CSE 442 - Data Visualization

The Value of Visualization

Jeffrey Heer  University of Washington
How much data (bytes) did we produce in 2010?
2010: 1,200 exabytes
10x increase over 5 years

Gantz et al, 2008, 2010
Physical Sensors

Image courtesy cabspotting.org
Health & Medicine
Records of Human Activity
Abortion

(from Wikipedia)

Abortion, in its most commonly used sense, refers to the deliberate early termination of pregnancy, resulting in the death of the fetus. (1) Medically, the term also refers to an early termination of pregnancy by natural means, such as spontaneous abortion or miscarriage, which is the death of a fetus before viability or before birth. This category includes pregnancies that end within the first trimester of pregnancy. In contrast, an abortion is defined as the death of a fetus after viability or before birth. This distinction is particularly relevant in the United States, where the legal definition of abortion is based on the viability of the fetus.

Methods

Depending on the stage of pregnancy and the context, abortion can be performed by a number of different methods. The most common method in the United States is the suction abortion, which is performed when the gestational age is less than 12 weeks. When the gestational age is more than 12 weeks, the dilation and evacuation (D&E) procedure is used.

The controversy

The morality and legality of abortion is a highly debated topic, particularly in the United States. Abortion has been a major political and social issue for many years, and the debate continues to be highly polarized. The controversy is not limited to the United States; it is also a significant issue in many other countries around the world. The pro-life/pro-choice debate continues to be a major topic of discussion, with both sides claiming their positions are based on moral and ethical principles.

The central question

The central question in the abortion debate is whether the rights of the woman and the rights of the fetus are compatible. On one side, the pro-life movement argues that the fetus is a human being with a right to life, and that terminating the pregnancy is equivalent to murder. On the other side, the pro-choice movement argues that the woman has the right to control her own body and make decisions about her own health and well-being. The debate is often characterized by strong emotions and polarized views.
The ability to take data–to be able to understand it, to process it, to extract value from it, to visualize it, to communicate it–that’s going to be a hugely important skill in the next decades, … because now we really do have essentially free and ubiquitous data. So the complimentary scarce factor is the ability to understand that data and extract value from it.

Hal Varian, Google’s Chief Economist
The McKinsey Quarterly, Jan 2009
A Poverty of Attention

“What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it.”

Herb Simon
as quoted by Hal Varian
Scientific American
September 1995
What is Visualization?

“Transformation of the symbolic into the geometric”
[Mccormick et al. 1987]

“... finding the artificial memory that best supports our natural means of perception.” [Bertin 1967]

“The use of computer-generated, interactive, visual representations of data to amplify cognition.”
[Card, Mackinlay, & Shneiderman 1999]
### Set A

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<td>8</td>
<td>7.91</td>
</tr>
<tr>
<td>8</td>
<td>6.89</td>
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### Summary Statistics

- \( u_X = 9.0 \) \( \sigma_X = 3.317 \)
- \( u_Y = 7.5 \) \( \sigma_Y = 2.03 \)

### Linear Regression

- \( Y = 3 + 0.5 \cdot X \)
- \( R^2 = 0.67 \)

[Anscombe 1973]
Why Create Visualizations?
Why Create Visualizations?

Answer questions (or discover them)
Make decisions
See data in context
Expand memory
Support graphical calculation
Find patterns
Present argument or tell a story
Inspire
Record Information
Gallop, Bay Horse “Daisy” [Muybridge 1884-86]
E.J. Marey’s sphygmograph [from Braun 83]
Support Reasoning
# History of O-Ring Damage on SRM Field Joints

## Cross Sectional View

<table>
<thead>
<tr>
<th>SRM No.</th>
<th>Erosion Depth (in.)</th>
<th>Perimeter Affected (deg.)</th>
<th>Nominal Dia. (in.)</th>
<th>Length Of Max Erosion (in.)</th>
<th>Total Heat Affected Length (in.)</th>
<th>Clocking Location (deg.)</th>
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<tbody>
<tr>
<td>22A</td>
<td>None</td>
<td>None</td>
<td>0.280</td>
<td>None</td>
<td>None</td>
<td>36° - 66°</td>
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<tr>
<td>22A</td>
<td>None</td>
<td>NONE</td>
<td>0.280</td>
<td>NONE</td>
<td>NONE</td>
<td>33° - 53°</td>
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<tr>
<td>15A</td>
<td>0.010</td>
<td>154.0</td>
<td>0.280</td>
<td>4.25</td>
<td>58.75</td>
<td>354</td>
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<td>0.038</td>
<td>130.0</td>
<td>0.280</td>
<td>12.50</td>
<td>29.50</td>
<td>354</td>
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<td>45.0</td>
<td>0.280</td>
<td>None</td>
<td>None</td>
<td>275</td>
</tr>
<tr>
<td>13B</td>
<td>0.028</td>
<td>110.0</td>
<td>0.280</td>
<td>3.00</td>
<td>None</td>
<td>275</td>
</tr>
<tr>
<td>11A</td>
<td>None</td>
<td>None</td>
<td>0.280</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<tr>
<td>10A</td>
<td>0.040</td>
<td>217.0</td>
<td>0.280</td>
<td>3.00</td>
<td>14.50</td>
<td>351</td>
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<tr>
<td>STS-2 RH Aft Field</td>
<td>0.053</td>
<td>116.0</td>
<td>0.280</td>
<td>--</td>
<td>--</td>
<td>90</td>
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</table>

*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.
**Soot behind primary O-ring.
***Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

## Other SRM-15 Field Joints Had No Blowholes in Putty and No Soot Near or Beyond the Primary O-Ring.

SRM-22 Forward Field Joint Had Putty Path to Primary O-Ring, But No O-Ring Erosion and No Soot Blowby. Other SRM-22 Field Joints Had No Blowholes in Putty.

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## Blow By History

**SRM-15 Worst Blow-By**
- 2 Case Joints (30°, 110°) Arc
- Much Worse Visually Than SRM-22

**SRM 22 Blow-By**
- 2 Case Joints (30-40°)

---

## History of O-RingTemperatures (Degrees - F)

<table>
<thead>
<tr>
<th>SBM</th>
<th>MTR</th>
<th>8mb</th>
<th>O-Ring</th>
<th>Wind</th>
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<td>DM-4</td>
<td>67</td>
<td>36</td>
<td>47</td>
<td>10 mph</td>
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<td>DM-2</td>
<td>76</td>
<td>45</td>
<td>52</td>
<td>10 mph</td>
</tr>
<tr>
<td>DM-3</td>
<td>72.5</td>
<td>40</td>
<td>48</td>
<td>10 mph</td>
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<tr>
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<td>76</td>
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<td>51</td>
<td>10 mph</td>
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<tr>
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<tr>
<td>SBM-25</td>
<td>55</td>
<td>26</td>
<td>29</td>
<td>25 mph</td>
</tr>
</tbody>
</table>
Make a Decision: Challenger
Make a Decision: Challenger

Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]
Data in Context: Cholera Outbreak

In 1854 John Snow plotted the position of each cholera case on a map. [from Tufte 83]
Data in Context: Cholera Outbreak

Used map to hypothesize that pump on Broad St. was the cause. [from Tufte 83]
Expand Memory: Multiplication

Class Exercise!
Find Patterns: NYC Weather

## The Most Powerful Brain?

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Body Weight</th>
<th>Brain Weight</th>
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<td>1</td>
<td>Lesser Short-tailed Shrew</td>
<td>5</td>
<td>0.14</td>
</tr>
<tr>
<td>2</td>
<td>Little Brown Bat</td>
<td>10</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>Mouse</td>
<td>23</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>Big Brown Bat</td>
<td>23</td>
<td>0.4</td>
</tr>
<tr>
<td>5</td>
<td>Musk Shrew</td>
<td>48</td>
<td>0.33</td>
</tr>
<tr>
<td>6</td>
<td>Star Nosed Mole</td>
<td>60</td>
<td>1</td>
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<td>7</td>
<td>Eastern American Mole</td>
<td>75</td>
<td>1.2</td>
</tr>
<tr>
<td>8</td>
<td>Ground Squirrel</td>
<td>101</td>
<td>4</td>
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<tr>
<td>9</td>
<td>Tree Shrew</td>
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<td>10</td>
<td>Golden Hamster</td>
<td>120</td>
<td>1</td>
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<tr>
<td>11</td>
<td>Mole Rate</td>
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<td>3</td>
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<td>12</td>
<td>Galago</td>
<td>200</td>
<td>5</td>
</tr>
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<td>13</td>
<td>Rat</td>
<td>280</td>
<td>1.9</td>
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<td>Chinchilla</td>
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<td>Tenrec</td>
<td>900</td>
<td>2.6</td>
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<td>20</td>
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<td>1000</td>
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<tr>
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<td>Mountain Beaver</td>
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<td>Phalanger</td>
<td>1620</td>
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The Dragons of Eden [Carl Sagan]
The Elements of Graphing Data
[Cleveland]

Log$_{10}$ Brain Weight $- \frac{2}{3}$ Log$_{10}$ Body Weight

Species: 
- Modern Man
- Dolphin
- Homo habilis
- Gracile Australopithecus
- Chimpanzee
- Baboon
- Crow
- Vampire Bat
- Wolf
- Gorilla
- Elephant
- Hummingbird
- Lion
- Rat
- Mole
- Opossum
- Blue Whale
- Sauromithoid
- Goldfish
- Ostrich
- Alligator
- Tyrannosaurus rex
- Coelacanth
- Eel
- Stegosaurus
- Brachiosaurus
- Diplodocus
Convey Information to Others
Inspire

Bones in hand [from 1918 edition]

Double helix model [Watson and Crick 53]
"to affect thro’ the Eyes what we fail to convey to the public through their word-proof ears"

1856 “Coxcomb” of Crimean War Deaths, Florence Nightingale
The Value of Visualization

Record information
   Blueprints, photographs, seismographs, ...

Analyze data to support reasoning
   Develop and assess hypotheses
   Find patterns / Discover errors in data
   Expand memory

Communicate information to others
   Share and persuade
   Collaborate and revise
Goals of Visualization Research

1. **Understand** how visualizations convey information
   - What do people perceive/comprehend?
   - How do visualizations inform mental models?

2. **Develop principles and techniques** for creating effective visualizations and supporting analysis
   - Leverage perception & augment cognition
   - Improve ties between visualization & mental model
## Data and Image Models

### Sémiologie Graphique [Bertin 67]

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<th>Points</th>
<th>Lignes</th>
<th>Zones</th>
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### Variables de Séparation des Images

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Visualization Design

SlicerDicers' Sales Compared to Other Products

July - December, 2003
(SlicerDicers' sales are displayed as black reference lines of 100%, the red bars represent the average monthly sales percentages for July through December.)

Problematic design

Redesign
Exploratory Data Analysis
Visualization Software

D3: Data-Driven Documents
The psychophysics of sensory function [Stevens 61]
Maps

Dymaxion Maps [Fuller 46]
Color Brewer

CIE 1931 xy chromaticity diagram showing the gamut of the sRGB and Adobe RGB color spaces including the Planckian locus, with temperatures indicated. Wavelengths of monochromatic light are shown in blue.
Animated transitions in statistical data graphics [Heer & Robertson 07]
Recent elections have placed a heavy emphasis on “swing states” — Ohio, Florida and the other competitive states. You can see how many states shifted between the Democratic and Republican parties. A look at how the states shifted vertically can help you see how they have shifted over past elections.

Obama Re-elected
The country voted about 5 percentage points more Republican in 2012 than in 2008. Obama lost North Carolina and Indiana, but won every tossup except Florida, which remains too close to call.

As Goes Ohio
Ohio, which has voted for the winner in every election since 1964, provided the decisive electoral votes in 2004, and it is the state likeliest to play that role again this year, according to the FiveThirtyEight model.
Hierarchies

Degree-Of-Interest Trees [Heer & Card 04]
Networks

Zephoria

User ID: 21721
Friends: 255
Age: 35
Gender: Female
Status: Single
Location: San Francisco, CA
Hometown: Lancaster, PA
Occupation: researcher, social networks, identity, context
Interests: apophenia, observing people, culture, questioning power, reading, Buddhism, indie, computer-mediated communication, social networks, technology, anthropology, stomping
Music: post-hardcore, Infected Mushroom, Sun Kil Mo, loop, Digital Structures, Ani Difranco, downtempo, Thievery Corporation, Beth Orton, Morcheeba, Vex
TV Shows: ??
Movies: Kevin Smith, Amelie, Watch Life, Tank Girl, The Matrix, Clockwork Orange, American Beauty, Fight Club, Boys Don't Cry
Member Since: ??
Last Login: 2003-10-21
Last Updated: 2003-10-21
About: Some know me as danah...

I'm a geek, an activist and an academic, fascinated by people and society. I see life as a very large playground and enjoy exploring its intricacies. I revel in life's chaos, while simultaneously providing my own insane element.

My musings:
http://www.zephoria.org/thoughts/

Want to Meet: Someone who makes life's complexities seem simply elegant.
A proponent for online victimology.
Visualizations: Word tree / Alberto Gonzales

Creator: Martin Wattenberg
Tags:

Search [i don't] [Back] [Forward] [Start] [End] [Occurrence Order] [Clicks/Will Zoom]

118 hits

i don't

recall

want to know

believe think have
Uncertainty
You should expect to:

1. Evaluate and critique visualization designs
2. Learn visualization techniques & theory
3. Implement interactive data visualizations
4. Develop a substantial visualization project
Instructors

Instructor

Jeffrey Heer
Assoc Prof, CSE
OH: Thu 9:30-10:30a, 642 CSE
http://jheer.org

Assistants

Jane Hoffswell
OH: Thu 1:30-2:30p, 674 CSE

Kanit (Ham)
OH: Tue 2:30-3:30p,

Wongsuphasawat
CSE 3rd Floor Breakout
Textbook

For learning D3!
Book available free online.
Code / examples on GitHub.

We will be using D3 v4.
https://d3js.org
Readings

Some from D3 book, others from papers & web. Material in class will loosely follow readings. Readings should be read by start of class. Post discussion comments on class Canvas forum. One comment per week. Comments must be posted by Friday 5pm. You have 1 “pass” for the quarter.
Assignments

Class Participation (10%)
A1: Visualization Design (10%) - Due 4/3
A2: Exploratory Data Analysis (15%) - Due 4/13
FP: Final Project (65%)
  Proposal (5%) - Due 4/18
  Interactive Prototype (20%) - Due 5/3
  Peer Evaluation (5%) - Due 5/10
  Project Deliverables (35%) - Due 5/31
Final Project

Produce **interactive web-based visualizations**

Initial **prototype** and **peer evaluation**

Project **check-ins** and **final presentation**

Submit and publish on GitHub

Projects from **previous classes** have been:

- Published as research papers
- Featured in the New York Times
- Released as successful open source projects
Final Project Theme

Data Visualization for Civic Participation

Goal: find data of **public import**, design visualizations to explore and/or communicate that data effectively.

The specific data domain is open-ended. Possibilities include **transportation, housing, public health, education, climate, campaign finance, voting records**, and so on...

You must identify a **focus audience**. May be general (WA state residents) or specialized (policy makers).

Use Assignment 2 to **explore a data set of interest prior to committing** to final project teams and topic.
Inspiration...
Wind Map by M. Wattenberg & F. Viegas
Locations of each train on the red, blue, and orange lines at 5:46 am. Hover over the diagram to the right to display trains at a different time.

Trains are on the right side of the track relative to the direction they are moving.

See the morning rush-hour, midday lull, afternoon rush-hour, and the evening lull.

Service starts at 5AM on Monday morning. Each line represents the path of one train. Time continues downward, so steeper lines indicate slower trains.

Since the red line splits, we show the Ashmont branch first then the Braintree branch. Trains on the Braintree branch "jump over" the Ashmont branch.

Train frequency increases around 6:30AM as morning rush hour begins.
Prior Course Projects

Harvard University | University of Utah

How is violence spreading? A timeline of reported violence.
Visualizing Galaxy Merger Trees

S. Loebman, J. Ortiz, L. Orr, M. Balazinska, T. Quinn et al. [SIGMOD '14]
Visualizing the Republic of Letters

Daniel Chang, Yuankai Ge, Shiwei Song

Republic of Letters
1700

FILTER BY AUTHOR
- Damien Desormes
- Daniel Carnabs
- Daniel de Pury
- Daniel Defoe
- Daniel Malthus
- Daniel Marc Antoine Chardon
- Daniel Moller

TOP CITIES AND AUTHORS

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<td>85</td>
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<tr>
<td>Alexander Pope</td>
<td>28</td>
</tr>
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Questions?
Assignment 1: Visualization Design

Design a static visualization for a data set.

College admissions can play a profound role in determining one’s future life and career. We’ve collected admissions data (grouped by gender) for selected departments at a major university.

You must choose the message you want to convey. What question(s) do you want to answer? What insight do you want to communicate?
Assignment 1: Visualization Design

Pick a **guiding question**, use it to title your vis.

Design a **static visualization** for that question.

You are free to **use any tools** (inc. pen & paper).

**Deliverables** (upload via Canvas; see A1 page)
- Image of your visualization (PNG or JPG format)
- Short description + design rationale (≤ 4 paragraphs)

Due by **5:00 pm, Monday April 3**.