CSE 512 - Data Visualization

Mapping & Cartography

Jeffrey Heer  University of Washington
(with significant material from Michal Migurski)
Ptolemy’s Geographica
Original ~150AD, This Map ~1300AD
Rail Passengers and Freight from Paris 1884
Black Rock City, Nevada
(Burning Man)

Google Maps 2005
Casualties of War

Use the slider below to investigate the demographics and military status of U.S. service members who died during the war in Iraq.

MARCH 16, 2003 JULY 5, 2008 (277 WEEKS)

4,097 deaths

<table>
<thead>
<tr>
<th>Age</th>
<th>18-24</th>
<th>25-34</th>
<th>35-44</th>
<th>45+</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>54%</td>
<td>33%</td>
<td>10%</td>
<td>2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Branch of Military</th>
<th>Air Force</th>
<th>Army</th>
<th>Marine Corps</th>
<th>Navy</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>1%</td>
<td>72%</td>
<td>24%</td>
<td>2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race</th>
<th>Black</th>
<th>Hispanic</th>
<th>White</th>
<th>Other</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>9%</td>
<td>10%</td>
<td>71%</td>
<td>5%</td>
<td>5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Duty</th>
<th>National Guard</th>
<th>Regular</th>
<th>Reserve</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>11%</td>
<td>77%</td>
<td>7%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Location of death
Circles sized according to percentage of deaths in each Iraqi province.

Show home

Casualties of War, New York Times 2006
A Rogue State Along Two Rivers

How ISIS Came to Control Large Portions of Syria and Iraq

By JEREMY ASHKENAS, ARCHIE TSE, DEREK WATKINS and KAREN YOURISH July 3, 2014

The militant group called the Islamic State in Iraq and Syria, or ISIS, seemed to surprise many American and Iraqi officials with the recent gains it made in its violent campaign to create a new religious state. But the rapid-fire victories achieved over a few weeks in June were built on months of maneuvering along the Tigris and Euphrates Rivers.

The Euphrates

Aleppo: Ejected by Other Rebel Groups

In 2013, ISIS emerged from the remnants of Al Qaeda in Iraq and began to operate in Syria. The vacuum created by the country’s civil war provided a place for ISIS to rebuild. Syrian rebel groups initially welcomed ISIS as an ally, but soon realized that they did not have the same goals. ISIS
Choropleth Map
[NY Times]
237
Joseph R. Biden Jr.
70,122,063 votes (50.2%)

87
remaining

270
TO WIN

67,075,300 votes (48.0%)

214
Donald J. Trump

Cartogram
[NY Times]
Cartography
The Making of Maps
Projections
Latitude, Longitude

$P = 40^\circ N, 60^\circ W$
A sphere tears when you flatten it.
Projections

\[ f(\varphi, \lambda) \rightarrow (x, y) \]
Projections

\[ f(\varphi, \lambda) \iff (x, y) \]
Cylindrical  Conical  Azimuthal
Exploring Projections...

https://observablehq.com/@vega/vega-lite-cartographic-projections
We can categorize projections by what they preserve...
Distance

Preserve distance / direction from center
Azimuthal Equidistant

Preserves:
Distance & direction from center point

Use cases?
Azimuthal Equidistant

Preserves:
Distance & direction from center point

Use cases:
Travel / propagation from center point
Equal-Area
Preserve proportional areas
Albers Equal-Area Conic

*Preserves*: Proportional area of geographic regions

*Use cases?*
Preserves: Proportional area of geographic regions

Use cases: Land surveys, choropleth (shaded) maps
Conformal
Preserve local angles ("shape")
Spherical Mercator

Preserves:
Compass bearing as a straight line

Use cases?
Spherical Mercator

Rhumb Line

Preserves:
Compass bearing as a straight line

Use cases:
Navigation
Tissot’s Indicatrix

Circle size indicates the amount of area distortion
Spherical Mercator is ubiquitous on the web. Why?
The Earth as a Square
Web Mercator

\[ x = \frac{128}{\pi} 2^{\text{zoom level}} (\lambda + \pi) \text{ pixels} \]

\[ y = \frac{128}{\pi} 2^{\text{zoom level}} (\pi - \ln \left[ \tan \left( \frac{\pi}{4} + \frac{\varphi}{2} \right) \right]) \text{ pixels} \]

World coordinates adjusted to map to 256 x 256 pixels.

**Latitude cut-offs** at 85.051129 degrees: the exact point at which the projection frames the world in a square.
But there are other ways to fit the Earth into a square...
Projections usually have a home.
Increased Border Enforcement, With Varying Results

There are now more agents along the 1,954 mile-long border than ever before...

Border agents per sector.

Satellite Projection, NY Times

Not appropriate for the whole Earth, but fits the chosen focus region!
WHAT YOUR FAVORITE MAP PROJECTION SAYS ABOUT YOU

MERCATOR

YOU'RE NOT REALLY INTO MAPS.

VAN DER GRIJNTEN

YOU'RE NOT A COMPLICATED PERSON. YOU LOVE THE MERCATOR PROJECTION; YOU JUST WISH IT WEREN'T SQUARE. THE EARTH'S NOT A SQUARE, IT'S A CIRCLE. YOU LIKE CIRCLES. TODAY IS GONNA BE A GOOD DAY!
You think that when we look at a map, what we really see is ourselves. After you first saw Inception, you sat silent in the theater for six hours. It freaks you out to realize that everyone around you has a skeleton inside them. You have really looked at your hands.
There are interesting ways to tear spheres
One notable interesting way to tear a sphere
Balances preservation of area and shape.

Provides different ways of thinking about the world!
Idea: switch *between* projections by location and zoom level
Mapping
Visualizing Geospatial Data
Symbol Maps
Convey Locations & Magnitudes
Dots are ubiquitous
Dots can be symbols
Guess the crime
Dots can be good symbols.
“Red Dot Fever”
Mapping America: Every City, Every Block

Browse local data from the Census Bureau's American Community Survey, based on samples from 2005 to 2009. Because these figures are based on samples, they are subject to a margin of error, particularly in places with a low population, and are best regarded as estimates.

Distribution of racial and ethnic groups

Chinatown

By MATTHEW BLOCH, SHAN CARTER and ALAN MCLEAN | Source: 2005-9 American Community Survey, Census Bureau; socialexplorer.com

Note: Dots are evenly distributed across each Census tract or county. Dollar amounts are adjusted for inflation.
This map is counting many small things

the black lines show Chicago's official community areas.

each dot represents twenty-five people. here, hispanic is exclusive of other categories.

block-level data from the U.S. census.

scale 1:200,000
Choropleth Maps
Convey Rates Across Regions
1826(?) Illiteracy in France, Pierre Charles Dupin
Choose colors with care
Seven quantiles
Focus on the foreground
Heatmaps / Contour Maps
Convey Continuous Data
Binning

Chorodot Maps: Alan MacEachren and David DiBiase, 1991
Don’t hide the context
Uber Wait Times, 2011

Expected Wait Times in San Francisco

Latitude

Longitude

Expected wait time (seconds)
Break data into buckets

The Boston 2007 murder of journalist Chauncey Bailey in Oakland, California, led Stamans partner Mike Migurski to make the city’s crime data more accessible. This heat map of downtown uses data from CrimeWatch, a community website, to show the gaps between crimes at a given intersection. White is high-crime, darker areas are safe. stamans.com
Meaningful buckets, isolines
“Iso” means “same”

Isolines for elevation
Isochrones are isolines for time
Cartograms
Distort Shape to Convey Quantities
Major distortions can stay recognizable
Block Cartogram: Discrete Units

New York Times ratings


[Map of the United States with district ratings and buttons for analyzing races and creating outcomes.]

NY Times
China Still Dominates, but Some Manufacturers Look Elsewhere

While China maintains its overwhelming dominance in manufacturing, multinational companies are looking for ways to limit their reliance on factories there. Related Article »

Economic Output

In this map, geography is distorted so that each country is sized according to its economic output in 2012. The countries are colored by their rate of growth; more established economies tend to grow more slowly.

China is both highly productive and growing rapidly. Considering individual provinces conveys its impressive scale: Guangdong, just one of 31 Chinese provinces, has an economic output greater than Indonesia.

Japan and South Korea have large economic output, but growth has slowed as they have caught up with the West and innovation becomes more difficult.

Rising wages and risk in China are encouraging businesses to consider alternatives, including Cambodia, Vietnam and the Philippines.

New York shown for comparison.
Dorling Cartogram: Sized Circles

Obesity Map  Vadim Ogievetsky
Dorling Cartogram: Sized Circles

Obesity Map  Vadim Ogievetsky
Physical Diffusion Model

[Newman 2004]
Flow Maps
Convey Flux Between Locations
Minard 1869: Napoleon’s march
1864 British Coal Exports, Charles Minard
Flow Map Layout

[Phan et al. 2005]
Migration from California, ’95–’00

Tobler 1987

Phan et al. 2005

Verbeek et al. 2011

Cui et al. 2008

Holten & van Wijk 2009
wind map

February 19, 2014
11:55 am EST
(time of forecast download)

top speed: 35.3 mph
average: 11.6 mph
Generalization
Abstraction to Convey Topology
1864 British Coal Exports, Charles Minard
London Underground [Beck 33]

Geographic version of map

Principle: Straighten lines to emphasize stop sequence

Technique used to emphasize/de-emphasize information
Map Design via Optimization [Agrawala ‘01]

Set of graphic elements
   Roads, labels, cross-streets, ...

Choose visual attributes
   Position, orientation, size, ...
   Distortions increase flexibility

Develop constraints based on design principles

Simulated annealing
   Perturb: Form a layout
   Score: Evaluate quality
   Minimize score
Road Layout Constraints [Agrawala ‘01]

**Length**
Ensure all roads visible
Maintain ordering by length

**Orientation**
Maintain original orientation

**Topological errors**
Prevent false
Prevent missing
Ensure separation

**Overall route shape**
Maintain endpoint direction
Maintain endpoint distance

Length
\[ \frac{(L_{\text{min}} - l(r_i))}{L_{\text{min}}}^2 \times W_{\text{small}} \]

Maintain ordering by length
\[ W_{\text{shuffle}} \]

Orientation
\[ |\alpha_{\text{curr}}(r_i) - \alpha_{\text{orig}}(r_i)| \times W_{\text{orient}} \]

Topological errors
\[ \min(d_{\text{origin}}, d_{\text{dest}}) \times W_{\text{false}} \]
\[ d \times W_{\text{missing}} \]
\[ \min(d_{\text{ext}}, E) \times \text{Ext} \]

Ensure separation

Overall route shape
\[ |\alpha_{\text{curr}}(v) - \alpha_{\text{orig}}(v)| \times W_{\text{enddir}} \]
\[ |d_{\text{curr}}(v) - d_{\text{orig}}(v)| \times W_{\text{enddist}} \]
Approaches to Mapping Data

Symbol Maps → plot data over a map
Choropleth Maps → colored regions
Heatmaps & Contours → show densities
Cartograms → distort to show quantities
Flow Maps → flux across regions
Generalization → distort/abstract to aid tasks
Resources
Software Tools

Web Tools

d3-geo: projections, paths and more
GeoJSON: JSON format for geo data
TopoJSON: topology -> compressed GeoJSON
MapShaper: online editor for map data
Leaflet: open-source, customizable map tile system

Other

PostGIS: Postgres DB extensions for geo data
Mapnik: Render your own map tiles!
Data Resources

Natural Earth Data
naturalearthdata.com

OpenStreetMap
openstreetmap.org

U.S. Government
nationalatlas.gov, census.gov, usgs.gov
Tutorials

Cartographic Visualization in Vega-Lite
https://observablehq.com/@uwdata/cartographic-visualization

Command-Line Cartography
https://medium.com/@mbostock/command-line-cartography-part-1-897aa8f8ca2c

How to Infer Topology
http://bost.ocks.org/mike/topology/