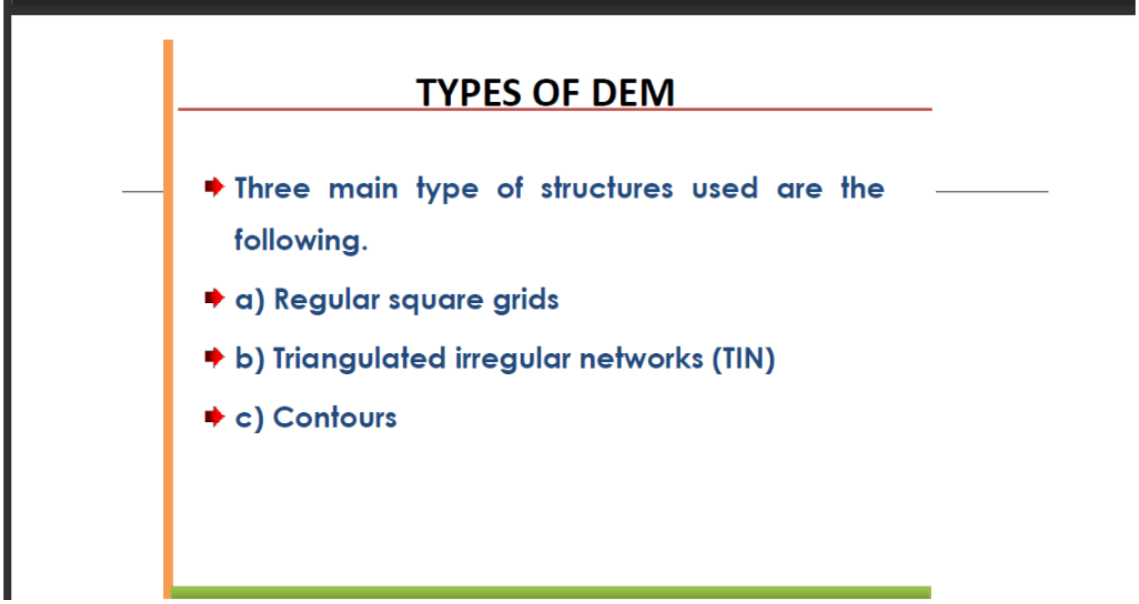
A Digital Elevation Model (DEM) is a digital representation of the topography or surface relief of the Earth's terrain. It provides a detailed and accurate description of the elevation (height) of the Earth's surface at various points and is commonly used in geographic information systems (GIS), remote sensing, and environmental modeling. DEMs are critical in various applications, including land use planning, hydrology, environmental analysis, and 3D visualization.

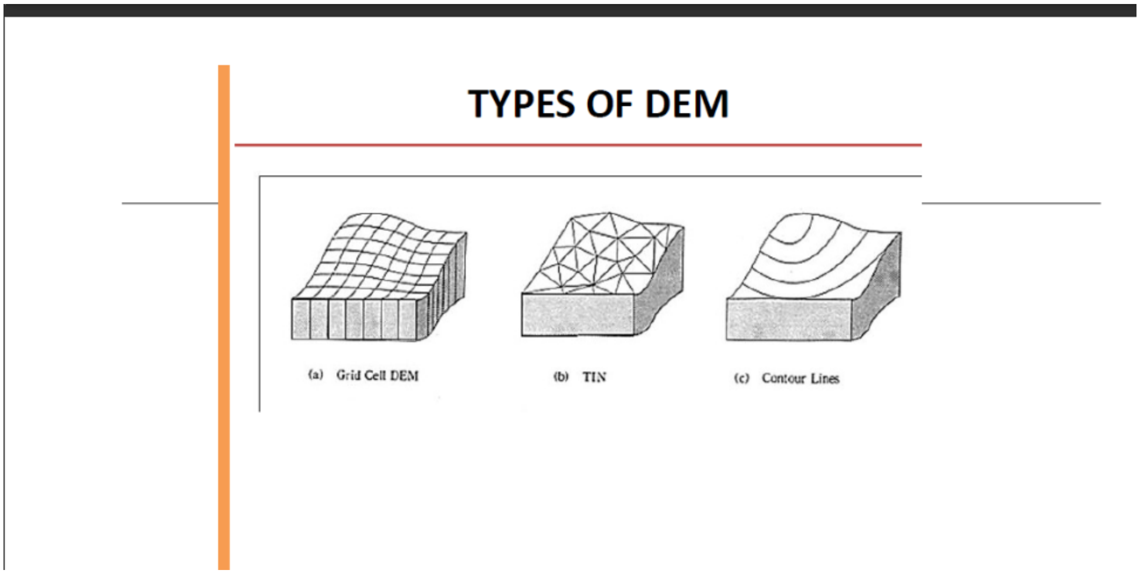
Key characteristics of Digital Elevation Models include:

1. **Grid Representation:** DEMs are typically represented as a grid or raster dataset, where each cell or pixel in the grid contains elevation data. The spacing between grid cells (known as the spatial resolution) varies and affects the level of detail in the DEM.
2. **Elevation Data:** Each cell in a DEM contains an elevation value, usually in meters or feet above a reference datum (e.g., mean sea level). These elevation values represent the height of the Earth's surface at that location.
3. **Coverage:** DEMs can cover a specific area or the entire Earth, depending on the source and purpose. Global DEMs, such as the Shuttle Radar Topography Mission (SRTM) DEM, provide elevation data for the entire planet.
4. **Data Sources:** DEMs are derived from various sources, including:
    - LiDAR (Light Detection and Ranging): LiDAR technology uses laser pulses to measure the distance between the sensor and the Earth's surface, creating highly accurate and detailed DEMs.
    - Photogrammetry: Aerial and satellite imagery can be used to create DEMs by analyzing the parallax and elevation information in stereo pairs of images.
    - Interferometric Synthetic Aperture Radar (InSAR): InSAR technology measures changes in surface elevation by comparing radar images acquired at different times.
5. **Accuracy:** The accuracy of a DEM can vary depending on the source data, spatial resolution, and the interpolation or processing methods used. High-resolution DEMs tend to be more accurate but also require more data and processing.
6. **Applications:** DEMs are used in a wide range of applications, including flood modeling, terrain analysis, viewshed analysis, route planning, 3D visualization, and natural resource management. They are crucial for understanding the Earth's surface and how it influences various processes.
7. **Derived Products:** From DEMs, additional products can be generated, such as slope maps, aspect maps, contour lines, hillshades, and watershed delineation, which provide valuable information for spatial analysis.

Digital Elevation Models play a vital role in various fields, such as civil engineering, environmental science, geology, agriculture, and urban planning, by helping professionals and researchers better understand and model the Earth's surface and make informed decisions based on terrain characteristics.







Digital Elevation Models (DEMs) can be categorized into different types based on their representation and structure. The types you mentioned, regular square grids, Triangulated Irregular Networks (TINs), and contours, represent three common methods for modeling terrain. Here's an explanation of each:

1. **Regular Square Grids:**
    - Regular square grids, also known as raster DEMs, are one of the most common types of DEMs. They divide the study area into a grid of equally sized square cells, and each cell contains an elevation value. The cells cover the entire area, providing a uniform and systematic representation of the terrain. Raster DEMs are well-suited for various GIS and spatial analysis tasks, such as surface modeling and hydrological analysis.
2. **Triangulated Irregular Networks (TIN):**
    - Triangulated Irregular Networks (TIN) are a different representation of terrain data. Instead of using a regular grid, TINs use a network of irregularly spaced triangles to model the surface. These triangles are formed by connecting a set of data points (e.g., elevation measurements) and creating a triangulated surface. TINs are useful for representing terrain in areas with irregular or sparse data points and can provide more accurate representations of terrain features such as ridges, valleys, and cliffs.

3. **Contours:**

   - Contours represent the elevation of the terrain by using contour lines. These lines connect points of equal elevation on the Earth's surface. Contour lines are particularly useful for visualizing terrain features and understanding elevation changes over a landscape. While not a typical DEM in the traditional sense, contour lines can be derived from DEM data and are often used in cartography, topographic maps, and land surveying.

Each type of DEM has its own advantages and applications. Regular square grids (raster DEMs) are suitable for many spatial analysis tasks due to their uniform structure, while TINs are valuable when dealing with irregular or sparse data. Contours, on the other hand, provide a visual representation of elevation and are widely used in cartography and map production. The choice of DEM type depends on the specific needs of a project and the nature of the terrain being modeled.

TYPES OF DEM

- Grid DEM : The result is a matrix whose indices are the coordinates and values are the elevation value at each point (raster representation)
- From this sample representation it is possible to get a representation of the relief.

REPRESENTATION OF DEM

- Grid DEM: They are based on the values of the elevation at the sampling points- one height per pixel (grid cell).
- The grid representation is the consequence of sampling elevation values in regular intervals of latitude and longitude.

DEM - PARAMETERS →

DEM - PARAMETERS

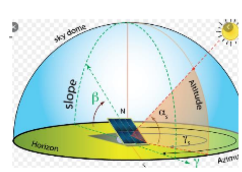
- A DEM (Digital Terrain Model) is digital representation of terrain features including elevation, slope, aspect, drainage and other terrain attributes.
- Usually a DTM is derived from a DEM or elevation data.
- Several terrain features including the following DTMs.
- 1. Slope and Aspect
- 2. Drainage network
- 3. Catchment area
- 4. Shading
- 5. Shadow
- 6. Slope stability

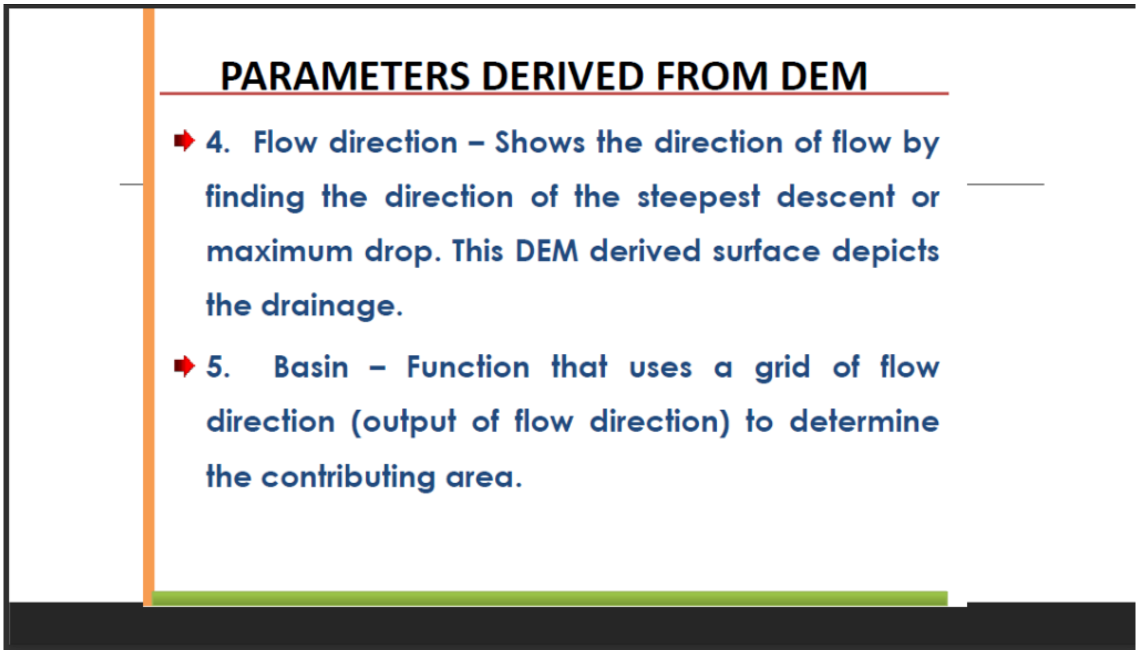
PARAMETERS DERIVED FROM DEM

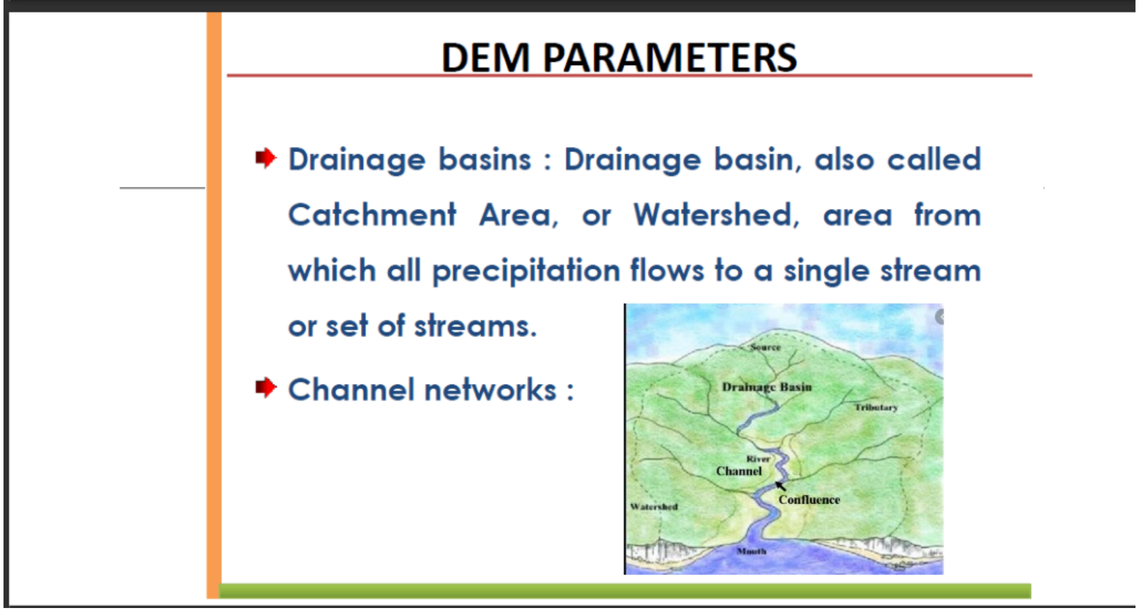
- Slope – Displays the grade of steepness expressed in degrees or as percent slope. This image can reveal structural lineaments, fault scarps, fluvial terrace scarps, etc.
- 2. Aspect – Identifies the down-slope direction. Aspect images may enhance landforms such as fluvial networks, alluvial fans, faceted fault related scarps, etc.

PARAMETERS DERIVED FROM DEM

- 3. Shaded topographic relief or hill-shading – This image depicts relief by simulating the effect of the sun's illumination on the terrain.
- The direction and the altitude of the illumination can be changed in order to emphasize faults, lineaments, etc.
- This image is probably the most useful to display geological data related to landforms in terrains that show a close correlation between geology and topography.







The analysis of Digital Elevation Models (DEMs) can provide valuable information about various terrain features. Here's a brief description of the terrain features you mentioned and how DEMs can be used to derive them:

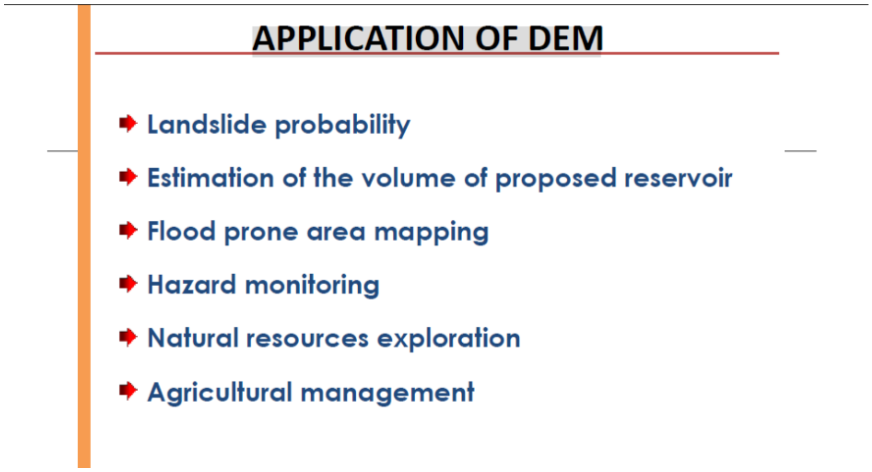
1. **Slope and Aspect:**
   - **Slope:** Slope represents the steepness or gradient of the terrain. It can be calculated from a DEM by measuring the rate of change in elevation over a certain distance.

- **Aspect:** Aspect indicates the compass direction (e.g., north, south, east, west) in which a slope faces. It is calculated based on the direction of steepest descent for each cell in the DEM.

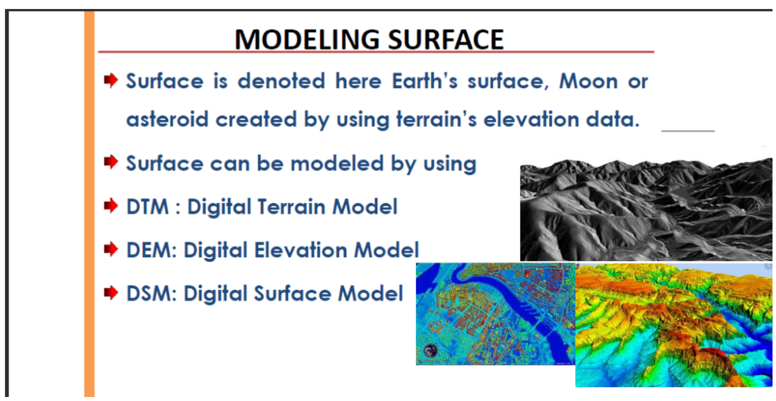
2. **Drainage Network:**
    - A drainage network or river network is derived from DEMs to identify the flow paths of surface water. By delineating flow directions and accumulation, you can map rivers, streams, and watersheds.
3. **Catchment Area:**
    - Catchment or watershed area represents the land area that drains into a specific point, such as a river mouth or outlet. DEMs are used to delineate catchment boundaries and calculate their areas.
4. **Shading:**
    - Shading in a DEM is used to create hillshading, which provides a visual representation of the terrain's three-dimensional nature. Hillshading can reveal the relief and elevation of the terrain using lighting and shadows.
5. **Shadow:**
    - Shadows are areas in the terrain that do not receive direct sunlight due to the elevation and the position of the sun. Analyzing shadows in a DEM can be useful for understanding sunlight exposure and shading in various applications, including solar energy planning.
6. **Slope Stability:**
    - DEMs can be used to assess slope stability, particularly in areas prone to landslides or erosion. Factors like slope, aspect, soil types, and land cover can be combined to evaluate slope stability and identify potential risks.

These terrain features are fundamental for various applications, including environmental modeling, natural resource management, land use planning, and civil engineering. DEMs play a central role in deriving and analyzing these features, providing valuable insights into the topography and landscape characteristics of an area.

APPLICATION OF DEM →



Modeling Surface (DTM , DEM ,DSM) →



Digital Terrain Model (DTM), Digital Elevation Model (DEM), and Digital Surface Model (DSM) are related but distinct representations of the Earth's surface, each serving specific purposes in geographic information systems (GIS) and spatial analysis. Here's an explanation of each:

1. **Digital Terrain Model (DTM):**
    - A Digital Terrain Model (DTM) represents the bare Earth's surface by removing all above-ground features, such as buildings, vegetation, and other structures. It focuses solely on the natural terrain, including mountains, valleys, and landforms. DTMs provide accurate elevation data and are used for terrain analysis, hydrological modeling, and topographic mapping. DTMs are particularly valuable when assessing the Earth's surface for engineering and environmental applications.

2. **Digital Elevation Model (DEM):**
    - A Digital Elevation Model (DEM) represents the elevation of the Earth's surface, including both natural terrain and any above-ground features like trees, buildings, and infrastructure. DEMs are a more general representation of elevation and are commonly used for various GIS and spatial analysis tasks. Depending on the source data and processing, DEMs may include features such as buildings and vegetation, making them less suitable for certain terrain-specific analyses compared to DTMs.
3. **Digital Surface Model (DSM):**
    - A Digital Surface Model (DSM) represents the elevation of the Earth's surface, including all objects and features on it. This includes natural terrain, buildings, vegetation, bridges, and other structures. DSMs capture the "surface" as seen from an aerial or satellite perspective, which means they include the height of all visible objects. DSMs are used in applications like 3D visualization, urban planning, and telecommunications for assessing line-of-sight and obstacle analysis.

In summary, DTMs focus exclusively on the natural terrain and are used for detailed terrain analysis. DEMs include both natural terrain and above-ground features and are more commonly used for general GIS tasks. DSMs incorporate all visible objects and structures on the Earth's surface and are often used for 3D visualization and infrastructure planning. The choice of which model to use depends on the specific requirements of a given application.

DIGITAL TERRAIN MODEL

- A Digital Terrain Model is a topographic model of the bare-earth terrain relief, that can be manipulated by computer programs.
- The data files contain the spatial elevation data of the terrain in a digital format which usually presented as a rectangular grid.
- Vegetation, buildings and other man-made (artificial) features are removed digitally- leaving just the underlying terrain.

DIGITAL TERRAIN MODEL

- DTM model is mostly related as raster data type, stored usually as a rectangular equal-spaced grid, with space of between 50 and 500 meters mostly presented in Geographic coordinate system.

DIGITAL SURFACE MODEL

- DSM : Surface model which captures the natural and built features on the Earth's surface.
- DSM's measure the height values of the first surface on the ground. This includes terrain features, buildings, vegetation and power lines etc. DSM's therefore provide a topographic model of the earth's surface. DSM's can be used to create 3D fly-through, support location-based systems and augmented simulated environments.

DIGITAL SURFACE MODEL

- DSM is generated using LIDAR (Light Detection and Ranging) system, which sends pulses of light to the ground and when the pulse of light bounces off/back its target and returns to the sensor, it gives the range of the Earth.
- LIDAR delivers a massive point cloud filled of varying elevation values (Height can come from the top of buildings, tree canopy, power lines, other built and natural features).
- DSM is useful in 3D modeling for telecommunications, urban planning and aviation (objects extrude from the earth, particularly useful in these application to identify obstructions).

Expert system and its components →

What is expert system and its components?

Expert system, a computer program that uses artificial-intelligence methods to solve problems within a specialized domain that ordinarily requires human expertise.
An **expert system** generally consists of four **components**: a knowledge base, the search or inference **system**, a knowledge acquisition **system**, and the user interface or communication **system**. Knowledge **systems** solve difficult problems of the real world by performing inference processes on explicitly stated knowledge

The internal **structure** of an **expert system** can be considered to consist of three parts: the knowledge base ; the database; the rule interpreter. the set of productions; the set of facts held as working memory and a rule interpreter. The knowledge base holds the set of rules of inference that are used in reasoning.

An expert system is a computer-based system that emulates the decision-making ability of a human expert in a specific domain or field. It uses knowledge, reasoning, and problem-solving techniques to provide solutions, make recommendations, or assist in decision-making. Expert systems typically consist of several key components:

You are correct, and I appreciate your concise summary. In the traditional expert system architecture, there are indeed four core components:

1. **Knowledge Base:**

- The knowledge base is a repository of domain-specific information, rules, facts, and heuristics that the expert system uses to make decisions and provide recommendations. It encapsulates the expertise of human domain experts.

2. **Inference Engine (Search or Inference System):**
   - The inference engine is responsible for processing the knowledge stored in the knowledge base. It uses various reasoning methods to draw conclusions, make decisions, and solve problems. This component is at the heart of the system's decision-making process.
3. **Knowledge Acquisition System:**
   - The knowledge acquisition system is the mechanism or tools used to capture and transfer expertise from human experts into the knowledge base. It facilitates the process of acquiring and structuring the knowledge within the system.
4. **User Interface (Communication System):**
   - The user interface provides a means for users to interact with the expert system. It can take various forms, including command-line interfaces, graphical user interfaces, natural language interfaces, or web-based interfaces. The user interface allows users to input queries and receive responses from the system.

These four components work together to create an expert system that can mimic the decision-making capabilities of a human expert in a specific domain. The knowledge base provides the foundational information, the inference engine processes this information, the knowledge acquisition system ensures the knowledge is kept up to date, and the user interface allows users to interact with the system effectively.

Limitations of Expert System

- The response of the **expert system** may get wrong if the knowledge base contains the wrong information.
- Like a human being, it cannot produce a creative output for different scenarios.
- Its maintenance and development costs are very high.
- Knowledge acquisition for designing is much difficult.

What is the purpose of an expert system?

In artificial intelligence, an **expert system** is a computer **system** emulating the decision-making ability of a human **expert**. **Expert systems** are designed to solve complex problems by reasoning through bodies of knowledge, represented mainly as if–then rules rather than through conventional procedural code.