The Purpose of Visualization
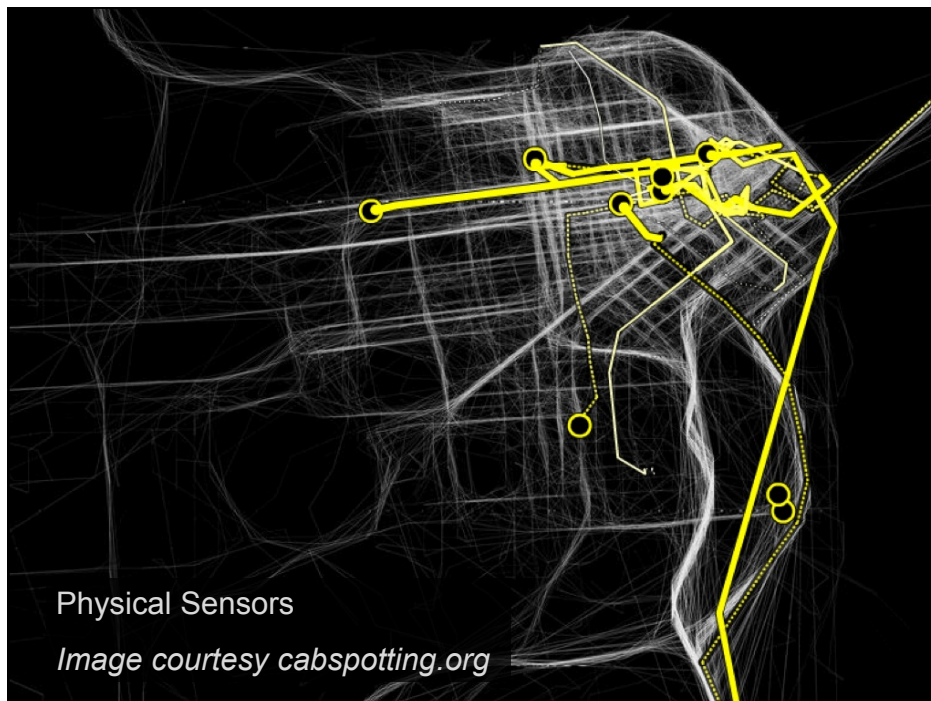
Maneesh Agrawala

CS 448B: Visualization
Spring 2016
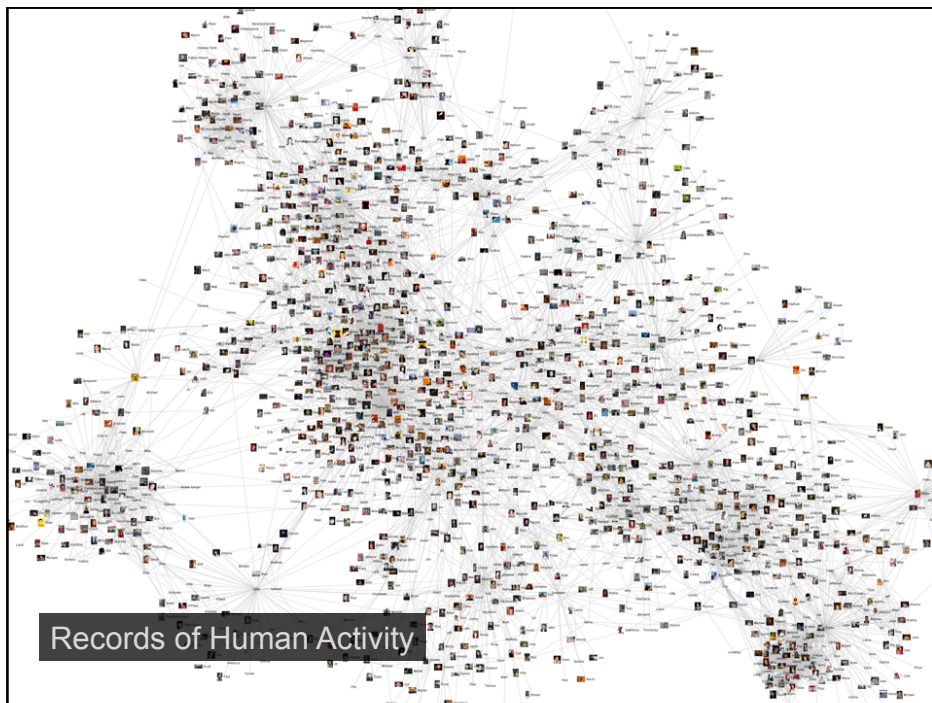

**How much data (bytes)
did we produce in 2011?**
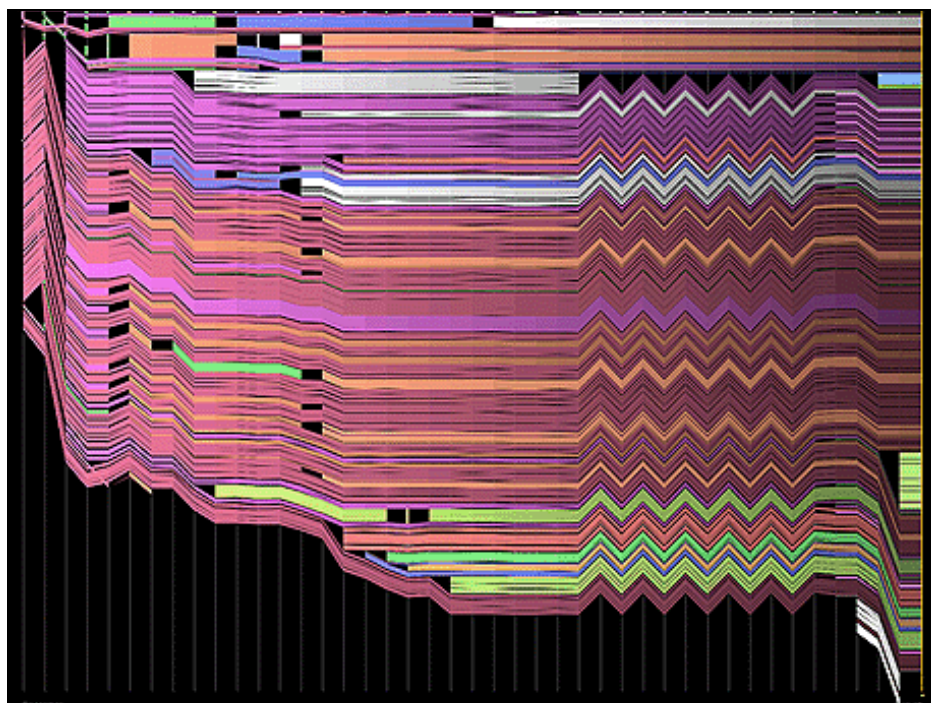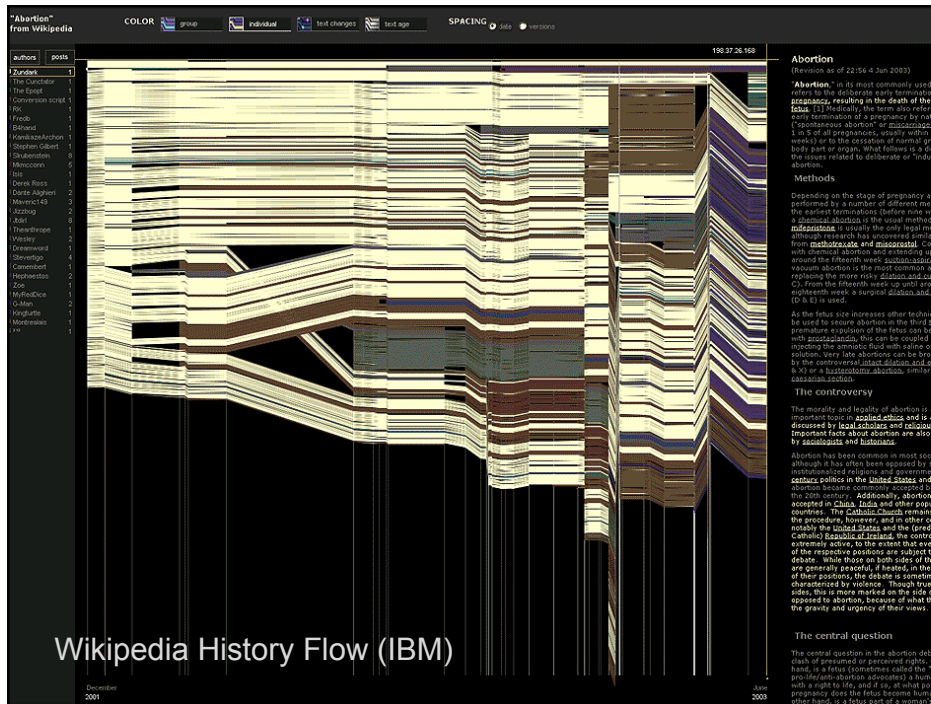
**2011: 1800 exabytes**
10x increase over 5 years

[Gantz 2007, 2011]

Physical Sensors

Image courtesy cabspotting.org

Health & Medicine

Records of Human Activity

Wikipedia History Flow (IBM)

"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."
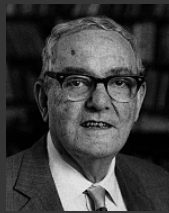
~Herb Simon
as quoted by Hal Varian
Scientific American
September 1995

What is visualization?

What is visualization?

Definition [www.oed.com]

1. The action or fact of visualizing; the power or process of forming a mental picture or vision of something not actually present to the sight; a picture thus formed.

2. The action or process of rendering visible.

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		Set B		Set C		Set D	
X	Y	X	Y	X	Y	X	Y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.1	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.1	4	5.39	19	12.5
12	10.84	12	9.11	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

Summary Statistics Linear Regression

$u_X = 9.0$ $\sigma_X = 3.317$ $Y = 3 + 0.5\,X$

$u_Y = 7.5$ $\sigma_Y = 2.03$ $R^2 = 0.67$ [Anscombe 73]
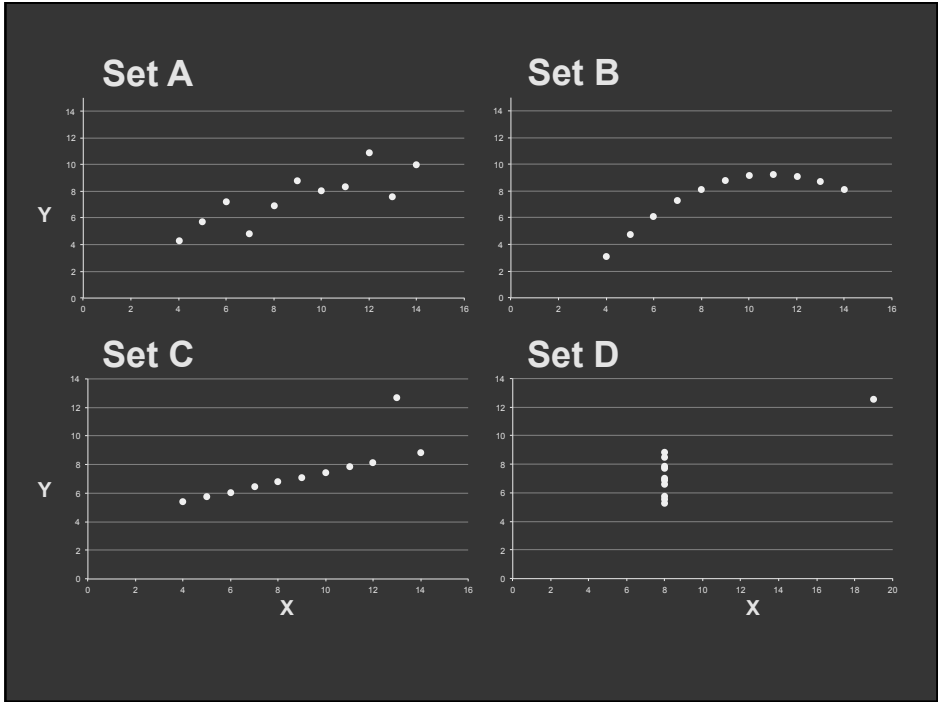
Why do we create visualizations?

Why do we create visualizations?

Make info easier/faster to grasp (communicate)
To show patterns – more readily visible
Detect outliers
To condense the information
Add emotion to the data (point of view)
May allow interaction
People less intimated
Help make predictions

Three functions of visualizations

Record information

- Photographs, blueprints, …

Support reasoning about information (analyze)

- Process and calculate
- Reason about data
- Feedback and interaction

Convey information to others (present)

- Share and persuade
- Collaborate and revise
- Emphasize important aspects of data

Record Information

Answer question

Gallop, Bay Horse "Daisy" [Muybridge 1884-86]

Answer question
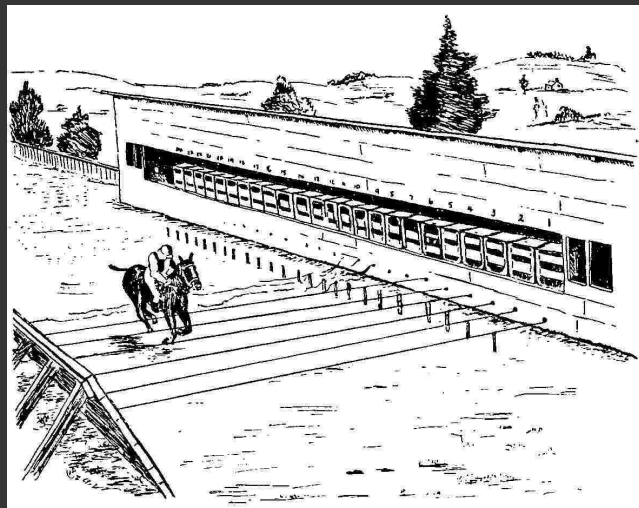
Gallop, Bay Horse "Daisy" [Muybridge 1884-86]

Photographs: Phases of the moon

Drawing: Phases of the moon
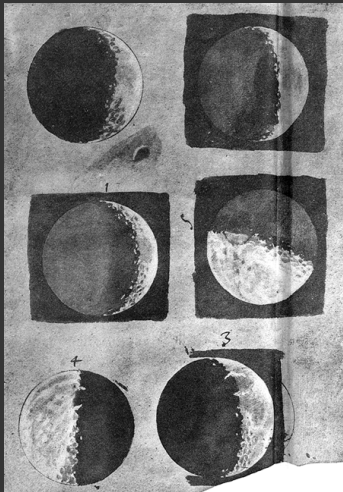
Galileo's drawings of the phases of the moon from 1616
http://galileo.rice.edu/sci/observations/moon.html

Other recording instruments

1.
Marey's sphygmograph in use,
1860. La méthode graphique dans
les sciences expérimentales et
principalement en physiologie et en
médecine.
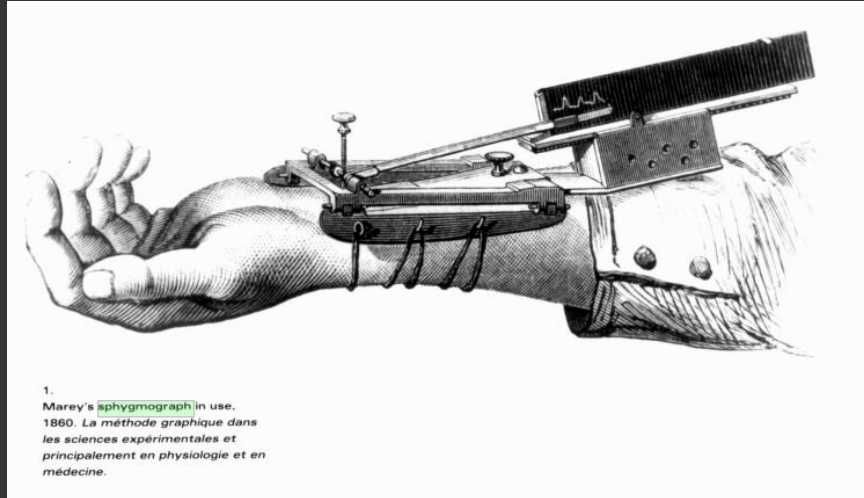
Marey's sphygmograph [from Braun 83]

Support Reasoning

Find patterns: New York weather
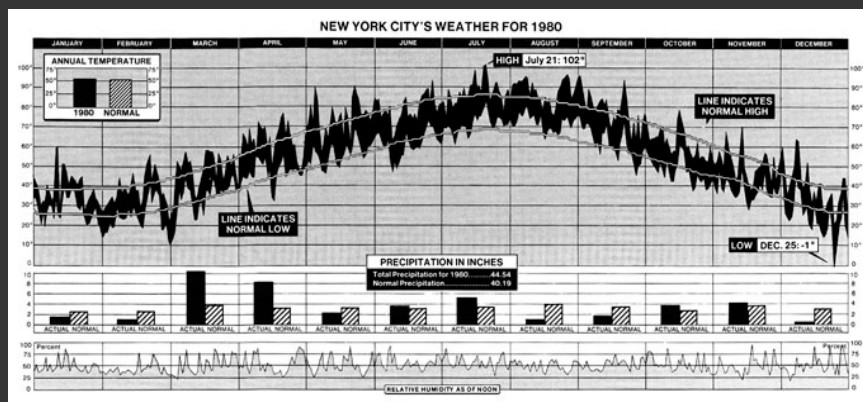
From the New York Times 1981

Make a decision: Challenger

2 of 13 pages of material faxed to NASA by Morton Thiokol [from Tufte 1997]
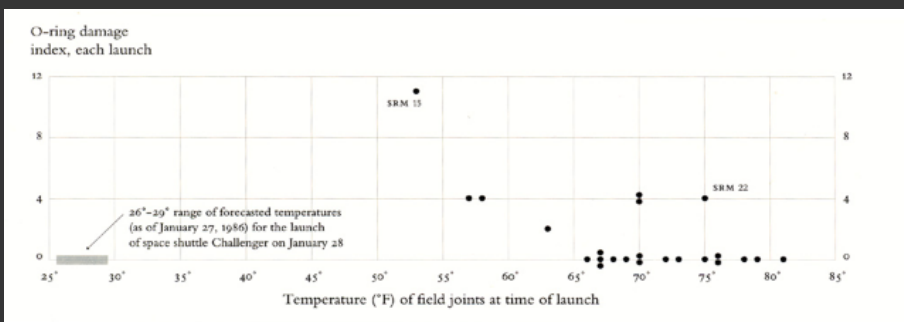
Make a decision: Challenger
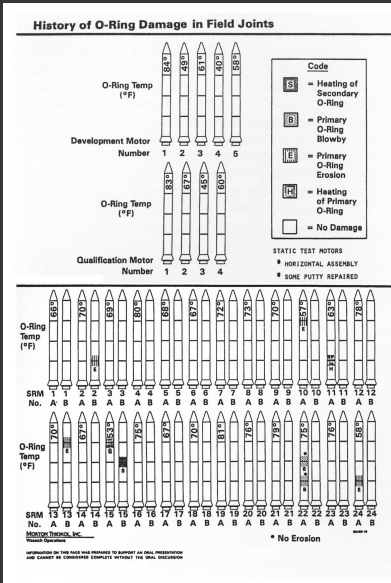
Make a decision: Challenger
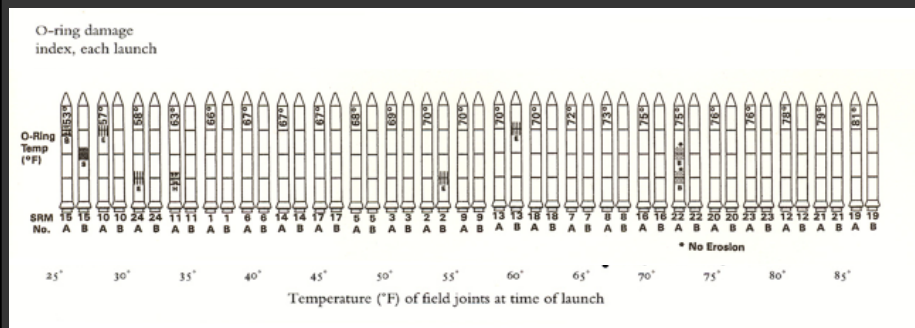
Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]

Make a decision: Challenger

O-ring damage
index, each launch

26°–29° range of forecasted temperatures
(as of January 27, 1986) for the launch
of space shuttle Challenger on January 28

Temperature (°F) of field joints at time of launch

Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]

See data in context: Cholera outbreak

In 1854 John Snow plotted the position of each cholera case
on a map. [from Tufte 83]

See data in context: Cholera outbreak
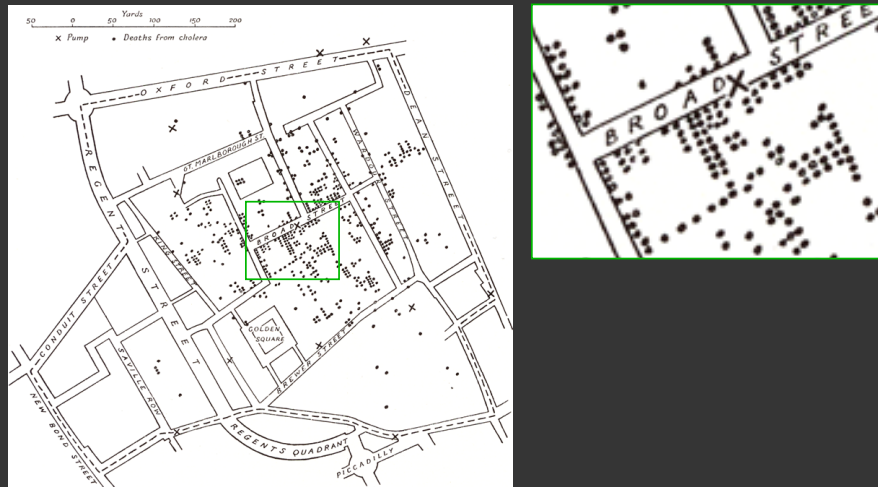
Used map to support hypothesis Broad St. pump was the cause. [from Tufte 83]
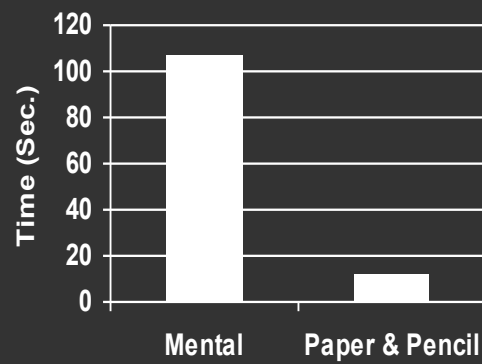
Expand memory: Multiplication
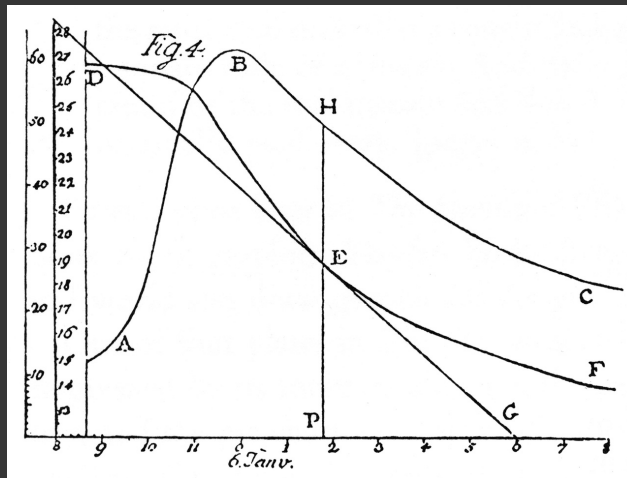
Class Exercise

Expand memory: Multiplication

34
x 78

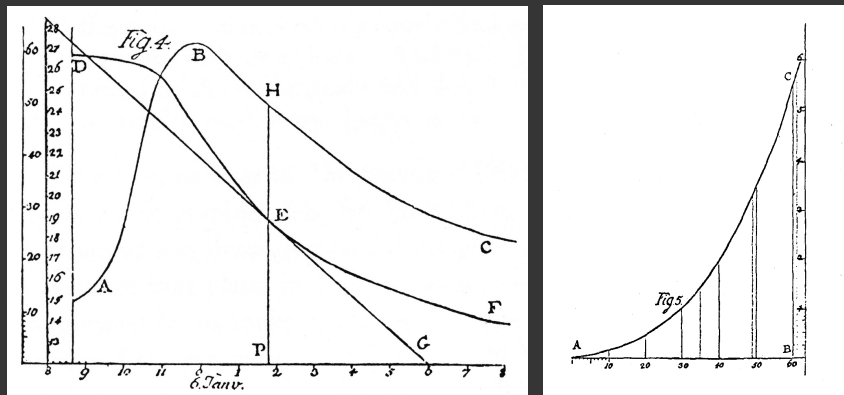## Expand memory: Multiplication

34
x 78
272
2380
2652

Graphical calculation: Evaporation

Johannes Lambert used graphs to study the rate of water evaporation as function of temperature [from Tufte 83]
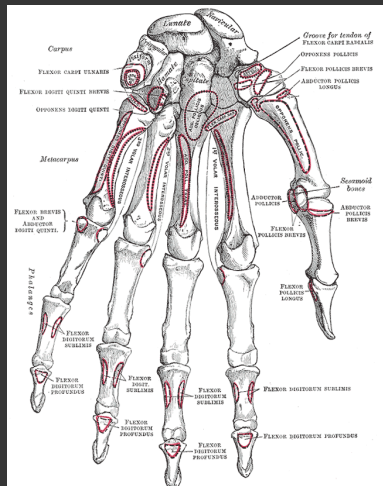
Graphical calculation: Evaporation

Johannes Lambert used graphs to study the rate of water evaporation as function of temperature [from Tufte 83]

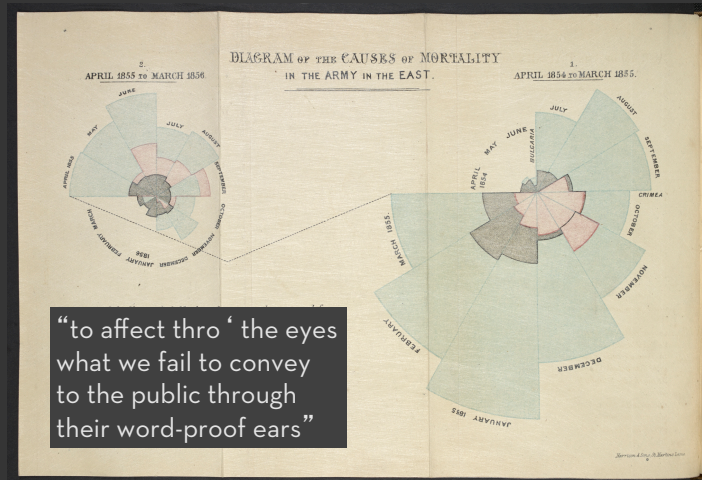# Convey Information to Others

Inspire

Bones in hand [from 1918 edition]

Double helix model [Watson and Crick 53]

Present argument

"to affect thro ' the eyes what we fail to convey to the public through their word-proof ears"

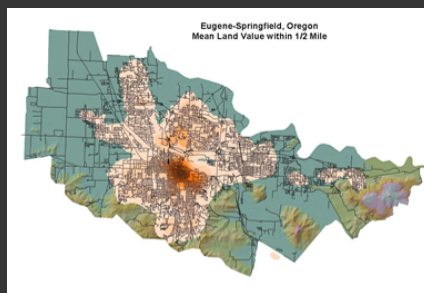Crimean War Deaths [Nightingale 1858]

Visualization Research

Challenge

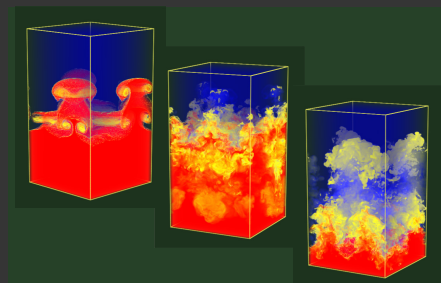**More and more unseen data**
- Faster creation and collection

Challenge

More and more unseen data
- Faster creation and collection

Urban development planning
www.urbansim.org

Fluid flow
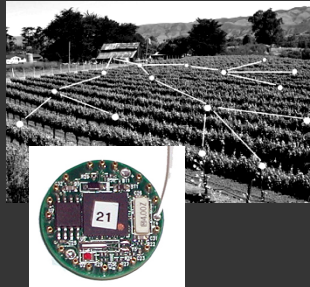ctr.stanford.edu

Simulation

Challenge

More and more unseen data
- Faster creation and collection

Sloan digital sky survey
www.sdss.org

Sensor networks [Hill 02]
www.xbow.com

Digital photography

Sensing

Challenge

More and more unseen data
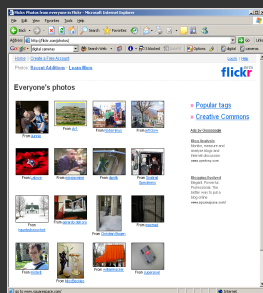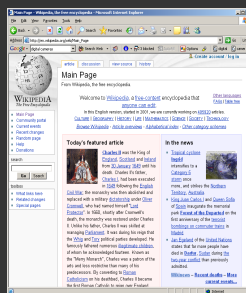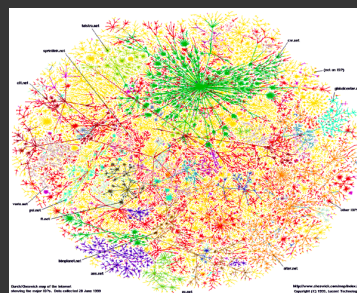- Faster creation and collection
- Faster dissemination

Photo sharing/annotation
flickr.com

Group Authored Encyclopedia
wikipedia.org

Map of the Internet [Cheswick 99]
research.lumeta.com

Internet

Challenge

More and more unseen data
- Faster creation and collection
- Faster dissemination

5 exabytes of new information in 2002 [Lyman 03]

161 exabytes in 2006 [Gantz 07]

1800 exabytes in 2011[Gantz 11]

Need better tools and algorithms for visually conveying information

---

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

Goals of visualization research

**1. Understand how visualizations convey information to people**
- What do people perceive/comprehend ?
- How do visualizations correspond with mental models of data?

2. Develop principles and techniques for creating effective visualizations
- Amplify perception and cognition
- Strengthen connection between visualization and mental models of data
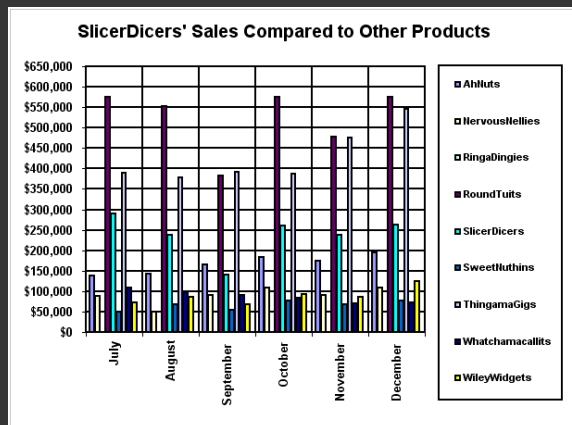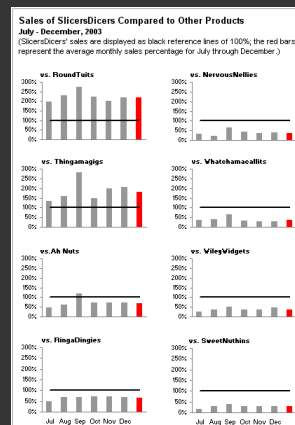
Topics

1. Data and image models
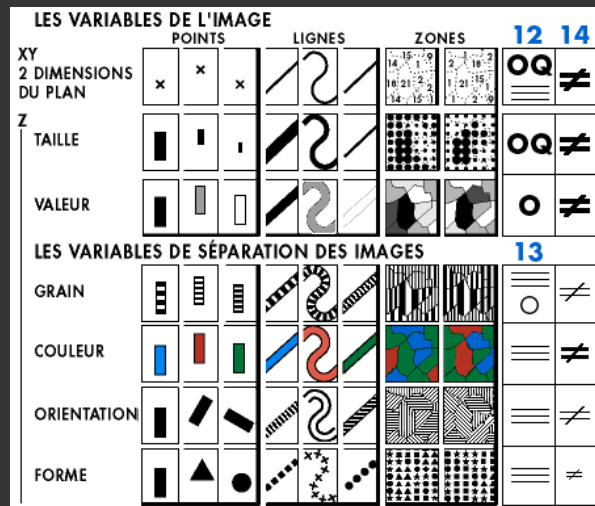
[Bertin, Graphics and Graphic Information Processing 1981]

2. Visualization Design

Problematic design

Redesign

3. Perception
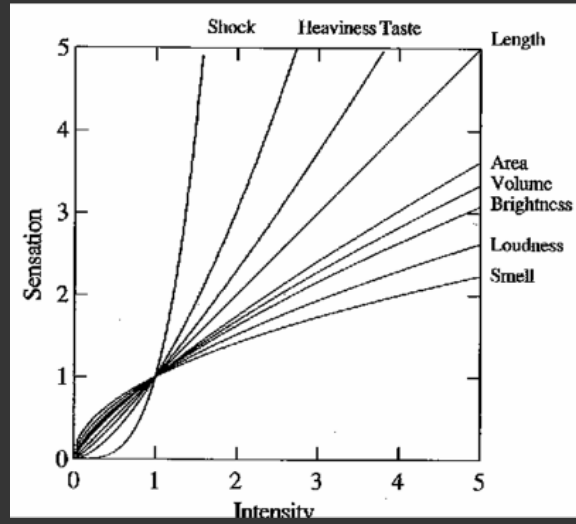
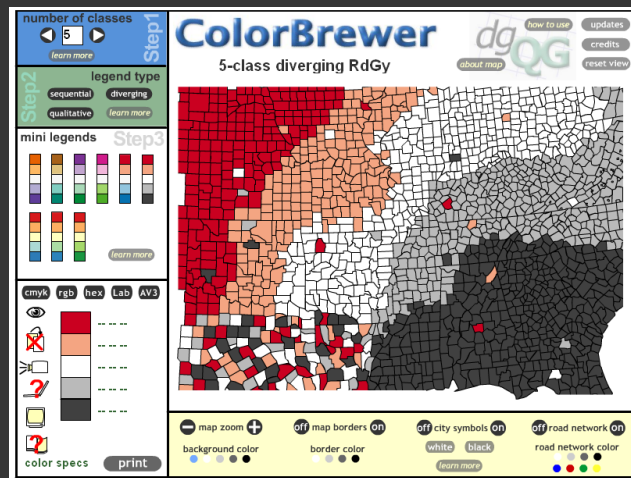The psychophysics of sensory function [Stevens 61]

4. Interaction
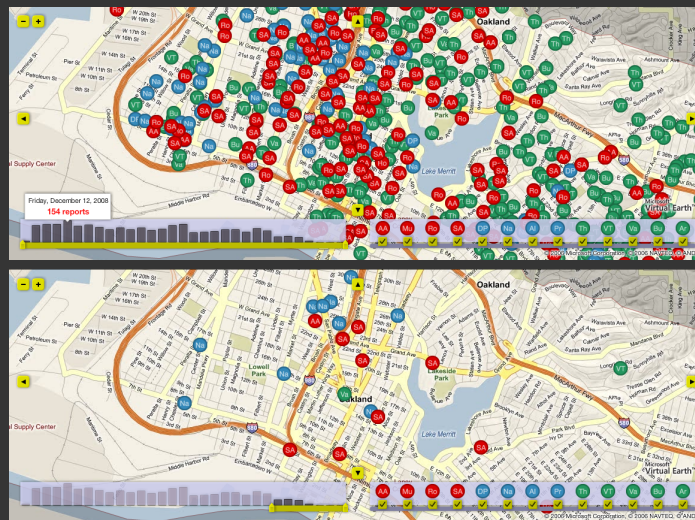
Oakland Crimespotting (crimespotting.org) [Stamen]
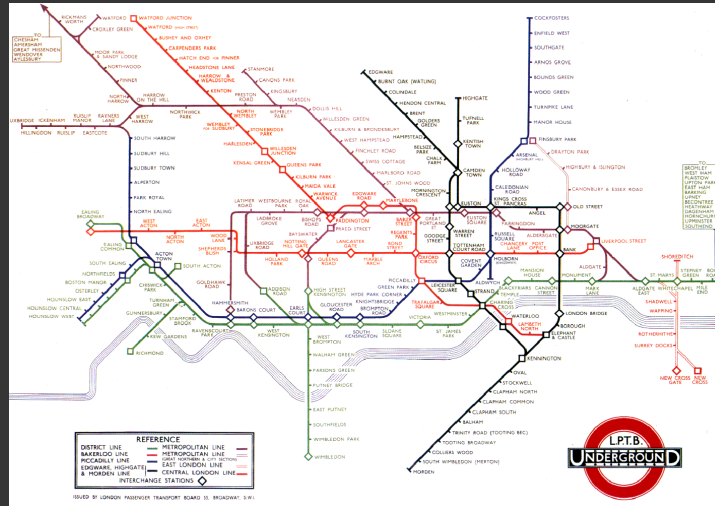
5. Building interactive visualizations with D3
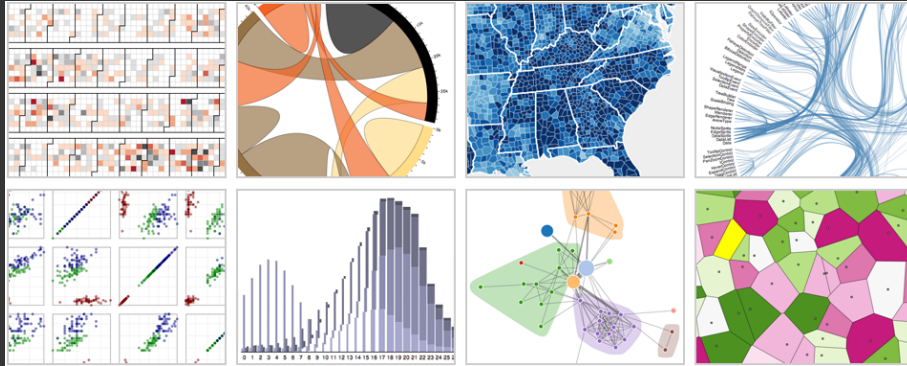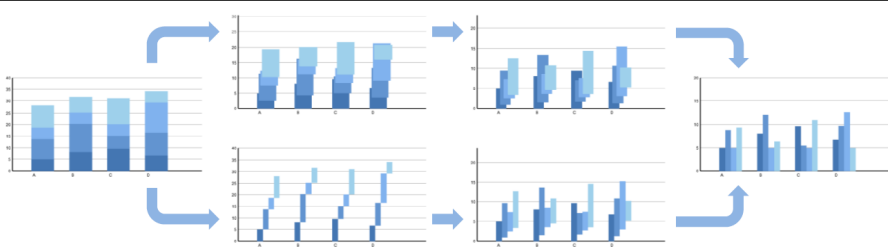

D3: Data Driven Documents [Bostock 2011]
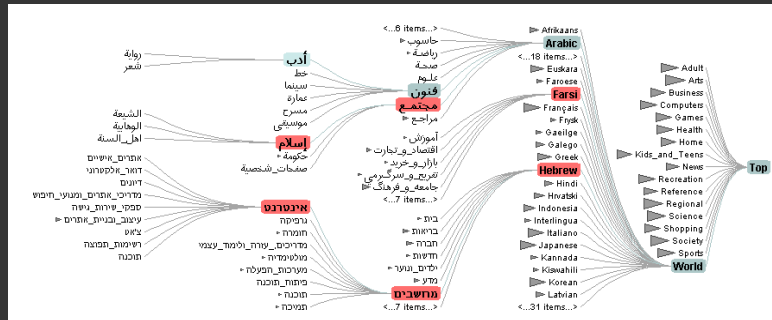
6. Color

[from Cynthia Brewer http://www.personal.psu.edu/faculty/c/a/cab38/]

7. Spatial Layout

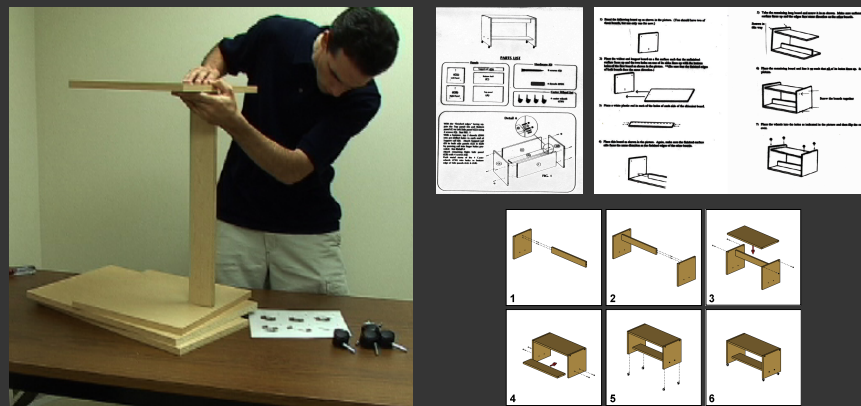London underground [Beck 33]

8. Animation

Animated Transitions [Heer 07]

9. Trees and graphs

Degree-of-Interest Trees [Heer 2004]

# 10. Identifying design principles

Testing effectiveness of 3 types of assembly instructions [Heiser 04]

Course Goals

1. *Design, evaluate and critique* visualizations
2. *Explore data* using existing visualization tools
3. *Implement* interactive data visualizations
4. *Gain* an overview of research and techniques
5. *Develop* a substantial visualization project

Course Mechanics

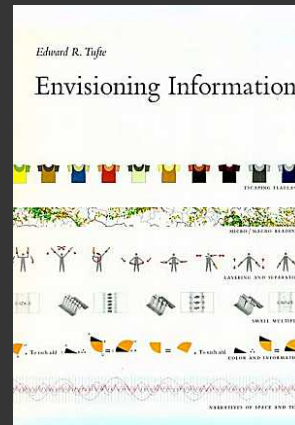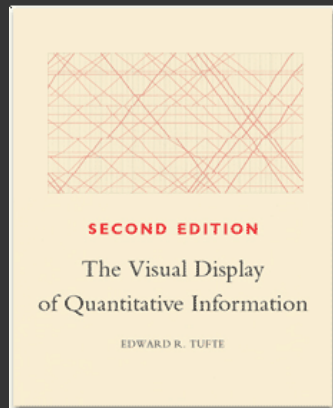# Instructor: Maneesh Agrawala
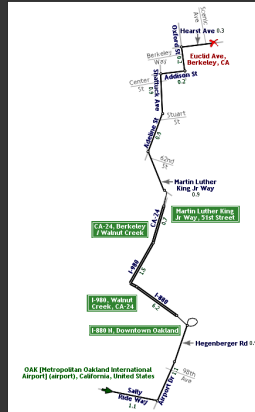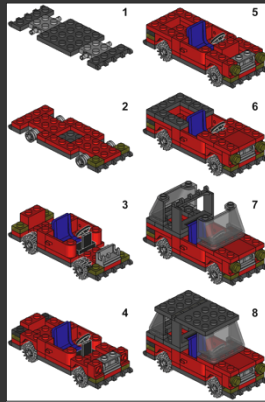
Course Assistants

Scott Cheng
Ludwig Schubert
Peter Washington

Piazza is the best way to interact with us
http://piazza.com/stanford/spring2016/cs448b

Laptops?

Textbooks

See also: www.edwardtufte.com

Readings

- **Some from textbooks, also many papers**
  - Many open to public, some require SUNetID/Password
- **Material in class will be loosely based on readings**
- **Readings should be read by start of class**
- **Post discussion comment using link on wiki**
  - Must post by 1:30pm on day of lecture
  - You have 2 passes for the quarter

Class home page
http://web.stanford.edu/class/cs448b/

Reading Responses

Good responses typically exhibit one or more
- **Critiques of arguments made in the papers**
- **Analysis of implications or future directions for ideas in readings**
- **Insightful questions about the readings**

Responses should not summaries

Requirements

Class participation (10%)

Assignment 1: Visualization Design **(10%)**

Assignment 2: Exploratory Data Analysis **(15%)**

Assignment 3: Creating Interactive Visualization Software **(25%)**

Final Project (40%)

Final project

- **Visualization research project on topic of your choice**
- **Last 4 weeks of course**
- **Project write-up in form of a research paper (6-8 pages)**
- **Two in-class project presentations**
    1. Initial in-class status report (dates TBD)
    2. Final poster presentation (tentatively 6/1)

Projects from previous classes have been published
- IEEE Visualization
- IEEE Information Visualization
- SIGGRAPH

Text Co-Occurrences
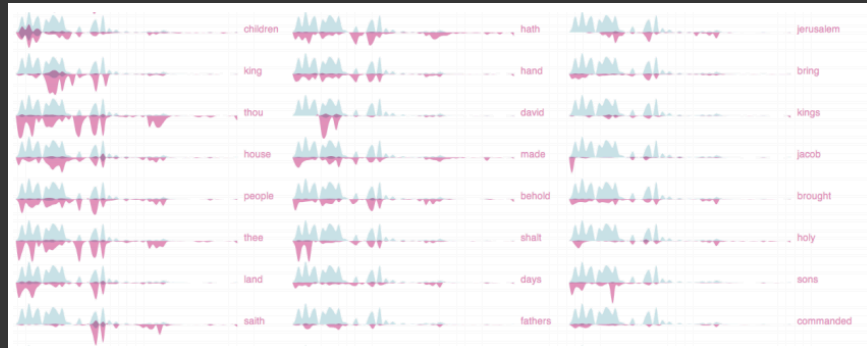
Words that co-occur with Israel in the King James Bible [Brandon Liu 2011]

Visualization of Narrative Structure
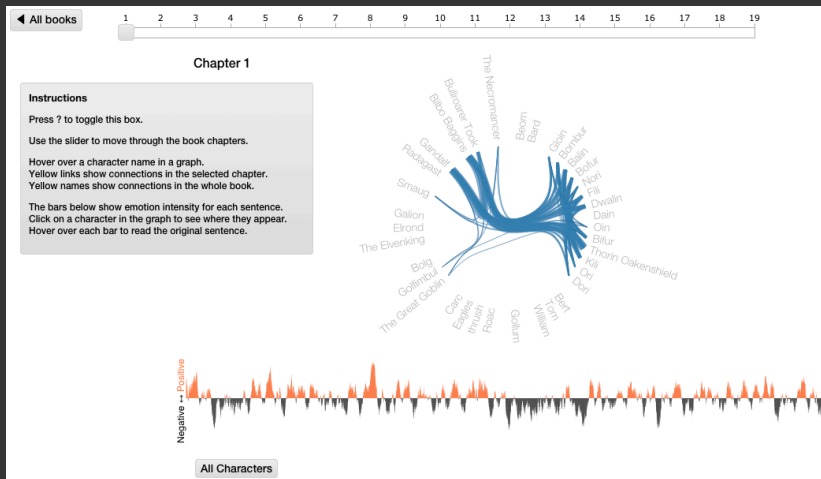
Character interactions and sentiment in The Hobbit [Bilenko,Miyakawa 2013]

deepviz: Visualizing Convolutional NNs
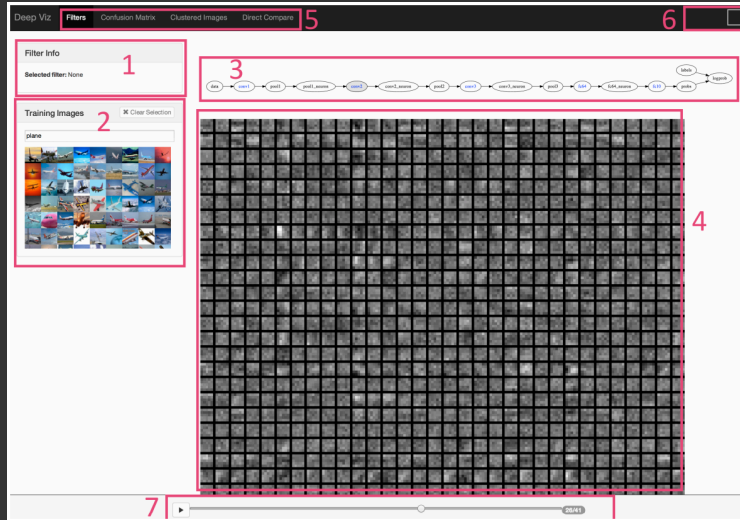
1) Filter details 2) Image selector 3) Network overview 4) Filter visualization
5) Visualization selector 6) Selection helper 7) Animation slider   [Bruckner,Rosen,Sparks 2013]

Assignment 1: Visualization Design

Police Killings 2015

Due by 11:59pm on Sun Apr 3