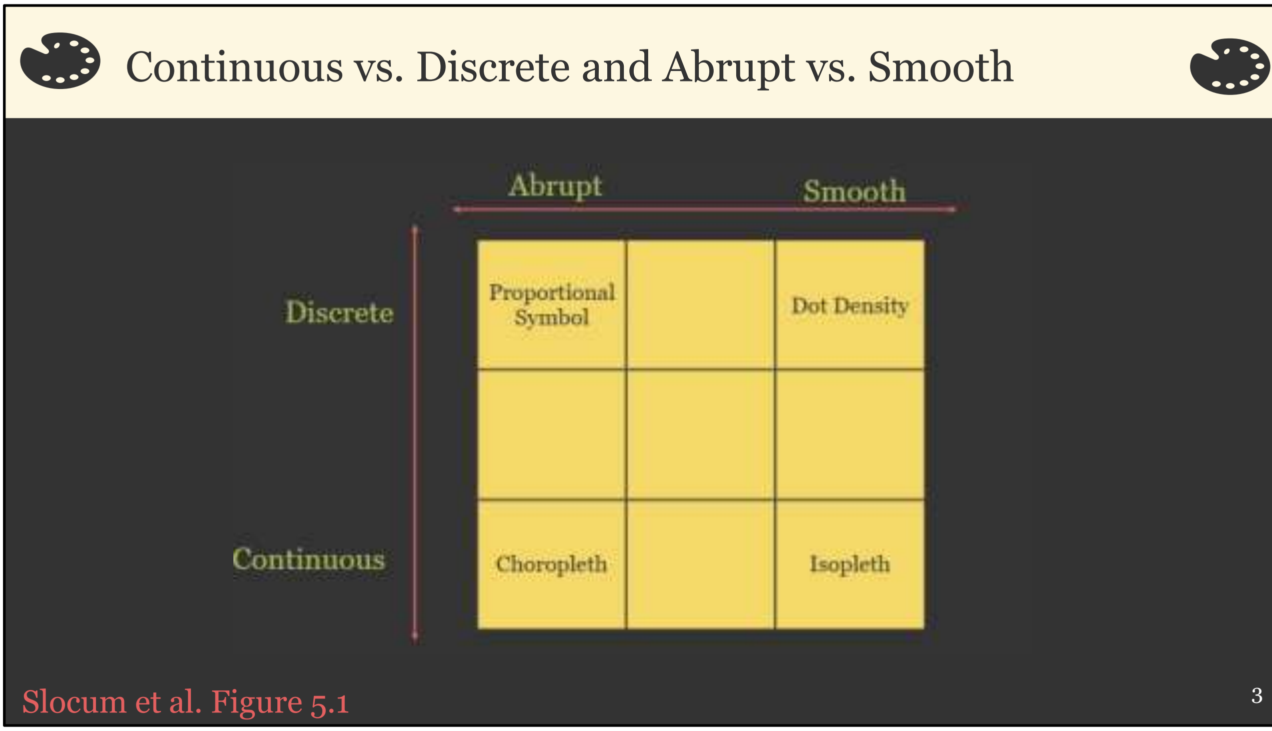
Expanding upon prior modules, we will now explore different methods for symbolizing continuous and categorical data in a map space using different graphical parameters or combinations of graphical parameters.

Module Topics

1. Using size: proportional symbol, graduated symbol, and cartograms
2. Selecting size ranges, scaling and/or binning methods
3. Using density: dot density maps
4. Selecting dot size and unit value
5. Isopleth maps
6. Generalizing isolines
7. Labeling isolines
8. Bivariate choropleth maps
9. Other multivariate maps
10. Flow maps

2

These are the topics covered in this module.



Deciding on what type of map is best to represent different variables partially depends on the type of data being mapped; however, the choice is also informed by the spatial patterns of the phenomenon.

For example, a variable that occurs at discrete locations on the landscape vs. one that occurs continuously (i.e., there is a value everywhere, like depth to bedrock or elevation) should not be visualized the same. For example, a proportional symbol map or dot density map is more appropriate for discrete data while a choropleth map or isopleth is more appropriate for continuous data. As another example, when representing data at a county-level, the number of employees at a single county high school would be discrete (this is because the data are for a discrete location within the county: the location of the high school), the number of employees at all schools in the county would be intermediate (this is because there are discrete measurements at multiple locations across the county), and the percent of the county population that is school-age would be continuous (this is because this value represents the entire county and there would be a value assigned to all counties and all locations).

You should also consider if the phenomenon can change abruptly vs. smoothly. Proportional symbol maps and choropleth maps are more appropriate when values can change abruptly whereas dot density and isopleth maps are more appropriate for smoothly changing phenomenon. For example, high school graduation rates could change abruptly between adjacent counties; however, average temperature would likely change smoothly.

Size

4

What's the difference?

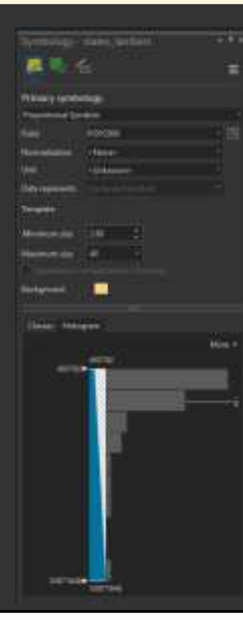
- Proportional Symbol Map = use size to represent a quantity (scaled continuously)
- Graduated Symbol Map = use size as bins or ranges to represent a quantity

5

A common means to display a quantitative variable is using size. If sizes are scaled continuously relative to the variable, then this is known as a proportional symbol map. If a finite number of sizes are used to represent ranges of the quantity, or binning is applied, then this is known as a graduated symbol map.

These types of maps tend to be used to visualize quantities that occur at discrete locations and can change abruptly.

What’s the difference?

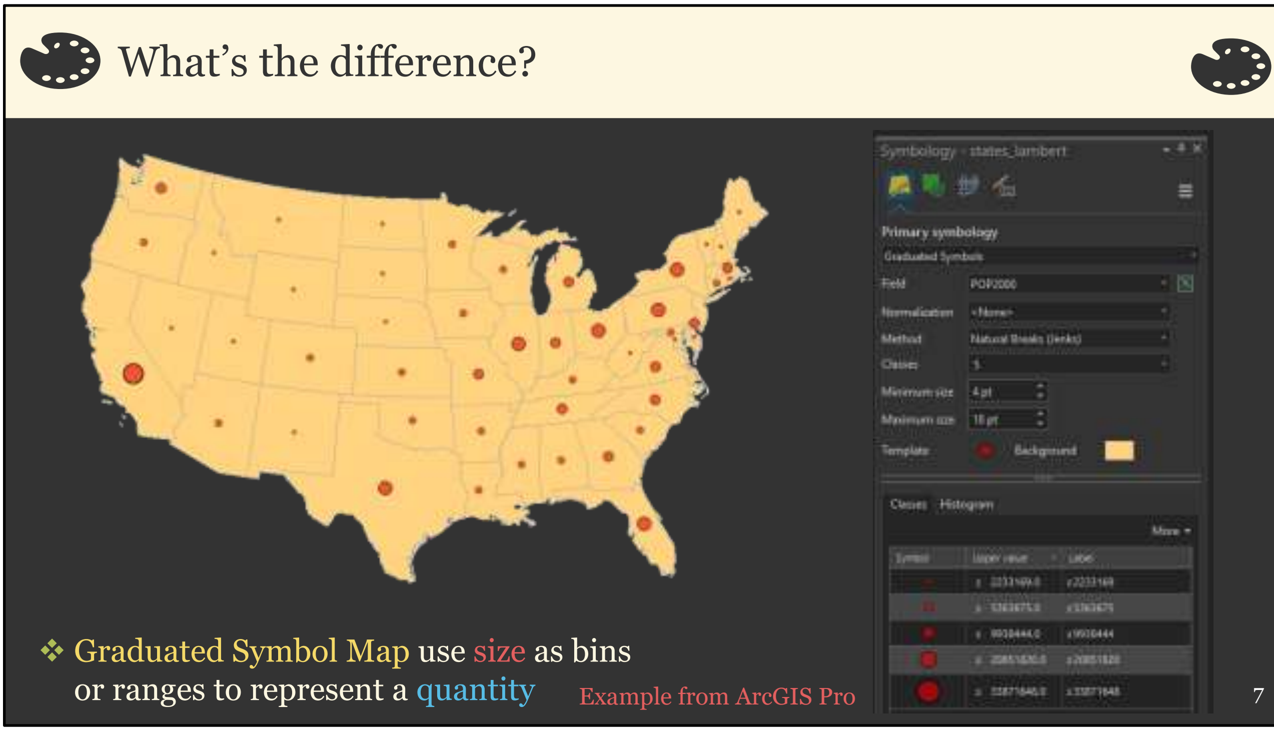


- Proportional Symbol Map use size to represent a quantity (scaled continuously)

Example from ArcGIS Pro

6

This is an example of a proportional symbol map. Size is scaled continuously to visualize quantitative data: there is no classification or binning applied. The circle is scaled continuously from a minimum to a maximum size mapped to the lowest and highest values, respectively. This example specifically represents population.



In contrast to proportional symbols, graduated symbol maps apply a classification or binning to represent the quantity with a finite number of bins. In this example, population is represented using five sizes from 4 to 19 point. The breaks, or ranges of population mapped to each size, is determined using a classification method, in this case Natural Breaks (Jenks).

Decisions

Proportional Symbol

1. Attribute to map
2. Normalization
3. Units
4. Symbol
5. Symbol color
6. Minimum Size
7. Maximum Size
8. Appearance compensation
9. Background color
10. Number of reference sizes to show in the legend

Graduated Symbol

1. Attribute to map
2. Normalization
3. Classification method
4. Symbol
5. Symbol color
6. Number of classes
7. Minimum size
8. Maximum size
9. Background color

8

This slide lists what decisions must be made when designing these size-based maps. Note that normalization can be applied but is not required for proportional and graduated symbol maps. In contrast, when using color to represent a quantity, the data should be normalized. For example, percent unemployment could be represented with a color but not the number of unemployed people. You must also choose the symbol to use (e.g., circle, square, triangle, hexagon, etc.), the fill and outline color to apply to the sized symbol, and the fill and outline color to apply to the map feature behind the applied symbol.

Size Compensation

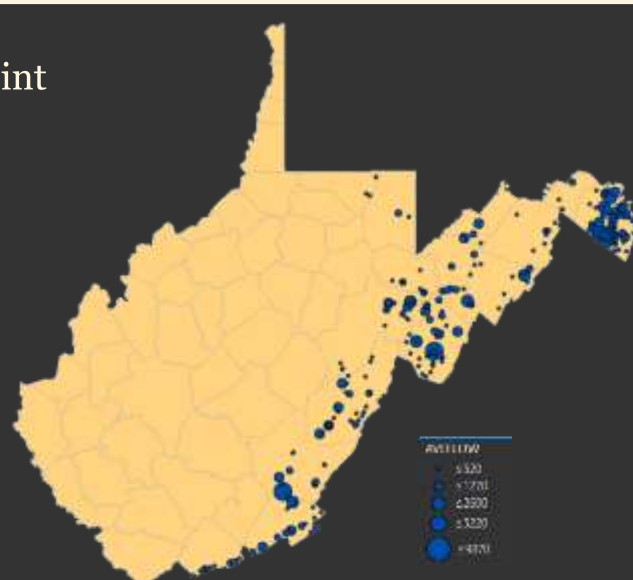
- Area is increasingly underestimated as higher magnitudes of the stimulus are judged
- Can compensate for underestimation
- Square root method = based on the radius of the circle
- Psychological scaling = scales to reflect underestimation by map users

9

Again, the goal here is to use size to represent a quantity. For a circle, the radius of the circle can be scaled relative to the quantity using the square root method. However, studies have shown that readers tend to underestimate the quantity being mapped for higher magnitudes or larger features. So, psychological scaling can be applied that takes this bias into account.

True Point Data

- Measurements made at point locations



Proportional symbol and graduated symbol maps can be used to represent true point features or conceptual point features. This slide provides an example of a true point feature, in this case spring locations. The circle symbol is centered on the point location of the spring, and the radius is scaled relative to the average flow rate.

Conceptual Point Data

- Areal data mapped as point locations

11

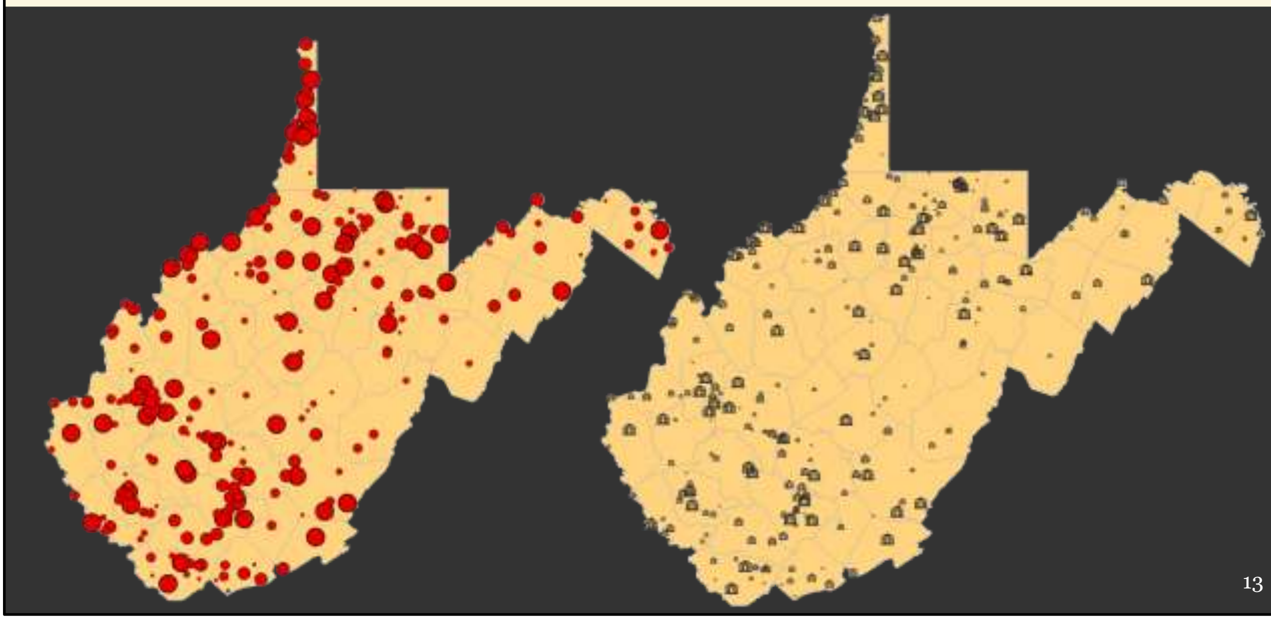
This example represents a conceptual point. The population associated with an areal feature, in this case states, is compared using a circular point symbol where the radius scales to represent population. So, the magnitude of an attribute associated with an areal feature is visualized as a point.

In Between

12

Some features fall between true point and conceptual point data. For example, this map uses the size of a circle to represent the population of major cities. Cities are areal features, but at this scale they can be represented as points.

Geometric vs. Pictorial



Referencing back to our prior discussion of point symbols, geometric shapes or pictorial symbols can be used to represent quantities in proportional and graduated symbol maps.

Mathematical Scaling

- Circle $r_i = \left(\frac{v_i}{v_L}\right)^{0.5} \text{ X } r_L$
- Square $s_i = \left(\frac{v_i}{v_L}\right)^{0.5} \text{ X } s_L$
- Bars $h_i = \left(\frac{v_i}{v_L}\right) \text{ X } h_L$
- Spheres $r_i = \left(\frac{v_i}{v_L}\right)^{1/3} \text{ X } r_L$
- Cubes $s_i = \left(\frac{v_i}{v_L}\right)^{1/3} \text{ X } s_L$

If specifying smallest and larges symbol size:

$$Z_i = \left(\frac{v_i - v_s}{v_L - v_s}\right)$$

$$A_i = Z_i(A_L - A_s) + A_s$$

V_i = data value
V_L = largest data value
V_s= smallest data value
A_s = smallest area desired
A_L = largest area desired
A_i= area of a symbol associated with the data value V_i
Z_i= proportion of the data range associated with the data value

14

Methodical scaling methods allow for size to be mapped to a quantity. However, these equations don't take into account perceptions of scale.

Let's explore a circle as an example. The output circular radius can be defined by dividing the current value to be mapped by the largest value then taking the square root. Lastly, this can then be multiplied by the largest defined radius. Similar methods exist for other geometric shapes including squares, bars, spheres, and cubes.

These equations can be modified to allow for the largest and smallest desired sizes to be defined using the equations on the right side of the slide.

Perceptual Scaling

$R = cS^n$ or $S = c_1R^{1/n}$

R = response (or perceived size)

S = stimulus (or actual size)

c/c_1 = constant

n = exponent

Example: Flannery Study

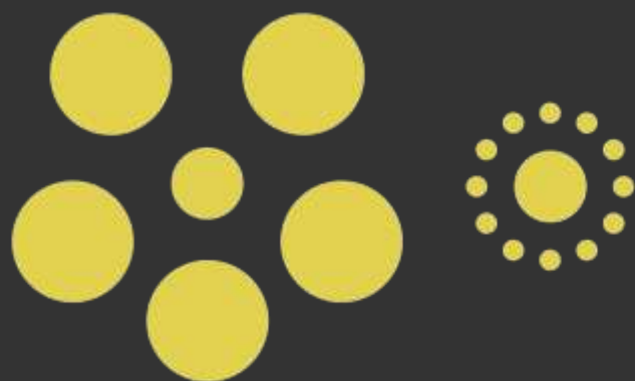
$r_i = (\frac{v_i}{v_L})^{0.57} \times r_L$

15

To deal with bias in the readers judgement of size, it is possible to apply perceptual scaling. Altering the constant and exponent in the equations on the left allow for different transformations between actual size and perceived size of features. The example on the left is from a study by Flannery and relates to a circle. Here, the exponent has been changed from 0.50 to 0.57 to adjust the scaling to match more closely with perception. ArcGIS Pro has options for applying perceptual scaling.

Ebbinghaus Illusion

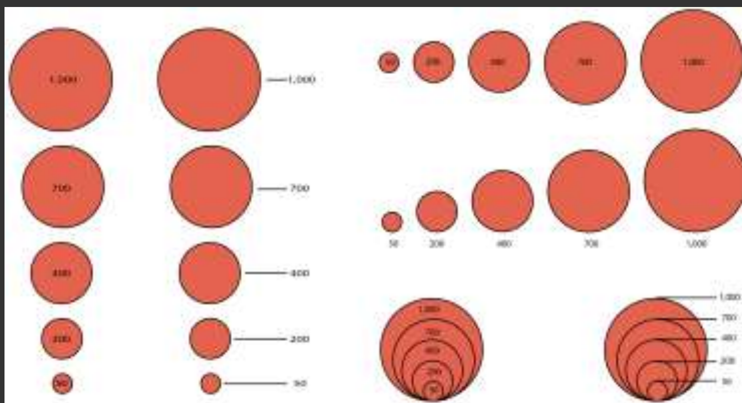
- Size of nearby features can impact the perceived size of a feature



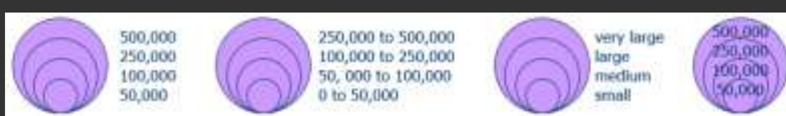
16

It should be noted that nearby features can also impact perceived size. This is known as the Ebbinghaus Illusion. In the example images, the center circle is the same size in both sets. However, it appears larger when surrounded by smaller circles. So, it is important to note that, even when perceptual adjustments are made, the spatial pattern of symbols can also impact perception.

Legends



Slocum et al. Figure 17.13



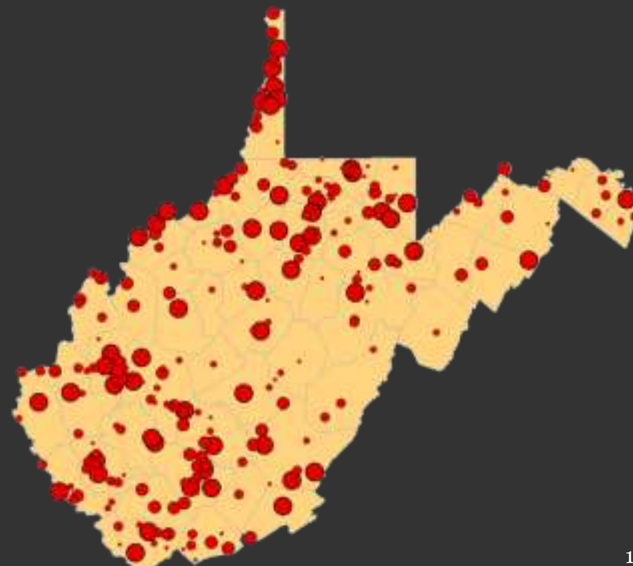
Example from Dr. Greg Elms

17

There are a variety of methods available for creating legends for proportional and graduated symbol maps. This slide provides a variety of examples that vary based on orientation, overlap, and location of labels. No method is necessarily better than the other, as this will depend on the layout and purpose of the map. Unfortunately, ArcGIS Pro does not allow for all these legend adjustments or arrangements, so you may need to edit the legend further in a graphics editing software.

Overlap

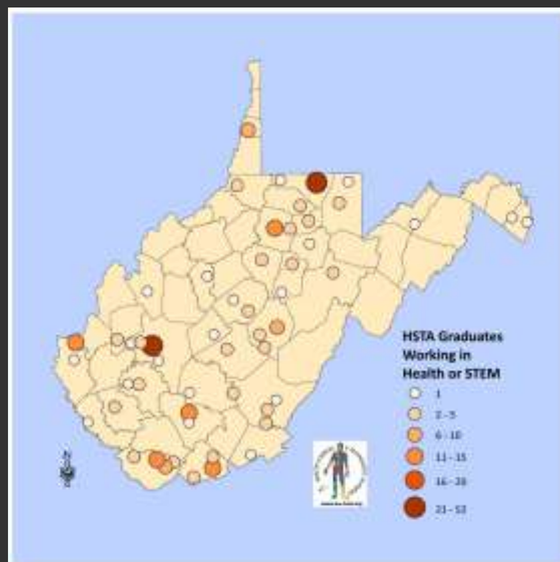
- No hard rules
- Robinson et al. (1984) = map should appear neither too full nor too empty
- Can include inset map for crowded areas



18

Another issue is dealing with overlapping symbols. Robinson et al. (1984) suggests that the map space should appear neither too full nor too empty. For crowded areas, you may want to consider adding inset maps to enhance differentiation.

Redundant Symbols



19

In this example map, color and size are used to represent the same quantity. This is known as redundant symbology. It is generally recommended to avoid this, since there is not a need to show the same value with multiple graphical parameters. In this specific example, the graduated symbol is more appropriate than color since the data are not normalized.

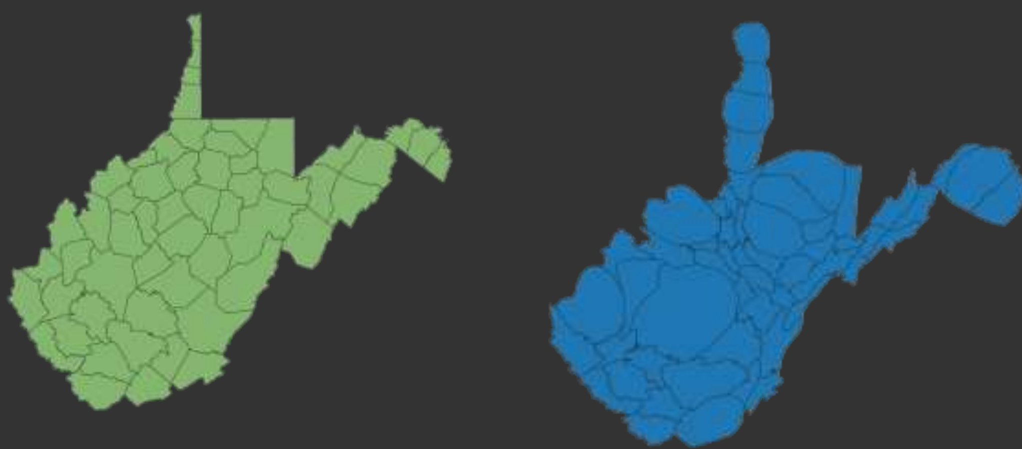
What are Cartograms?

- Distort feature size to represent a quantity
- Distance Cartograms = distance is distorted to represent an attribute
- Area Cartograms = area/size is distorted to represent an attribute
- Contiguous Cartograms = maintains contiguity but not shape of map units
- Noncontiguous Cartograms = does not maintain contiguity but does maintain shape of map units

20

Cartograms offer an alternative for displaying or mapping a quantity using size. In contrast to proportional and graduated symbol maps, cartograms make use of resizing the actual map features, as opposed to a symbol. Different methods are available to accomplish this resizing. Distance cartograms distort distance to represent a quantity while area cartograms distort area or size. Contiguous cartograms maintain contiguity or topology between map features while noncontiguous cartograms do not. We will explore some examples in the following slides.

Contiguous Cartograms



Population by County

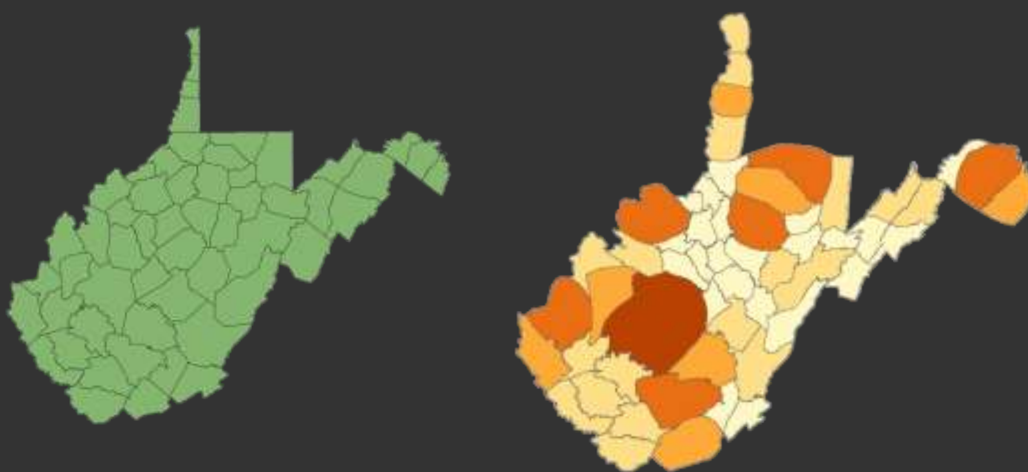
https://plugins.qgis.org/plugins/cartogram3/

21

This is a contiguous cartogram used to represent county-level population. Note that the topology or contiguity is maintained: adjacent features still share boundaries. However, the sizes are distorted. This example was created using the Cartogram3 plugin in QGIS.

Cartograms are generally used for relative comparison, as it is difficult to generate a legend to help interpret the meaning of the size distortions.

Contiguous Cartograms



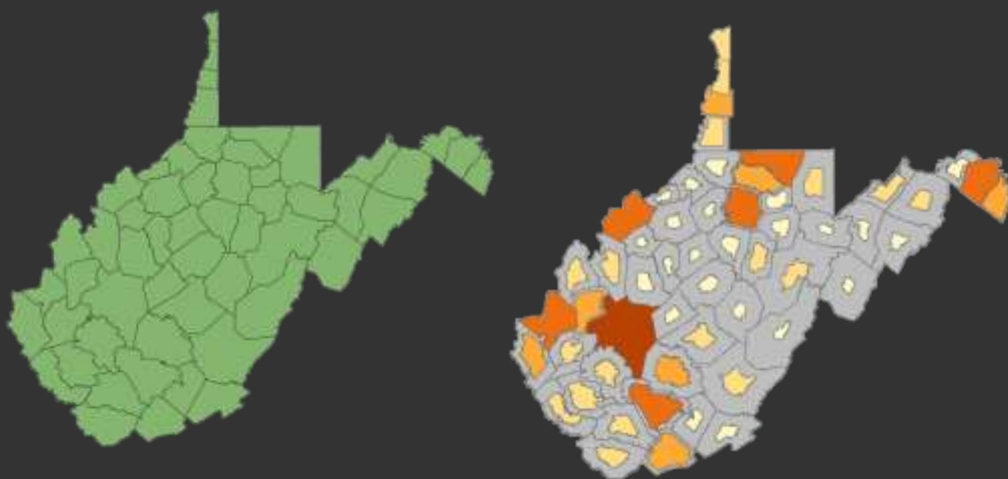
Population by County

https://github.com/sjewo/cartogram

22

This is another example of a contiguous cartogram, which was created with the cartogram package in the statistical/data science software R.

Noncontiguous Cartograms



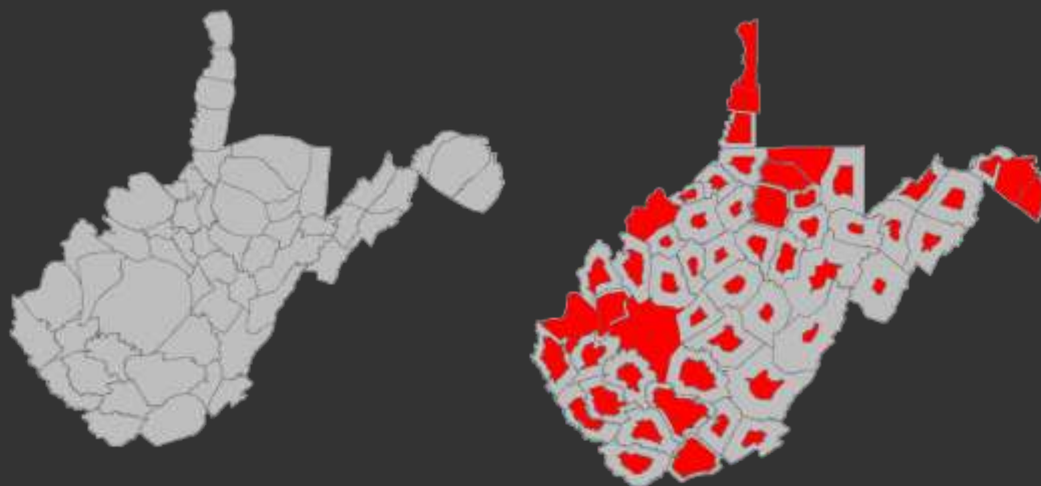
Population by County

https://github.com/sjewo/cartogram

23

In contrast to the last example, this example represents the population information using a noncontiguous cartogram. The feature shapes have been maintained, but their sizes have been altered relative to the population quantity. In order to alter size but maintain shape, it is not possible to maintain contiguity or topology. I have placed the original boundaries behind the cartogram in gray for comparison. Here, I have also used color to represent the population quantity. However, this is redundant and not necessary. This was generated using the cartogram R package.

Cartograms



Population by County

https://github.com/sjewo/cartogram

24

Here is a side-by-side comparison of a contiguous and noncontiguous cartogram for the same dataset and quantity. Again, both show population data and were created using the cartogram R package.

Cartograms in ArcGIS Pro

- Generate Contiguous Cartogram Tool
- https://doc.esri.com/en/arcgis-pro/latest/tool-reference/cartography/generate-contiguous-cartogram.html?tabs=dialog

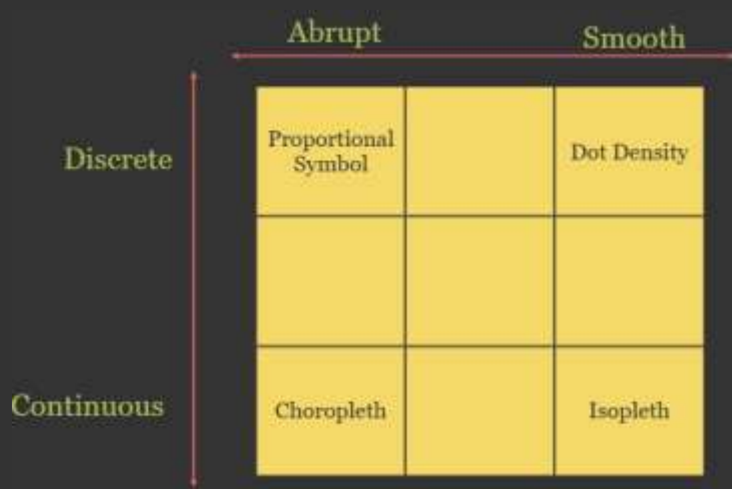
25

ArcGIS Pro provides a tool for creating contiguous cartograms.

Density

26

Continuous vs. Discrete and Abrupt vs. Smooth



Slocum et al. Figure 5.1

27

We will now move on to discuss dot density maps. In contrast to proportional and gradational symbol maps, dot density maps tend to be used to visualize variables that occur at discrete locations but vary smoothly over space.

Decisions

1. Dot symbol
2. Dot size
3. Dot color
4. Quantity one dot represents (1 Dot = 400 Units)
5. Dot placement
6. Background symbol

Example from ArcGIS Pro

28

Several decision must be made when generating a dot density map including the dot symbol, size, and color; what quantity or amount will be represented by a single dot; how dots will be placed within the associated geographic feature; and what background symbol will be applied.

Dot Placement

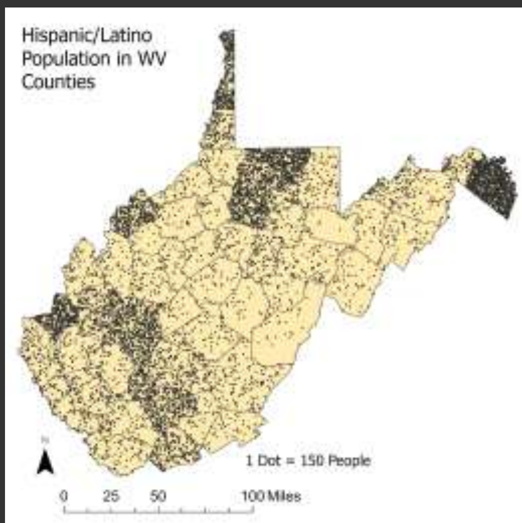
- Random
- Uniform
- Use ancillary data to assign density at valid locations (geographically-based)
- Weighted toward neighboring units with high values (geographically weighted)

29

Dot placement can be random, uniform, geographically-based, or geographically weighted.

Random placement uses a random number generator to randomly locate the number of required dots within the extent of each feature. In contrast, uniform will use a regularly spaced pattern. Random is commonly used as opposed to uniform. Geographically-based uses some ancillary data to determine dot locations. For example, if you are interested in visualizing the acreage of cropland by county, dots could be placed over agricultural fields as defined by a land cover or agricultural dataset. Geographically weighted will take into account the characteristics of neighboring features. The dot placement will be weighted such that dots will be denser nearer to neighboring features with higher values for the quantity being mapped.

Dot Size and Unit Value



- Small dots = sparse distribution and insignificance
- Large dots = impression of excessive density
- Small unit value = unwarranted impression of accuracy
- Large unit value = lacks pattern or character

Robinson et al. 1995

30

Determining what dot size and unit value to use is a balance between a sparse distribution and excessive density. Both can be adjusted to balance the visual effect.

Mackay (1949) Nomograph

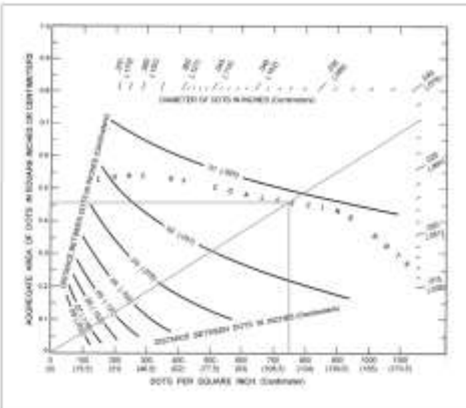


Figure 1. The Mackay nomograph, with metric units added. The gray lines illustrate using the nomograph to find the dot density and aggregate area of dots for 2-point dots 0.028 inches (0.071 mm) in diameter.

Mackay, J.R., 1949. Dotting the dot map: An analysis of dot size, number, and visual tone density. *Surveying and Mapping*, *9*(1), pp.3-10.

Kimerling, A.J., 2009. Dotting the dot map, revisited. *Cartography and Geographic Information Science*, *36*(2), pp.165-182.

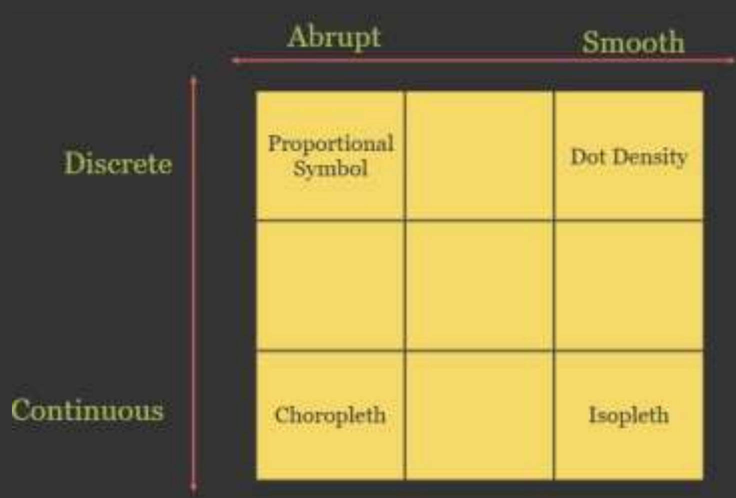
31

Mackay (1949) introduced the Mackay nomograph that can be used to determine appropriate dot densities.

Isopleth Maps

32

Continuous vs. Discrete and Abrupt vs. Smooth



Slocum et al. Figure 5.1

33

Isopleth maps are generally used to map continuous data that varies smoothly. For example, every location has a temperature, and temperature is not likely to change abruptly over short spatial extents.

Selecting Data

- Phenomenon is continuous and smooth
- Examples: elevation, temperature, barometric pressure, relative humidity, depth to water table, depth to bedrock, etc.
- Can incorporate discontinuities (example: faults in geologic data)
- True point data = phenomenon measured at a point location (isometric)
- Conceptual point data = phenomenon measured over an area or volume and generalized to points (isopleth)

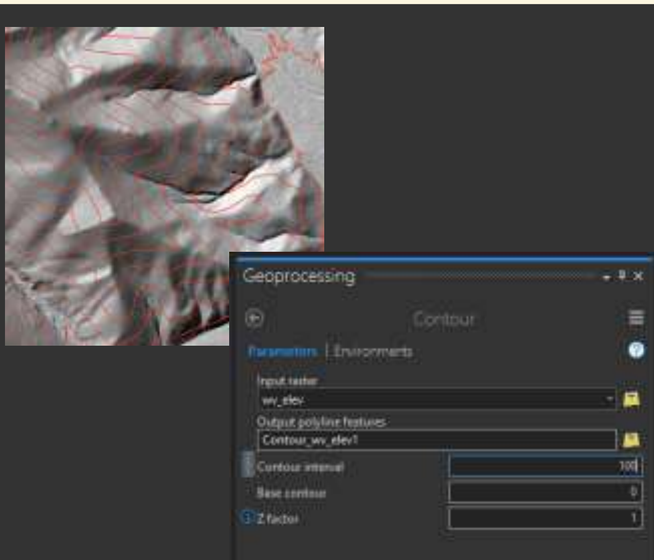
34

Again, isopleth maps should be used to visualize data that are continuous and do not change abruptly, as the use of isolines implies a continuous measure and can be difficult to apply when values change abruptly. This slide lists some example use cases.

It is possible to incorporate discontinuities if there are some isolated, abrupt changes. Examples include elevation break lines to represent cliffs or steep slopes and geological faults where units are offset.

Isometric maps represent true point phenomenon while isopleth maps represent conceptual point phenomenon.

Contours



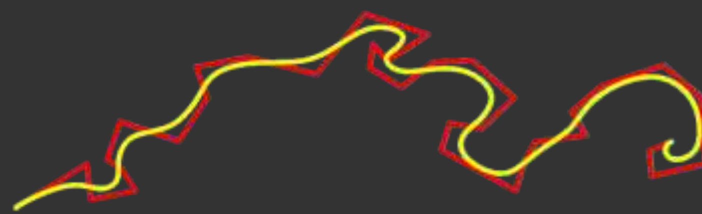
- Raster → vector
- Must define an interval
- Make principal or index contours thicker
- Make intermediate contours thinner
- May require some smoothing

35

Continuous raster surfaces can be converted into isolines. For example, a digital elevation model (DEM) can be converted to elevation contours. When generating contours from continuous raster data, it is important to consider what principle and intermediate contour intervals are most appropriate. For detailed and/or noisy data, you may need to apply some smoothing to make the resulting lines more generalized and cartographically pleasing.

Line Generalization

- Remove unnecessary vertices
- Smooth curves
- For cartographic generalization
- Simplify Line Tool
- Smooth Line Tool



Available under Generalization Tools in the Cartography Toolbox

36

Again, GIS software generally provides a variety of tools to simplify or smooth line features.

Contours

- Visualizing the surface requires careful examination of the position and values of individual contour lines

37

You should also make sure that your contour lines can be interpreted easily.

Contour Labels

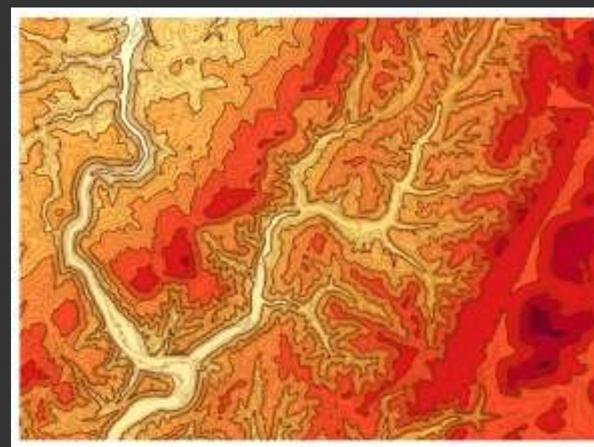
- Create ladders
- Label only principal contours
- Never upside down
- Top of the label facing uphill

38

There are generally some preferred labeling standards for contour lines specifically. First, it is common to align labels between adjacent contours to aid readability and make the directions of increasing and decreasing values easily interpreted. Generally, only principal contours will be labeled as opposed to all contours. Labels should never be placed upside down, and the top of the label should face uphill.

Contours + Hypsometric Tints

- Enhances ability to visualize 3D surfaces
- Limited number of tones can suggest a stepped surface, rather than the smooth one that occurs in reality



39

Colors, or hypsometric tinting, can be combined with contour lines to reinforce the patterns. When this is attempted, color breaks should align with the principal contours. Although visually pleasing, one drawback is that this tends to suggest a stepped surface, rather than the smooth one that occurs in reality.

Tones

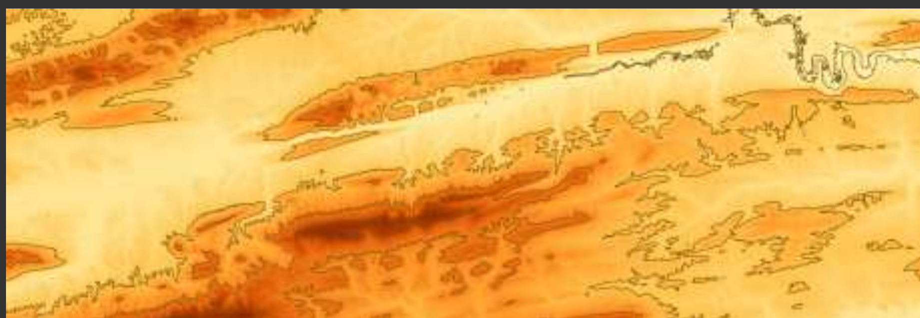
- Continuous tones (not binned)
- Can be difficult to associate quantities in legend with tones at a specific position

40

Instead of using contours or isolines, data that are continuous and tend to change smoothly can also be visualized as a raster surface using continuous tones. However, it can be difficult to associate a specific value or quantity with the associated color in the legend.

Contours + Tones

❖Adding contour lines can enhance readability

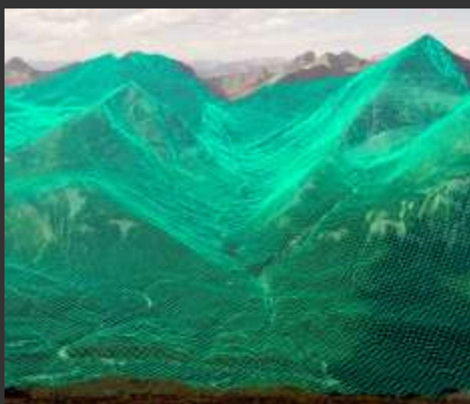


41

Adding some contour lines can enhance readability.

Fishnets

❖Will need to decide on orientation



McCaffrey, D. and Hopkinson, C., 2020. Repeat Oblique Photography Shows Terrain and Fire-Exposure Controls on Century-Scale Canopy Cover Change in the Alpine Treeline Ecotone. *Remote Sensing*, *12*(10), p.1569.

42

Another option is to use a fishnet pattern when mapping in 3D space. This will require you to determine a “camera position” or map orientation.

Multivariate Maps

43

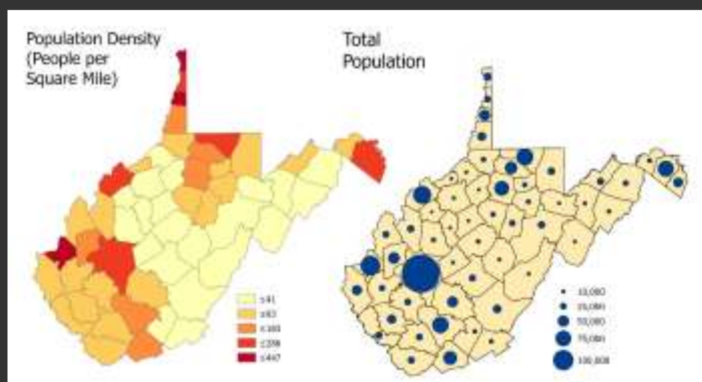
Multivariate

- Use different graphical parameters to represent different attributes

We will now explore methods for symbolizing multiple parameters, quantities, or categories using multiple graphical parameters. This is known as multivariate mapping.

Proportional Symbol + Choropleth

- ❖Use proportional symbol to show raw totals
- ❖Use choropleth to show standardized/normalized data

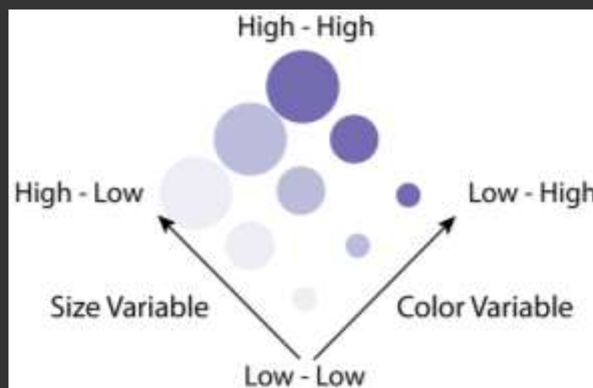


45

A single map layout can contain multiple maps to represent different values for the same geographic features. Here, a choropleth map is used to show population density while a proportional symbol map shows total population. When using this method, only normalized data should be visualized with the choropleth component.

Proportional Symbol + Choropleth

- Use proportional symbol to show raw totals
- Use choropleth to show standardized/normalized data

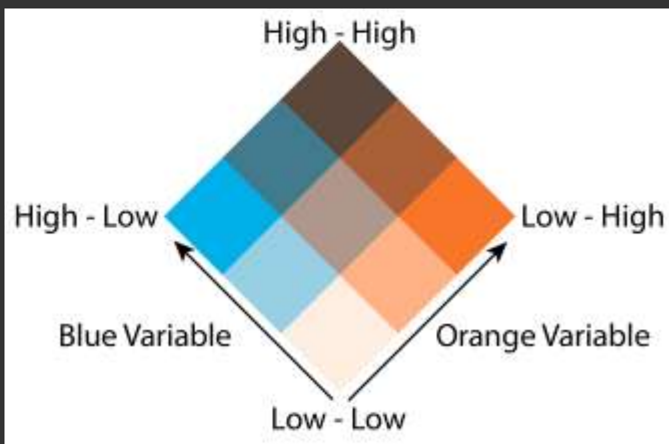


46

Instead of using two separate maps, you could combine the symbols for use in a single map space. Here, I am using size and color to show two different variables. In this bivariate map, the user could then interpret the colors and sizes to understand the values and their relationships.

Bivariate Choropleth

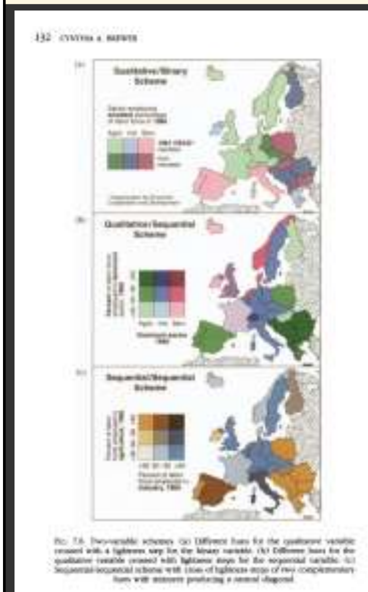
❖Use complimentary colors



47

Alternatively, two separate colors could be used to create a bivariate choropleth map, as opposed to color and size. When this symbology is applied, complimentary colors can be used.

Suggestions from Brewer (1994)

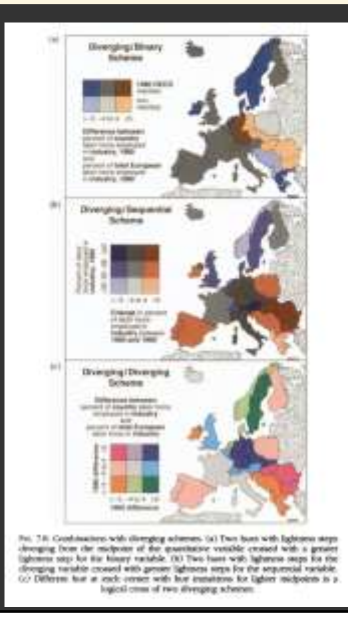


- ❖If both attributes are unipolar = use complementary scheme or two subtractive primaries
- ❖If one attribute is unipolar and the other is bipolar = use sequential scheme for unipolar and diverging scheme for bipolar
- ❖If both are bipolar = use two diverging color schemes

Brewer, C.A., 1994. Color use guidelines for mapping. *Visualization in modern cartography, 1994*, pp.123-148.

Brewer (1994) provides some additional guidelines for bivariate choropleth mapping. If both attributes are unipolar (i.e., increase in one direction), then you should use complementary colors or two subtractive primaries. If one is unipolar and the other is bipolar (i.e., diverges from a central value), you can use a sequential scheme for the unipolar variable and a diverging color scheme for the bipolar variable. When mapping two bipolar variables, you should use two different diverging color schemes. Have a look at the examples from Brewer (1994) included on this slide and the following two slides.

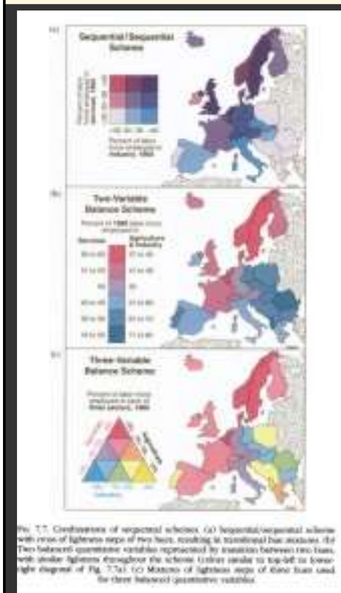
Suggestions from Brewer (1994)



- If both attributes are unipolar = use complementary scheme or two subtractive primaries
- If one attribute is unipolar and the other is bipolar = use sequential scheme for unipolar and diverging scheme for bipolar
- If both are bipolar = use two diverging color schemes

Brewer, C.A., 1994. Color use guidelines for mapping. *Visualization in modern cartography*, *1994*, pp.123-148.

Suggestions from Brewer (1994)



- ❖If both attributes are unipolar = use complementary scheme or two subtractive primaries
- ❖If one attribute is unipolar and the other is bipolar = use sequential scheme for unipolar and diverging scheme for bipolar
- ❖If both are bipolar = use two diverging color schemes

Brewer, C.A., 1994. Color use guidelines for mapping. *Visualization in modern cartography, 1994*, pp.123-148.

Trivariate Choropleth Map

- Best if attributes add to 100%

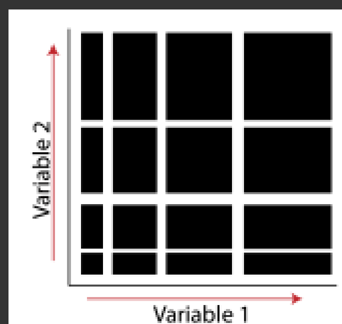
https://commons.wikimedia.org/wiki/File:SoilTexture_USDA.svg

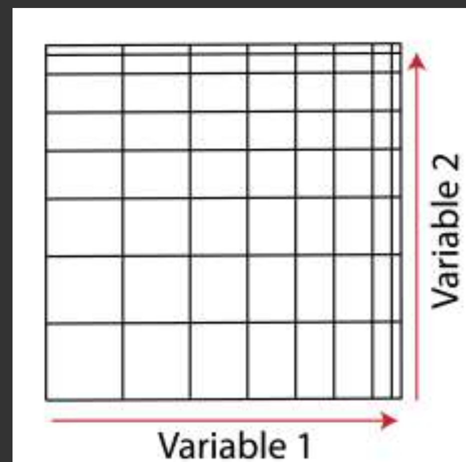
51

Trivariate choropleth maps make use of three colors to show three quantities. The three values should sum to 100%. A good example of this is soil texture diagrams. The symbol depends on the relative proportion of sand, silt, and clay particle sizes and must sum to 100%.

Alternatives to Bivariate Choropleth

- ❖Cross-hatch shading
- ❖Bivariate Point Symbols
- ❖Color + Texture

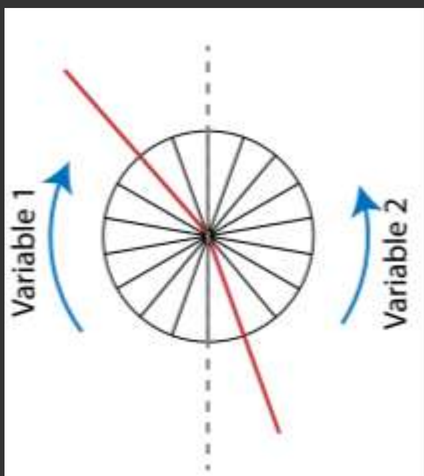




52

In the next set of slides, we will explore some alternatives to bivariate choropleth maps. On this slide, I have provided examples of a bivariate point symbol and cross-hatch shading. For the point symbol (the image on the left), the width of the symbol maps to the Variable 1 quantity while the height maps to the Variable 2 quantity. So, the reader can interpret the width and height to understand the quantities and their relationship. The cross-hatch shading example is similar. The density of the cross-hatching in the left-to-right and up-and-down directions correspond to separate variables. Lastly, it is also possible to use a combination of color and texture as opposed to multiple colors.

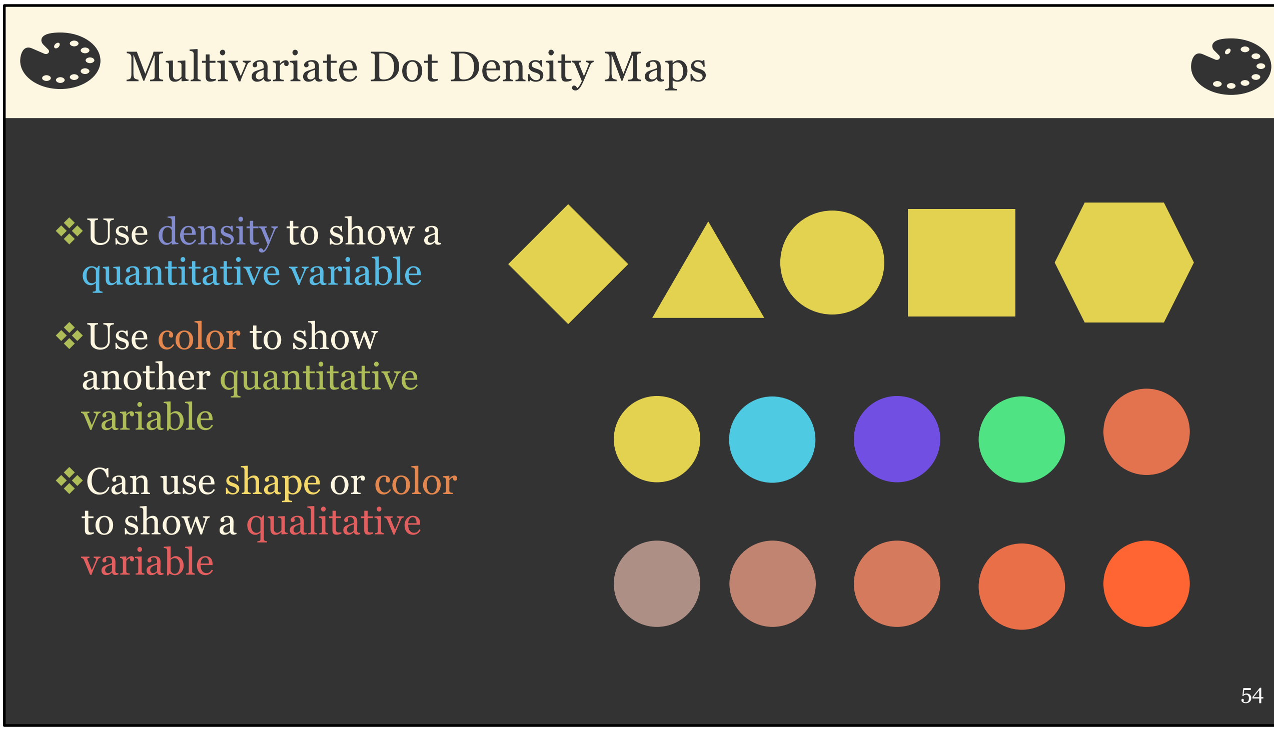
Alternatives to Bivariate Choropleth



- Bivariate Ray-Glyph

53

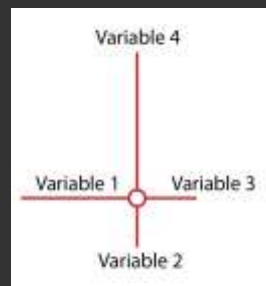
A bivariate ray glyph can be used to represent two quantities on separate sides of a circle. The position of the red lines in the example correspond to each quantity. In this example, the value for Variable 1 is high and the value for Variable 2 is low. So, these can be read similar to gauges.

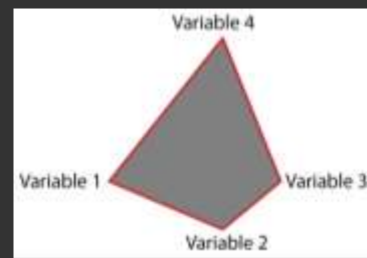


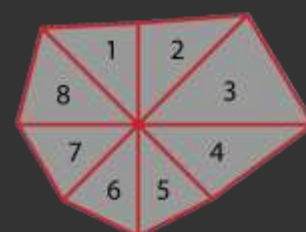
Dot density maps can also incorporate other symbols to show additional variables. For example, color can be used to differentiate another quantitative variable while shape or unordered colors can be used to represent a qualitative or categorical variable. For example, acreage for different crops within a county could be represented using different dot shapes or unordered colors.

Multivariate Point Symbols

- Related attributes = pie charts
- Nonrelated attributes = glyphs
  - Star Glyph
  - Polygonal Glyph
  - Star + Snowflake
  - Three-Dimensional Bar Plot
  - Data Jack Glyph
  - Chernoff Face Glyph







https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/chernoff-faces/

55

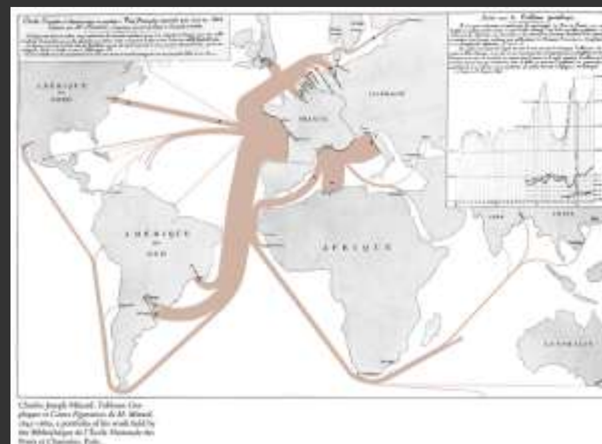
There are also a wide variety of options for multivariate point symbols including pie charts and glyphs. Example glyphs included star, polygonal, star + snowflake, 3D bar plots, data jacks, and Chernoff's face. The image on the top-left represents a star glyph where the magnitude of four separate variables are represented by 4 separate line lengths. The polygonal glyph at the upper-right was generated by connecting the end points of the lines from the star glyph. Here, the distance from the center is scaled relative to the magnitude of each variable. The example on the bottom-right is an example of a star + snowflake glyph where the magnitude of 8 variables are represented by the size of a triangle. Chernoff's face allows for different attributes of a face (such as nose size, nose shape, face width, face height, face shape, and mouth position) to represent different quantities or categories. The ESRI link provided on this slide offers some examples and further explanation of Chernoff's face.

Flow Maps

56

Flow Maps

- Use arrows to indicate direction of movement, flow, or migration
- Can use arrow/line size to indicate magnitude or a quantitative variable
- Can use color to represent a quantitative or qualitative variable



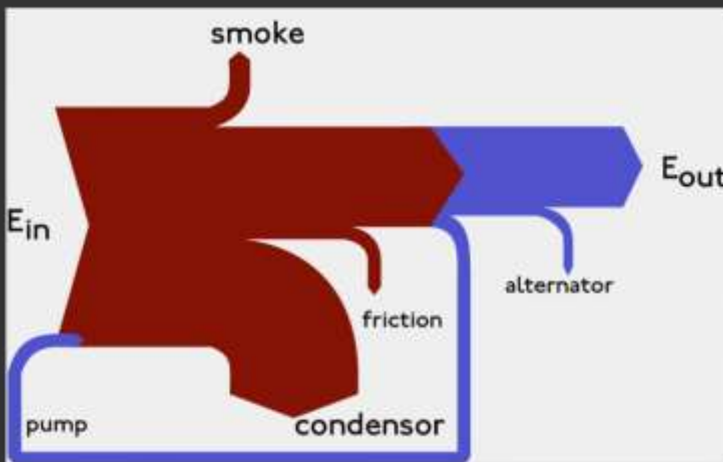
https://gistbok.ucgis.org/bok-topics/flow-maps

https://commons.wikimedia.org/wiki/File:Minard%E2%80%99s_map_of_French_wine_exports_for_1864.jpg

57

Migration, movement, or flow in geographic space can be represented with flow maps. Arrows can be used to denote the direction of flow (from-to-to) while size can show magnitude or a quantitative measure, such as the number of migrants from one location to another. Color can be used to show a quantitative or qualitative variable.

Sankey Diagram



❖ Arrow/line width is proportional to flow rate

https://commons.wikimedia.org/wiki/File:Sankeysteam.png

58

Flow maps are built upon the concept of Sankey diagrams where the arrow width is proportional to flow rate. Flow maps expand this framework for use in map space and to visualize different variables.

Type of Flow Maps

- ❖Distributive flow maps = movement between locations; size can indicate magnitude
- ❖Network Flow Map = flow or movement along a network (for example, traffic flow and volume on road network)
- ❖Radial Flow Map = highlight flow in different directions from locations
- ❖Continuous Flow Map = for continuous variables, such as wind speed

59

This slide provides an overview of different types of flow maps. Please read through these descriptions.

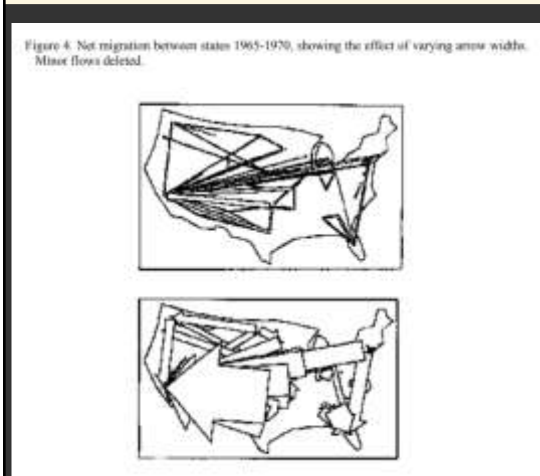
Geographical Distortion

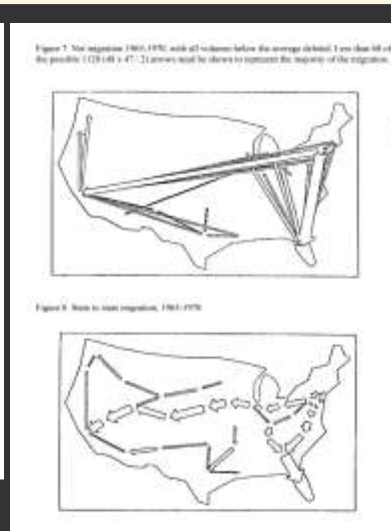
- No Geographical Distortion = geographic position and relationships maintained
- Geographical Distortion = connections, direction, and magnitude of movement highlighted; geographic relationships not maintained

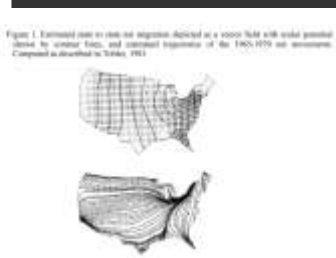
60

Not all flow maps maintain correct feature shape or geographic position, as these attributes may not be necessary to understand the data or message. However, important information of connections, directions, and magnitudes are maintained.

Tobler, W.R., 1987. Experiments in migration mapping by computer. *The American Cartographer*, *14*(2), pp.155-163.



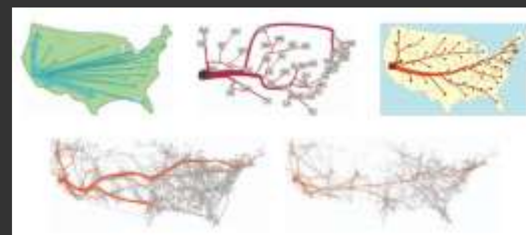




61

This slide provides some flow maps from Tobler (1987). Specifically, these figures highlight the impact of changing the arrow width, removing small arrows, and using vector fields to represent a more geographically continuous variable.

Buchin, K., Speckmann, B. and Verbeek, K., 2011. Flow map layout via spiral trees. *IEEE transactions on visualization and computer graphics*, *17*(12), pp.2536-2544.



62

This page highlights The work of Buchin et al. (2011) relating to spiral tree methods. These types of flow maps tend to be used when the pattern being mapped takes on a branching or tree-like structure.

Issues in Designing Flow Maps (Dent, 1999)

1. Flow lines are highest in intellectual importance and therefore highest in visual/graphic importance
2. Smaller flow lines should appear on top of larger flow lines
3. Arrows are necessary if direction of flow is critical to map meaning
4. Land and water contrasts are essential (if the mapped area contains both)
5. Projection, its center and aspect, are used to direct readers' attention to the flow pattern important to the map's purpose
6. All information should be kept simple, including flow line scaling
7. Legends should be clear and unambiguous, and include units where necessary

63

This slide highlights some issues and considerations for making flow maps as documented by Dent (1999).

Make a Flow Map in ArcGIS Pro

- Can manually draw lines to symbolize as flow paths
- Can symbolize quantitative variables using line size or color
- Can symbolize qualitative variables using line color or shape
- Can convert start and end points to line using the XY To Line Tool

64

Making flow maps using ArcGIS Pro and graphic editing software will involve some manual editing. However, the XY to Line Tool can be used to create lines connecting two locations. The associated attribute information, quantitative and/or qualitative, can then be visualized with other graphical parameters, such as size (quantitative) or color (quantitative or qualitative).

This is the end of this lecture module.

Please return to the West Virginia View Webpage for additional content.

Thanks! Hope you found this useful.