

# IAT 355

## Visual Analytics

### Spatial visualization

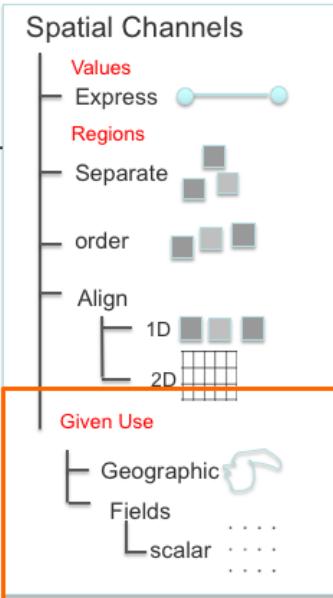
Lyn Bartram



*Some slides adapted from April Webster, 2008, CS 533, UBC*

## Given Space

- spatial semantics and relationships are of primary importance.
- Spatial layout is used as the **layout substrate**.
- Maps and GIS



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T. Munzner, Visualization Analysis and Design.

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## ]Geographic Information System (GIS)

- An "information system" that works with data referenced by spatial/geographic coordinates
- observations about spatial features, activities or events, definable in space as points, lines, or areas.
  - *Georeferencing and geocoding*
- link geographic location data with attribute data
  - ?find all left handed hockey players who play within 100 miles of Vancouver

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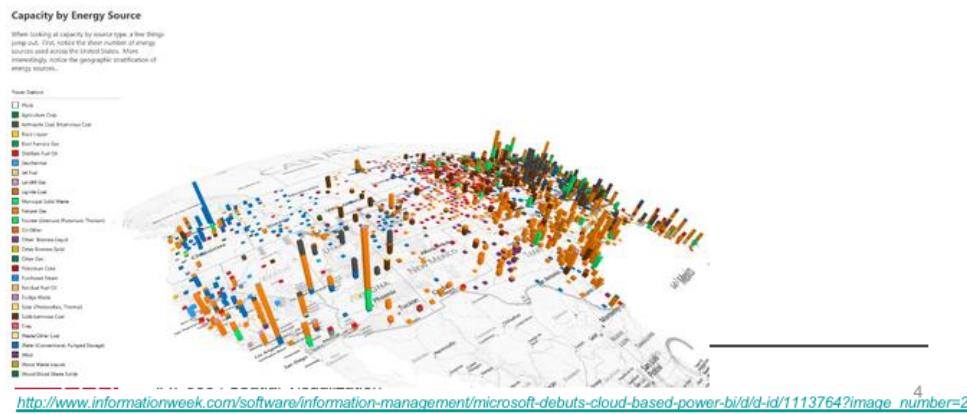
3

dB for modeling and storing data

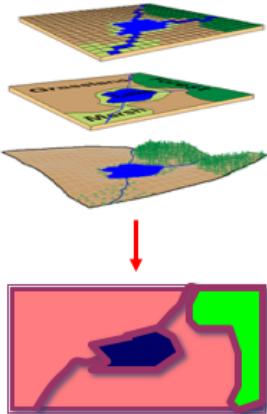
Tools for operating and displaying the data

## Geographic Visualization (geovis)

- relatively new development in cartography
- Geovisualization essential to visual analytics

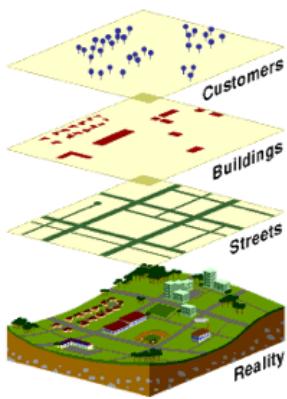


## A GIS primer: spatial data



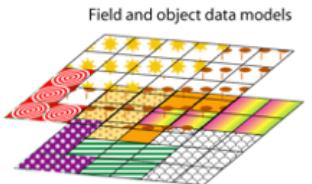
- Raster – Grid
  - “pixels”
  - a location and value
  - Satellite images and aerial photos are already in this format
- Vector – Linear
  - Points, lines & polygons
  - “Features” (house, lake, etc.)
    - Attributes
    - size, type, length, etc.

A GIS stores information as a collection of thematic layers that can be linked together by spatial location



- Layer is a collection of geographic objects that are alike or that have the same class
  - Same dimensionality
  - Association or Relationship
- Layers may be features or surfaces
  - Features have shape
  - Surfaces have numbers

## Spatial/geographic data types



- Discrete objects
  - Points, lines, and areas
  - Biological organisms
  - Human-made objects
  - Countable
  - Persistent through time, perhaps mobile
- Fields
  - Properties that vary continuously over space
  - Value is a function of location
  - any attribute type, including direction

## Georeferences

- Metric
  - measures of distance from fixed places
  - E.g., distance from the Equator or from the Greenwich Meridian
- Relative ordering
  - street addresses
- nominal
  - Place names do not involve ordering or measuring

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Reference is either **explicit** (such as latitude and longitude coordinates), or **implicit** such as an address, road name, or postal code

Unique, linking information to exactly one location

Shared, so different users understand the meaning of a georeference

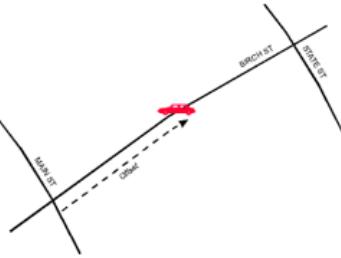
Persistent through time, so today's georeferences are still meaningful tomorrow

Georeference can be globally or locally unique

City Hall

## Georeferences

- Postal/zip codes
- Linear measures
  - Point + offset
  - Roads, rivers, rail, etc
- Cadasters (property map boundaries)
- Latitude and longitude (several formats)



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- Unless you are using a more sophisticated GIS API, most of the time you will not be dealing with all of these measures. But if you want to compute distance or area you will need to understand the underlying addressing system .
- Geographic coordinates are the earth's latitude and longitude system, ranging from 90 degrees south to 90 degrees north in latitude and 180 degrees west to 180 degrees east in longitude.
- A line with a constant latitude running east to west is called a *parallel*.
- A line with constant longitude running from the north pole to the south pole is called a *meridian*.
- The zero-longitude meridian is called the *prime meridian* and passes through Greenwich, England.
- A grid of parallels and meridians shown as lines on a map is called a *graticule*.

## Case 1: THE I2Sim project (JIIRP)

- Goal: investigate interdependencies between infrastructures and the consequent effects in an earthquake
- Test case: UBC campus



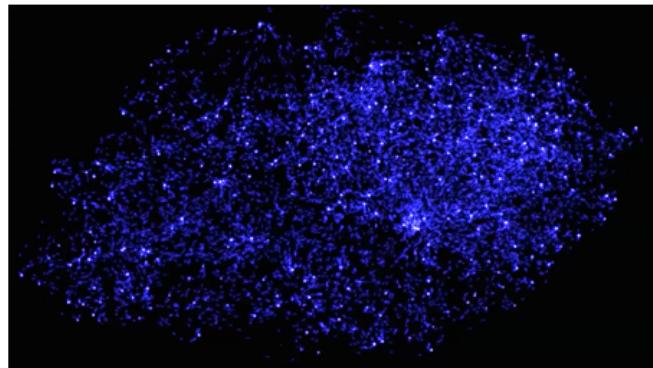
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## Case 2: Spatial storytelling Human Terrain Visual Analytics

Bike use and bike systems in London and the UK



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## Case 2: Real-time monitoring Human Terrain Visual Analytics

Bike use and bike systems in London and the UK



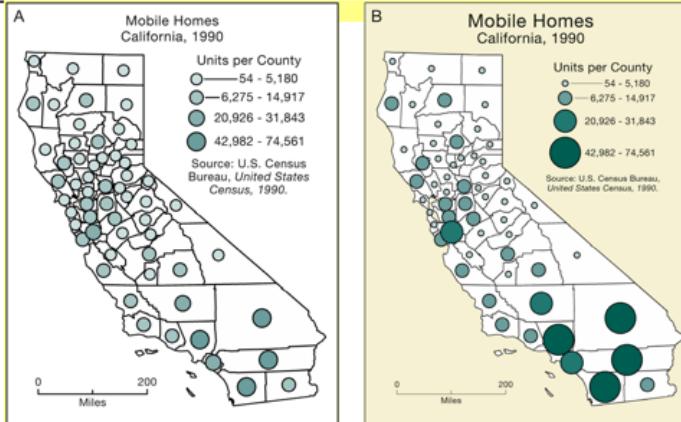
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## Map design: Principles

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- Visual contrast
- Legibility
  - Familiar conventions
  - Features
- Figure-ground
- Hierarchical organization
- Balance
  - Visual weight
  - Visual direction

## Contrast



Inappropriate Contrast

Appropriate Contrast

Howard, Cartographic Design, American River College

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Map on the left lacks appropriate contrast in four respects

Lightness and size of thematic symbols

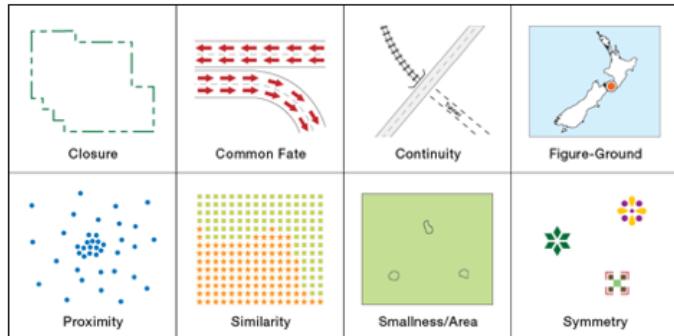
Size of lines (line width)

Type size

Difference between the mapped area and the background

## Legibility: Gestalt principles

- Closure
- Common Fate
- Continuity
- Figure-Ground
- Proximity
- Similarity
- Smallness/Area
- Symmetry



Howard, *Cartographic Design*, American River College

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## Methods of representation

### Marks

- Line
- Point
- Polygon
- Area
- Surface

### Channels

- Colours
- Thickness
- Size
- Texture
- Orientation

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## Visual variables

Area	Line	Point
<b>Lightness:</b>		
Water use levels	Pedestrian traffic	Water use levels
<b>Saturation:</b>		
<b>Size:</b>		
	Vehicle traffic	
<b>Spacing:</b>		

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IATC Quantitative Visualization

Area	Line	Point
<b>Hue:</b>		
Land use	Land use	Services
<b>Shape:</b>		
<b>Arrangement:</b>		
<b>Orientation:</b>		

Qualitative

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## Legibility: Visual variables

Must be learned!

- Quantitative (interval,ratio) Magnitude tasks

Visual Variables for Quantitative Phenomena					
	Point	Linear	Areal	2½-D	True 3-D
Spacing	○ ○ ○	— — —	       	         	         
Size	• • •	— — —	████████ ████████ ████████	████████ ████████ ████████	████████ ████████ ████████
Perspective Height	     	— — —	       	         	None Possible

Color Visual Variables for Quantitative Phenomena					
	Point	Linear	Areal	2½-D	True 3-D
Hue	Yellow Orange Red	— — —	Yellow Orange Red	Yellow Orange Red	Yellow Orange Red
Lightness	White White Black	— — —	White White Black	White White Black	White White Black
Saturation	White White Black	— — —	White White Black	White White Black	White White Black

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## Legibility: Visual variables

- Qualitative/nominal Identity tasks

Visual Variables for Qualitative Phenomena					
	Point	Linear	Areal	2½-D	True 3-D
Orientation	◆ ■ ▲			None Recommended	
Shape	● ■ ★			None Recommended	
Arrangement	● ■ ●			None Recommended	

Color Visual Variables for Qualitative Phenomena					
	Point	Linear	Areal	2½-D	True 3-D
Hue	● ● ●				None Recommended

- Differentiate major characteristics (water, land)
- Use familiar symbols!
- Limit complexity

Howard, Cartographic Design, American River College

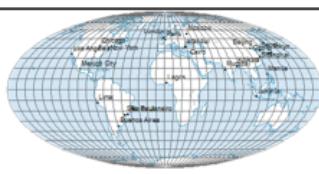
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## Legibility: Metadata Elements

- Graticules (grids)



- Scale



- orientation



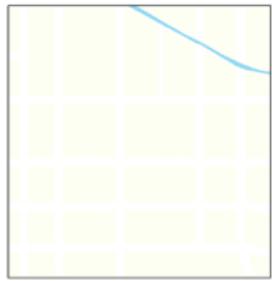
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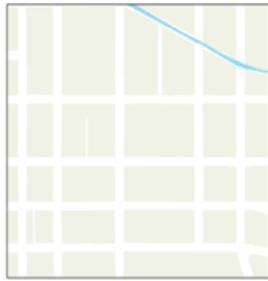
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## Figure-Ground

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Poor Figure-Ground



OK Figure-Ground



Good Figure-Ground

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MacEachren 1994. © 1994 Association of American Geographers

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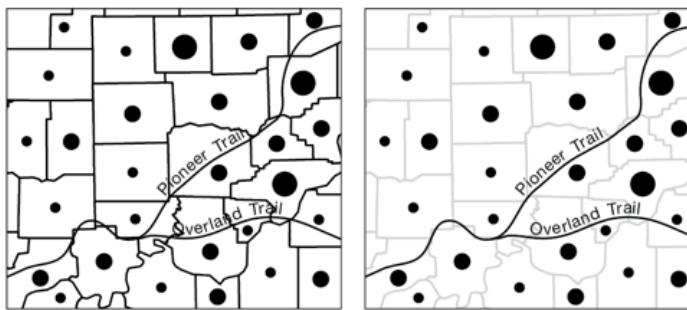
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objects that stand out in the field are seen as figures

## FIGURE-GROUND

- To accentuate points and/or lines
  - Make the points or lines *darker* than their surroundings



Base information has been lightened through “screening”

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objects that stand out in the field are seen as figures

## FIGURE-GROUND

- To accentuate areas
  - Make the area *lighter* than its surroundings



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## FIGURE-GROUND

- Making an area lighter than its surroundings is not always appropriate
  - When the mapped area is dense with areal thematic symbols (esp. when color is limited to shades of gray)



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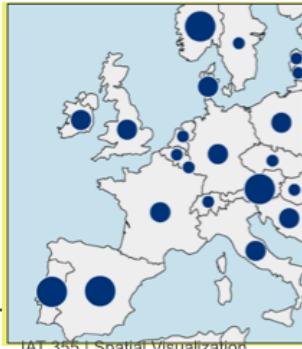
Areal thematic symbols provide enough contrast between the mapped area and its surroundings

Gray background might be confused with thematic symbols

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## FIGURE-GROUND

- Multiple layers of importance can be represented
  - Features can be assigned relative importance, based on relative proximity to the map user



Circles act as figures in relation to countries (which act as ground)

Countries, while subordinate to circles, act as figures in relation to water (which acts as ground)

Countries appear further away than circles, yet closer than water

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A special case of figure-ground accentuating a lighter area

The “ground” is water

## FIGURE-GROUND

- Alternative methods of establishing figure-ground that accentuates areas
  - Imposition on a graticule
  - Vignette

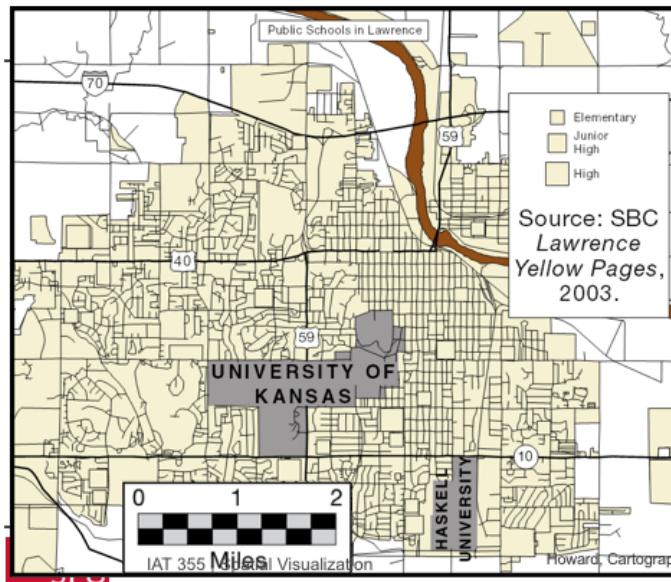


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## Visual Hierarchy



### Inverted (incorrect) Visual Hierarchy

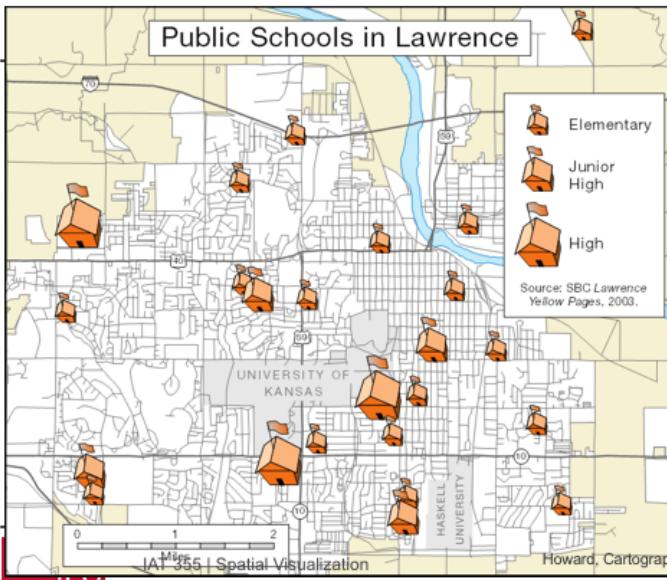
#### Based on an Inverted Intellectual Hierarchy

- Frame and neat lines
- Data source and notes
- Scale and north arrow
- Base information
- Title, subtitle, and legend
- Thematic symbols and type

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## Visual Hierarchy



### Correct Visual Hierarchy

#### Based on a Correct Intellectual Hierarchy

- Thematic symbols and type
- Title, subtitle, and legend
- Base information
- Scale and north arrow
- Data source and notes
- Frame and neat lines

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## Map types

### Point data

- Dot
- Graduated dot
- Symbol
- Icon/glyph



### Area data

- Chloropleth
- Area qualitative
- Stepped surface
- Hypsometric



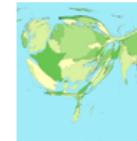
### Line data

- Network
- Flow
- Isopleth



### Geometry

- Projections

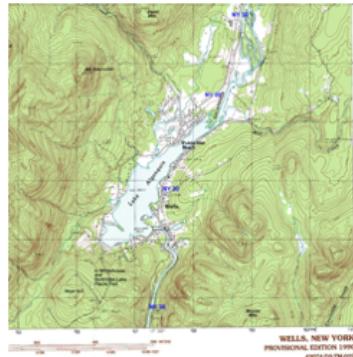


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## Reference and topographical maps



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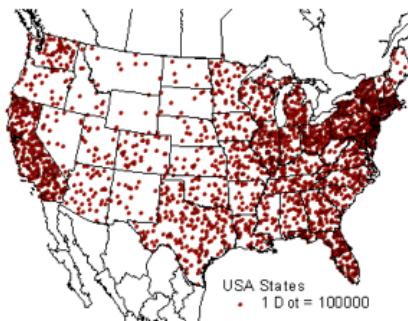
These are the traditional maps we are all accustomed to. Note that the basic principles of map design have been respected here, but most if not all of the data is directly associated with geography itself.

Point Data



## Dot distribution maps

- dots to show quantity in given areas



*Wheatear bird breeding, UK, 2008*

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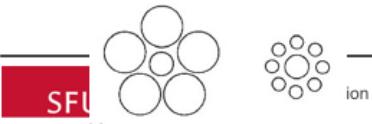
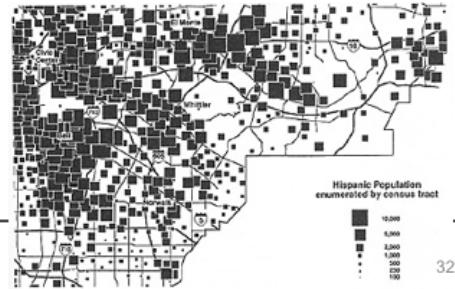
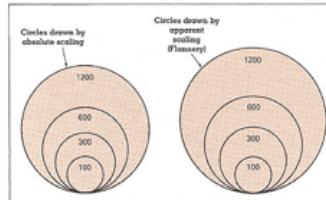
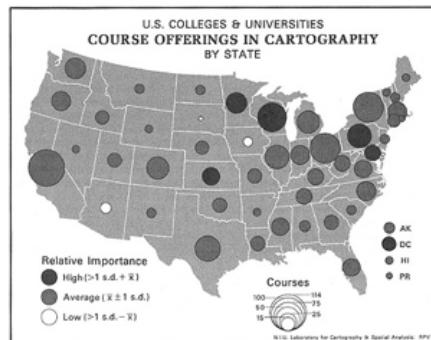
31

Point Data



## Symbol maps (*graduated symbol*)

- Symbols → value



## Icon / picture maps



## Point Data



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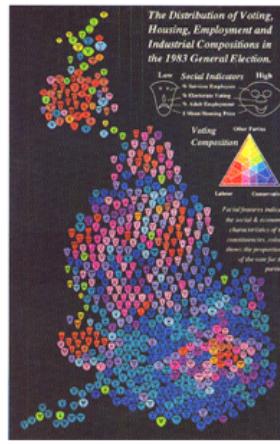
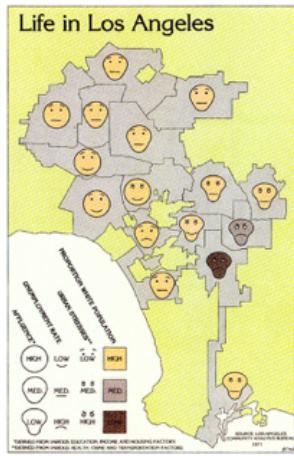
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Here we have both categorical (icon or glyph) and value meaning

Point Data



## Multivariate symbol/ glyph maps



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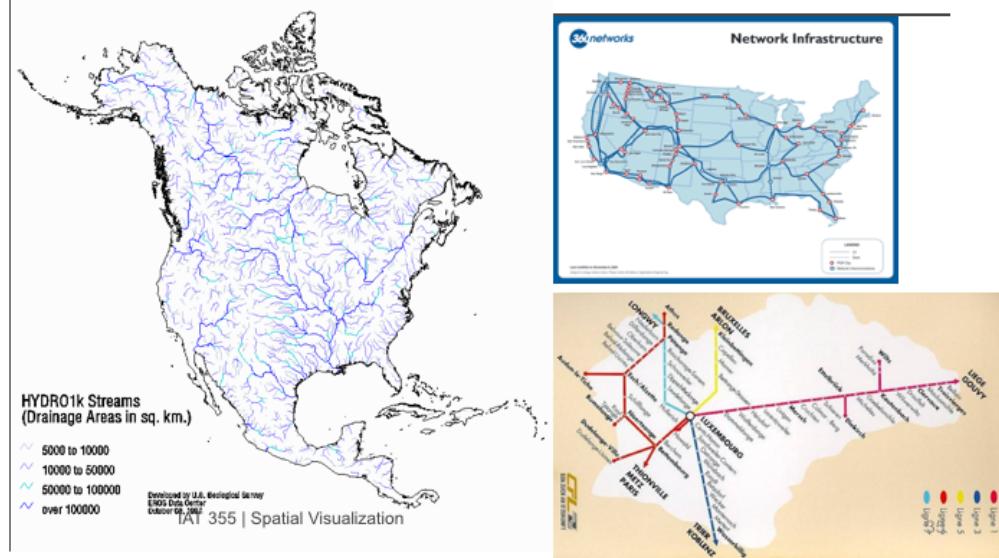
34

Line Data



## Network Maps

<http://www.360.net>    <http://www.luxembourg.co.uk/pics/railnetw.jpg>

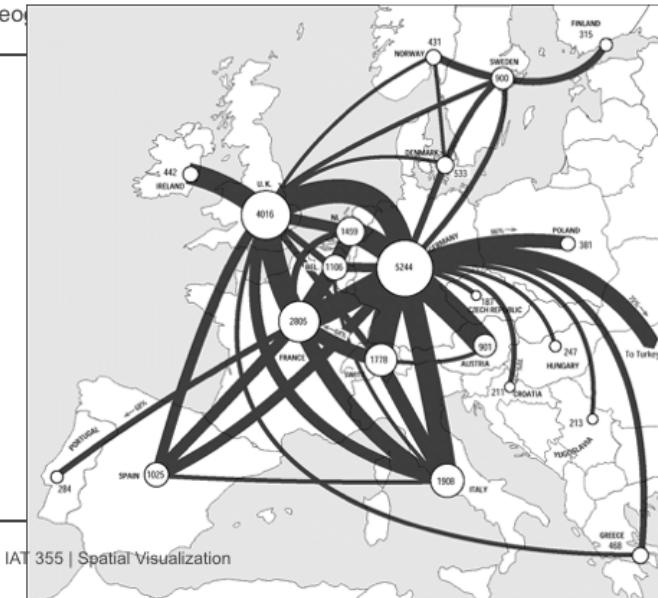


Line Data



## Flow Map: Europe Internet Traffic

[www.cybergeo.org](http://www.cybergeo.org)



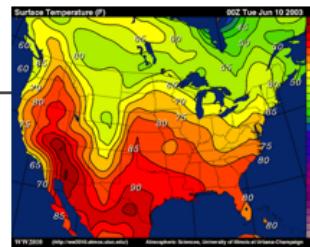
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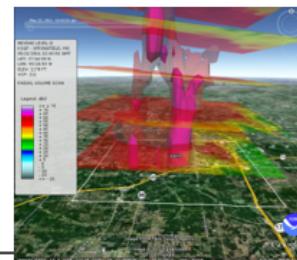
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## Isopleth maps

- Isolines:
    - A line on a map, chart, or graph connecting points of equal value
    - Contour lines
  - Isosurface
    - 3D surface connecting “slices” of equal value



Isolines showing temperature values  
[oliviasmapcatalog.blogspot.ro/2012/03/isotherms.html](http://oliviasmapcatalog.blogspot.ro/2012/03/isotherms.html)



Visualization of NEXRAD data for the May 22, 2011 Joplin, MO tornado overlaid on Google Earth: [NOAA](#)



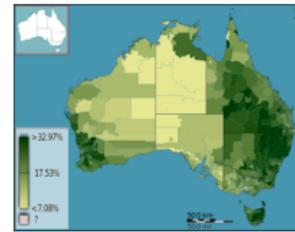
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Area Data



## Chloropleth Maps

- Nominal
  - Ownership
  - Electoral vote
- Quantitative
  - %



Most common infovis map !

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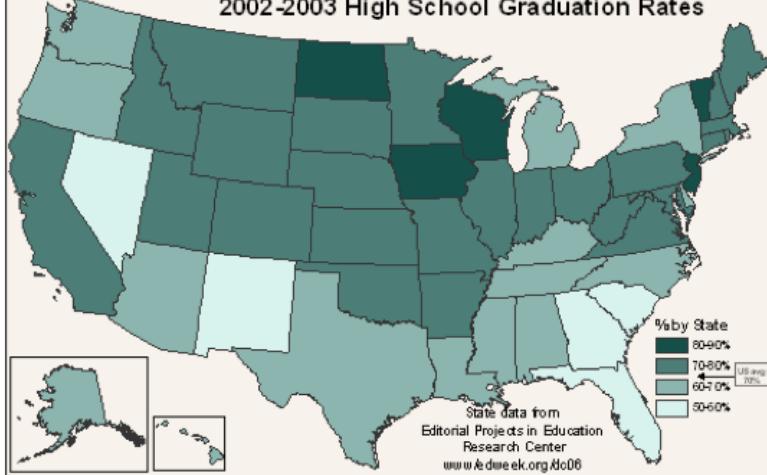
38

Most common inforvis maps. Each area/region filled with colour or texture representing some variable

Area Data



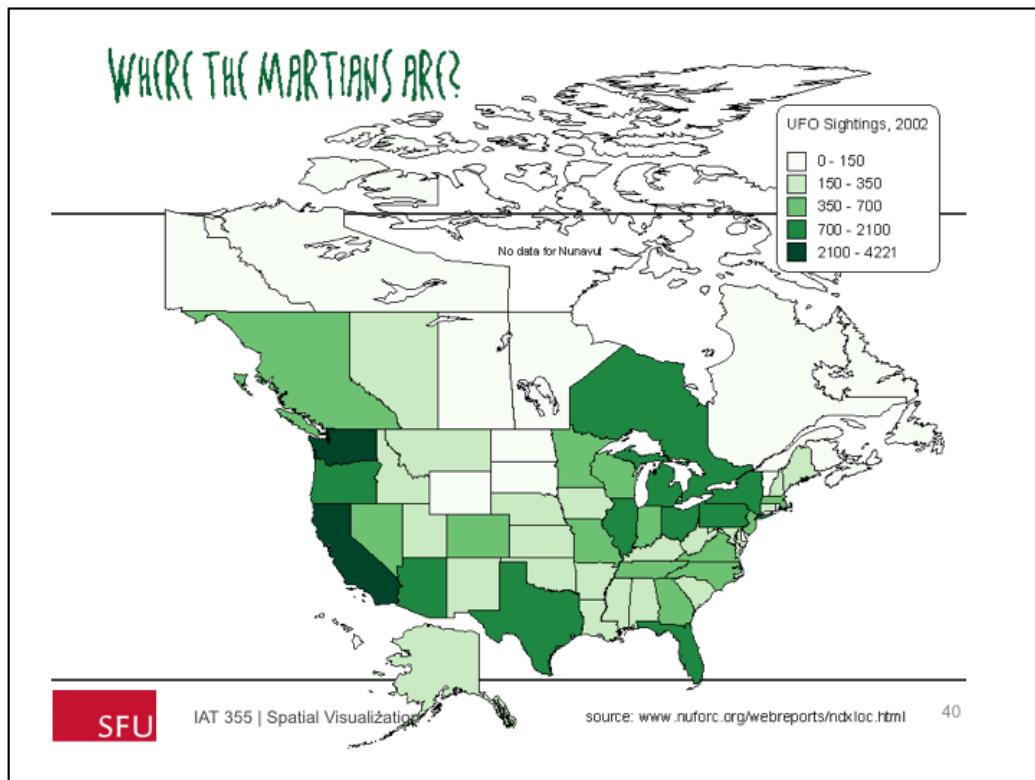
2002-2003 High School Graduation Rates



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My favourite chloroplet map

Area Data



# Area Qualitative Map

<http://www.townofbrighton.org/>

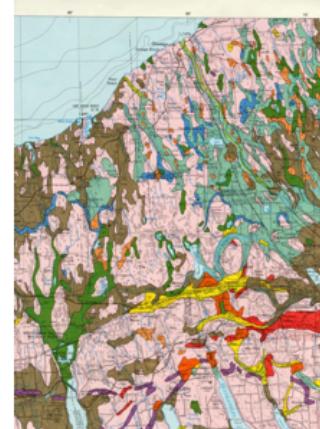
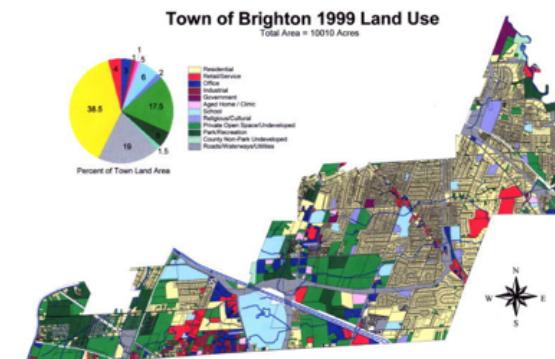


Fig. 2

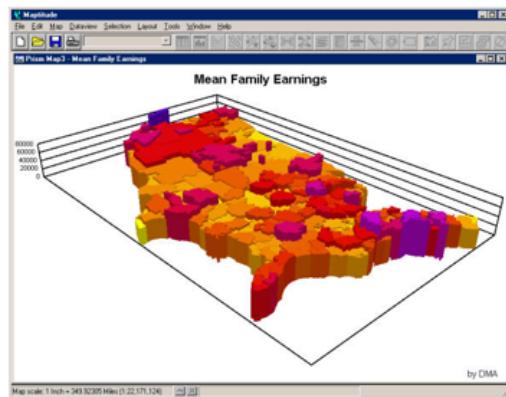
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## Stepped Surface



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Point Data



## Advantages of dot maps

- easy to understand
  - show varying density
- dot placement relates to the distribution of other phenomena:
  - a dot map of crop acreage would not place dots in urban areas, a dot map of population would cluster dots near urban areas, etc..



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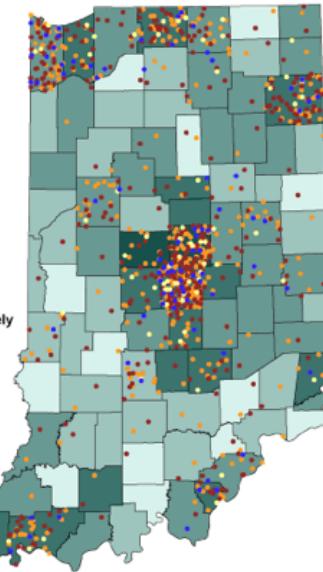
## Dot maps

- Can overlay on other mapping feature such as area
- Good for complex maps

**Luxury Cars and Per Capita Income**

Per Capita Personal Income in 2002

■ \$33,742 to \$42,891 (2 counties)
■ \$27,666 to \$33,741 (17 counties)
■ \$24,541 to \$27,665 (32 counties)
■ \$21,882 to \$24,540 (28 counties)
■ \$19,382 to \$21,881 (13 counties)



One dot equals approximately 50 registered cars in 2003

■ Porsche (3,747 total cars)
■ Jaguar (4,539 total cars)
■ BMW (19,928 total cars)
■ Mercedes (20,460 total cars)

Source: U.S. Bureau of Economic Analysis and Indiana Bureau of Motor Vehicles  
Indiana Business Research Center, Kelley School of Business, Indiana University, June 2004

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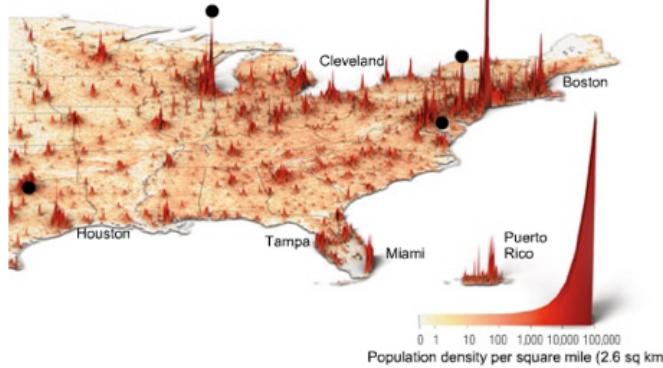
Point Data



## Height field (dot) maps

bers.

80% of the U.S. population lives in a metropolitan area. Top five population centers are numbered



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Height fields are often used with dot maps to redundantly show value when overplotting is an issue.

There are obvious disadvantages, as now we have occlusion in 2.5D – perspective distortion. If what we want is to only emphasize a few great differences this can alleviate the density issues of dot and symbol maps, but it needs to be used with great caution.

Point Data



## Disadvantages of dot maps

- There is a human tendency to underestimate density
  - Dot map density is difficult to accurately calculate
- If dots get too dense, it is difficult to read
- Dot placement is critical – if jittered, pattern is less meaningful

Point Data



## Advantages of symbol maps

- Easiest to make
- Show actual point of data occurrence
- Show absolute values
- Symbol can be multidimensional (glyph)



Crowdsourced repair reporting, [FixMyStreet.com](http://FixMyStreet.com)

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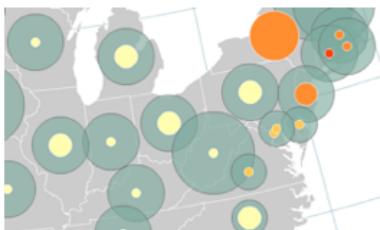
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## Disadvantages of symbol maps

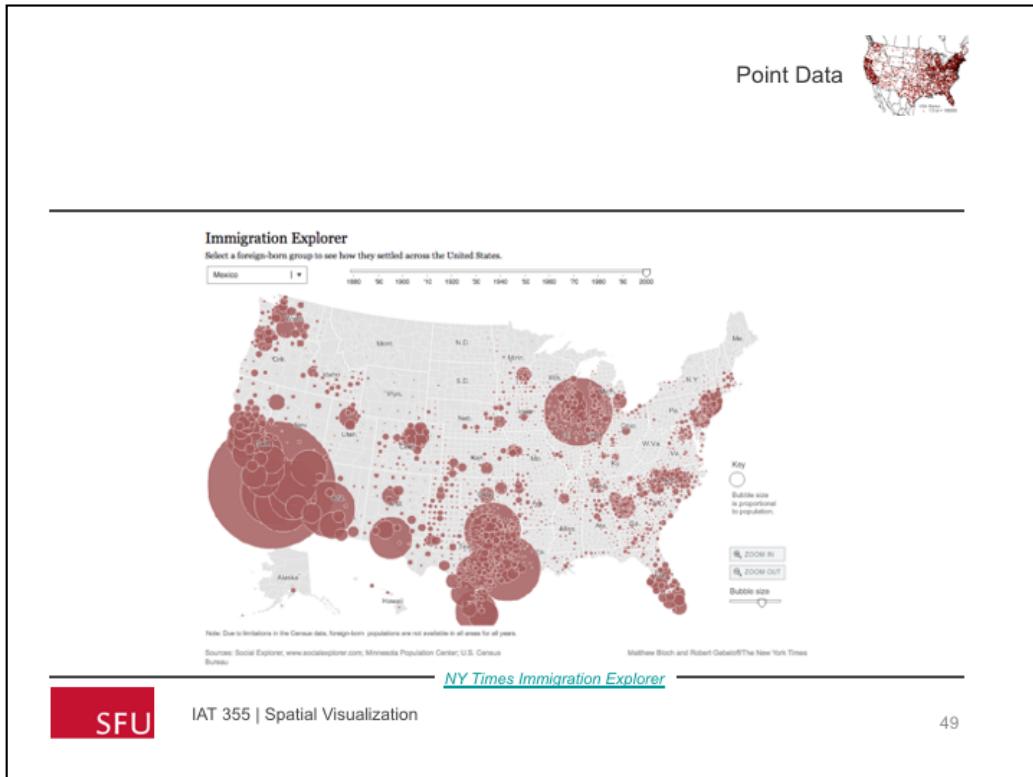
- Densities and ratios hard to show
- overplotting



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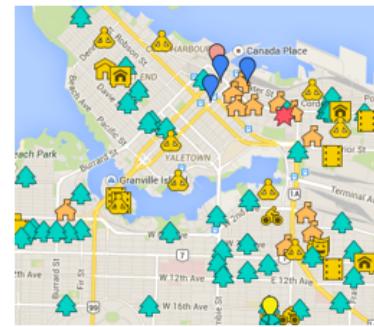
Even with only one hue, overplotting makes understanding relative values difficult.

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## Disadvantages of icon maps

- Difficult to tell relations between different symbol values
  - Between
  - Among



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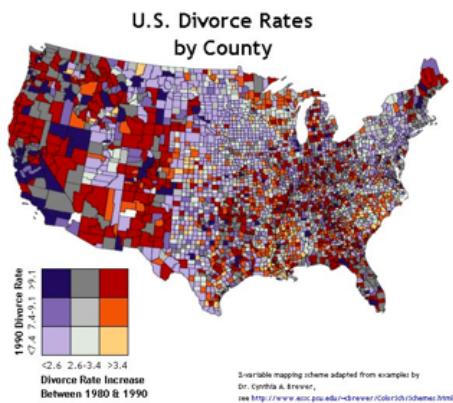
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## Advantages of chloropleth map

- easy way to visualize how a measurement varies across an area.
- Qualitative and quantitative
- Good for defining regions (as in an election map)
- appropriate for indicating differences in land use, like the amount of recreational land or type of forest cover.



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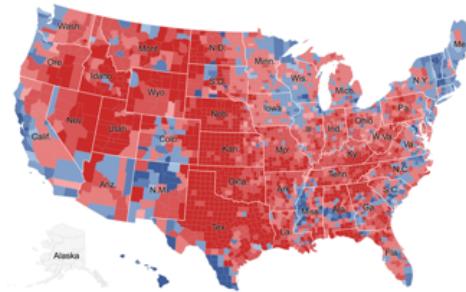
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Area Data



## Disadvantages of chloropleth map

- gives a false impression of abrupt change at the boundaries of shaded units.
- It can be difficult to distinguish between different shades in the maps.
  - problems with induction (e.g.: even though not everyone voted Republican in a state, when they color it red on a map on TV it LOOKS like everyone did)



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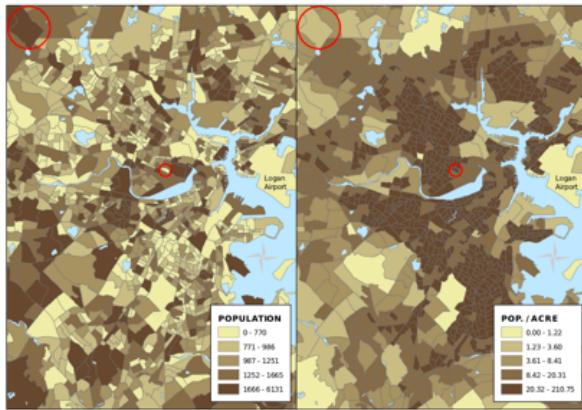
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## Correct data choice is critical

Population

Total Population of 2000 Census Block Groups   Population Density of 2000 Census Block Groups



Population Density

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A common error in choropleths is the use of raw data values to represent magnitude rather than normalized values to produce a map of densities.[3] This is problematic because the eye naturally integrates over areas of the same color, giving undue prominence to larger polygons of moderate magnitude and minimizing the significance of smaller polygons with high magnitudes. Compare the circled features in the maps at right

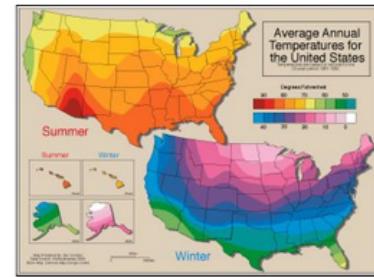
Darker colors are perceived as greater in magnitude

Line Data



## Advantages of iso maps

- Good for showing gradual change over space
- avoid the sudden changes which boundary lines produce.
  - Temperature, for example, temperature exists at every point (is continuous)



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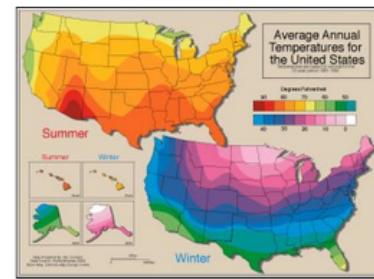
54

Line Data



## Disadvantages of iso maps

- not suited for showing discontinuous or 'patchy' distributions
- 
- A large amount of data is required for accurate drawing
- Differences not seen in small regions

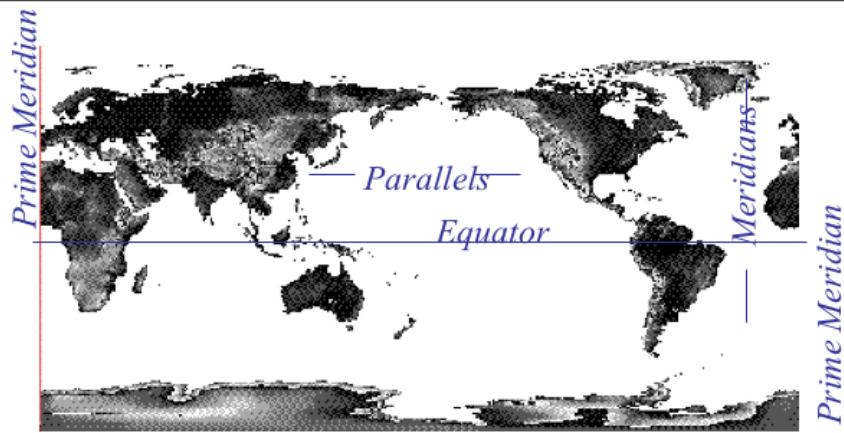


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## Projections



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: how can a flat map describe locations on a sphere/ellipse?



## Projections

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- Any projection must distort the Earth in some way
- Two types of projections are important in GIS
  - *Conformal* property:
  - *Equal area* property:
  - Both types of projections will generally distort distances
  - CAN'T HAVE BOTH

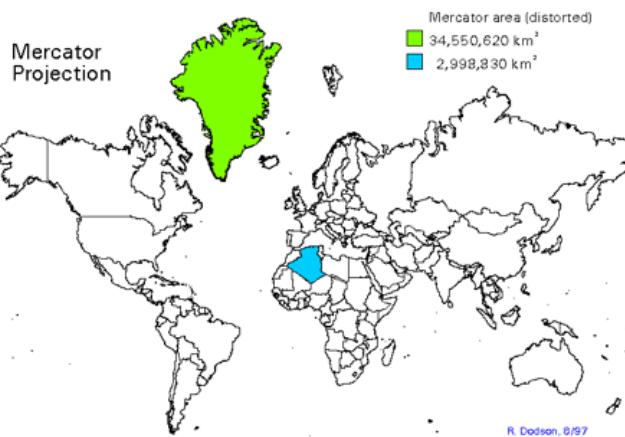
Conformal : Shapes of small features are preserved: anywhere on the projection the distortion is the same in all directions

Equal area: Shapes are distorted, but features have the correct area

Projections



## The familiar may be misleading



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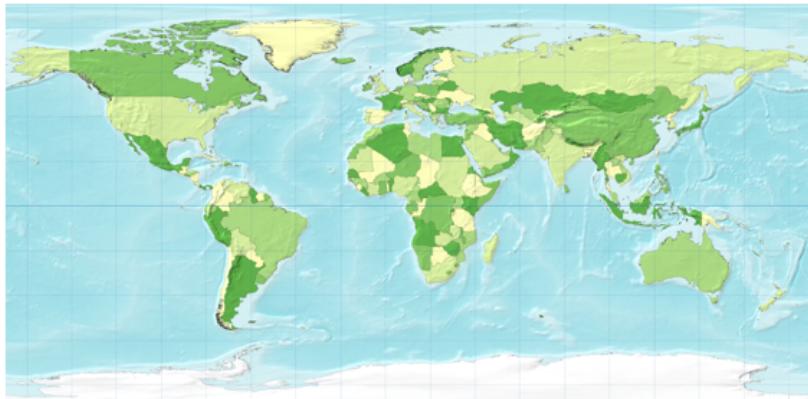
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Greenland appears larger than Africa, when in reality Africa's **area** is 14 times greater and Greenland's is comparable to Algeria's alone

## Cartograms

- Any projection is a distortion



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A **cartogram** is a map in which some thematic mapping variable – such as travel time, population, or Gross National Product – is substituted for land area or distance

## Cartograms

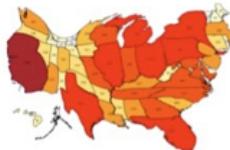
- Geometry or spatial layout is distorted to represent a variable (quantitative)
- show the amount of something by increasing or decreasing the size of the area in which the “something” is found

  
Save money. Live better.



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STARBUCKS COFFEE



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## Cartograms

- Population

Mark Newman, [Cartograms](#), 2009



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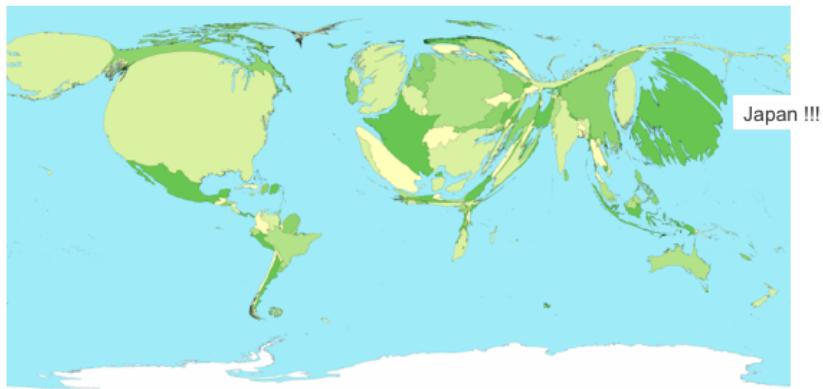
61

A **cartogram** is a map in which some thematic mapping variable – such as travel time, population, or Gross National Product – is substituted for land area or distance

## Cartograms

- GDP

Mark Newman, [Cartograms](#), 2009



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## Cartograms

- Good at showing relationships between attributes of spatial units
- emphasizes weights and concentrations
- provocative
- Distortions are difficult to parse/decode for accurate value
- comparative judgments are difficult (as opposed to more geometrically defined areas that can be decomposed into singular spatial features)

Area variability means comparisons are difficult because they are involve both the typical problems of area calculation as well as the complexity of the area outlines.

## Making maps: philosophy

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**Phenomena** are all the stuff in the real world. **Data** are records of observations of phenomena. Maps show us data, not phenomena. Carefully consider the data you are mapping, how they relate to the stuff in the world, how they are similar, how they are different, and how that may affect our understanding of the phenomena.

--John Krygier and Denis Wood, *Making Maps*, Third Edition. 2016