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
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.
Symbol Map

By winner  Electoral votes  Size of lead  Shift from 2016

LEADER:  Biden  Trump
Circle size is proportional to the amount each county's leading candidate is ahead.

237  Joseph R. Biden Jr.

70,122,063 votes (50.2%)

87  remaining

270 TO WIN

214  Donald J. Trump

67,075,300 votes (48.0%)
Cartography
The Making of Maps
Projections
Latitude, Longitude

P = 40°N, 60°W
A sphere tears when you flatten it.
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:
Travel / propagation from center point
Equal-Area
Preserve proportional areas
Preserves: Proportional area of geographic regions

Use cases?
Albers Equal-Area Conic

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

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
Scale
This is not “scale”
Scale is an idea imported from print.
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).
Questions?
Administrivia
A2: Deceptive Visualization

Design **two** static visualizations for a dataset:
1. An *earnest* visualization that faithfully conveys the data
2. A *deceptive* visualization that tries to mislead viewers

Your two visualizations may address different questions. Try to design a deceptive visualization that appears to be earnest: *can you trick your classmates and course staff?*

You are free to choose your own dataset, but we have also provided some preselected datasets for you.

Submit two images and a brief write-up on Gradescope.

Due by **Wed 4/19 11:59pm**.
A2 Peer Reviews

On Thursday 4/20 you will be assigned two peer A2 submissions to review. For each:

• Try to determine which is earnest and which is deceptive
• Share a rationale for how you made this determination
• Share feedback using the “I Like / I Wish / What If” rubric

Assigned reviews will be posted on the A2 Peer Review page on Canvas, along with a link to a Google Form. You should submit two forms: one for each A2 peer review.

Due by **Wed 4/26 11:59pm.**
I LIKE...
Praise for design ideas and/or well-executed implementation details. Example: "I like the navigation through time via the slider; the patterns observed as one moves forward are compelling!"

I WISH...
Constructive statements on how the design might be improved or further refined. Example: "I wish moving the slider caused the visualization to update immediately, rather than the current lag."

WHAT IF?
Suggest alternative design directions, or even wacky half-baked ideas. Example: "What if we got rid of the slider and enabled direct manipulation navigation by dragging data points directly?"
Create an interactive visualization. Choose a driving question for a dataset and develop an appropriate visualization + interaction techniques, then deploy your visualization on the web.

Due by 11:59pm on **Monday, May 8**.

Work in project teams of 3-4 people.
Form A3 + Final Project Team

Form a team of 3-4 for A3 and the Final Project. Submit signup form by Thur 4/27, 11:59pm.

If you do not have team mates, post on Ed about your interests/skills/project ideas!

We will send out a reminder early next week.
Requirements

Interactive. You must implement interaction methods! However, this is not only selection / filtering / tooltips. Also consider annotations or other narrative features to draw attention and provide additional context.

Web-based. D3/Vega-Lite are encouraged, but not required. Deploy to web using GitHub pages.

Write-up. Provide design rationale.
Interactive Prototype Tips

**Start now.** It will take longer than you think.

**Keep it simple.** Choose a *minimal* set of interactions that enables users to explore and generate interesting insights. Do not feel obligated to convey everything about the data: focus on a compelling subset.

**Promote engagement.** How do your chosen interactions reveal interesting observations?
Mapping
Visualizing Geospatial Data
Symbol Maps
Convey Locations & Magnitudes
Dots are ubiquitous
Dots can be symbols
Guess the crime
Dots can be good symbols.
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.
Let patterns emerge
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

Longitude

Latitude

Expected wait time (seconds)
Break data into buckets

The heinous 2007 murder of journalist Chauncey Bailey in Oakland, California, led Stamatakis 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 safer. stamak.com

**CRIMESPOTTING**

**KEY**

- Colours show how recently a crime was reported in a given part of Oakland

- A week ago
- Two weeks ago
- A month ago
- Two months ago
- Three months ago
- Four months ago
- Five months ago
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
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.
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
February 19, 2014
11:55 am EST
(time of forecast download)

top speed: 35.3 mph
average: 11.6 mph
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.
Generalization
Abstraction to Convey Topology
1864 British Coal Exports, Charles Minard
**Principle:** Straighten lines to emphasize stop sequence

Technique used to emphasize/de-emphasize information
People love tube maps... [Huffman]
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

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

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

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

Overall route shape
\[ |\alpha_{\text{curr}}(v) - \alpha_{\text{orig}}(v)| \times W_{\text{enddir}} \]
\[ |d_{\text{curr}}(v) - d_{\text{orig}}(v)| \times W_{\text{enddist}} \]
Tools
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/