Lecture 5: Choropleth and bivariate maps and classification
Cartographic symbolization
What is symbolization?

• Assumes map objects are thematic, and purpose of map is related to point, line, area, or volume objects
• Assumes choice of scale and granularity
• Assumes choice of continuity model
• Assumes choice of data level (adds cyclical, counts, fuzzy, bipolar)
• Goal is to use data to visualize phenomenon
• Make choices of cartographic method (e.g. choropleth, proportional symbol, isopleth, dot)
• Apply and adjust visual variables
Fuzzy Features
Continuity

A

Abrupt

Discrete

# of employees at county courthouse

# of government employees

# of employed people

# of telephone subscribers

# of AIDS cases

# of influenza cases

Continuous

percent sales tax

average income

average farm size

Smooth
Dots, proportional symbols, isopleths, choropleths
### Visual Variables for Quantitative Phenomena

<table>
<thead>
<tr>
<th></th>
<th>Point</th>
<th>Linear</th>
<th>Areal</th>
<th>2½-D</th>
<th>True 3-D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spacing</strong></td>
<td><img src="image1.png" alt="Spacing Diagram" /></td>
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<td><img src="image3.png" alt="Spacing Diagram" /></td>
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<tr>
<td><strong>Size</strong></td>
<td><img src="image6.png" alt="Size Diagram" /></td>
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<td><img src="image15.png" alt="Perspective Height Diagram" /></td>
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<tr>
<td><strong>Color (Hue)</strong></td>
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<td><img src="image17.png" alt="Color Diagram" /></td>
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<tr>
<td><strong>Color (Lightness)</strong></td>
<td><img src="image21.png" alt="Color Lightness Diagram" /></td>
<td><img src="image22.png" alt="Color Lightness Diagram" /></td>
<td><img src="image23.png" alt="Color Lightness Diagram" /></td>
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<td><img src="image25.png" alt="Color Lightness Diagram" /></td>
</tr>
<tr>
<td><strong>Color (Saturation)</strong></td>
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<td><img src="image30.png" alt="Color Saturation Diagram" /></td>
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## Bertin’s Visual Variables

### Visual Variables for Quantitative Phenomena

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<td><img src="image14.png" alt="Perspective Height" /></td>
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</tr>
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Pattern: Combining visual variables

Microbreweries and Brewpubs 1996

Number of Establishments

3 to 10
11 to 15
20 to 32
44 to 72
149
Choropleth

A  Wheat Harvested in Kansas, 1993
   (unstandardized)

B  Wheat Harvested in Kansas, 1993
   (standardized)

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Each Dot Represents 12,000 Acres of Wheat
A Perspective Height

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Slocum’s Symbolization conclusion

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<th></th>
<th>Nominal</th>
<th>Ordinal</th>
<th>Numerical</th>
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<tbody>
<tr>
<td>Spacing</td>
<td>P</td>
<td>M</td>
<td>M</td>
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<tr>
<td>Size</td>
<td>P</td>
<td>M</td>
<td>M</td>
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<tr>
<td>Perspective Height</td>
<td>P</td>
<td>M&lt;sup&gt;a&lt;/sup&gt;</td>
<td>G&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>Orientation</td>
<td>G</td>
<td>P</td>
<td>P</td>
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<tr>
<td>Shape</td>
<td>G</td>
<td>P</td>
<td>P</td>
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<td>G</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Lightness</td>
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<td>G&lt;sup&gt;d&lt;/sup&gt;</td>
<td>M&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
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<td>M</td>
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**P** = Poor, **M** = Marginally Effective, **G** = Good

<sup>a</sup> Since height differences are suggestive of numerical differences, use with caution for ordinal data.

<sup>b</sup> Hidden enumeration units and lack of a north orientation are problems.

<sup>c</sup> Not aesthetically pleasing.

<sup>d</sup> The particular hues selected must be carefully ordered, such as yellow, orange, red.
Next, choropleth in detail
Greek χώρο ("area/region") + πλήθος ("multitude")

Key factors

• Resolution of base map
• Data
  • Source and processing
  • Classification
  • MAUP
  • Legend
• Symbolization
• Figure/ground and details
Units or “Geography”

• Do the data collection units have meaning, or are they simply a sampling frame?

• Are the boundaries crisp, continuous or fuzzy?
  • Census divisions
  • Zip codes
  • Neighborhoods
  • Counties
  • States
  • Nations
Census units

Change in Census Tract Boundaries 1990-2010
Providence, RI Neighborhoods

1990

2000

2010

Note: In 1990, the City of Providence was not exactly comprised by tracts 1-37 (as it was in 1990 and 2000). Portions of additional tracts were within municipal limits and portions of 1-37 were actually within other municipalities. 1990 tracts 1-37 are shown for simplicity.

Major Differences 1990-2000:
- Tract 36 split
  - Tract 36.01 absorbed some of tract 35
  - Tract 1 split and absorbed part of 2
  - Tract 5, 6 and 7 changed boundaries
- Tract 28 absorbed some of tract 17
- Tract 20 absorbed some of tract 21
- Tract 25 absorbed some of tract 22
- Tract 31 absorbed some of tract 26
- Tract 30 no longer exists- absorbed by tracts 29, 31 and 33

Major Differences 2000-2010:
- Tract 21 split

ProvPlan

The Providence Plan
12 Shrewsbury, Suite 300
Providence, RI 02903
www.provplan.org
MAUP

• Modifiable area unit problem
• Also called the ecological fallacy
• Source of statistical bias that can radically affect the results of statistical hypothesis tests
• Results when measures of spatial phenomena (e.g. population density) are aggregated into districts, usually for counting
• Openshaw (1983) "the areal units (zonal objects) used in many geographical studies are arbitrary, modifiable, and subject to the whims and fancies of whoever is doing, or did, the aggregating."
MAUP in a nutshell

Uniform

Spread bias
Methods for classification

- How many classes (vs. none)
- Eyeball, interactive -> Histogram
- Natural breaks
- Equal intervals
- Unequal i.e. non-linear
- Quantiles
- Standard deviations
- Jenks-Caspall analytical method
For example

Michigan Percent Unemployment: March 2012

Equal interval
4 classes

Quantile
5 classes

Standard Deviations
6 classes
Choropleth Maps Without Class Intervals?

W. R. Tobler

It is now technologically feasible to produce virtually continuous shades of grey by using automatic map drawing equipment. It is therefore no longer necessary for the cartographer to "quantize" data by combining values into class intervals. As a simple illustration an automatic line plotter can be programmed to draw lines virtually any distance apart (Fig. 1). Thus, one can obtain any desired density of inked area to white area. For example, if the geographical data, symbolized by \( z \), are normalized to lie in the range from zero to one, then an appropriate spacing of orthogonal lines of width \( w \) is given by

\[
\ell = \frac{w^2}{s^2} \cdot \left[ 1 + \left( 1 - s^2 \right)^{1.4} \right].
\]

Here an exponent \( x = 1.4 \) of \( s \) has been chosen to approximate the nonlinear response of the human eye [13]. The units of the spacing \( s \) are those of \( w \).
Histograms

A

B

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Jenks and Caspall (1971)

- Calculate the sum of squared deviations between classes (SDBC)
- Calculate the sum of squared deviations from the array mean (SDAM)
- Subtract the SDBC from the SDAM (SDAM-SDBC). This equals the sum of the squared deviations from the class means (SDCM)
- After inspecting each of the SDBC, a decision is made to move one unit from the class with the largest SDBC toward the class with the lowest SDBC
- New class deviations are then calculated, and the process is repeated until the sum of the within class deviations reaches a minimal value
- Final classes are uneven, but optimal
Symbolizing the choropleths

• Include areas?
• Patterns of lines (do not vary orientation)
• Dots (beware Moire patterns)
• Monochrome Shading
  • Darker is more
  • Vary density
  • Different schemas: Munsell vs. Stevens
• 2 color shading
• Color shading
  • Hue not a good variable, unless bipolar distribution
  • Use saturation or intensity
The legend

Legend for images:

A

- 1 - 2
- 7 - 12
- 15 - 19
- 27 - 34

B

- 27 - 34
- 15 - 19
- 7 - 12
- 1 - 2

C

- 27 - 34
- 15 - 19
- 7 - 12
- 1 - 2

D

- 1 - 2
- 7 - 12
- 15 - 19
- 27 - 34
Handling the areas
Bivariate choropleth maps

• Method for comparing two dissimilar distributions on the same map
• Popularized in the Census Atlas
• For choropleth, best with few classes
• Uses overlay legend
• Need contrasting colors
• Can do with Inkscape using automatic registration and transparency
Median Age in Years: 2010
Factors contributing to desert climate - temperature and precipitation.
Immigration Explorer

Select a foreign-born group to see how they settled across the United States.

Note: Due to limitations in the Census data, foreign-born populations are not available in all areas for all years.

Sources: Social Explorer, www.socialexplorer.com; Minnesota Population Center; U.S. Census Bureau

Matthew Bloch and Robert Gebeloff/The New York Times
Multivariable by multimethod

El Porvenir Impact:

- Improve living standards in Nicaragua through lower incidences of water-related diseases (e.g., diarrhea, skin infections, cholera, parasites, etc.) and mortalities.
- Improve productivity and educational opportunity for women and children by freeing time previously spent carrying water.
- Improve the lives of women and children who carry water great distances by helping them construct water projects closer to their homes.
- Reduce environmental contamination caused by poor sanitation (human excrement).

Water and Sanitation in Nicaragua
Statistics for Water and Hygiene Services by Municipios

No Access to Potable Water
Percent of Population
- 0.0 - 29.9
- 30.0 - 49.4
- 50.5 - 61.8
- 61.9 - 71.2
- 71.3 - 86.9

No Access to Hygienic Services
Number of Households
- 0 - 442
- 443 - 1920
- 1921 - 3312
- 3313 - 5633

Source: El Porvenir
Data: 2015

Chernov Faces  (Dorling, 1995)
Summary

- Map symbolization depends on data dimensions, level, and scale
- Must often first standardize and classify
- Choose method or map type: choropleth, isopleth, dot, proportional symbol
- Take care with visual variables and their interactions
- Examined choropleth mapping in detail: classification critical
- Looked at bivariate and multivariate methods
- Complexity bad, simplicity good