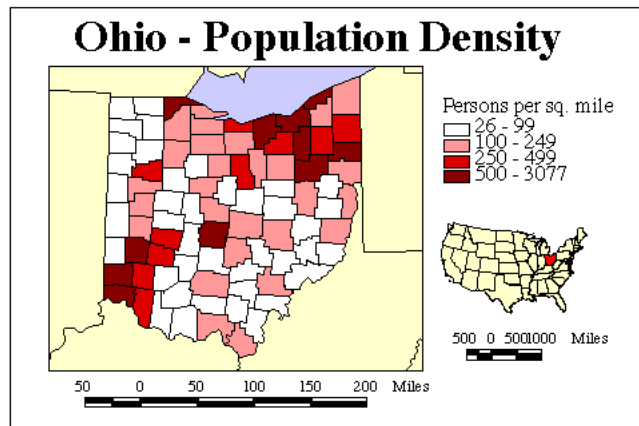


Introduction to Map Design



Introduction

This document is intended to help people without formal training in map design learn to produce maps for publication or electronic display using ArcView, a desktop geographic information system (GIS). A GIS is a system for the display, analysis, storage and retrieval of information about places on the earth. GIS is a useful tool for exploring information and communicating your discoveries to others using maps and other graphic images.

GIS can be used either as a research tool, where maps are intermediate steps in an analysis, or as a map production tool, where publication-ready maps are the end product. In either case, knowing something about the basic principles of map making (cartography) will help you use GIS more effectively.

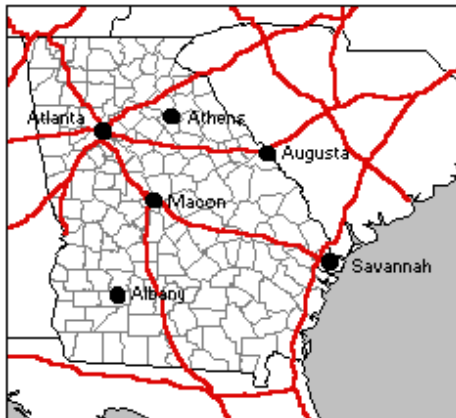
When GIS is part of the analysis process, the maps will be changing constantly, and the design of any one map depends on the overall design of the project. It may not be necessary to create an elaborate layout for each map, because some maps may be temporary - useful only as intermediate steps in the analysis process.

When GIS is used as a map production tool, however, it is important to make each map as informative as possible. The map user and the map designer probably will be different people, and the map user is not necessarily familiar with the information in the GIS - the “data behind the maps.”

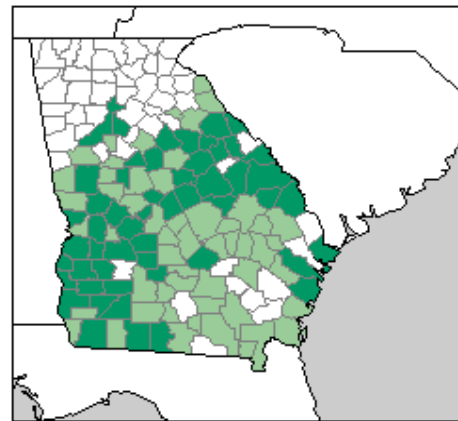
Cartography is both an art and science. This document is not a “paint-by-numbers” set of rules, but rather a guide to some of the general principles that cartographers have refined over many years. Remember, however, that creative control ultimately rests with you.

Types of Maps

There are two general types of maps. Maps that give general information about the location of features are **reference** maps. Maps in a road atlas are an example of reference maps, as are topographic maps. Those that show the distribution of a specific topic are **thematic** or statistical maps. A map showing population distribution by county is a thematic map.



Reference Map



Thematic Map

Although both reference and thematic maps can be constructed from the data contained in a GIS, this document will focus on thematic maps. Thematic mapping involves some activities that aren't necessary for reference maps. However, most of the information concerning good map design applies equally well to reference maps.

General Mapping Concepts

All maps are representations. It is not possible to show features at their actual size nor is it possible to show full detail. A map is a model of the earth at a reduced **scale**. Some maps, such as diagrams of chromosomes or atoms, are at an enlarged scale, but generally, maps are smaller than the things they represent. Because features cannot be shown at their true size, they must be **generalized**. Some details are omitted to make the most important characteristics of a feature more apparent. In addition, three-dimensional objects have been flattened for a two-dimensional display. The transfer of features from three dimensions to two involves the use of a **map projection**.

When you look at a map, you don't see real features like buildings or people; you see **symbols** that represent these things. These symbols should be easily understood by the map reader. If they are not, the map will not communicate its message. Guidelines exist to help you use symbols effectively, but they are not absolute laws, like one might

find in physics. There is also room for artistic expression - an attractive map will catch the eye more easily than a dull one.

By now, the map you see on the screen or page might look quite different than the things you see in the real world. Is it still an accurate view of reality? **Map accuracy** is difficult to assess. All maps show a selective view of reality, so rather than ask "Is the map accurate?" it might be better to ask "Is the map appropriate for my purposes?"

Once all the decisions about data, classification and symbols have been made, you'll want to create a **map composition** that includes the map, a title, a legend, a scale and any other information needed for a complete presentation of your data.

As you can see, designing a good map involves more than choosing colors and typestyles. Fortunately, a geographic information system such as ArcView makes it easy to see the effects of your map design decisions quickly and to try several alternatives before committing to a final design.

Map Scale

Maps are scale models of the earth. Real world objects have been reduced by a constant amount, and the map scale tells us the amount of reduction (or enlargement). A map scale is a ratio, where one unit on the map represents many times that value in the real world. Thus, if a map scale is "1:100", one inch on the map represents 100 inches in the real world. The unit of measurement is not important; one could just as easily say one foot on the map represents 100 feet on the ground; the ratio remains constant. However, you should be careful not to mix units (e.g., one inch represents 100 feet).

Representing scale

A map scale can be represented graphically as well as verbally. You probably have seen a scale bar on a highway map - a line with distances marked off, often in both miles and kilometers. Many people find graphic scales easier to use than verbal scales. For example, a one inch line labeled 1 mile might be easier to interpret than the equivalent ratio, 1:63,360. In addition, a graphic scale remains true even if a map is reduced or enlarged by photocopying or other means of reproduction.

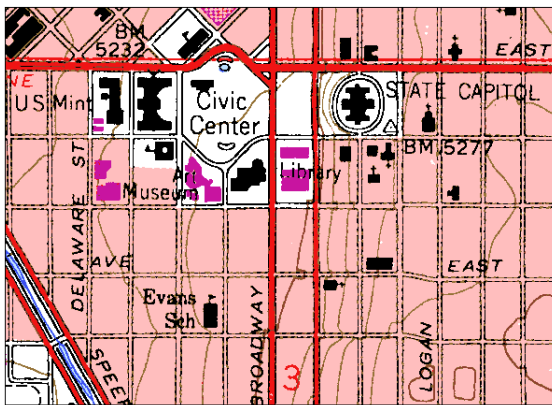


Suppose you had a map at this scale - 1 inch to the mile (63,360 inches), and you need to reduce it to 80% of its original size. When you reduce the map, a graphic scale will be reduced by the same proportion and will still be accurate. A verbal scale, however, will be in error by 25%. One inch on the map now will represent 79,200 inches (1.25 miles), not 63,360 inches. It is probably safest to use a graphic scale, because you can't always control how others will use your map.

Describing Scale

Maps often are referred to as being “large scale” or “small scale”. Oddly enough, a large scale map shows more detail than a small scale map, which confuses many people. If you think of scale in terms of fractions, however, this makes sense. The fraction $1/10,000$ is larger than $1/25,000,000$. Thus, a map at $1:10,000$ would be larger scale than a map at $1:25,000,000$. There are no rules about what is considered large scale or small scale, but generally, $1:24,000$ and larger is large scale and $1:250,000$ and smaller is small scale.

The following maps provide examples of large scale and small scale maps. The map on the left is at a scale of approximately $1:24,000$, and shows a small portion of downtown Denver. The map on the right is at a scale of approximately $1:50,000,000$, and shows western Europe.



Large Scale



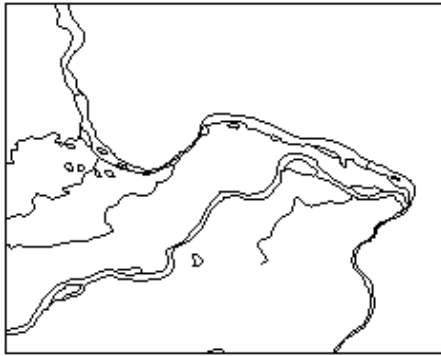
Small Scale

Selecting a scale for your map

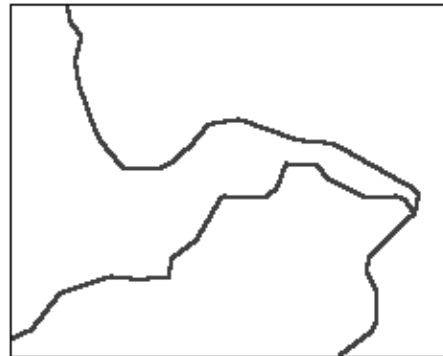
Our discussion of map scale up to this point has focused on the map display. However, scale is also important in the selection of data sources, which occurs early in the map-making process. Every data set is designed for display at a particular scale (or within a range of scales). For example, a $1:500,000$ data set will look “right” when displayed at that scale, but will look too sketchy if displayed at $1:50,000$. If displayed at $1:5,000,000$, it will look too “busy” or crowded and will take too long to draw.

Here are two maps of the same area; eastern Missouri, where the Missouri River flows into the Mississippi River north of St. Louis. The map on the left is drawn from $1:2,000,000$ scale data; the map on the right, from $1:25,000,000$ scale data. Notice that

both maps show the same general features, but give you very different impressions. The 1:2,000,000 scale data are much more detailed. Because this data set contains more information, it will take longer to draw on-screen and will require more storage space than the 1:25,000,000 scale data set.



1:2,000,000 scale data



1:25,000,000 scale data

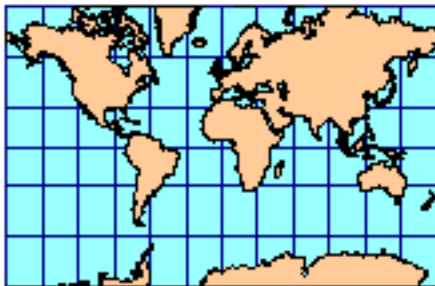
Whenever possible, you should match the scale of your source data to the intended display scale. However, if you are using data collected by someone else, this may be difficult. Fortunately, some types of data are available at multiple scales. For example, the ArcUSA database includes 1:2,000,000 and 1:25,000,000 scale data. The 1:2,000,000 scale data could be used for a map of a single state, while the 1:25,000,000 data would be appropriate for a map of the entire US.

If you are displaying multiple data sets, be sure they are compatible. Data gathered for display at 1:1,000,000 should not be displayed with 1:10,000 scale data. When you display small scale data (1:1,000,000) at a large scale (1:10,000), your map could be misinterpreted as being more precise than the data warrants. Also, because the small scale data will be more generalized than the large scale data, features in different layers might not be aligned correctly.

Map Projections

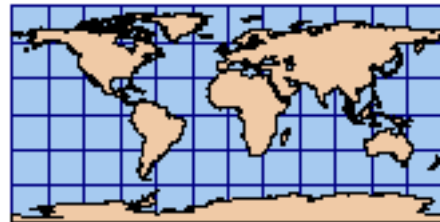
A map projection is a set of rules for transforming features from the three-dimensional earth onto a two-dimensional display. No flat representation of the earth can be completely accurate, so many different projections have been developed, each suited to a particular purpose. Map projections differ in the way they handle four properties: area, angles, distance and direction. No projection can preserve all four simultaneously, although some combinations can be preserved, such as area and direction. No projection can preserve both area and angles, however. The map-maker must decide which property is most important and choose a projection based on that.

Equal Area projections preserve area, and are also called **equivalent** projections. Most thematic maps should use an equal area projection. The Albers Equal Area Conic projection is commonly used for the United States; common projections for the world are Equal Area Cylindrical and Sinusoidal.



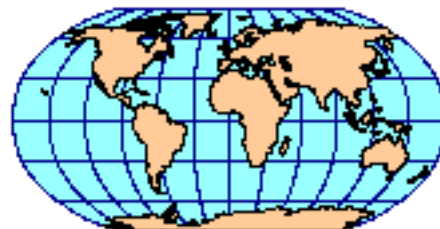
Conformal projections preserve angles, and are useful for navigational charts and weather maps. Shape is preserved for small areas, but the shape of a large area such as a continent will be significantly distorted. Common conformal projection are the Lambert Conformal Conic projection and the Mercator projection.

Equidistant projections preserve distances, but no projection can preserve distances from all points to all other points. Instead, distance can be held true from one point to all other points or from several points to all other points. Several projections have the property of equidistance.



Azimuthal projections preserve direction from one point to all other points. This property can be combined with any of the other three. Thus, it is possible to have an Equal Area Azimuthal projection, such as Lambert, or an Equidistant Azimuthal projection.

Compromise projections minimize overall distortion, but preserve none of the four properties. The Robinson projection, for example, is neither equal area nor conformal, but is aesthetically pleasing and useful for general mapping.



Map Generalization

Generalization is an umbrella term for several processes, all intended to remove unnecessary detail. Because maps cannot show everything, the mapmaker must **select** which features to show and which to omit. Features may need to be **simplified** to be legible at a smaller scale. In many cases, data need to be **classified** - divided into groups of similar values. Finally, **symbols** must be chosen to represent features on the map.

Selection and Simplification

Typically, selection and simplification activities occur during the compilation of a database, rather than during the map-making process. However, you may find that a data set has more features than you need, and that you want to map only a subset of the features. You could generalize the data base by selecting a set of features for your map (e.g., select only cities with a population greater than 500,000 or select only Interstate highways).

Simplification is a more complex process, and actually modifies the features stored in the database. Map makers have developed elaborate methods for simplification that are beyond the scope of both this document and most desktop GIS software. Although you might not be involved in map generalization directly, you should be aware that many data sets you use are generalizations of the original source data.

Classification

For most maps, it will be necessary to classify the data before mapping them. It is not usually practical to have a unique symbol for each data record. For example, on a map of population density by state, it would not be possible to distinguish fifty shades of grey. Instead, states with similar values should be grouped together and shown with the same symbol. Most people can distinguish about seven classes. Depending on the quality of your monitor or printer, however, five classes may be a more practical limit.

You should be sure that your classification adequately describes the phenomenon you are mapping. Classes should be exhaustive (describe all possible values) and should not overlap (no value can fall into two classes). For example, suppose you are mapping land use using the following categories: residential, industrial, park, and institutional. As you are assigning parcels to these classes, you find a parcel that is farmland. It does not fit into any of these classes; how do you classify it? Your choices are to create a new class for farmland or to expand the definition of one of the existing classes to include farmland.

There are several approaches to classifying data, and the characteristics of your data set and the purpose of your map will determine which is best. An understanding of basic

statistical concepts, such as mean, standard deviation, and data distribution, is invaluable for understanding data classification. Below is a description of some common classification schemes:

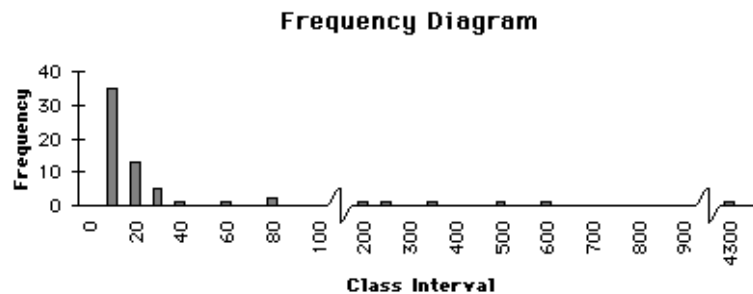
Equal range. Equal distance between class breaks. Useful when diagram of data distribution is rectangular, and enumeration areas are of equal size.

Quantiles. Equal number of observations in each class. Class intervals can be dramatically different in size.

Standard deviation. Class breaks based on distance of standard deviation from the mean. Useful if diagram of data distribution is a normal curve. Good for showing deviation from the mean.

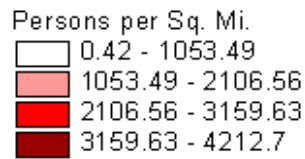
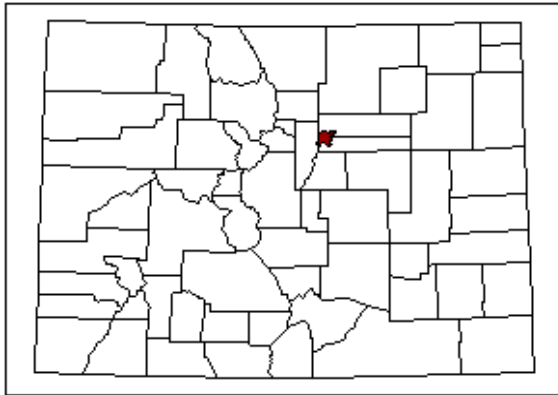
Natural breaks. Class breaks conform to gaps in data distribution. George Jenks developed a classification similar to this that mathematically minimizes variation within classes, and maximizes variation between classes.

Below are examples of these four classification schemes, using the same data set and geographic area. The maps show population density by county in Colorado. The data distribution is quite skewed, with most of the values below the mean, and a few very high values.

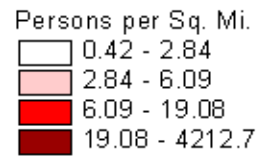
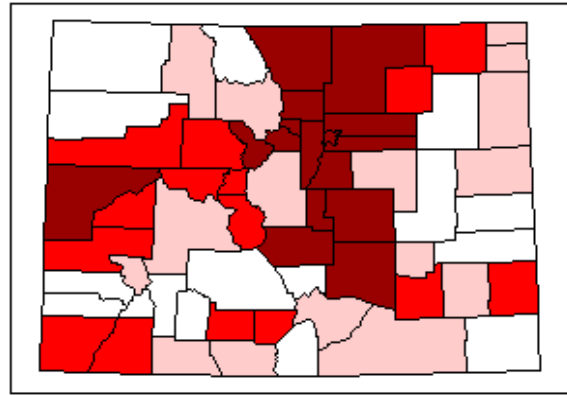


Because there is such a large range of values with one extreme value, the Equal Interval classification is not very informative, as every county but one falls in the lowest class. The Quantile classification, which puts the same number of observations in the highest class as in the lowest class, is misleading because it gives the impression that several counties have high population densities, which is not true. Both the Standard Deviation and Natural Breaks classifications highlight the areas of high population density, although the Natural Breaks map reveals more detail about other areas.

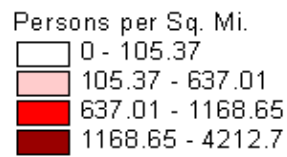
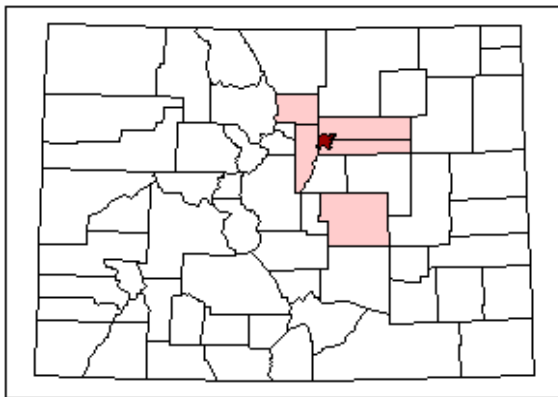
Equal Interval



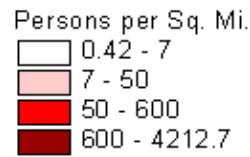
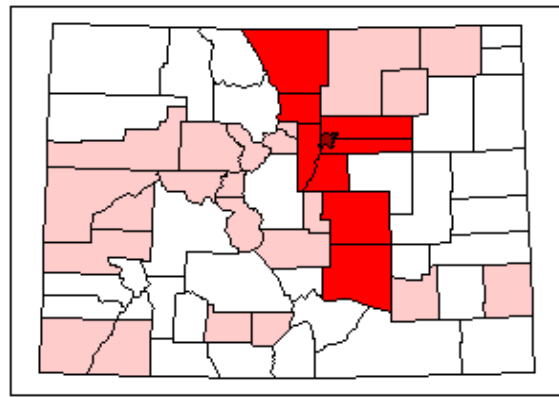
Quantiles



Standard Deviation



Natural Breaks



When you make maps using ArcView 2, your data will be classified automatically into a quantiles scheme. This may not be the best scheme for your data, however, so you have the option of changing the classification. Although it might be easy to accept the default classification, spending a moment to examine your data. Using this information to determine an appropriate classification scheme will help you produce a better map.

Symbolization

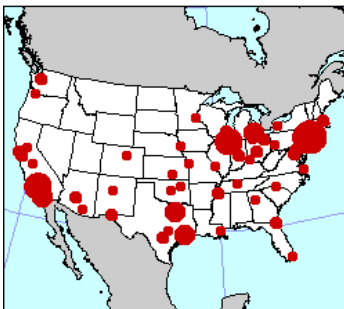
Symbolization is the processing of assigning symbols to represent features. Some symbols are pictorial, and look like the features they represent. For example, on a highway map the symbol for a campground is a tent. Many symbols are abstract, such as a population density map, where colored polygons represent varying concentrations of people.

Many factors must be considered when selecting symbols for a map, such as the scale of the map, the nature of the phenomenon being mapped, the available data, and the display method of the finished product. The following sections explore the symbolization process in greater depth.

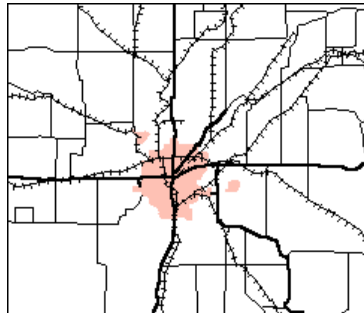
Understanding your data

Geographic Dimension. The first step in map making is to determine which type of geographic features are involved. That is, does the phenomenon being mapped occur at points, along lines or over areas? Airports and oil wells are points features, while highways and railroads are line features. Counties and forest stands are areal features. In some cases, the scale of the map determines whether a feature should be considered an area or a point. For example, on a map of Los Angeles County, the city of Los Angeles would appear as a large area; on a map of the United States, in contrast, Los Angeles would appear as a point.

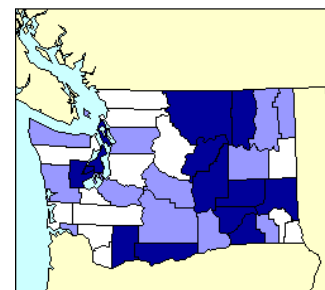
The following examples show the different geographic data types: cities as point features, roads and railroads as linear features, and counties as areal features.



Point data



Linear data



Areal data

Measurement Level. Another task is to determine how the data are measured. Generally speaking, data can be considered qualitative or quantitative. Qualitative data show differences in kind or type, with no numerical values attached. Quantitative data indicate differences in amount, and can be expressed as a number, although they don't have to be.

Data can also be described by measurement level. Map makers are generally concerned with three levels: nominal, ordinal, and interval/ratio data. Nominal data differ in type, and cannot be ranked. Examples of nominal data are land use (residential, commercial, park) or tree species (maple, oak, fir). Ordinal data can be ranked, but have only relative values (low, medium, high). With ordinal data, it is possible to say that one thing is greater than another, but because there are no numerical values attached to items, it is not possible to measure the difference between them. Interval/ratio data, in contrast, do have numerical values attached to them. Thus, it is possible to measure the difference between things as well as rank them. Examples of interval/ratio data are elevation or population.

Data Processing. In addition to knowing the measurement level, it's important to consider how the data have been manipulated. Some statistics are reported as raw values, such as total population. Others have been standardized by some other measure, such as population per square mile. For maps of areal features, it is often preferable to use standardized statistics. This is to compensate for the differences in size between data collection areas.

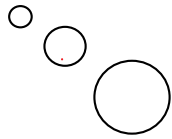

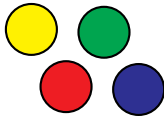
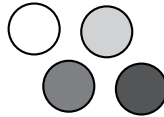
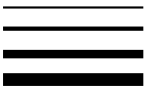



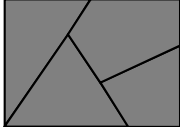


If you are making a comparison between data items, they should be in comparable units. This may require converting one variable to a different unit of measure. For example, if you have elevation data from two different sources, one data set may need to be converted from feet to meters to match the other.

Choosing symbols

Visual Variables

There are several characteristics of a symbol that can be manipulated, which are often referred to as the visual variables. These are size, shape, orientation, pattern, hue, and value. Hue and value are two characteristics of color. The names we assign to different colors correspond to different hues (e.g., blue, red, yellow). Value refers to how light or dark a color is, although value can also apply to gray.

Not all variables apply equally well to different kinds of phenomenon. Size and shape are useful for point symbols but not areal symbols; pattern can be used for areal symbols but not points. The following matrix illustrates which visual variables are useful with different geographic data types.

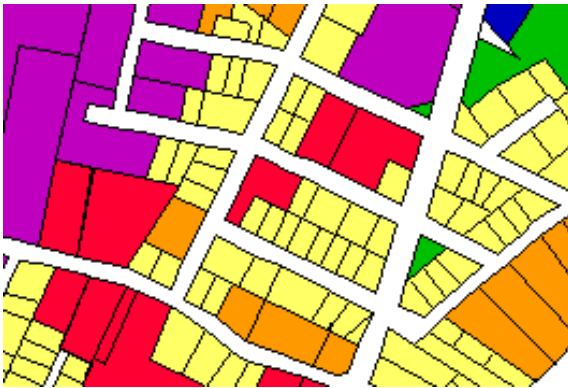
	Size	Shape	Pattern	Hue	Value
Point					
Line					
Area					

In addition, not all variables apply equally well to different types of data. Shape and pattern can be used for qualitative data, but not quantitative data; size and value can be used for quantitative data but not for qualitative data. The following tables summarizes which kinds of symbols should be used with each data type.

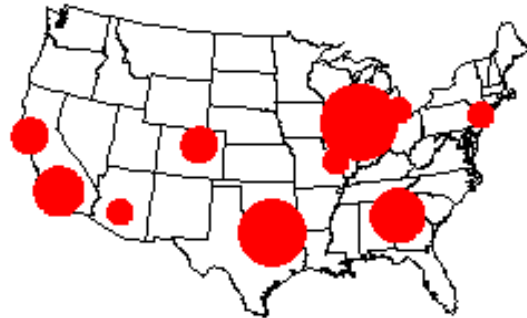
	Qualitative	Quantitative
Size		Yes
Shape	Yes	
Pattern	Yes	
Hue	Yes	
Value		Yes

While there are many possible combinations of data and symbols, a large proportion of thematic maps are shaded area maps. Graduated symbol, dot density and pin maps are also common. Following are examples of these four types of maps. These examples are by no means exhaustive of the types of maps you can make, they merely are intended to show a range of possibilities.

Shaded Area - Land Use



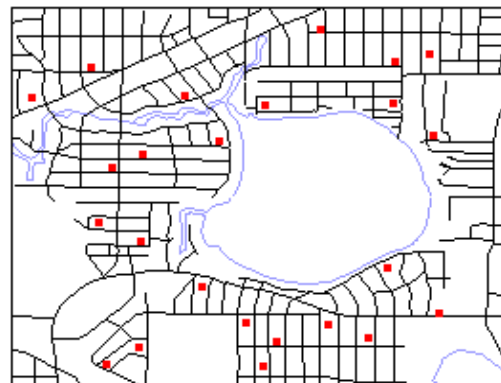
Graduated Symbol - Passengers flying into airports



Dot Density - Population

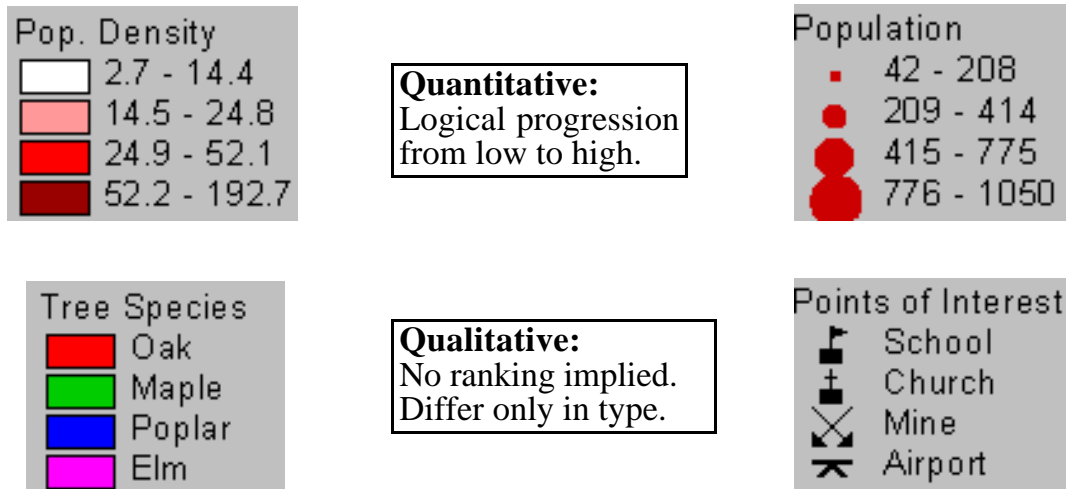


Pin - Location of Customers



When making thematic maps, your goal is to choose symbols that are intuitive to the map reader. Thus, with quantitative data, low values should be light and high values should be dark. When using color in a shaded area map, you should use different shades of a single hue (e.g., light red, medium red, dark red) rather than multiple hues (e.g., green, blue, red). If you are dealing with points, low values should be small symbols and high values should be large symbols. Any progression from low to high should follow a logical sequence.

For qualitative data, your symbols should not imply any ranking, they should only differentiate between classes. Thus, for a shaded area map, use different hues or different patterns. On a point map, use different shapes rather than different sizes.



Map Accuracy

Map accuracy (data quality) depends on several factors, such as positional accuracy, logical consistency within the data set, and the age of the data. Some of these factors can be evaluated by examining individual records, while others concern the data set as a whole.

Map accuracy and map detail are **not** synonymous. Accuracy refers to the amount of distortion (or lack thereof) in the representation of features. Detail refers to the amount of information or the number of features that are shown. The two are often confused, but a high level of detail does not guarantee a high level of accuracy.

Six elements of map accuracy are discussed below. The first four (positional accuracy, attribute accuracy, resolution, logical consistency) concern the individual elements of a data set. The remaining items (currency, completeness) concern the data set as a whole.

Positional Accuracy

Positional accuracy concerns the measurement of feature locations, and how well the measurements in the data set conform to a standard. The positional accuracy of a GIS database depends on the reliability of source data and the ways it has been manipulated. Base maps can be compiled from any of a number of sources: original surveys, air

photos, other maps, or remotely sensed data. Knowing the source of your basemap data can help you evaluate its reliability. Original surveys are likely to be very accurate, while a basemap drawn from another map will compound any errors in the first map.

Positional accuracy can be evaluated by taking measurements from randomly selected features in your database and comparing them to the position of those features in a database known to be reliable. After doing this, you can analyze the errors and look for patterns. For example, is the average error large or small? Are the data points offset consistently in one direction? If the errors are systematic, you may be able to correct them. Knowing about the quality of your database will help you to decide if it is appropriate for your project.

Attribute Accuracy

Attribute accuracy concerns the measurement of the characteristics of a feature, and can be greatly affected by data classification. Attribute can be difficult to assess, but some of the same methods used to measure positional accuracy can be used to measure attribute accuracy, such as sampling random features.

However, attribute accuracy can be affected by the manner in which features are represented. For example, the boundary between a forest and a meadow may be a transition zone rather than a sharp edge. If this boundary is shown on a map as a line, sample points near the line may be more likely to be in error.

Resolution

Resolution refers to the size of the smallest feature in a data set that can be discerned. This term “minimum mapping unit” is also used. If your map has a resolution of 10 meters, you will be able to object that are 10 meters by 10 meters or larger. Thus, you would be able to see a large building but you wouldn’t be able to see a car or a person. Resolution and positional accuracy are related, in that the positional accuracy of any object cannot be greater than the resolution of the map. Thus, if a map’s resolution is ten meters, you can’t measure the position of objects on the map in inches and expect them to be accurate.

Resolution and scale are also related, in that the resolution of a data set should influence the scale at which those data are displayed. For example, a data set with a resolution of 10 meters can be displayed at large scales (e.g., 1:24,000 or 1:50,000). However, a data set with a resolution of 10 kilometers should be displayed at smaller scales.

Logical consistency

Logical consistency refers to the relationships between data items, and whether or not the relationships make sense. One way to test this is to check whether any given feature has contradictory attributes. For example, suppose your database contains

information about land cover, slope, and soil type. Areas with a value of “lake” for land cover should have a value of “0%” for slope, not “10%” or “20%.”

Currency

The world is a dynamic place - goods are bought and sold, people are born and die, and even the continents are moving. However, some changes occur more quickly than others. Thus, some types of information change quickly, as well, while other do not. If you're mapping sales figures for your company, you don't want to use data that are five years old. If, however, you're mapping soil types, five year old data will be acceptable. You will have to decide how current data need to be to be useful.

Completeness

Completeness can describe both the areal extent of a data set, and the level of detail in the data classification. It is important to make sure have information for the entire area that you are mapping. A data set of the United States that omits California is incomplete. However, it may not be possible always to get 100% of the data you need. In such cases, you should note the omissions on your map, perhaps with a note in the legend. You may also find that you need to use several data sets to get complete coverage of your area of interest. Make sure these are compatible in terms of scale, age, and content.

The completeness of a classification may be difficult to assess, but generally, you want to be sure the classification provides enough detail to describe all the features in the data set. In addition, the level of detail should be consistent across different classes. For example, suppose you are mapping tree species in a forest, and are using the following classes: Coniferous, Oak, Maple, Elm, Poplar. One class is very general and the other four are specific. It would be better to break the class Coniferous into individual tree species, such as Pine, Spruce and Fir. If this information is not available, however, an alternative is to make both classes general; for example, Coniferous and Deciduous.

Map Composition

To communicate its message effectively, your map needs context: a title, a legend, a scale bar. Thus, the map is really just one element in the page layout (or map composition). Your layout can be designed for many types of display: a paper printout, a computer monitor, or a wall-sized poster. You should have some idea of how the map composition will be displayed before you begin designing the final layout, because that will influence some of the choices you will make. For example, if you are making a wall-sized map, you will need to make your text very large so it can be read from far away.

Map composition is really an exercise in graphic design. There are some guidelines to help you, but there are so many possibilities that it would be impractical to come up with a set of rules. Much of the design process is common sense: focus the viewer's attention on the important information and communicate your message as clearly as possible. In practical terms, however, it may not be immediately obvious how to achieve these goals.

Let's begin by looking at some of the basic elements of design: balance, hierarchy, figure-ground relationships, and contrast. Much of the following discussion deals with perception, which is obviously subjective; the discussion is therefore very general. For more information about any of these topics, consult an introductory cartography or design textbook.

Balance refers to the arrangement of elements within the overall composition, and whether these elements appear stable or unsettled. A map with all the elements grouped on the left side will probably look unbalanced. If these elements are redistributed on the page, however, balance can be achieved.



Unbalanced



Balanced

Research has shown that the visual center of a display is slightly above the geometric center of the display. This is the point that “naturally” attracts the viewer's attention. Organizing the map elements around the visual center can help achieve a balanced design.

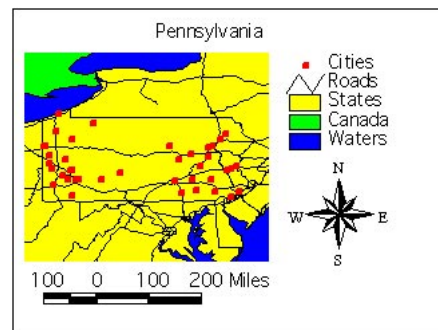
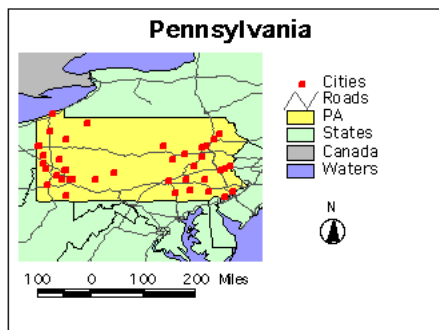
Hierarchy refers to the perceived importance of the map elements. The most important information on a map should have more visual impact than the background information. This can be achieved by several methods, such as making important elements larger, or by using bright colors.

Generally, the map itself should attract the most attention, and the title also should be prominent. Secondary information such as a scale bar or notes about data sources should be less conspicuous. You might want to put the map in the center of the page and use a large type size for the title to draw attention to these elements.

The following examples illustrate how the overall presentation of a given set of information can be changed dramatically by varying the position, sizing and coloring of

various elements. By using bright colors, bold symbols, and large text, a clear visual hierarchy can be established.

The map on the left draws attention to the state of Pennsylvania, and specifically to the large towns. Using a bright color for towns and subdued colors for states and water bodies draws attention to the towns. Different symbols have been used for state boundaries and roads, making it possible to distinguish between the two. Also, larger text has been used for the title than for secondary information, such as the scale bar.



In the map on the right, attention is drawn as much to the water bodies as to the cities of Pennsylvania. It is difficult to distinguish between roads and state boundaries. Because all of the text is the same size, one hardly notices the title. Also, the compass takes up as much space as the legend. There is no visual hierarchy; nothing on the page says “Look at me!”

The **figure-ground relationship** is part of the visual hierarchy. Objects that appear to stand out are “figures” while the background information is the “ground.” Important information such as symbols should appear as figure, while the context information should appear as ground. For example, black symbols on a white background will have a clear figure-ground relationship. The symbols will appear to be “above” the background. Transparent symbols on a white background will be less clear in figure ground representation.

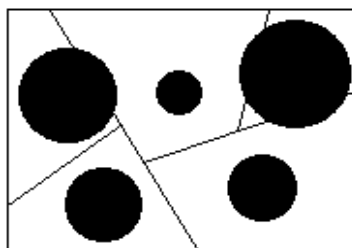


Figure-ground clear

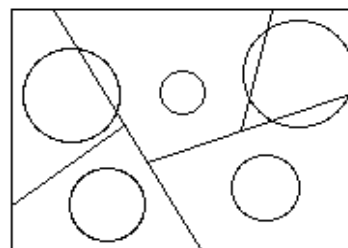


Figure-ground unclear

Whenever you map has both land and water bodies, you should establish the figure-ground relationship so that it is clear what is land and what is water. Doing this can be as easy as shading the water bodies blue.

Contrast refers to the degree to which different elements are distinguishable from one another. Objects that stand out from their back-ground have high contrast, while objects that seem to blend together have low contrast. Contrast, therefore, is useful for establishing figure-ground relationships. Contrast can be achieved through variations in color, value, pattern, line weight or type size.

Using these design principles effectively will take some practice. Just as learning to type does not magically lead to a Pulitzer Prize, learning to operate GIS software does not magically lead to beautiful maps. Fortunately, software makes it easy to experiment with several alternative designs. In the days of hand-drawn maps, changing the typeface might require days of work; now, it can be done in seconds. Remember, also, that people's taste differ, and there is no one "perfect" map.

Moving Beyond the Basics

This document introduced you to some basic principles of map design. By no means did it teach you everything you'll ever need to know about making maps. Many resources exist to help you learn more about the concepts presented here. Introductory college textbooks on statistics, cartography, or graphic design can be useful reference aids. Just looking at maps produced by others (such as those in ESRI's annual *Map Book*) can be instructive and provide ideas for innovative map compositions.

Remember, also, that maps do not have to be static images on a page. Maps can be integrated with text, sound and video as part of a multimedia presentation. Maps have even been turned into movies - a series of maps showing population changes in a city, for example, can be turned into an animated sequence. Technology is changing at a phenomenal rate, providing new tools for visualization and communication all the time. Keep your mind open to the possibilities.