**GIS Notes**

Everything you experience from day to day happens somewhere in geographic space. As a result, you can represent your world and your experiences in it by using maps. You use those maps to find places, save time while traveling, decide where to locate a new store, plan cities, guide the development of wildlife preserves, and satisfy hundreds of other applications.

The computer systems that enable you to store and access all this information are collectively called geographic information systems (GIS).

Examples of people that may use GIS:

* Business owners and marketers
* Urban planners
* Merchandise distributors

Using GIS software, you can put maps and other geographic data into the computer. After you have the data in the computer, you can store, retrieve, and edit that data. You can analyze it (for example, find geographic features, measure distances, or compare patterns) and produce output from it (create new maps from what you find).

A GIS system is comprised of:

* Data
* Computers and software
* Geographic concepts that drive the analysis of data
* People that operate the GIS
* The organizations within which the GIS exists

Primary data are collected firsthand by you, for a particular project. Primary data are usually the best data for the job because you collect them with your specific goals in mind. Secondary data come from others who collect the data for unrelated tasks or gather it with remote sensors.

The process of entering data into a GIS system can be summed up as:

1. Define where, how, and what kind of data to sample
2. Collect that data directly or indirectly
3. Use the software to transform that data

You may need to change some data from hard copy to digital forms; you may need to convert some from uncategorized to categorized data (for example, aerial photo interpretation); and you may need to attach coordinates to digital data so that you can find them in your digital maps.

Hardware used to collect GIS data includes:

* Devices to collect information
* Devices to enter information
* Storage and analysis devices
* Output devices

Grid cells: one method of storing data in squared boxes, that may be utilized by a GIS system.

Organizations that use GIS work best when the organization adapts itself to the technology. If GIS helps the organization perform its tasks, if the employees are adapting to and benefitting from the changes, if the organization provides training, and if GIS enhances the organization's overall goals, that organization can likely incorporate GIS successfully, long-term.

A system designer reviews an organization's structure, products, workflow, and needs. He or she then determines the costs and benefits of GIS for that organization, as well as how the organization might best include GIS in critical operations.

Geographers know that all things are related in geographic space, but close things are more related than far things. This statement describes one aspect of geographic space — closeness — that makes space so important to you as a geographic decision-maker. Listed below are some terms that also relate to geographical space as it is used in GIS.

Density: refers to the measure of how concentrated or dispersed a phenomenon is within a specific geographic area.

Sinuosity: refers to the degree of curvature or winding of a linear feature, such as a river, road, or coastline. Sinuosity is a measure of how much a linear feature deviates from a straight line.

Connectivity: refers to the degree to which geographic features or locations are linked or able to interact with each other. Connectivity can be evaluated in terms of physical connections, such as roads or transportation networks, as well as conceptual connections, such as social or economic linkages between places.

Pattern Change: refers to the observed modifications or transformations in the spatial distribution, arrangement, or characteristics of geographic features over time

Movement: refers to the study and analysis of the spatial trajectories, patterns, and dynamics of objects, people, or phenomena as they change location over time.

Shape: refers to the geometric properties and configuration of geographic features and objects.

Size: refers to the physical dimensions and measurement of geographic features and objects.

Isolation: refers to the degree to which a geographic feature or location is physically or functionally separated from its surrounding environment or other features.

Adjacency: refers to the spatial relationship between geographic features or locations that are next to or bordering one another.

Geographic data come in four basic forms: points, lines, polygons (or areas), and surfaces. A fifth form, related to surfaces, is volumes.

* Points: refer to the simplest form of geographic feature, represented by a single x,y coordinate location on a map or in a spatial dataset.
* Lines: refer to linear geographic features represented by a series of connected x,y coordinate points.
* Polygons: refer to geographic features that are represented by enclosed two-dimensional areas defined by a series of connected x,y coordinate points.
* Surfaces: refer to continuous geographic features or phenomena that can be represented and analyzed as three-dimensional spatial data.
* Volumes: refer to the three-dimensional representation and analysis of geographic features and phenomena that have measurable depth or thickness, not just length and width.

Most GIS systems contain database tables that allow you to store all sorts of descriptive information about the points, lines, areas, and surfaces that you're depicting in your GIS. The nature of database tables requires you to be just as picky about assigning descriptive information to your objects as you are about choosing the right graphics to depict the objects themselves.

Nominal information: Geographic features that have names only. So, you can't compare their descriptive information to any other.

Ordinal information: Geographic features that you can compare by rank. You could have short, medium, and tall trees; dirt roads, paved roads, highways, and superhighways; or large, medium, and small chemical spills.

Interval information: Geographic features that have detailed increments (intervals) that you can measure. One limiting characteristic of interval data is that, although you can get very accurate measurements, you can't form ratios because the starting point is arbitrary.

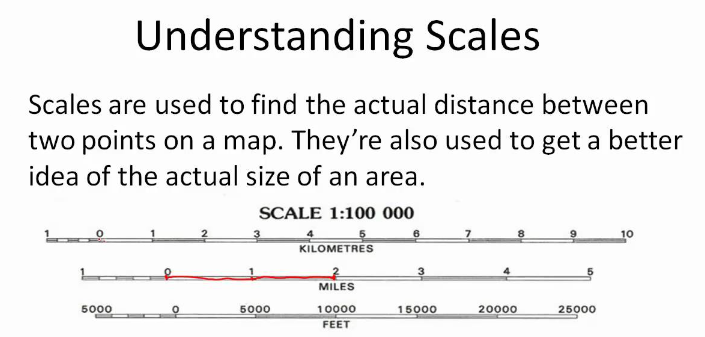
Ratio information: Geographic data that have measurable units, like interval data, but also allow you to make the ratio comparisons that interval data won't. If you own a parcel of land that's worth $20,000 and your neighbor has a parcel worth $10,000, then your parcel isn't just worth $10,000 more, it's also twice as expensive. The key point is that ratio data have an absolute 0.

Scalar information: data are a bit difficult to define, but here's my take: Scalar data have a proprietary measurement system. That is, you create your own scale that applies to only a particular set of data. So, if you're ranking the beauty of a scenic overlook on a scale of 1 to 10, you first have to decide what each number in the scale means. GIS allows you to establish a scalar description for features that you can't really measure any other way.

Map Extent: refers to the geographic area or region that is visible and displayed within the current map view or window.

Map scale refers to the relationship between the distance on a map and the corresponding distance on the earth's surface. Specifically, map scale is the ratio or proportion that expresses how much the map has been reduced or enlarged compared to the actual geographic space it represents.

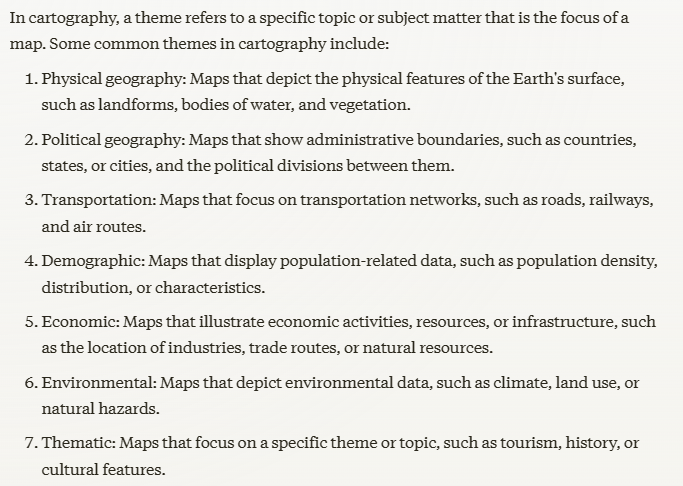
You can often find a map's scale represented by a graphic bar and a fraction that shows the relationship between the size of the map in the numerator (the fraction's top part) and the size of the Earth in the denominator (the fraction's bottom part). Using this mathematical approach, the smaller the fraction (one with a small numerator and a large denominator), the smaller the scale.



Cartographers use symbols that represent point features (such as towns), symbols that represent linear features (such as roads and rivers), and symbols that represent area features (such as lakes and towns).

Cartographers have to carefully consider certain things when they create a map:

* Scale: Determines how many geographic features can be symbolized on a map.
* Data availability: Determines what type of information can be put on the map.
* Limitations of output devices: The cartographer also has to consider how symbols will print.
* Reader characteristics: Not all readers have 20/20 vision, color vision, or any vision at all.



Reference maps offer a great deal of information on a single document. Atlases generally contain reference maps so that many related maps can be contained in the same place. Reference maps often cover very large portions of the Earth.

A thematic map provides as much accurate, detailed information as possible about a particular subject, such as roads or hills, as compared to a reference map, which tries to select the most important information about several subjects.

A road map is one example of a thematic map because it focuses on communicating information about roads.

Thematic maps are the primary kind of maps that you use in your GIS activities.

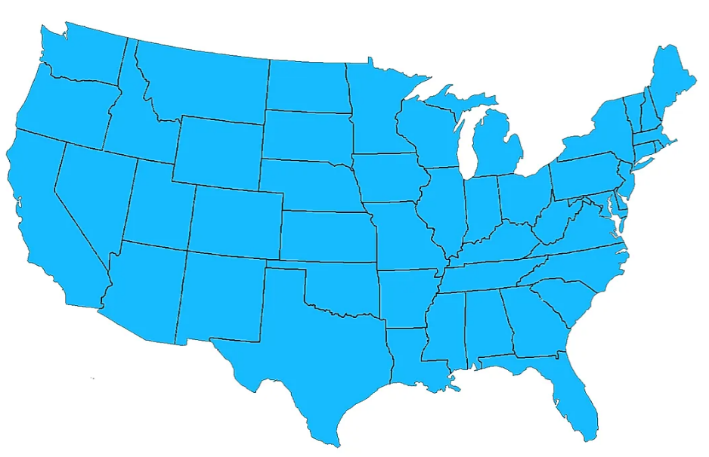
A good rule of thumb is that the larger the map scale, the smaller the area covered and the greater the detail. Larger scale maps are generally better for your GIS activities because they provide the largest amount of detail.

The “weakest link” hypothesis: the success or failure of a complex production process or system depends on the performance of the weakest component or link in the chain. This is mentioned in GIS as a way to remind the GIS operator that quality of a geographic product depends on it’s worst/lowest quality input.

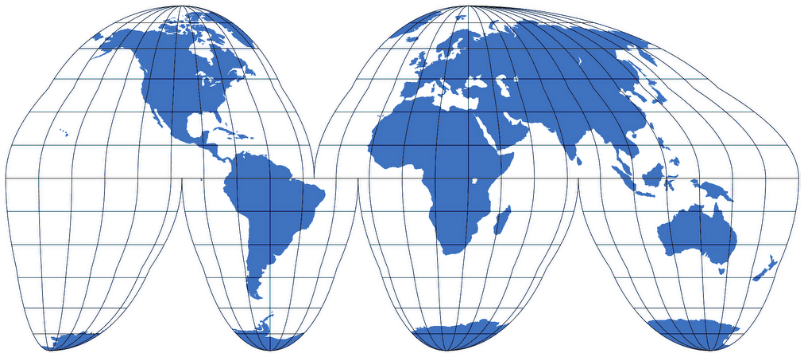
The earth’s spherical shape has some major drawbacks for the mapmaker who's faced with producing a flat map that correctly represents the shapes, angles, distances, and sizes of objects on the Earth. It is expected that some distortion will occur when translating a round object to a flat object.

Map projections —the process of converting the spherical Earth to a flat surface — come in many different types, from contiguous to interrupted, from those that look like photographs of the Earth to those placed on cones or cylinders.

Contiguous map: a type of map in which all the geographic areas or units depicted are connected to each other, with no gaps or disconnected regions. Example shown below:

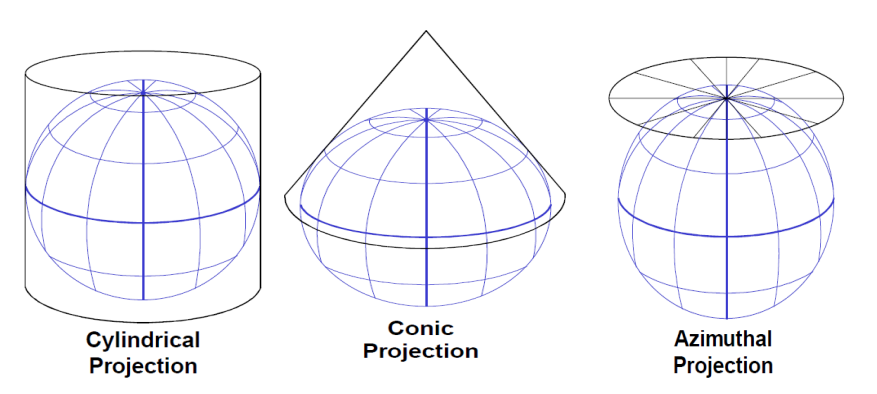


Interrupted map: a type of cartographic projection that intentionally breaks or interrupts the continuity of the map in order to better display certain geographical features or regions. Example shown below:



Another way to describe map projections is:

* Planar or Azimuthal
* Conical
* Cylindrical



When working with GIS, pick the map projection that best represents the properties you want preserved when you create output maps from your analysis. Most high-end GIS software has the capability to convert back and forth from one projection to another. Most have more map projections than you'll ever use.

Having an accurate representation of distance and area measurements in any projected map depends on having accurate measurements of the spherical Earth. The science of geodesy deals specifically with these measurements.

Geodesy is the scientific discipline focused on the measurement and representation of the Earth, including its gravitational field and geometric shape. It encompasses a range of activities and techniques related to accurately determining the size, shape, and position of the Earth.

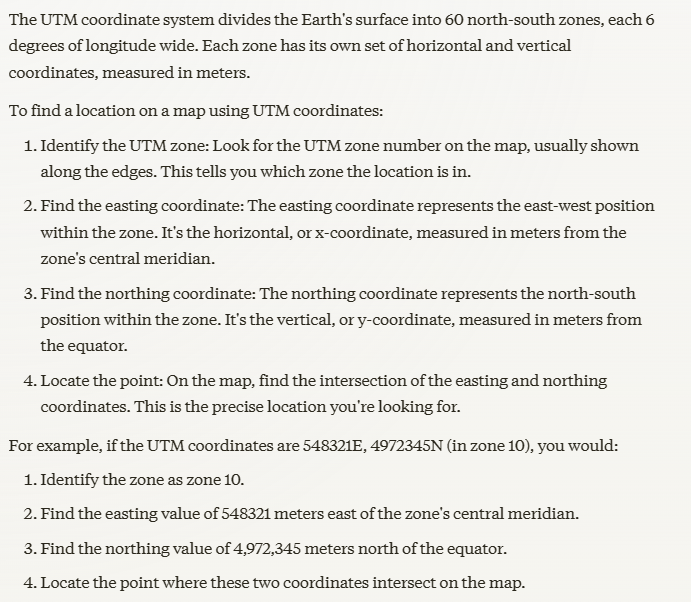
A datum is a set of parameters and control points that define the size, shape, and orientation of the Earth's surface within a particular coordinate system. It provides a frame of reference for accurately locating and positioning geographic features and coordinates.

Your GIS software needs to know what datum you're using for each set of map data that you put into your database. Attaching your coordinates to the wrong datum can result in location and measurement errors.

When loading up your GIS, be sure to use the correct datum for each map source as you add it. Also, convert all your map data to a common datum when you work with more than one source map at a time.

Coordinate systems in GIS (Geographic Information Systems) are reference frameworks used to define and represent the location of geographic features and data on a map or within a digital mapping environment.

One of the many possible coordinate systems that you may encounter in GIS is called the UTM system. UTM stands for Universal Transverse Mercator, which is the most commonly used system. This system divides the Earth from latitude 84° north and 80° south into 60 numbered vertical zones, each 6 degrees of longitude wide.



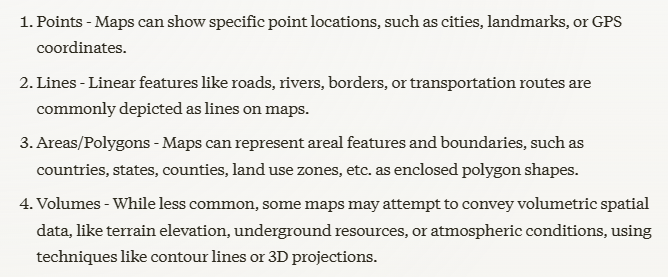
The PLSS, or Public Land Survey System, is a method used in the United States to survey and identify land parcels. Here are some key points about the PLSS:

* Origins: The PLSS was established in the Land Ordinance of 1785 and later refined in the General Land Office Survey Act of 1796. It was created as a way to systematically survey and divide up the public lands in the western United States after the American Revolution.
* Grid System: The PLSS divides land into a grid system based on principal meridians and base lines. The basic unit is the township, which is a 6-mile by 6-mile square. Each township is further divided into 36 one-mile square sections.
* Surveying Methodology: PLSS surveys are conducted using a rectangular system of section lines, rather than following natural features of the land. Surveyors use instruments like theodolites and chains to establish the grid.
* Land Ownership: The PLSS was used to measure and distribute public lands to private owners through mechanisms like the Homestead Act. It also laid the groundwork for the current system of land titles and property ownership in much of the western U.S.
* Significance: The PLSS has been critical for the orderly settlement and development of the American West. It provides a consistent, standardized way to identify and describe land parcels across large geographic areas.
* Continued Use: The PLSS is still in use today and forms the basis for all official land surveys and property descriptions in the 30 states where it was originally implemented.

The baseline is a critical east-west line that serves as the starting point and reference for the PLSS grid system. Surveyors establish the baseline, often along a prominent geographic feature. All township lines run parallel to the baseline, forming a grid of 6-mile by 6-mile townships. The townships are then numbered north and south from this fixed baseline. Baselines provide the foundational reference points that allow for the systematic division and description of land parcels across an entire state or region using the PLSS township and range system.

A principal meridian is a north-south line that, along with a baseline, forms the origin and framework for the Public Land Survey System (PLSS) in the United States.

Symbols are lines, objects, or pictures on the map that represent real objects on the ground.



Those are important concepts related to the measurement scales used in spatial data and maps. Here's a brief explanation of each:

1. Nominals:

* Nominal scale is a basic level of measurement that assigns unique labels or categories to objects or places.
* Nominal data has no inherent order or numerical value, it simply classifies things into discrete groups.
* Examples on a map could include different land use types (residential, commercial, industrial) or political boundaries (countries, states, counties).

1. Ordinals:

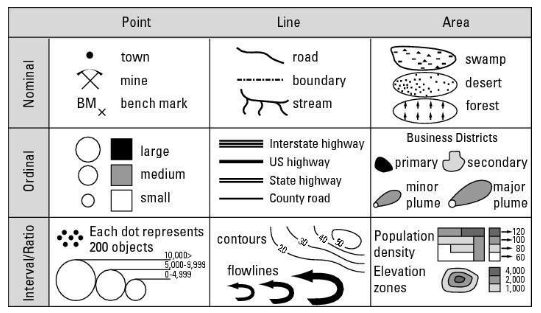
* Ordinal scale indicates a ranked order or hierarchy between different values.
* Ordinal data can be sorted or sequenced, but the differences between values may not be uniform.
* Examples on a map could include elevation levels shown by contour lines or socioeconomic status represented by income quintiles.

1. Intervals:

* Interval scale data has a consistent, measurable distance between values.
* Interval data has a meaningful zero point and the differences between values are equal.
* Examples on a map could include temperature, precipitation, or population density shown using a quantitative color scale.

In GIS, a ratio scale has a meaningful zero point and equal intervals between values, allowing for measurement of absolute magnitudes. Examples include population density, income, and elevation. Ratio data enables powerful quantitative spatial analysis and visualization techniques in GIS.

Geographic features and how they are measured:



In GIS (Geographic Information System), non-comparative data refers to a type of data that represents a single point in time or a snapshot of a particular phenomenon. This type of data is not intended to be compared or analyzed in relation to other data, but rather to provide a standalone representation of a geographic feature or attribute.

Non-comparative data is often used to:

* Describe a single event or occurrence
* Represent a static condition or state
* Provide a baseline or reference point for future comparison

Line features: Streets, rail lines, and boundaries, for example, are unique entities and can't be compared to one another.

Areas: A swamp, the range of a wild species, the land owned by the federal or state government, or the type of zoning for a particular parcel of land.

Volume features: Water aquifers, hills, and buried ore bodies all take up volume and are named on maps.

In GIS (Geographic Information System), comparisons of kind refer to a type of analysis that involves comparing different types of data or phenomena that share a common attribute or characteristic. This type of comparison is used to identify similarities or differences between different datasets or features that are fundamentally distinct, but share a common theme or category.

Graduated symbols are a type of symbol used in mapping and Geographic Information Systems (GIS):

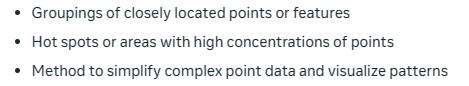
* Symbol size: Graduated symbols vary in size to represent quantitative differences between mapped features.
* Data classification: Data is grouped into classes, with each class assigned a symbol size to represent the range.
* Color: The color of the symbols remains the same, while the size changes to represent different classes.
* Used for: Graduated symbols are used to show differences in magnitude or quantity, such as population density or earthquake magnitude.

In GIS (Geographic Information System), a class refers to a category or group of features or data that share similar characteristics or attributes.

One cool thing about maps is that the symbols represent a scaled-down version of real geography. As much as possible, the map's symbolic objects, features, and background are distributed and located in ways that closely resemble the locations and distributions of real objects.

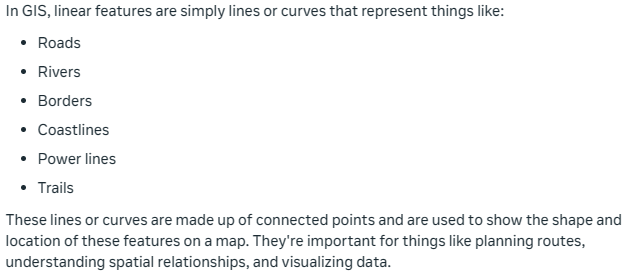
When you identify patterns, you look for a degree of predictability in the arrangement of the objects you're interested in. To make the best use of GIS information, the trick is to notice patterns that you may not be used to seeing, such as patterns of trees, houses, roads, rivers, or any other features you encounter.

Clusters help identify and visualize spatial patterns and concentrations.



Hotspots: refers to clusters of criminal activity in an area.

Uniform distribution in GIS is a probability distribution where all values within a specified interval have the same probability. A good example might be an orchard, where trees are planted in lines that are even to one another.



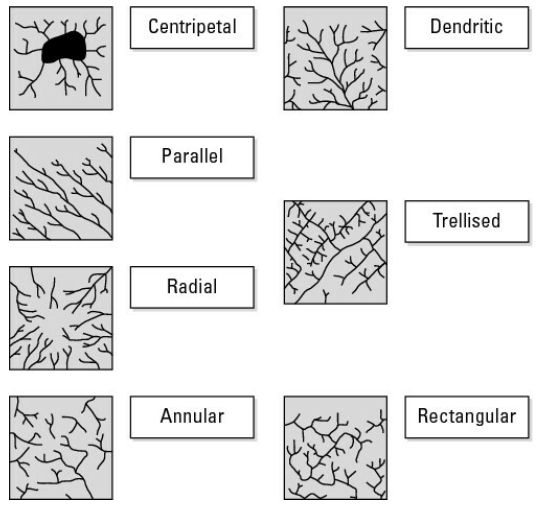
Connectivity: Refers to the physical communication links between devices and the ability of plants and animals to move freely between different wildland areas.

Some road networks and highways allow you to go around obstructions, rather than just through them. These networks form closed loops, or circuits, just like in an electrical circuit. When road networks have circuits, traffic has an alternative because it can flow around obstacles that drivers might want to avoid.

In GIS, linkages are connections between different devices, systems or areas. Linkage Mapper is a GIS tool designed to support regional wildlife habitat connectivity analyses. Linkage Mapper uses GIS maps of core habitat areas and resistances to identify and map linkages between core areas.

Some stream pattern types include:

* Dendritic: The easiest one for me to remember is called dendritic and looks like the branches of a tree. These branches (called tributaries) go out in all directions and seem to have a mind of their own.
* Radial: Another common pattern that streams take is called radial. A radial pattern looks like a dendritic pattern, except that all the streams flow outward, away from a center, like the spokes of a wheel.
* Centripetal: The opposite of radial patterns, centripetal patterns occur when a low spot or depression affects the flow.
* Parallel and sub-parallel streams run along the gentle slopes that result from either natural topography or from land manipulation because of road or mining construction activities.
* Trellis: Trellis stream patterns result from rock strata that's jointed, exposed, and folded from geological forces acting over time. Trellis patterns resemble the street patterns in neighborhoods loosely organized along a grid.
* Rectangular: Rectangular stream patterns show strong right-angle turns and are often the result of cross-cutting joints in the underlying rock.
* Annular: Annular stream patterns occur in areas which have a dome that is eroded.



There are three things that a GIS operator must be able to do with patterns:

1. Accurately describe the patterns in a way that the layperson can understand.
2. Quantitatively compare and contrast your descriptions of the patterns to those of other features and feature sets.
3. Analyze the quantities that you identify to determine a measure of their pattern or shape, and to provide a baseline for changes that might take place over time.

Your GIS software knows which values you need for your analysis because when you put your spatial data into the computer, you tell the software exactly where each point is and how that point relates to the feature's real position on the surface of the Earth.

The nearest neighbor statistic in Geographic Information Systems (GIS) is a way to measure how objects, like points, are distributed across a space. It’s often referred to as the Nearest Neighbor Index (NNI). This statistic helps determine whether the distribution is clustered, random, or uniform:

* Clustered: Points are closer together than expected if randomly distributed.
* Random: Points are neither too close nor too far apart; their distribution is as likely as by chance.
* Uniform (or regular): Points are evenly spaced out, more so than in a random pattern.

The Nearest Neighbor Index is calculated by comparing the average distance from each point to its nearest neighbor with what would be the average distance in a perfectly random distribution. An NNI less than 1 indicates clustering, an NNI greater than 1 indicates a uniform distribution, and an NNI close to 1 suggests a random distribution. This statistic is particularly useful in spatial analysis to understand patterns and their implications in various fields such as ecology, urban planning, and public health.

You use nearest neighbor statistics to make sure that what your eye has already told you is real and not a figment of your imagination.

You can use certain techniques to determine the average direction of linear objects, such as tornado paths, fallen trees, boulder distributions, shelterbelts (protective barriers such as windbreaks), and many other objects. Without going into the trigonometry, it simply gives you a summary statement of the direction in which these events and objects occur. This calculation might, for example, tell you the direction of wind during storms, the movement of a glacier while it leaves debris behind, or the way that farmers line up planted trees to protect their crops from the wind.

After you become familiar with the idea of seeing and recognizing patterns for your own specialty, you next need to use your specialized knowledge to identify the reasons they exist. A process creates every pattern, and every pattern has an effect on the process that created it.

Follow these steps when analyzing GIS data:

1. Recognize and acknowledge the existence of the patterns.
2. Analyze and verify that the patterns are real.
3. Identify the causes and consequences of these patterns based on your knowledge of the study area.
4. Apply this knowledge in your own profession for prediction and planning.

GIS software allows you to create new scenarios and model the consequences of change to help you decide which of your scenarios works best. But the GIS can't tell you what the functional relationships are. It allows you to test different ideas and make pattern comparisons, but you, as the expert, have to decide which factors to examine and which patterns to compare.

GIS specialists can't always apply the software to effectively solve problems because they're often not subject matter experts. So, subject matter specialists need to communicate the possible causes and consequences of patterns to the GIS applications developer.

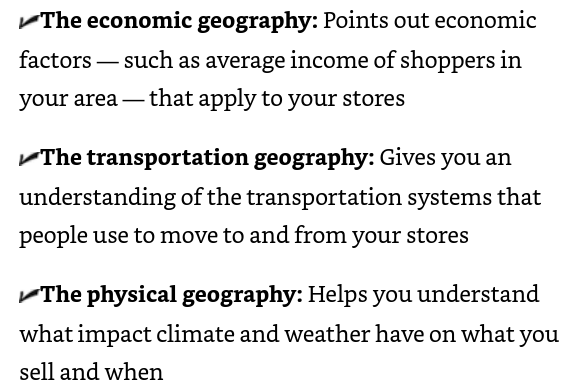
Maps are complex, and human map readers (like you) interpret much of the information that those maps contain. So, to create a GIS that has both complex and useful information, you have to show the computer how to think like you do as a map reader.

A good first step in deciding what to do in your GIS maps is to formulate a conceptual model, or a picture in your mind, of how you plan to tell the computer all the information you gather from a map.

When starting a Geographic Information Systems (GIS) project, the key is first to clearly understand the desired outcome. Begin by envisioning what the final product should look like. Next, break down this final product into the different types of maps or themes that will be needed. Finally, identify the specific elements of each map—like features and their related data—that are necessary for the project. These elements will then be combined to construct the final map. This structured approach ensures that the GIS project is both organized and purposeful.

Sometimes, composing a flowchart before starting is a good way to organize and gain a visual idea of what the GIS will need to look at to get good output.

A few different types of geography for an area include:



By starting at the final product, you can break the final map down into the individual data component that are required to construct it.

Most major GIS decision-making operations deal with the locations or distributions of features.

Outline details of your project and ask the specific questions that tell you exactly what data you need from the thematic maps you've already chosen.

Each digital thematic map is part of a larger group of digital maps that you use to answer your GIS question. Each map has features represented by points, lines, areas, and volumes that contain useful information for you. If you're just starting your current GIS decision-making process, you need to know what data you have in the GIS database in the first place.

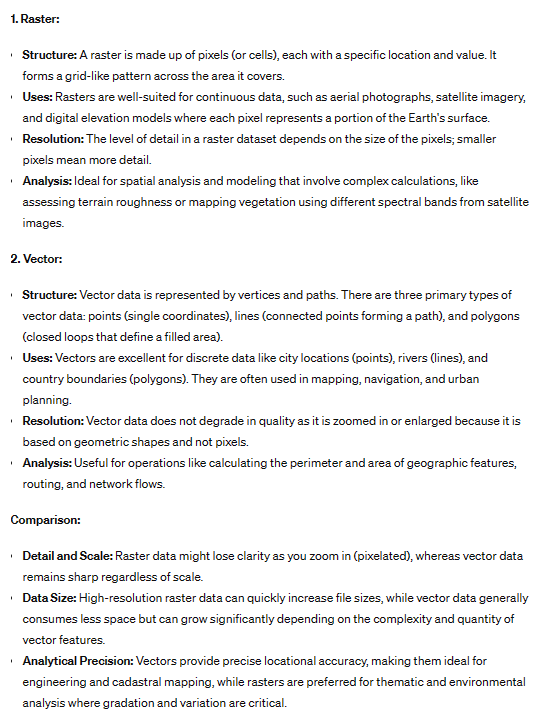
You will need to know characteristics of the data you’re working with. This includes:

* Data measurement- is it nominal, ordinal, interval, or ratio
* Level of detail- what scale is needed from the map to show all the features

A good point to keep in mind is that you want to start off with as much detailed data as necessary. It’s easier to generalize from a detailed dataset, than it is to get specifics from a generalized dataset.

In GIS terms, polygon refers to area, and surface means that a feature has a third dimension (for example, height).

Cartographers use two general data forms that translate the map into digital form: raster (little squares or grid cells) and vector (or points, lines, and polygons).



In a conceptual model of geography, points have no dimensions (length or width).

In grid cell-based GIS, a string of grid cells represents a linear object (such as a road, a railroad, or a walking path). This string of cells can be lined up orthogonally (edge to edge), diagonally (along the corners), or some combination, depending on how curvy the feature is. Line objects are considered to have only one dimension (length), even though they usually have some width in the real world.

Polygons are a fundamental data type used to represent and model spatial features on the Earth's surface or within a defined spatial reference system. Polygons are closed, multi-sided shapes that have no gaps or overlaps, and they are commonly used to represent various geographic entities such as land parcels, administrative boundaries, building footprints, water bodies, and vegetation cover. These cells may be connected (contiguous) or disconnected (noncontiguous). Polygons usually are used to measure area in a GIS.

When you're representing surfaces or their volumes, each grid cell has, in addition to length and width, a number associated with the height or depth of the space. This number may represent elevation above sea level or depth to groundwater for a point at the center of a grid cell. In some GIS, grid-cell values even represent non-physical surfaces, such as population density or land appraisals.

Raster GIS represents points by using a single grid cell, lines by using a line of grid cells, areas by using a group of grid cells, and surfaces by using groups of grid cells that have additional unique values.

In GIS, vectors are a fundamental data model used to represent geographic features as discrete points, lines, and polygons. Vectors are based on coordinate geometry and allow for the precise representation and analysis of spatial data.

A Triangulated Irregular Network (TIN) is a vector-based data structure used in Geographic Information Systems (GIS) to represent continuous surfaces or terrain models. A TIN is particularly useful for modeling irregular or complex terrain surfaces, as it allows for variable resolution and can accurately represent features like ridges, valleys, and steep slopes. The neat thing about the TIN model is that you can use it to predict (interpolate) missing values, create cross sections through surfaces and volumes, draw contour lines, and create 3-D visualizations.

Most modern GIS software has both raster and vector data components, or it can convert from one format to another. You need to determine the most important functionality, accuracy, and storage issues for the work you want to do when you decide on GIS software.

The differences between Raster and Vector data models in GIS are:

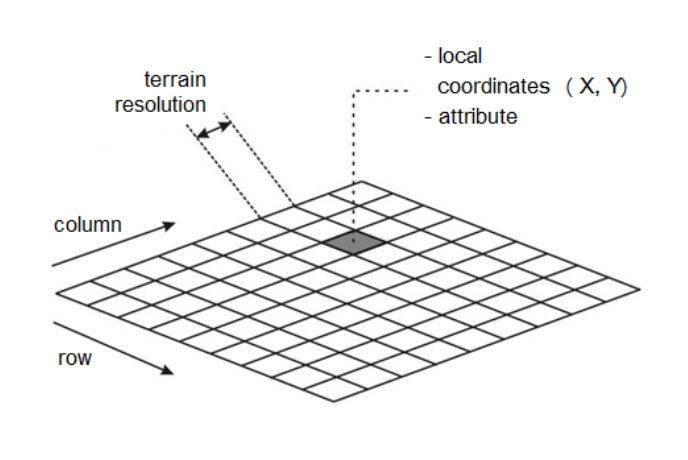
Raster Data Model:

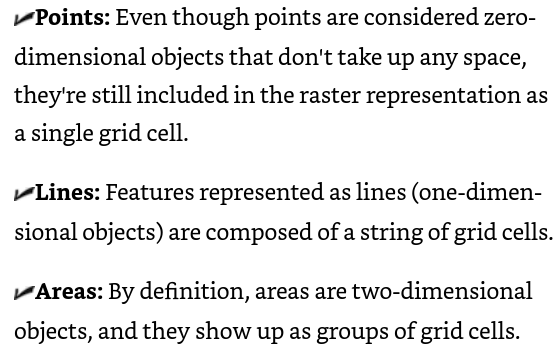
* Represents spatial data as a grid of cells/pixels
* Each cell stores a single value (e.g., elevation, land cover)
* Good for continuous data like satellite imagery, terrain models
* Resolution depends on cell size
* Spatial operations can lead to data degradation

Vector Data Model:

* Represents spatial features as geometric primitives (points, lines, polygons)
* Defined by precise x,y coordinate pairs
* Good for discrete features with well-defined boundaries (roads, parcels)
* Can maintain high precision at any scale
* Efficient representation of topology and spatial relationships

A grid overlay shows how each square represents a portion of real geographic space.





Cell grid resolution: The smaller the dots, the higher the resolution, and the more accurate the representation.

Using layered grids for modeling requires that:

* All the grids represent the same portion of the Earth.
* Grids are co-registered (meaning they lie directly on top of one another).
* Each grid cell is the same size in every map layer.

Raster GIS gives you the power to search the grid in two ways. You can search by coordinates to examine what the grid cell represents, or you can search by grid-cell quality to find out where grid cells with that quality are located.

A map theme typically corresponds to a thematic layer or a collection of related layers that share a common attribute or characteristic. For example, a map theme could represent roads, land use, population density, or vegetation cover.

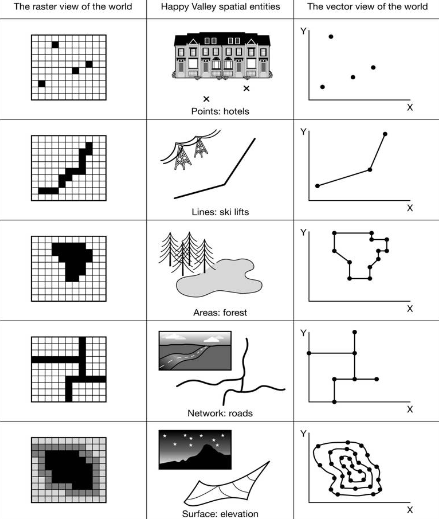
Map data breaks down into these components:

* Theme
* Category
* Value

The Map Analysis Package (MAP) data model makes it easy to find individual categories in a single thematic grid. Map packages are portable files that contain a map document (.mxd), the data referenced by the layers, and the page layout. They can be used to share maps between colleagues, across departments, or with other GIS users. Map packages can also be used to create an archive of a map or a snapshot of its current state.

Extending the raster data model by including a database management system gives you a lot more flexibility. But you need to make sure that you know where to look for the categories and that you give them names you can remember. Always use meaningful and memorable names for categories, ID-codes (codes you use for categories), and maps, if at all possible.

Simple forms of vector representation focus more on the accurate graphic depiction of features and less on the subsequent analysis of geographic information.



In a spaghetti representation of vector data:

1. Linear features are stored as individual line segments without any topological structure or relationships defined between them.
2. Line segments that should be connected (e.g., at intersections or nodes) are not explicitly linked or defined as connected entities.
3. Line segments may overlap, resulting in redundant data and potential inconsistencies.
4. Gaps or undershoots may exist between line segments that should be connected.