

The Purpose of Visualization

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CS 294-10: Visualization
Spring 2011

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]

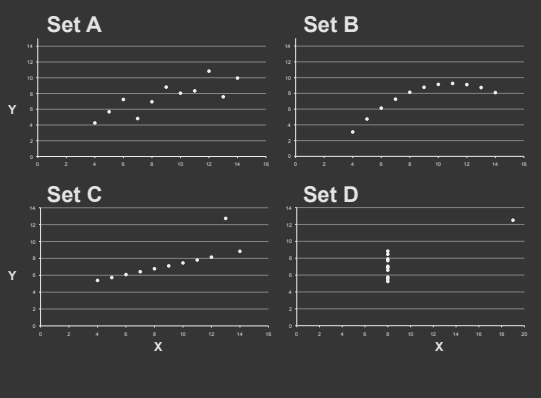
“The use of computer-generated, interactive, visual representations of data to amplify cognition.”
[Card, Mackinlay, & Shneiderman 1999]

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

$u_x = 9.0$ $\sigma_x = 3.317$ $Y^2 = 3 + 0.5 X$
 $u_y = 7.5$ $\sigma_y = 2.03$ $R^2 = 0.67$

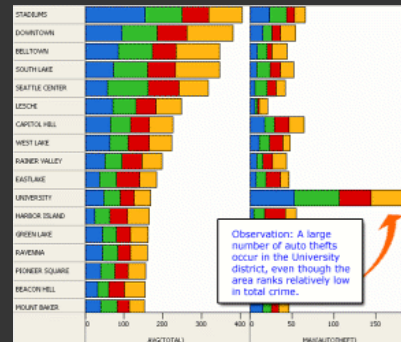
[Anscombe 73]



Examples



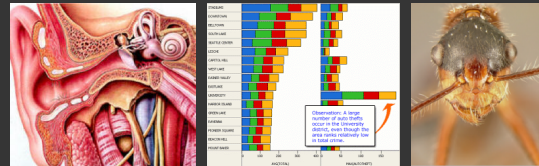
Examples



Examples



Examples



Other examples?

Why do we create visualizations?

Why do we create visualizations?

- Higher bandwidth to visual system
- Make easier to understand data (trends more apparent)
- Aggregate more data in a visualization
- Compare data more easily
- Artistic/Aesthetic purposes
- Helps to communicate ideas better
- Overriding language barriers
- Add meaning to data (structures the data)
- To persuade
- Helps avoid confusion and help with safety
- Emphasize different parts of the data
- Make data available/understandable to more people

Why do we create visualizations?

- 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

Record information

- Photographs, blueprints, ...

Support reasoning about information (analyze)

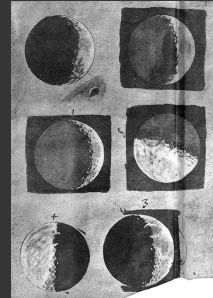
- Process and calculate
- Reason about data
- Feedback and interaction

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

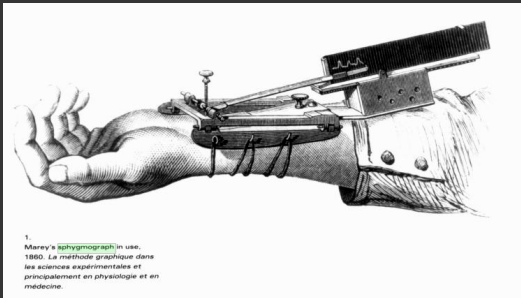


Answer question



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
principalement en physiologie et en
médecine.

Marey's sphygmograph [from Braun 83]

Support Reasoning

Make a decision: Challenger

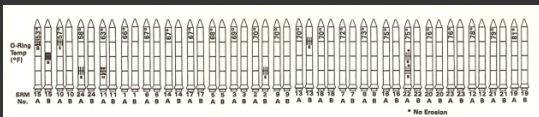
RECORD OF O-RING DAMAGE ON SHUTTLE JOINTS

	FLIGHT	O-RING DAMAGE	REPAIRS	STATUS	REMARKS
3	SRM-15	SRM-15 (SRM-15)	SRM-15 (SRM-15)	SRM-15 (SRM-15)	SRM-15 (SRM-15)
4	SRM-16	SRM-16 (SRM-16)	SRM-16 (SRM-16)	SRM-16 (SRM-16)	SRM-16 (SRM-16)
5	SRM-17	SRM-17 (SRM-17)	SRM-17 (SRM-17)	SRM-17 (SRM-17)	SRM-17 (SRM-17)
6	SRM-18	SRM-18 (SRM-18)	SRM-18 (SRM-18)	SRM-18 (SRM-18)	SRM-18 (SRM-18)
7	SRM-19	SRM-19 (SRM-19)	SRM-19 (SRM-19)	SRM-19 (SRM-19)	SRM-19 (SRM-19)
8	SRM-20	SRM-20 (SRM-20)	SRM-20 (SRM-20)	SRM-20 (SRM-20)	SRM-20 (SRM-20)
9	SRM-21	SRM-21 (SRM-21)	SRM-21 (SRM-21)	SRM-21 (SRM-21)	SRM-21 (SRM-21)
10	SRM-22	SRM-22 (SRM-22)	SRM-22 (SRM-22)	SRM-22 (SRM-22)	SRM-22 (SRM-22)
11	SRM-23	SRM-23 (SRM-23)	SRM-23 (SRM-23)	SRM-23 (SRM-23)	SRM-23 (SRM-23)
12	SRM-24	SRM-24 (SRM-24)	SRM-24 (SRM-24)	SRM-24 (SRM-24)	SRM-24 (SRM-24)
13	SRM-25	SRM-25 (SRM-25)	SRM-25 (SRM-25)	SRM-25 (SRM-25)	SRM-25 (SRM-25)
14	SRM-26	SRM-26 (SRM-26)	SRM-26 (SRM-26)	SRM-26 (SRM-26)	SRM-26 (SRM-26)
15	SRM-27	SRM-27 (SRM-27)	SRM-27 (SRM-27)	SRM-27 (SRM-27)	SRM-27 (SRM-27)
16	SRM-28	SRM-28 (SRM-28)	SRM-28 (SRM-28)	SRM-28 (SRM-28)	SRM-28 (SRM-28)
17	SRM-29	SRM-29 (SRM-29)	SRM-29 (SRM-29)	SRM-29 (SRM-29)	SRM-29 (SRM-29)
18	SRM-30	SRM-30 (SRM-30)	SRM-30 (SRM-30)	SRM-30 (SRM-30)	SRM-30 (SRM-30)
19	SRM-31	SRM-31 (SRM-31)	SRM-31 (SRM-31)	SRM-31 (SRM-31)	SRM-31 (SRM-31)
20	SRM-32	SRM-32 (SRM-32)	SRM-32 (SRM-32)	SRM-32 (SRM-32)	SRM-32 (SRM-32)
21	SRM-33	SRM-33 (SRM-33)	SRM-33 (SRM-33)	SRM-33 (SRM-33)	SRM-33 (SRM-33)
22	SRM-34	SRM-34 (SRM-34)	SRM-34 (SRM-34)	SRM-34 (SRM-34)	SRM-34 (SRM-34)
23	SRM-35	SRM-35 (SRM-35)	SRM-35 (SRM-35)	SRM-35 (SRM-35)	SRM-35 (SRM-35)
24	SRM-36	SRM-36 (SRM-36)	SRM-36 (SRM-36)	SRM-36 (SRM-36)	SRM-36 (SRM-36)
25	SRM-37	SRM-37 (SRM-37)	SRM-37 (SRM-37)	SRM-37 (SRM-37)	SRM-37 (SRM-37)
26	SRM-38	SRM-38 (SRM-38)	SRM-38 (SRM-38)	SRM-38 (SRM-38)	SRM-38 (SRM-38)
27	SRM-39	SRM-39 (SRM-39)	SRM-39 (SRM-39)	SRM-39 (SRM-39)	SRM-39 (SRM-39)
28	SRM-40	SRM-40 (SRM-40)	SRM-40 (SRM-40)	SRM-40 (SRM-40)	SRM-40 (SRM-40)
29	SRM-41	SRM-41 (SRM-41)	SRM-41 (SRM-41)	SRM-41 (SRM-41)	SRM-41 (SRM-41)
30	SRM-42	SRM-42 (SRM-42)	SRM-42 (SRM-42)	SRM-42 (SRM-42)	SRM-42 (SRM-42)
31	SRM-43	SRM-43 (SRM-43)	SRM-43 (SRM-43)	SRM-43 (SRM-43)	SRM-43 (SRM-43)
32	SRM-44	SRM-44 (SRM-44)	SRM-44 (SRM-44)	SRM-44 (SRM-44)	SRM-44 (SRM-44)
33	SRM-45	SRM-45 (SRM-45)	SRM-45 (SRM-45)	SRM-45 (SRM-45)	SRM-45 (SRM-45)
34	SRM-46	SRM-46 (SRM-46)	SRM-46 (SRM-46)	SRM-46 (SRM-46)	SRM-46 (SRM-46)
35	SRM-47	SRM-47 (SRM-47)	SRM-47 (SRM-47)	SRM-47 (SRM-47)	SRM-47 (SRM-47)
36	SRM-48	SRM-48 (SRM-48)	SRM-48 (SRM-48)	SRM-48 (SRM-48)	SRM-48 (SRM-48)
37	SRM-49	SRM-49 (SRM-49)	SRM-49 (SRM-49)	SRM-49 (SRM-49)	SRM-49 (SRM-49)
38	SRM-50	SRM-50 (SRM-50)	SRM-50 (SRM-50)	SRM-50 (SRM-50)	SRM-50 (SRM-50)

THIS SET OF DATA IS INTENTED TO BE USED AS A GUIDE TO THE INVESTIGATION OF O-RING DAMAGE ON SHUTTLE JOINTS. IT IS NOT INTENDED TO BE USED AS A GUIDE TO THE INVESTIGATION OF O-RING DAMAGE ON SHUTTLE JOINTS. IT IS NOT INTENDED TO BE USED AS A GUIDE TO THE INVESTIGATION OF O-RING DAMAGE ON SHUTTLE JOINTS.

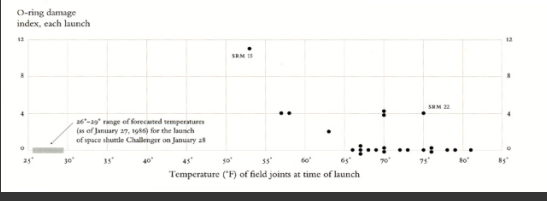
2 of 13 pages of material faxed to NASA by Morton Thiokol [from Tufte 1997]

Make a decision: Challenger



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

Make a decision: Challenger



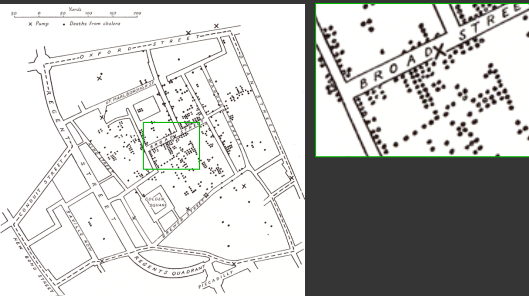
Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]

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

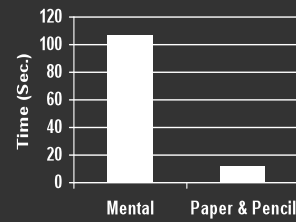
Class Exercise

Expand memory: Multiplication

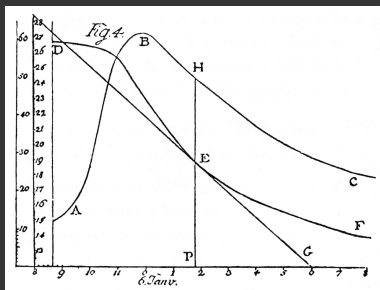
$$\begin{array}{r} 34 \\ \times 72 \\ \hline \end{array}$$

Expand memory: Multiplication

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

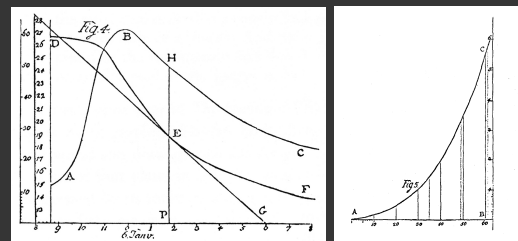


Graphical calculation: Evaporation



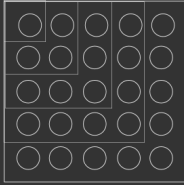
Johannes Lambert used graphs to study the rate of water evaporation as function of temperature [from Tufte 83]

Graphical calculation: Evaporation

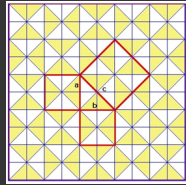


Johannes Lambert used graphs to study the rate of water evaporation as function of temperature [from Tufte 83]

Graphical calculation: Visual proofs

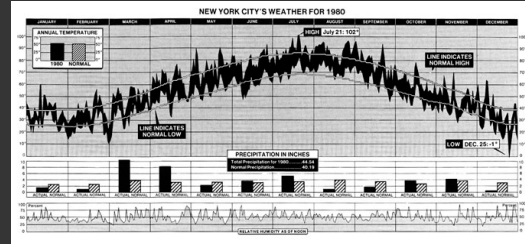


Sum of odd numbers:
 $1 + 3 + 5 + 7 + 9 = 5^2$



Pythagorean theorem:
 Chinese proof by dissection

Find patterns: New York weather



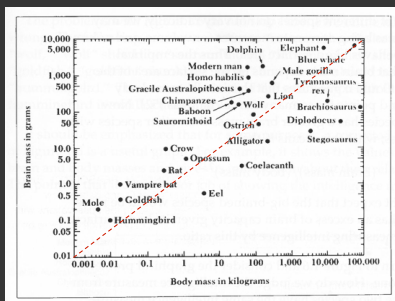
From the New York Times 1981

Convey Information to Others

Tell a story: Most powerful brain?

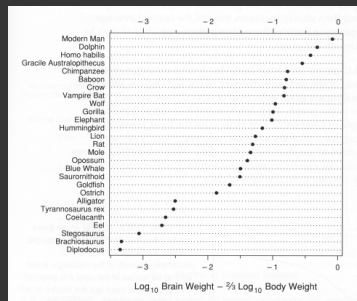
ID	Name	Body Weight	Brain Weight
1	Lesser Short-tailed Shrew	5	0.14
2	Little Brown Bat	10	0.25
3	Mouse	23	0.3
4	Big Brown Bat	23	0.4
5	Mask Shrew	40	0.33
6	Star Nosed Mole	60	1
7	Eastern American Mole	75	1.2
8	Ground Squirrel	101	4
9	Tree Shrew	104	2.5
10	Golden Hamster	120	1
11	Male Rat	122	3
12	Galago	200	5
14	13 Rat	200	1.9
16	14 Chinchilla	425	6.4
16	15 Desert Hedgehog	550	2.4
17	16 Rock Hyrax (A)	750	12.3
16	17 European Hedgehog	785	3.6
16	18 Tenrec	900	2.6
20	19 Arctic Ground Squirrel	900	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 Siam Loris	1400	12.6
25	24 Genet	1410	17.5
26	25 Phalanger	1620	11.4

Tell a story: Most powerful brain?



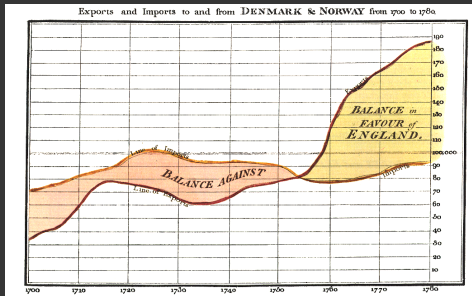
The Dragons of Eden [Carl Sagan]

Tell a story: Most powerful brain?



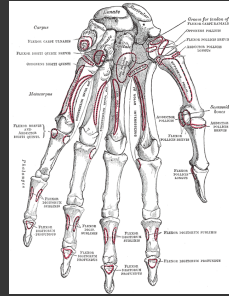
The Elements of Graping Data [Cleveland]

Present argument: Exports and Imports



[Playfair 1786]

Inspire



Bones in hand [from 1918 edition]



Double helix model [Watson and Crick 53]

Visualization Research

Challenge

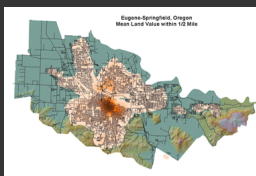
More and more unseen data

- Faster creation and collection

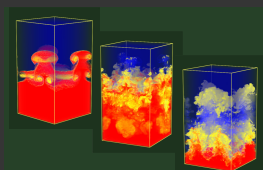
Challenge

More and more unseen data

- Faster creation and collection



Urban development planning
www.urbansim.org



Fluid flow
ctr.stanford.edu

Simulation

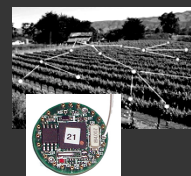
Challenge

More and more unseen data

- Faster creation and collection



Sloan digital sky survey
www.sdss.org



Sensor networks [Hill 02]
www.xbow.com



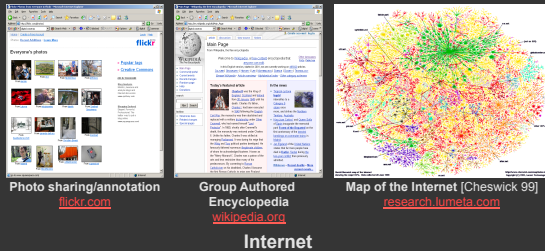
Digital photography

Sensing

Challenge

More and more unseen data

- Faster creation and collection
- Faster dissemination



Challenge

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

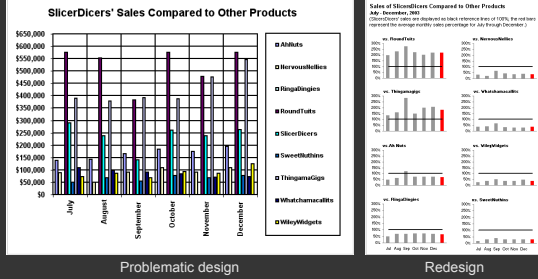
Topics

1. Data and image models

LES VARIABLES DE L'IMAGE		POINTS	LIGNES	ZONES	12 14
XY 2 DIMENSIONS DU PLAN		x x	∞	∞	∞ ∞
Z TAILLE		∞	∞	∞	∞ ∞
VALEUR		∞	∞	∞	∞ ∞
LES VARIABLES DE SÉPARATION DES IMAGES					13
GRAIN		∞	∞	∞	∞ ∞
COULEUR		∞	∞	∞	∞ ∞
ORIENTATION		∞	∞	∞	∞ ∞
FORME		∞	∞	∞	∞ ∞

[Bertin, Graphics and Graphic Information Processing 1981]

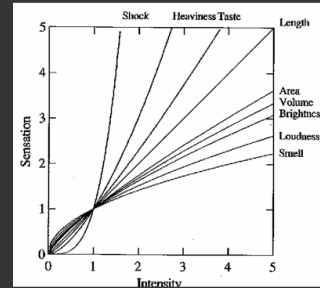
2. Visualization Re-Design



Problematic design

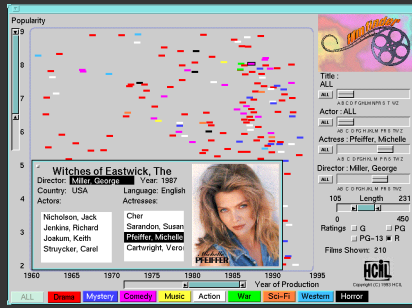
Redesign

3. Perception



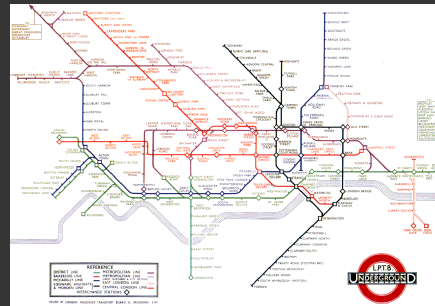
The psychophysics of sensory function [Stevens 61]

4. Interaction



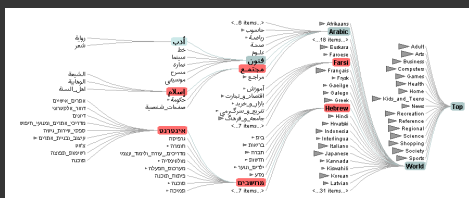
FilmFinder [Ahlberg 94]

5. Spatial Layout



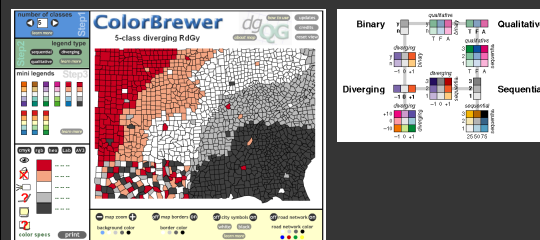
London underground [Beck 33]

6. Trees and graphs



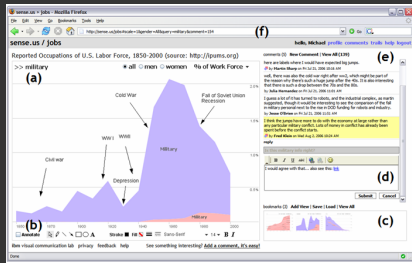
Degree-of-Interest Trees [Heer & Card, 2004]

7. Color



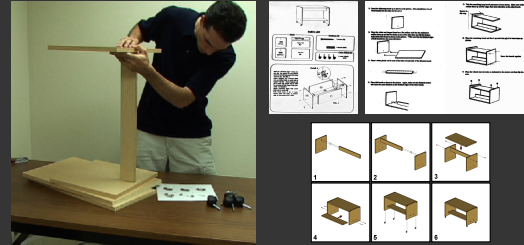
[from Cynthia Brewer <http://www.personal.psu.edu/faculty/c/a/cab38/>]

8. Collaborative visualization



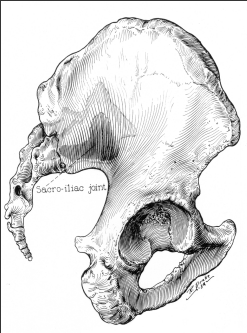
sense.us [Heer 07]

9. Identifying design principles



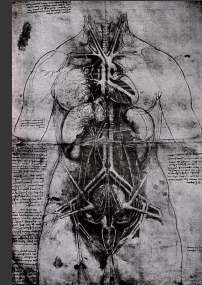
Testing effectiveness of 3 types of assembly instructions [Heiser 04]

10. Conveying shape

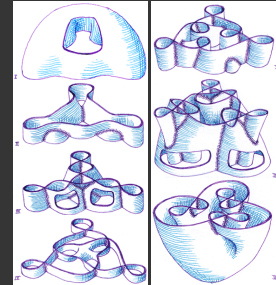


Lumbosacral and Sacro-iliac fusion
Russell Drake, medical illustrator,
Mayo Foundation, 1932.

11. Conveying structure

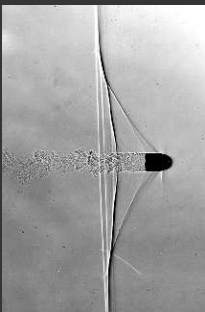


Principal Organs & Vascular System
[Leonardo da Vinci ca. 1490]



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

13. Depicting processes & actions



Wearing a sari [from Mijksenaar 99]



Visualizing dance steps [from Tufte 90]

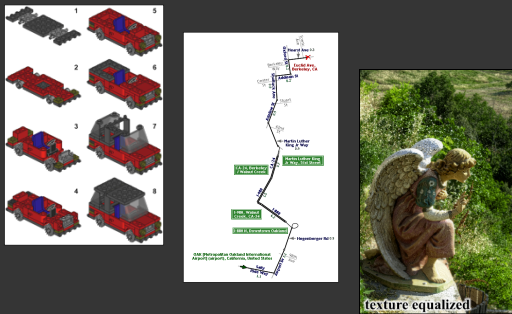
14. Animation



Outside-In, Geometry Computing Center

Course Mechanics

Instructor: Maneesh Agrawala



Course Goals

- 1 *Evaluate and critique* visualization designs
- 2 *Implement* interactive data visualizations
- 3 *Gain* an overview of research & techniques
- 4 *Develop* a substantial visualization project

Textbooks



See also: www.edwardtufte.com

Readings

- Some from textbooks, also many papers
Username/Password: vis/visReadings
- Material in class will be loosely based on readings
- Readings should be read by start of class
- Post discussion comments on class wiki
Must post within 1 day of lecture
Important: Create a wiki account

Class home page

<http://vis.berkeley.edu/courses/cs294-10-sp11/wiki>

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
- 2nd 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

Assignment 1: Visualization Design

The screenshot shows the DATABLOG website interface. At the top, there is a navigation bar with 'News' and 'Database' links. The main content area features an article titled 'Top-selling 100 books of all time' with a sub-headline 'The Top-selling 100 books of all time (well, since Nielsen records began in 1958) are published today. Download the data for yourself and see how they compare.' Below the text is a small image of a person's face. The article is dated '1/21/2014 10:00 AM'.

The screenshot shows a data table with columns for 'Rank', 'Title', 'Author', 'Year', and 'Sales'. The table contains 100 rows of data, with the top few rows highlighted in yellow. The first row is '1. The Hobbit by J.R.R. Tolkien, 1937, 1,000,000'. The second row is '2. The Lord of the Rings: The Fellowship of the Ring by J.R.R. Tolkien, 1954, 1,000,000'. The third row is '3. The Catcher in the Rye by J.D. Salinger, 1951, 1,000,000'. The fourth row is '4. The Hobbit by J.R.R. Tolkien, 1937, 1,000,000'. The fifth row is '5. The Lord of the Rings: The Two Towers by J.R.R. Tolkien, 1954, 1,000,000'. The sixth row is '6. The Hobbit by J.R.R. Tolkien, 1937, 1,000,000'. The seventh row is '7. The Hobbit by J.R.R. Tolkien, 1937, 1,000,000'. The eighth row is '8. The Hobbit by J.R.R. Tolkien, 1937, 1,000,000'. The ninth row is '9. The Hobbit by J.R.R. Tolkien, 1937, 1,000,000'. The tenth row is '10. The Hobbit by J.R.R. Tolkien, 1937, 1,000,000'.

Due by 9am on Jan 26