

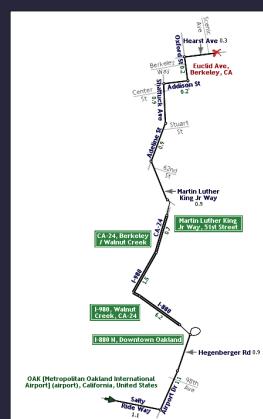
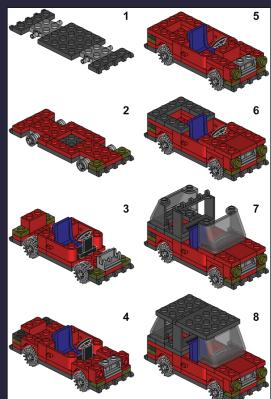
# The Purpose of Visualization

*Maneesh Agrawala*

CS 294-10: Visualization

Fall 2007

## Maneesh Agrawala



# What is visualization?

## What is visualization?

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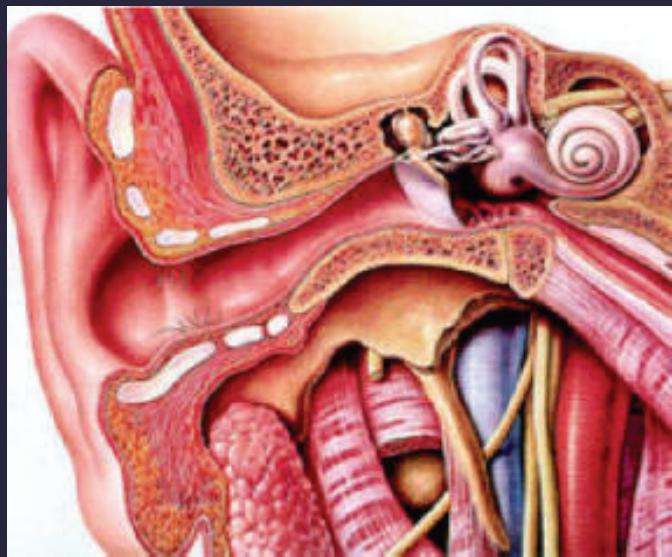
**Definition** [\[www.oed.com\]](http://www.oed.com)

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.

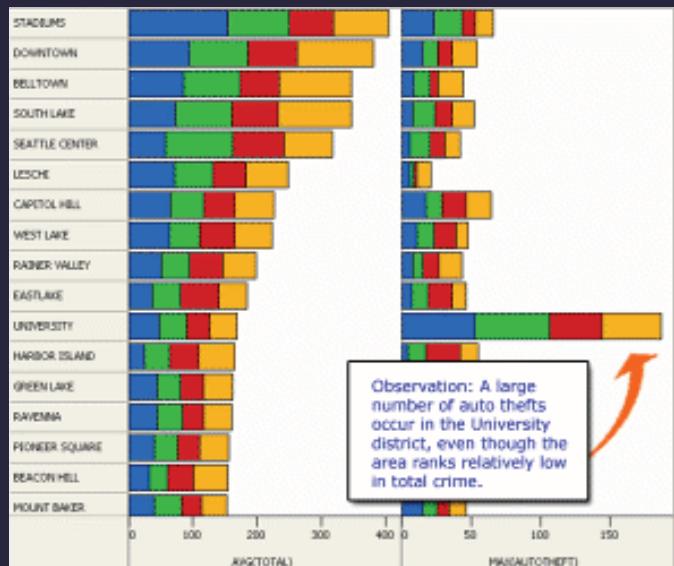
**Why do we create visualizations?**

## **Examples**

---



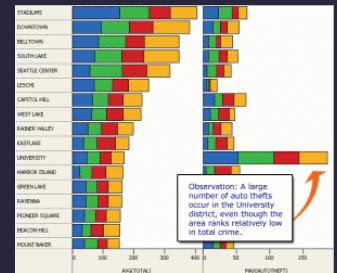
## Examples



## Examples



## Examples



Other examples?

## Why do we create visualizations?

- Easier Interpretability
- Emotional impact
- Simplify data
- Communication
- Reveal/conceal trends
- Visual bandwidth
- Use Human Perception/Cognition
- Crystallization of abstract ideas
- Articulates relationships
- Focuses on relevant data

## Why do we create visualizations?

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- Answer questions
- Make decisions
- See data in context
- Expand memory
- Support graphical calculation
- Find patterns
- Present argument
- Tell a story
- Inspire

## Three functions of visualizations

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### Record information

- Photographs, blueprints, ...

### Support reasoning about information (analyze)

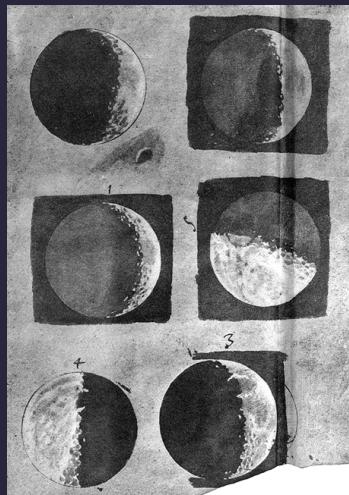
- Process and calculate
- Reason about data
- Feedback and interaction

### Convey information to others (present)

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

## Record Information

### Drawing: Phases of the moon



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

## Photographs: Phases of the moon

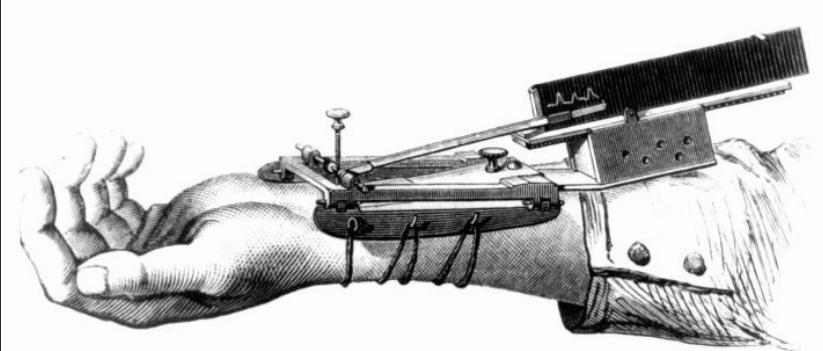


## Answer question



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

## Other recording instruments



1.  
Marey's **sphygmograph** in use,  
1860. *La méthode graphique dans  
les sciences expérimentales et en  
principalement en physiologie et en  
médecine.*

Marey's sphygmograph [from Braun 83]

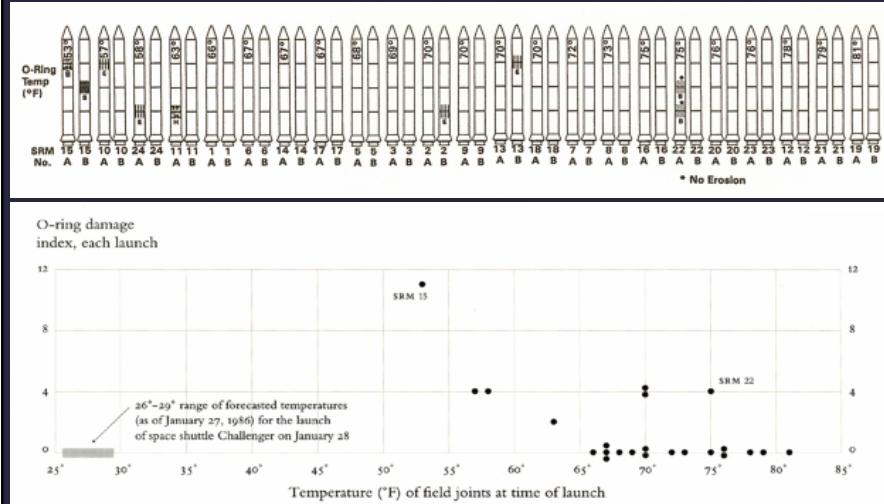
**Support Reasoning**

# Make a decision: Challenger

| SRM No.  | Cross-Sectional View |                       |               | Top View                     |                                  |                        |
|--|----------------------|-----------------------|---------------|------------------------------|----------------------------------|------------------------|
|  | Torsion Depth (in.)  | Perimeter Angle (deg) | Nominal (in.) | Length of Non-Affected (in.) | Total Heat Affected length (in.) | Cooling location (deg) |
| <b>61A LH Center Field**</b>   |                      |                       |               |                              |                                  |                        |
| 22A  | None                 | 0.280                 | None          | None                         | 35° - 65°                        |                        |
| 22A  | None                 | 0.280                 | None          | 4.25                         | 5.15                             |                        |
| 15A  | 110.0                | 0.280                 | 110.0         | 12.25                        | 15.5                             |                        |
| 15B  | 0.038                | 135.0                 | 0.280         | 12.50                        | 58.75                            | 354                    |
| 15B  | None                 | 0.280                 | None          | 29.50                        | 354                              |                        |
| <b>61A RH Center Field (prim)***</b>   |                      |                       |               |                              |                                  |                        |
| 15A  | 110.0                | 0.280                 | 110.0         | 12.25                        | 15.5                             |                        |
| 15B  | 0.038                | 135.0                 | 0.280         | 12.50                        | 58.75                            | 354                    |
| 15B  | None                 | 0.280                 | None          | 29.50                        | 354                              |                        |
| <b>41D RH Forward Field</b>  |                      |                       |               |                              |                                  |                        |
| 13B  | 0.028                | 110.0                 | 0.280         | 3.00                         | None                             | 275                    |
| 11A  | None                 | 0.280                 | None          | None                         | None                             |                        |
| 10A  | 0.040                | 217.0                 | 0.280         | 3.00                         | 14.50                            | 351                    |
| <b>STS-2 RH Aft Field</b>  |                      |                       |               |                              |                                  |                        |
| 2B   | 0.053                | 116.0                 | 0.280         | --                           | --                               | 90                     |
| *Hot gas path detected in putty. Indication of heat on O-ring, but no damage.<br>**Soot behind primary O-ring.<br>***Soot behind primary O-ring, heat affected secondary O-ring. |                      |                       |               |                              |                                  |                        |
| Clockwise location of leak check port - 0 deg.   |                      |                       |               |                              |                                  |                        |
| OTHER SRM-15 FIELD JOINTS HAD NO BLOHOLENS 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 BLOMBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOHOLENS IN PUTTY.                      |                      |                       |               |                              |                                  |                        |
| <b>Blow By History</b>   |                      |                       |               |                              |                                  |                        |
| SRM-15 WORST Blow-By   |                      |                       |               |                              |                                  |                        |
| o 2 CASE JOINTS (80°), (110°) AFG  |                      |                       |               |                              |                                  |                        |
| o MUCH WORSE VISUALLY THAN SRM-22  |                      |                       |               |                              |                                  |                        |
| SRM 22 Blow-By   |                      |                       |               |                              |                                  |                        |
| o 2 CASE JOINTS (80-90°)   |                      |                       |               |                              |                                  |                        |
| SRM-12, 15, 16A, 18, 23A 24A   |                      |                       |               |                              |                                  |                        |
| o NOZZLE BLOW-BY   |                      |                       |               |                              |                                  |                        |
| <b>HISTORY OF O-RING TEMPERATURES (DEGREES - F)</b>  |                      |                       |               |                              |                                  |                        |
| MOTOR  | MOT                  | AMB                   | O RING        | WIND                         |                                  |                        |
| DM-6   | 68                   | 36                    | 47            | 10 MPH                       |                                  |                        |
| DM-2   | 76                   | 45                    | 52            | 10 MPH                       |                                  |                        |
| DM-3   | 72.5                 | 40                    | 48            | 10 MPH                       |                                  |                        |
| DM-4   | 76                   | 48                    | 51            | 10 MPH                       |                                  |                        |
| SRM-15   | 52                   | 64                    | 53            | 10 MPH                       |                                  |                        |
| SRM-22   | 77                   | 78                    | 75            | 10 MPH                       |                                  |                        |
| SRM-25   | 55                   | 26                    | 29            | 10 MPH                       |                                  |                        |
|  |                      |                       | 27            | 25 MPH                       |                                  |                        |

2 of 13 pages of material faxed to NASA by Morton Thiokol [from Tufte 1997]

# Make a decision: Challenger



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



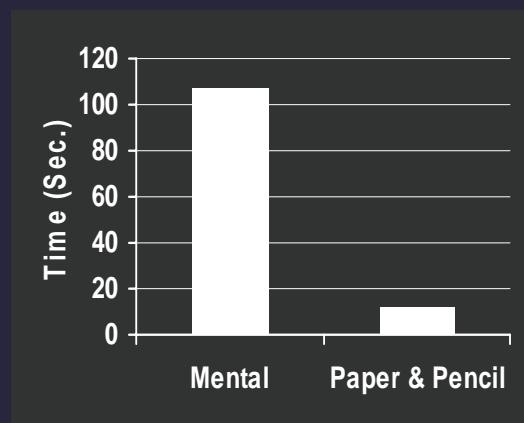
Used map to hypothesize that pump on Broad St. was the cause. [from Tufte 83]

## Expand memory: Multiplication

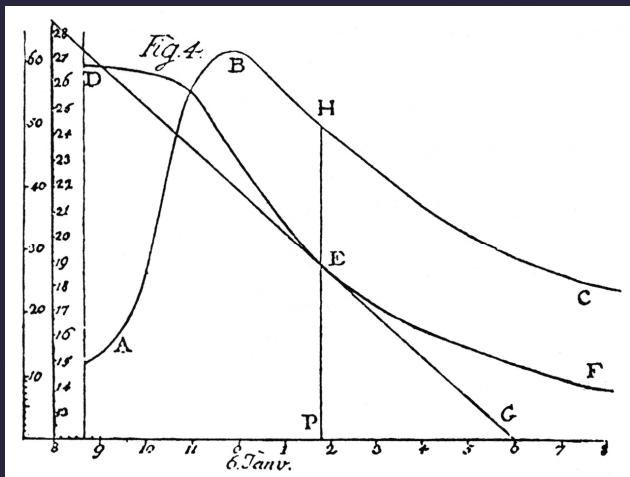
$$\begin{array}{r} 34 \\ \times 72 \\ \hline \end{array}$$

## Expand memory: Multiplication

$$\begin{array}{r} 34 \\ \times 72 \\ \hline 68 \\ 2380 \\ \hline 2448 \end{array}$$

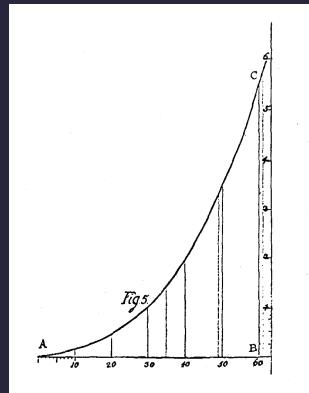
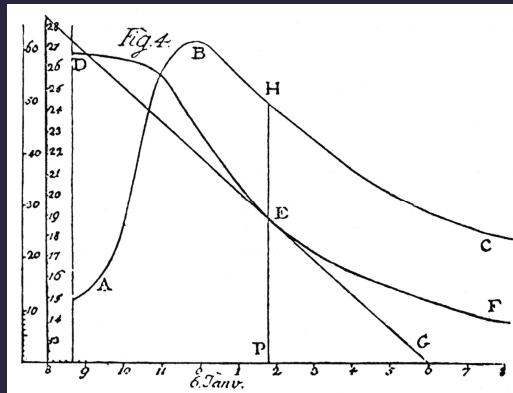


## Graphical calculation: Evaporation



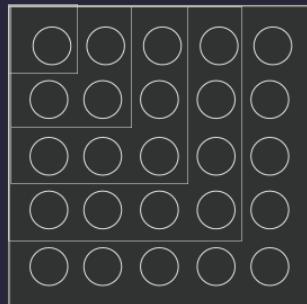
Johannes Lambert used graphs to study the rate of water evaporation as function of temperature [from Tufte 83]

## Graphical calculation: Evaporation



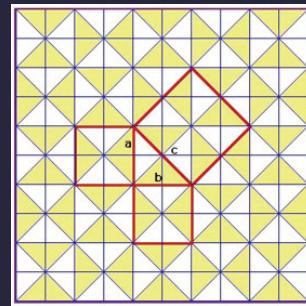
Johannes Lambert used graphs to study the rate of water evaporation as function of temperature [from Tufte 83]

## Graphical calculation: Visual proofs

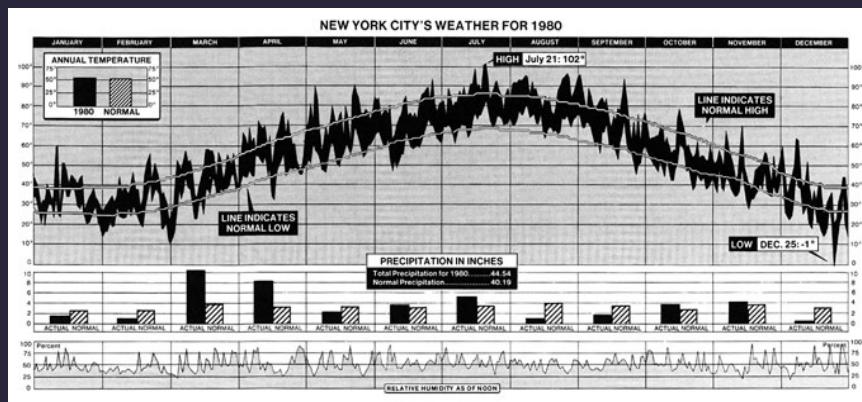


Sum of odd numbers:  
 $1 + 3 + 5 + 7 + 9 = 5^2$

Pythagorean theorem:  
Chinese proof by dissection



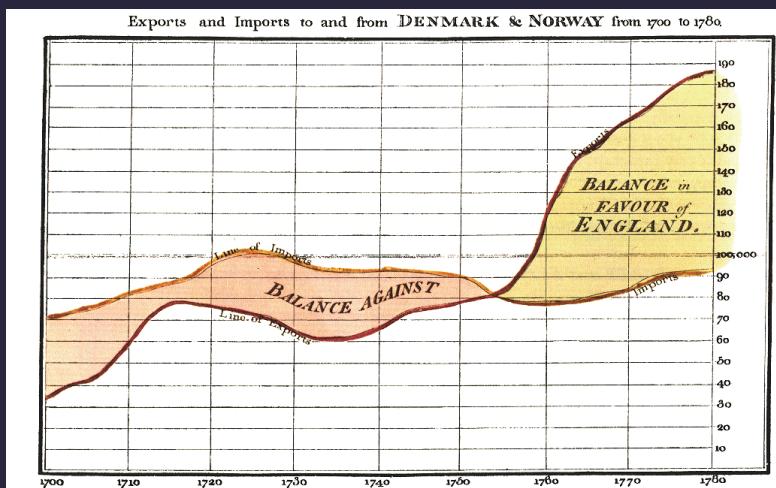
## Find patterns: New York weather



From the New York Times 1981

## Convey Information to Others

### Present argument: Exports and Imports

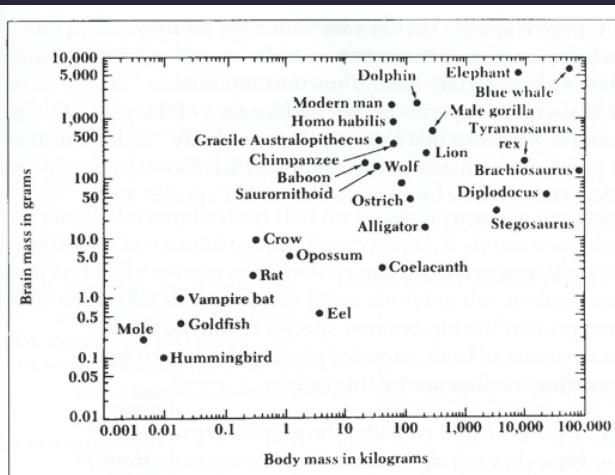


[Playfair 1786]

## Tell a story: Most powerful brain?

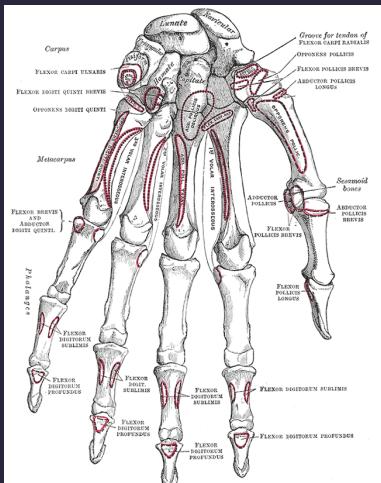
| ID | Name                         | Body Weight | Brain Weight |
|----|------------------------------|-------------|--------------|
| 2  | 1 Lesser Short-tailed Shrew  | 5           | 0.14         |
| 3  | 2 Little Brown Bat           | 10          | 0.25         |
| 4  | 3 Mouse                      | 23          | 0.3          |
| 5  | 4 Big Brown Bat              | 23          | 0.4          |
| 6  | 5 Musk Shrew                 | 48          | 0.33         |
| 7  | 6 Star Nosed Mole            | 60          | 1            |
| 8  | 7 Eastern American Mole      | 75          | 1.2          |
| 9  | 8 Ground Squirrel            | 101         | 4            |
| 10 | 9 Tree Shrew                 | 104         | 2.5          |
| 11 | 10 Golden Hamster            | 120         | 1            |
| 12 | 11 Mole Rat                  | 122         | 3            |
| 13 | 12 Galago                    | 200         | 5            |
| 14 | 13 Rat                       | 280         | 1.9          |
| 15 | 14 Chinchilla                | 425         | 6.4          |
| 16 | 15 Desert Hedgehog           | 550         | 2.4          |
| 17 | 16 Rock Hyrax (s)            | 750         | 12.3         |
| 18 | 17 European Hedgehog         | 785         | 3.5          |
| 19 | 18 Tenrec                    | 900         | 2.6          |
| 20 | 19 Arctic Ground Squirrel    | 920         | 5.7          |
| 21 | 20 African Giant Pouched Rat | 1000        | 6.6          |
| 22 | 21 Guinea Pig                | 1040        | 5.5          |
| 23 | 22 Mountain Beaver           | 1350        | 8.1          |
| 24 | 23 Slow Loris                | 1400        | 12.5         |
| 25 | 24 Genet                     | 1410        | 17.5         |
| 26 | 25 Phalanger                 | 1620        | 11.4         |

## Tell a story: Most powerful brain?

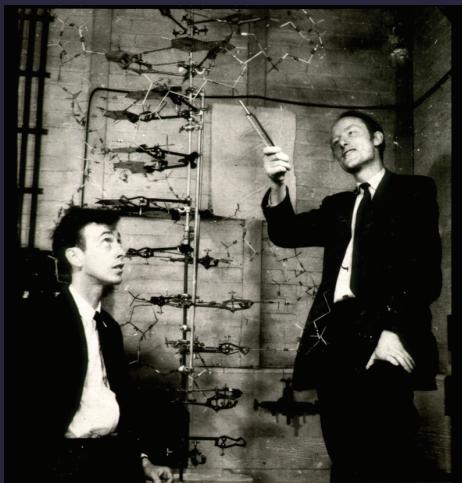


The Dragons of Eden [Carl Sagan]

# Inspire



Bones in hand [from 1918 edition]



Double helix model [Watson and Crick 53]

# Visualization Research

# Challenge

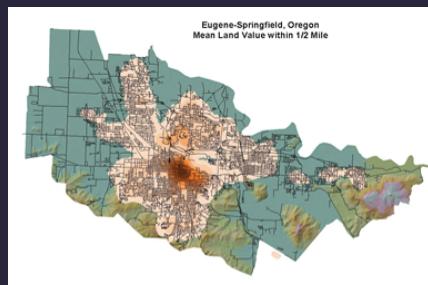
## More and more unseen data

- Faster creation and collection

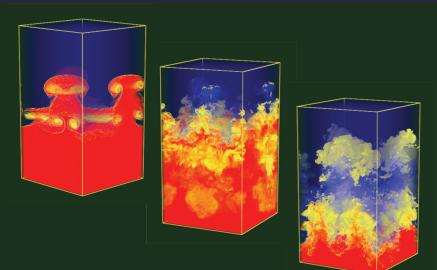
# Challenge

## More and more unseen data

- Faster creation and collection



Urban development planning  
[www.urbansim.org](http://www.urbansim.org)



Fluid flow  
[ctr.stanford.edu](http://ctr.stanford.edu)

Simulation

# Challenge

## More and more unseen data

- Faster creation and collection



Sloan digital sky survey  
[www.sdss.org](http://www.sdss.org)



Sensor networks [Hill 02]  
[www.xbow.com](http://www.xbow.com)



Digital photography

## Sensing

# Challenge

## More and more unseen data

- Faster creation and collection
- Faster dissemination

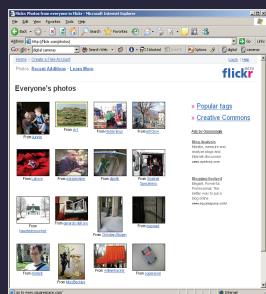
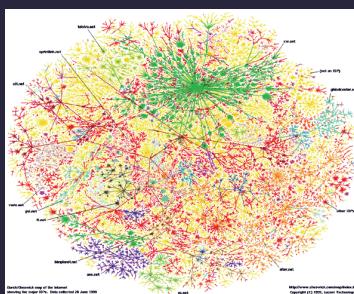


Photo sharing/annotation  
[flickr.com](http://flickr.com)



Group Authored Encyclopedia  
[wikipedia.org](http://wikipedia.org)



Map of the Internet [Cheswick 99]  
[research.lumeta.com](http://research.lumeta.com)

## Internet

## Challenge

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### More and more unseen data

- Faster creation and collection
- Faster dissemination

**5 exabytes of new information in 2002** [Lyman 03]

- 37,000 Libraries of Congress

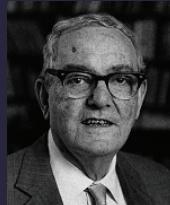
**161 exabytes in 2006** [Gantz 07]

**Need better tools and algorithms for visually conveying information**

## 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

[slide from PARC UIR group]

## Goals of visualization research

---

### 1. Understand how visualizations convey information to people

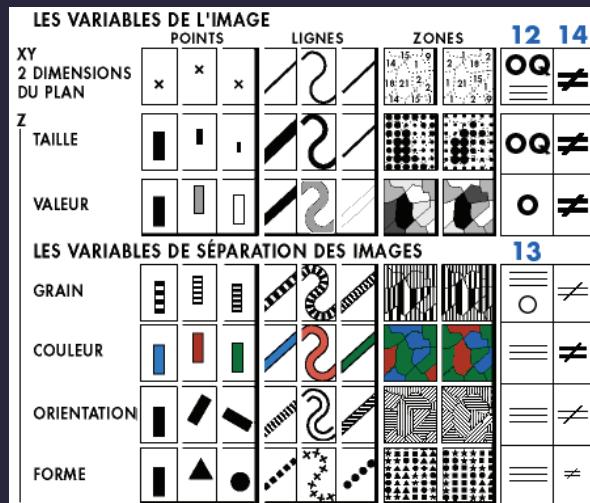
- What do people perceive/comprehend ?
- How do visualizations correspond with mental models of data?

### 2. Develop principles and techniques for creating effective visualizations

- Amplify perception and cognition
- Strengthen connection between visualization and mental models of data

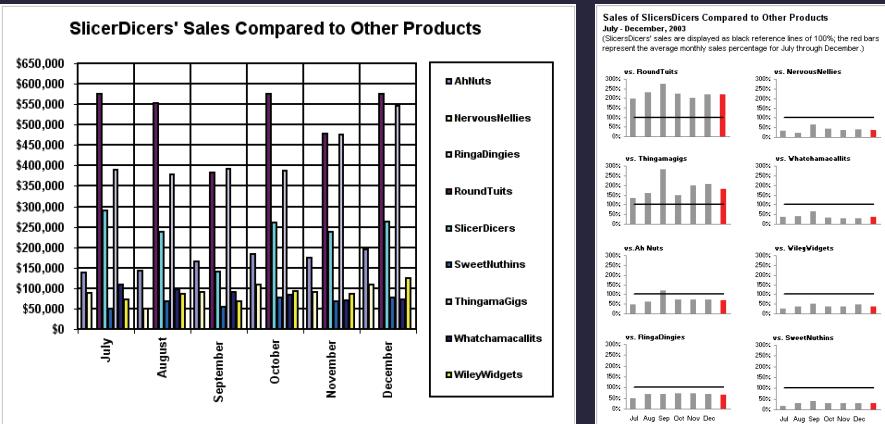
Topics

## 1. Data and image models

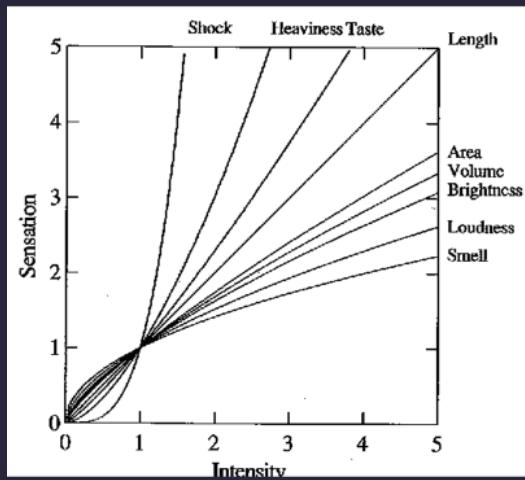


[Bertin, Graphics and Graphic Information Processing 1981]

## 2. Good and bad visualizations

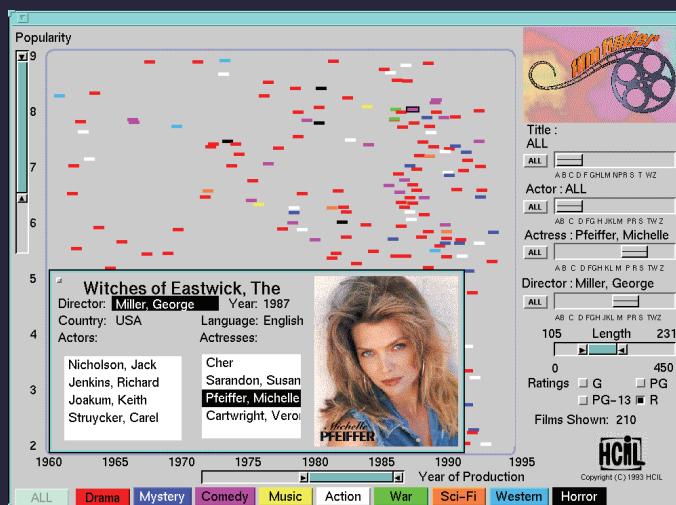


### 3. Perception



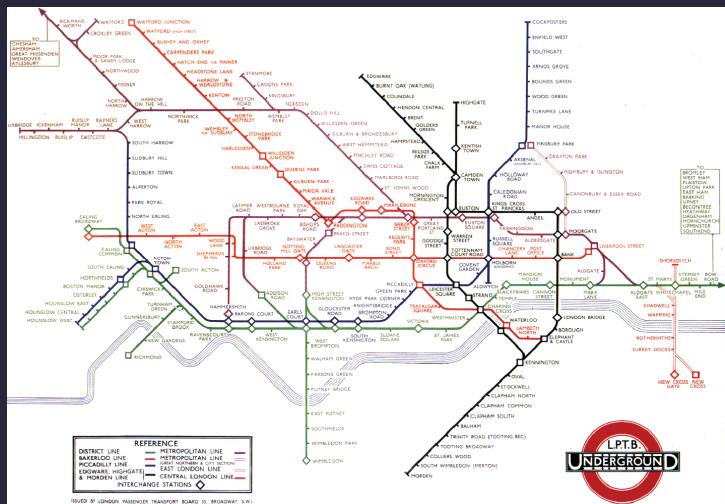
The psychophysics of sensory function [Stevens 61]

### 4. Interaction



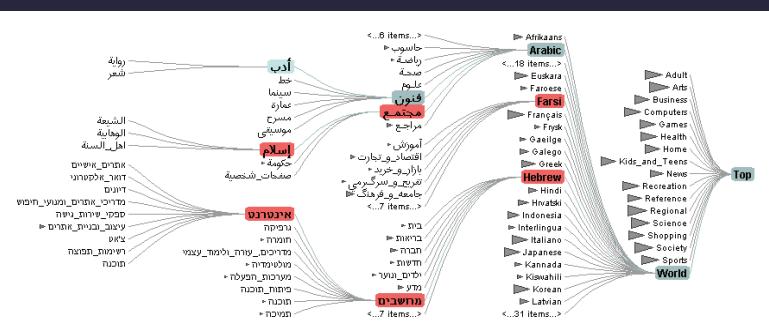
FilmFinder [Ahlberg 94]

## 5. Spatial Layout



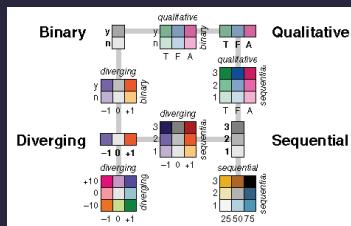
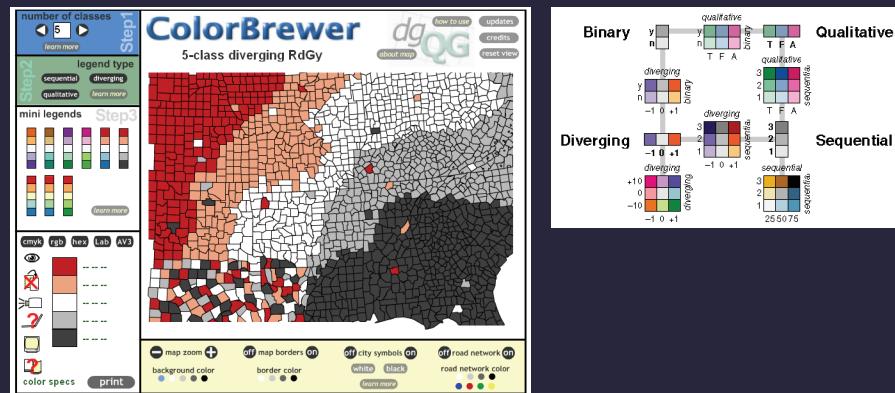
London underground [Beck 33]

## 6. Trees and graphs



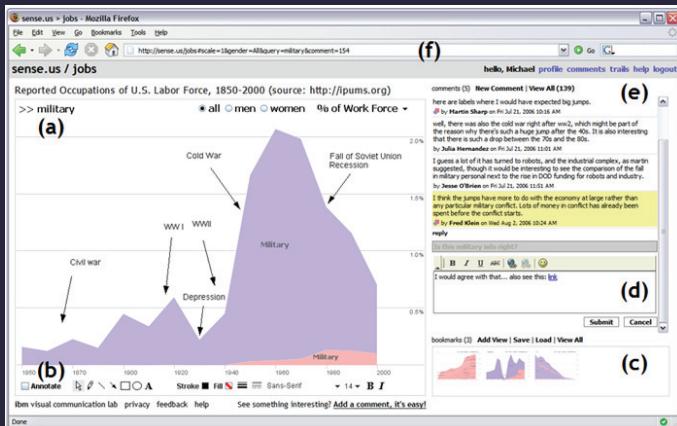
Degree-of-Interest Trees [Heer & Card, 2004]

## 7. Color



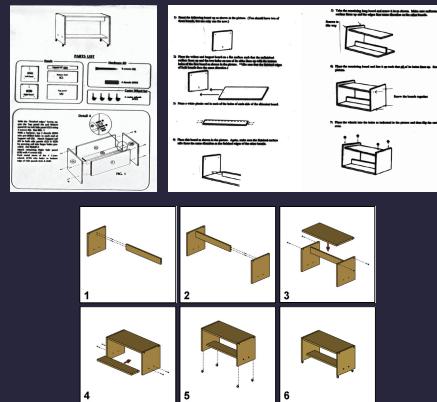
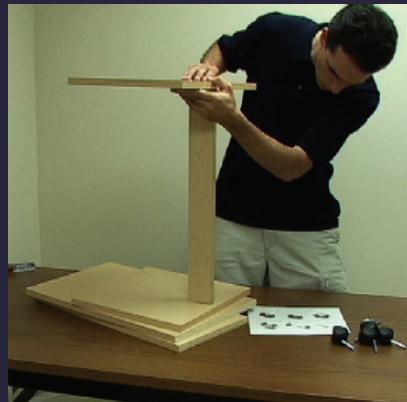
[from Cynthia Brewer <http://www.personal.psu.edu/faculty/c/a/cab38/> ]

## 8. Collaborative visualization



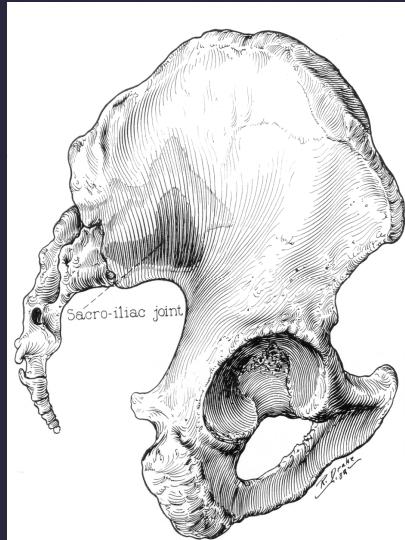
sense.us [Heer 07]

## 9. Identifying design principles



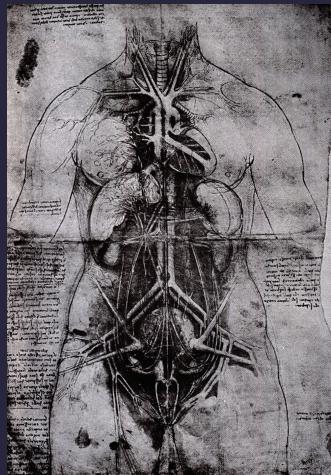
Testing effectiveness of 3 types of assembly instructions [Heiser 04]

## 10. Conveying shape

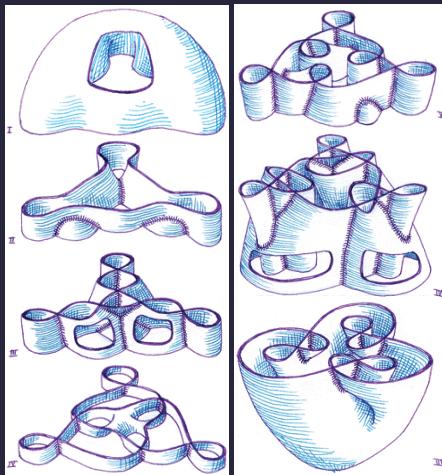


*Lumbosacral and Sacro-iliac fusion*  
Russell Drake, medical illustrator,  
Mayo Foundation, 1932.

## 11. Conveying structure

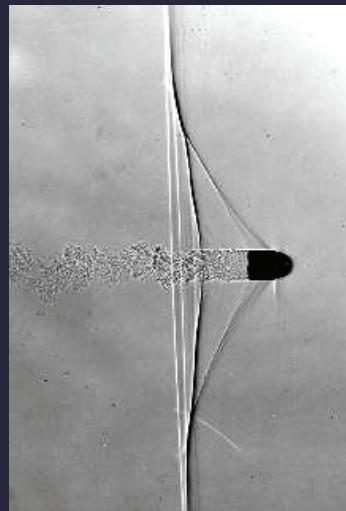


Principal Organs & Vascular System  
[Leonardo da Vinci ca. 1490]



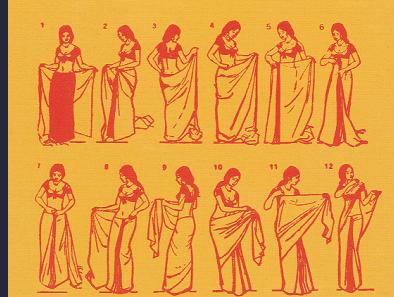
Strange Immersion of Torus in  
3-Space [Curtis 92]

## 12. Photography



Shadowgraph of a .22-caliber bullet in flight  
Taken by an MIT freshman in 1962, in Edgerton's  
lab. The flash was triggered by the shock wave  
(shown) hitting a microphone (out of frame). The  
picture shows no solid object except the bullet  
[http://en.wikipedia.org/wiki/Doc\\_Edgerton](http://en.wikipedia.org/wiki/Doc_Edgerton)

## 13. Depicting processes & actions



Wearing a sari [from Mijksenaar 99]



Visualizing dance steps [from Tufte 90]

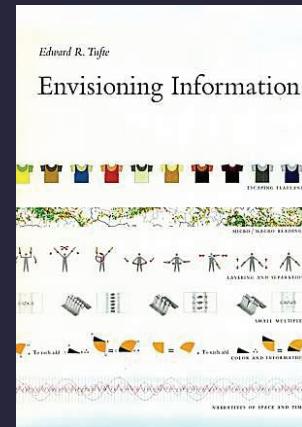
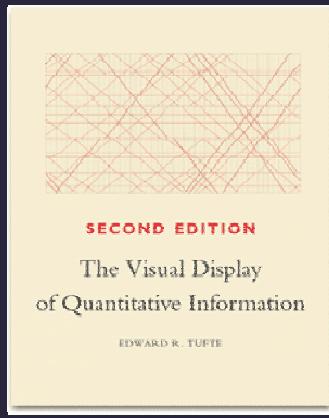
## 14. Animation



Outside-In, Geometry Computing Center

# Course Mechanics

## Textbooks



See also: [www.edwardtufte.com](http://www.edwardtufte.com)

## Readings

---

- **Some from textbooks, also many papers**  
Username/Password: vis/vislSfun
- **Material in class will be loosely based on readings**
- **Readings should be read by start of class**
- **Post discussion comments on class wiki**  
Important: Create a wiki account

**Class home page**

<http://vis.berkeley.edu/courses/cs294-10-fa07/wiki>

## Requirements

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**Class participation (10%)**

**Assignment 1a:** Good and Bad Visualizations (5%)

**Assignment 1b:** Visualization Deconstruction and Redesign (5%)

**Assignment 2:** Creating Visualizations with Existing Software (10%)

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

**Final Project (45%)**

# Final project

---

- **Visualization research project on topic of your choice**
- **2<sup>nd</sup> half of class**
- **Project write-up in form of a research paper**
- **Project presentations**
  1. Background research on project area
  2. Midway presentation on prototype solutions
  3. Final presentation – exact time to be determined

Projects from previous classes have been published

- IEEE Visualization
- IEEE Information Visualization
- SIGGRAPH

Final presentations to outside experts on visualization