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
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

Age
- 18-24: 54%
- 25-34: 33%
- 35-44: 10%
- 45+: 2%

Branch of Military
- Air Force: 1%
- Army: 72%
- Marine Corps: 24%
- Navy: 2%

Race
- Black: 9%
- Hispanic: 10%
- White: 71%
- Other: 5%
- Unknown: 5%

Type of Duty
- National Guard: 11%
- Regular: 77%
- Reserve: 7%
- Unknown: 5%

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

Show home

Casualties of War, New York Times 2006
Texas oil boom is visible from space

Lighting and natural gas flares from drilling on the 400-mile-long Eagle Ford shale formation can be seen from space in this image.

The new formation has helped make Texas the No. 1 oil-producing state in the nation.

**Oil production from different U.S. regions** (in thousands of barrels per day)

Source: Energy Information Administration

LA Times 2014
Ramadi: The Government Provides an Opening for ISIS

Tensions between this city’s residents, who are mostly Sunni, and the central government had been brewing here for at least a year. Then in December, Iraq’s prime minister, Nuri Kamal al-Maliki, ordered security forces to dismantle a protest camp — an outlet for disenchanted Sunnis angered at their treatment by the Shiite-dominated government. The action ignited days of violence and created the opening ISIS needed to seize parts of the city, the provincial capital.

Falluja: A Symbolic Fall

Just days after the raid on the camp in Ramadi, ISIS fighters destroyed the Police Headquarters and mayor’s office here, planted their flag on government buildings and decreed the city to be theirs. Ten years earlier, American forces had captured this city from Qaeda-style insurgents at a considerable cost of American lives.
Cartography
The Making of Maps
Projections
Latitude, Longitude

P = 40°N, 60°W

Point

Center

Equator
A sphere tears when you flatten it
Three example ways to categorize projections…
Azimuthal
Preserves direction / distance
Azimuthal Equidistant

The azimuthal equidistant projection is available as d3.geo.azimuthalEquidistant.
Equal-Area
Preserves area
The Albers equal-area conic projection is available as d3.geo.albers. See also the interactive version.
Conformal Preserves local angles
Spherical Mercator is ubiquitous on the web—why?
Tissot’s Indicatrix
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.
The Peirce quincuncial projection is implemented as `d3.geo.peirceQuincuncial` in the `geo-projection` D3 plugin. It is derived from the Guyou projection.
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.

<table>
<thead>
<tr>
<th>SAN DIEGO</th>
<th>EL CENTRO</th>
<th>YUMA</th>
<th>TUCSON</th>
<th>EL PASO</th>
<th>BIG BEND</th>
<th>DEL RIO</th>
<th>LAREDO</th>
<th>RIO GRANDE VALLEY</th>
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Satellite Projection, NY Times
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
You can drag the map with your mouse, and use the +/- buttons to zoom. The circle in the center will always indicate North for that point, and when you stop dragging the map will re-orient itself automatically. Read more about this on my blog.
Scale
This is not “scale”
Scale is an idea imported from print

<table>
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<tr>
<th>Scale Mapping</th>
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<td>1:625,000</td>
<td>1:250,000</td>
<td>1:50,000</td>
<td>1:25,000</td>
<td>1:10,000</td>
</tr>
</tbody>
</table>
Choose the right content at different scales
Four maps, same area
What shows at different scales?
Shapes change at different scales.

Figure 11. Fragmentation of a river into polygons and lines with different thresholds leading to different results (c, d, e).
Mapping

Visualizing Geospatial Data
Symbol Maps
Dots can be symbols
Guess the crime
Dots can be good symbols.
Dots can include data
Dots are ubiquitous
“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

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

http://sta.mn/zzz
Clustering, grouping
Three dimensions shown by color
One dimension, shown by hue

http://sta.mn/hn9
Let patterns emerge
Continuous Data
“Chorodots”

http://sta.mn/527
Don’t hide the context
Uber Wait Times, 2011

Expected Wait Times in San Francisco

Latitude

Longitude

Expected wait time (seconds)

≥ 720

660

600

540

480

420

360

300

240

180

120
Try smooth gradations?
Break data into buckets

The brazum 207 murder of journalist Quancey Bailey in Oakland, California, led Stamen partner Mike Migurski to make the city’s crime data more accessible. This heat map of downtown Oakland uses data from CrimeMap to show the gaps between crimes at a given Intersection; white is high-crime; darker areas are safer.
Meaningful buckets

http://sta.mn/b6
"Iso" means "same" Isolines for elevation
Isochrones are isolines for time
Flow Maps
Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.

Les nombres d'hommes perdus sont représentés par les largeurs des zones colorées à raison d'une millimètre pour six mille hommes, de sorte que plus on est enlevé de gènes. Le rouge désigne les hommes qui sont restés en Russie, le noir ceux qui en sont sortis. Les ensembles qui ont servi à dresser la carte ont été prises dans les ouvrages de M. M. Chico, de M. M. de Franca, de Chambry en le journal mis en Jacob, pharmaque à l'Armée depuis le 25 Octobre.

Pour mieux faire juger à l'œil la diminution de l'armée, j'ai représenté que les corps de Béziers, à Montel et du Maréchal Davoust qui avaient été détachés sur Minard en revenus vers Mecklenbourg, avaient toujours marché avec l'Armée.

TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.
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
How Obama Won Re-election

Romney’s Shift Wasn’t Enough

Most of the nation shifted to the right in Tuesday’s vote, but not far enough to secure a win for Mitt Romney.
Five quantiles

Polymaps is a project from SimpleGeo and Stamen.
Choose colors well
Focus on the foreground
What is obscured?
Regions -> Symbols
Cartograms
Obesity Map (Dorling Cartogram)  Vadim Ogievetsky
Obesity Map (Dorling Cartogram)  Vadim Ogievetsky
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.

New York shown for comparison.
Major distortions can stay recognizable.
Generalization
Harry Beck’s London tube diagram
London Underground [Beck 33]  
Geographic version of map

**Principle:** Straighten lines to emphasize stop sequence

Technique used to emphasize/de-emphasize information
People *love* the tube map
Time to Travel from Arnos Grove

Tube map + isochrones
Route Maps: Bellevue to Seattle
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

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

\[ W_{\text{shuffle}} \]

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

\[ \min(d_{\text{origin}}, d_{\text{dest}}) * W_{\text{false}} \]

\[ d * W_{\text{missing}} \]

\[ \min(d_{\text{ext}}, E) * Ext \]

\[ |\alpha_{\text{curr}}(v) - \alpha_{\text{orig}}(v)| * W_{\text{enddir}} \]

\[ |d_{\text{curr}}(v) - d_{\text{orig}}(v)| * W_{\text{enddist}} \]
Tools
Software Tools

Web Tools
d3.geo: projections, paths and more
GeoJSON: JSON format for geo data
TopoJSON: topology -> compressed GeoJSON
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

Let’s Make a Map!
http://bost.ocks.org/mike/map/

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