1

INFORMATION VISUALIZATION

INTRODUCTION

Sungahn Ko
sako@unist.ac.k

1

Disclaimer

2

- The slides cannot be distributed, posted or used outside of this class
- Slides in this course courtesy of
  - Dr. Ross Maciejewski (ASU)
  - Dr. Niklas Elmqvist (UMD)
  - Dr. David Ebert (OU)
  - Dr. Yun Jang (Sejong Univ.)

2

About Topics

3

- http://ivader.unist.ac.kr
- This course will cover the topics in
  - (Mainly) Information visualization
    - IEEE VIS InfoVis and VAST
      - https://ieeevis.org/year/2022/welcome
  - User Interfaces and HCI, if necessary

3

Lecture Logistics

4

- Class uses BlackBoard
  - Sharing slides
  - Post questions in BB (expect answers within 2 days)
  - If not, email TA and/or me
- Will have Q&A sessions
  - ~5 minutes, Every class
- In-class Programming Lab. Sessions
  - More than 2~3 times
  - A programmer and TA will lead the sessions
  - Few exercises may be covered
- Office hour: Monday 4:30pm 106/401-10
  - Or by appointment

4

Grading

5

- Attendance (5%)
- Participation (5%)
  - Answer questions
- Midterm (20%)
- Final (20%)
- Quiz (15%)
- Assignments & Exercises (35%)

5

Tentative Assignments and Exercise

6

- Example Exercise
  - Draw line charts, SVG
- Example Assignments
  - Implement visualization
  - Analyze datasets
  - using your visualizations
- Example datasets
  - Time series data (e.g., Weather), Text data (Yelp Review)
- Assignment Results examples
  - https://www.students.cs.ubc.ca/~cs-436v/22Jan/fame/

Activity	Grade (%)
Exercise 1	5
Exercise 2	5
Assignment 1	30
Exercise 3	5
Exercise 4	5
Assignment 2	40

6

TA

7

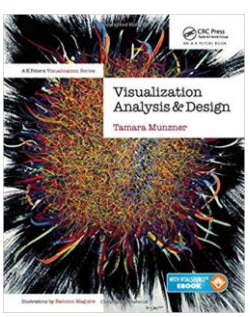
- Joohee Kim (lab: 106/404)
  - joohee@unist.ac.kr
  - AIGS, Ph.D student
  - Will lead some of lab sessions
- Seungmin Jin (email contact only)
  - dryjins@gmail.com
  - Research Programmer
  - Will lead most lab sessions

7

Textbook and reference materials

8

- **Prof. Tamara Munzner's book**
  - **Exam and quiz questions from slides and videos**
  - https://www.students.cs.ubc.ca/~cs-436v/22Jan/



W.	Date (Mo-Fr)	Async Video Lecture	Tue Class	Wed Tutorial Quizzes (due 6pm)	Thu Sync Class (11-12:20)	TA Office Hours	Fri Assign (due 6pm)
1	Jan 10-14	Intro & Abstractions	Logistics **(livestream 11am)**		Abstractions *Released: P0, F1*	*no office hours first week*	**Refresher (No Quiz):** Web c **Tut/Quiz 1:** Intro to D3
2	Jan 17-21	Marks & Channels	*no class*	**Tut/Quiz 2:** Making a chart, reuseable chart components	Marks & Channels	P0	**Foundations 1**
3	Jan 24-28	Multivariate Tables	*no class*	**Tut/Quiz 3:** Enter/update, Joins	Multivariate Tables *Released: P1, F2*	P1	**Programming 0**
4	Jan 31-Feb 4	Interactive Views	*no class*	**Tut/Quiz 4:** Animated transitions, tooltips	Interactive Views *Released: Project*	P1	**Foundations 2**
5	Feb 7-11	Color	*no class*	**Tut/Quiz 5:** Multiple views, advanced interactivity	Color *Released: F3*	P2	**Programming 1**
6	Feb 14-18	Maps	*optional stream Released: P2*	**Tut/Quiz 6:** Geographic maps	Maps	P2	**Foundations 3**
7	Feb 21-25	*Reading Week*				P2	
8	Feb 28-Mar 4	Aggregation	*no class*	**Tut/Quiz 7:** Advanced concepts	Aggregation	Project Consult	**Programming 2 Project Team Formation**
9	Mar 7-11	Networks & Trees	*no class*		Networks & Trees	Project Consult	**Milestone 1: Proposal**
10	Mar 14-18	Rules of Thumb	*no class*		Midterm Review	Project Consult	
11	Mar 21-25	*none*	**Midterm exam**		*none*	Project Consult	
12	Mar 28 - Apr 1	Advanced Topics 1	*no class* **Milestone 2: WIP**		Advanced Topics	Project Consult	
13	Apr 4-8	Advanced Topics 2	*no class*		Wrapup	Project Consult	
	Apr 11-15		**Milestone 3: Final Project**			(project marking demo sessions)	

8

Quiz (15%)

9

- Questions from lecture and Prof. Munzner's lecture video
- https://www.youtube.com/watch?v=1GhZisgc6DI&list=PLT4XLHmqHJBeB5LwmRmo6ln-m7K3lGvrk&index=1
- Watch Prof. Munzner's lecture video before our lecture
  - I will let you know which video you have to watch

9

FAQ: Will I Need to Program?

- Short answer: YES
  - This is a computer engineering course
  - Will be easier if you are able to build software
    - Web-programming is easy (JavaScript etc)
    - Good opportunity to (force yourself to) learn
- Programming Lab. Sessions
  - More than 2~3 times
  - A programmer and TA will be in charge
  - During lecture hours
  - To find out which parts students have difficulties in coding and to improve lab session materials
    - The TA may conduct surveys and ask information on how you perform web programming during lab sessions
    - Everyone is encouraged to participate

12

Exams

13

- Midterm (4/24 or 4/26)
  - Typical midterm exam
  - Questions from slides, videos, and others covers during lectures
- Final exam (6/7 or during exam period)
  - Covers all the topics discussed in the class
    - Guidelines, principles, and theories in Graphical SW interface design and evaluation
  - Questions from slides, videos, and others covers during lectures

13

Slides

14

- The slides will be available in BB
- You are not allowed to distribute the slides
- Read materials and ask questions during class

- Some sentences/words on slides would be missing! See them in class

14

Q&A Board

15

- Link
- shorturl.at/btFX5
- or
- https://docs.google.com/document/d/1TXBa5h_pmO5w7RQyTPlnbgPag3C6r0akhgiNfgyfFlk/edit?usp=sharing

15

Missing Assignments / Quiz / Projects

16

- No additional submission allowed after deadlines
- If you do not submit exercises and assignments (more than three times)
- If you are absent 8 times,
- You will get

'F'

16

What will we cover in class?

17

- Purposes and goals of visualization:
  - applications, challenges, sources of data
  - measurement, simulation, modeling
  - data dimensionality: 1D, 2D, 2.5D, 3D, …, nD
  - time-dependent
  - data types: scalar, vector, nominal, multivariate
  - grid types: regular, rectilinear, curvilinear, unstructured, hybrid, point-based or scattered data

17

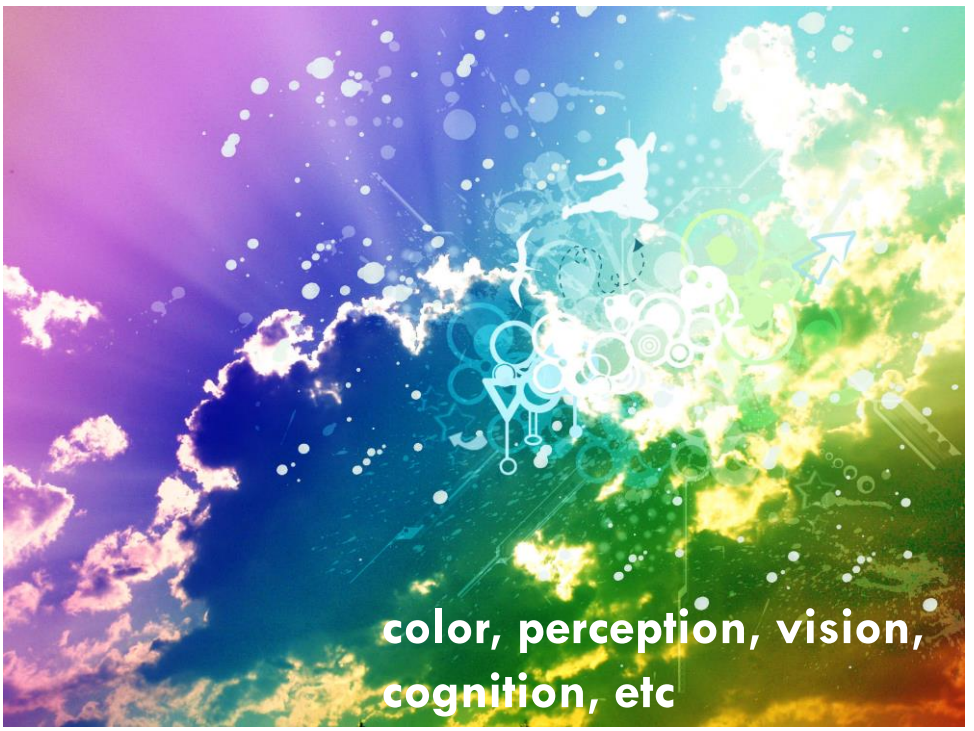
Academic Integrity

18

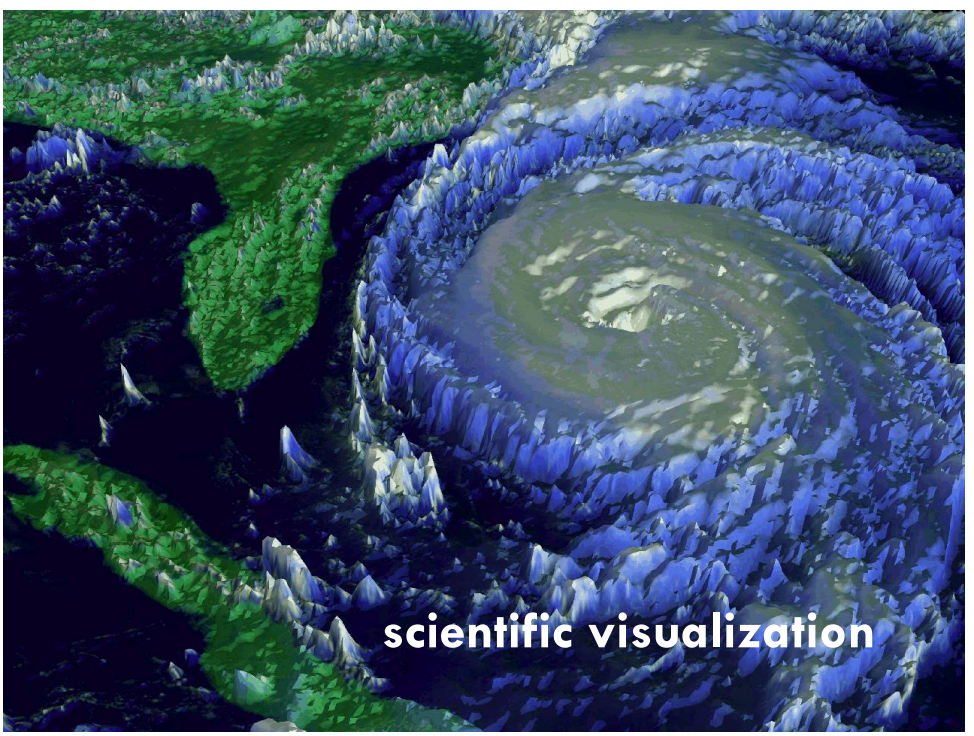
- Violations of academic integrity include (but are not limited to) cheating, fabrication, tampering, plagiarism or facilitating such activities.
- I have a zero-tolerance policy. Any perceived cheating will make your grade F.

- Check guidelines
- If you have any question, ask me

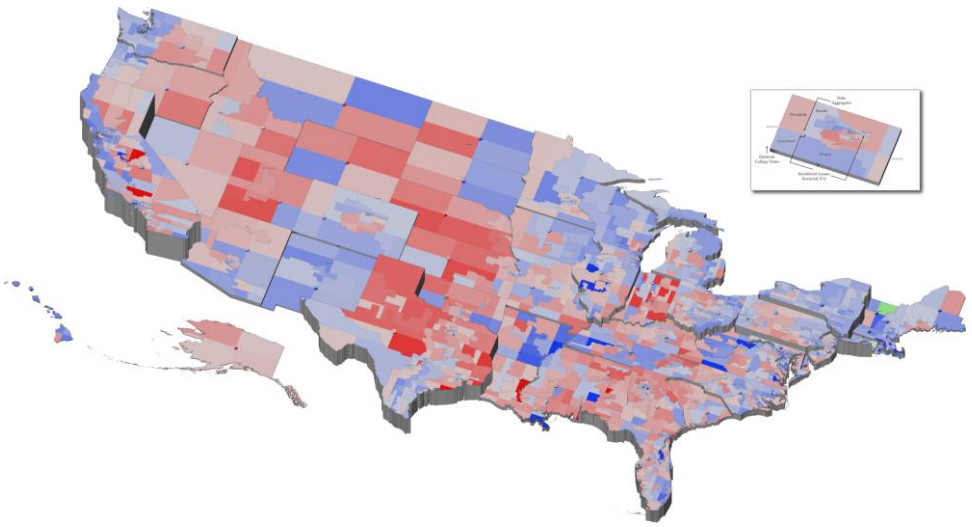
18


color, perception, vision,
cognition, etc

23

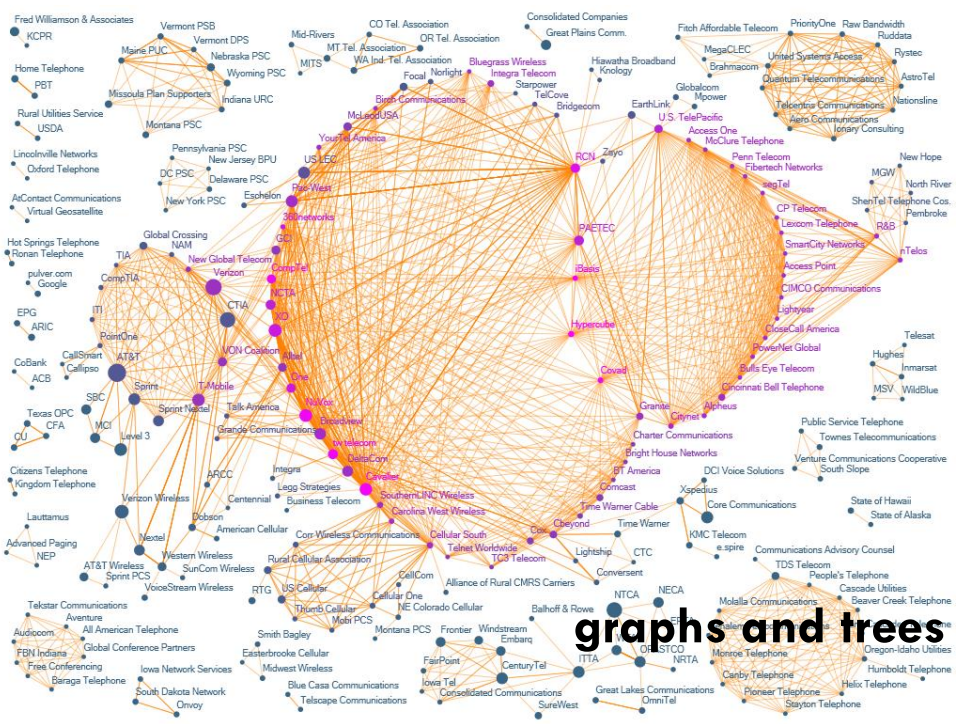

scientific visualization

24



multidimensional visualization

25



graphs and trees

26

text

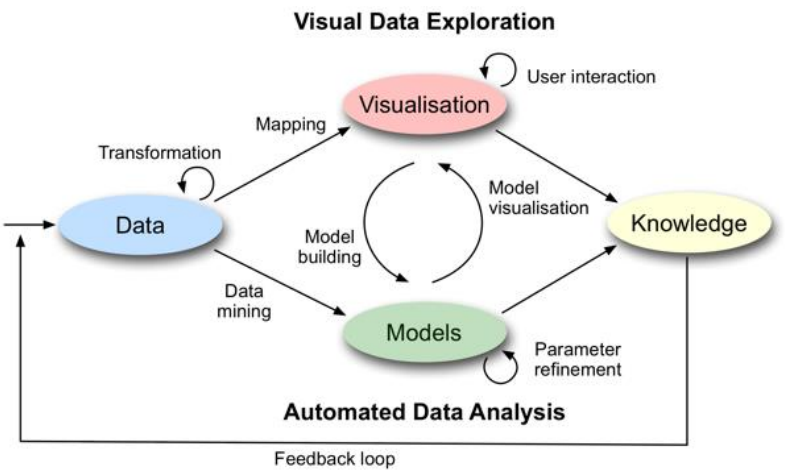
27

animation

28

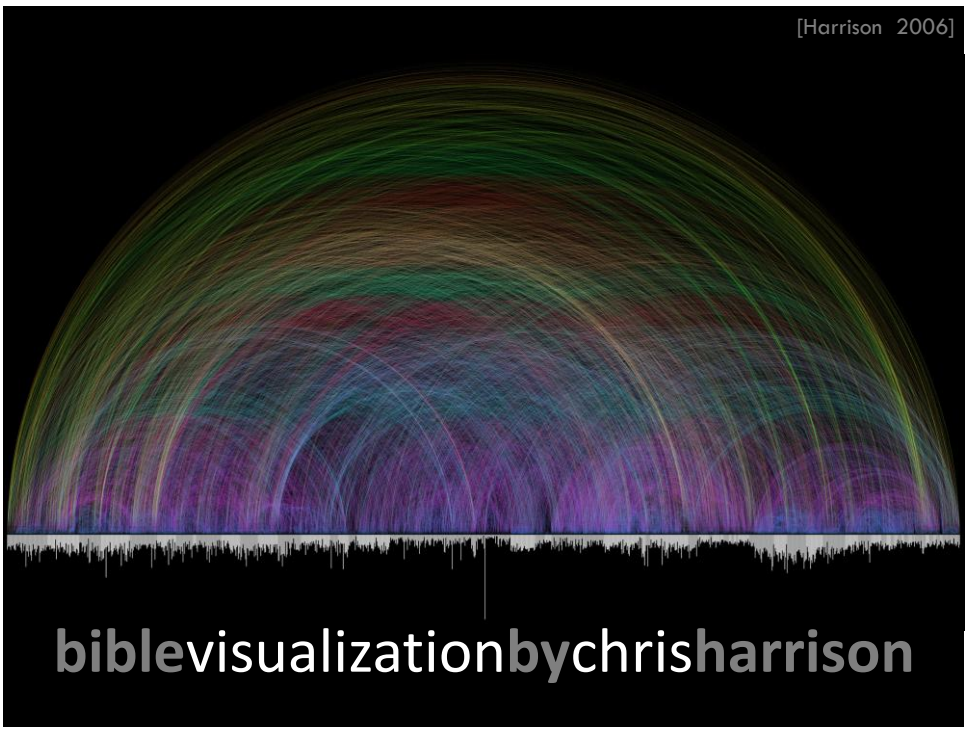
collaboration

29



visual analytics

30



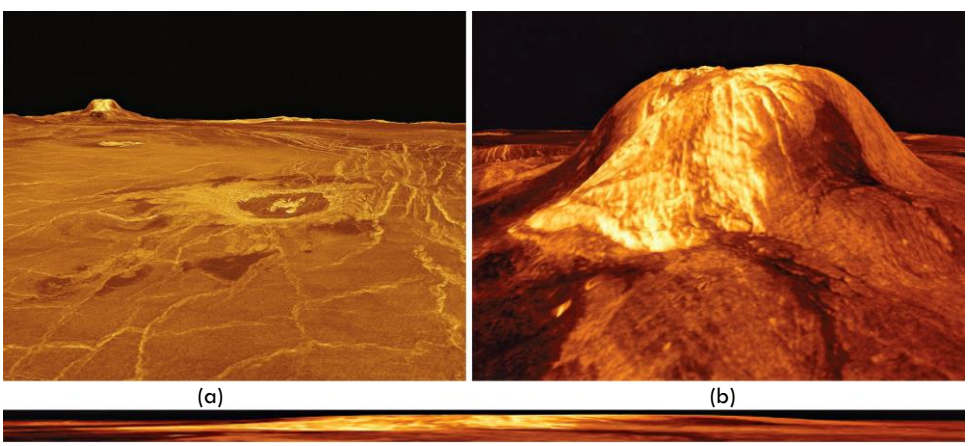
31

[Viola et al. 2004]

32

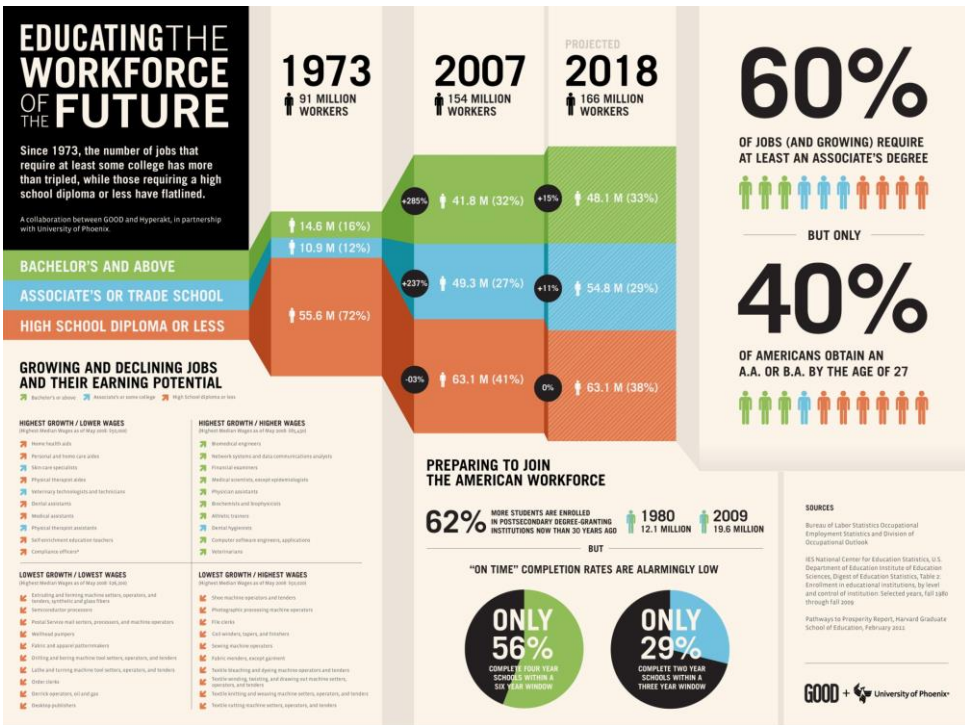
33

[Hanson 2014]



Eistla Regio region of the surface of Venus

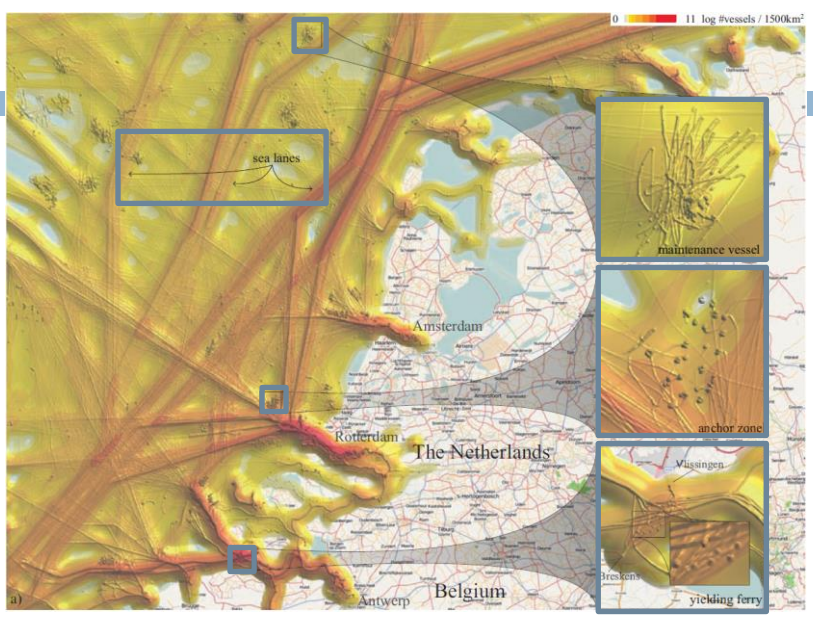
34



35

[Willems et al., 2009]

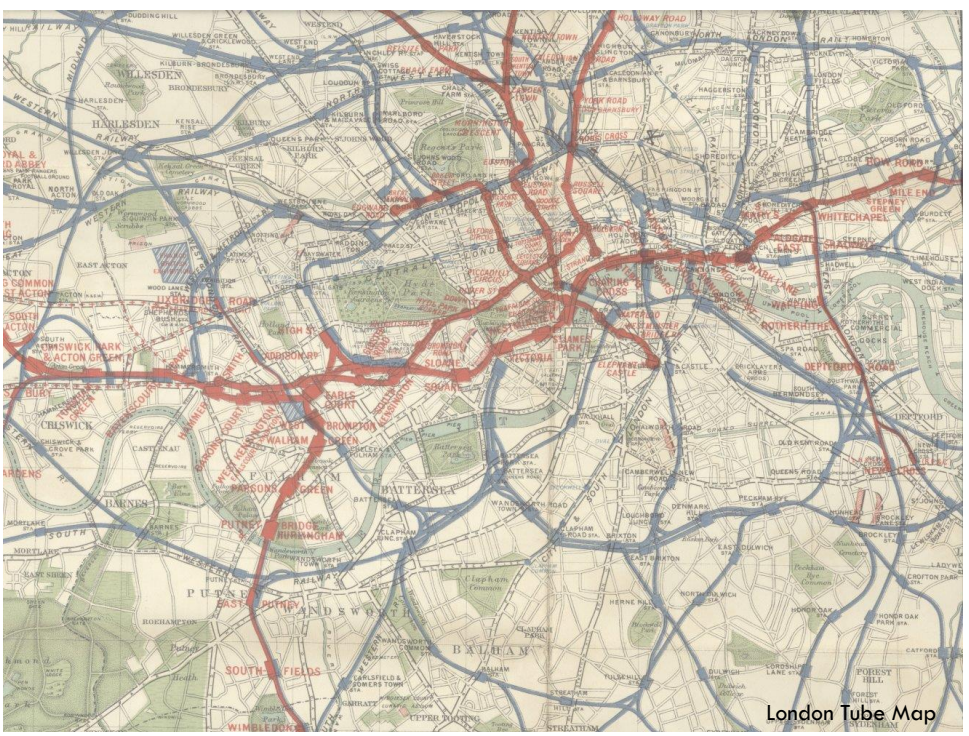
36



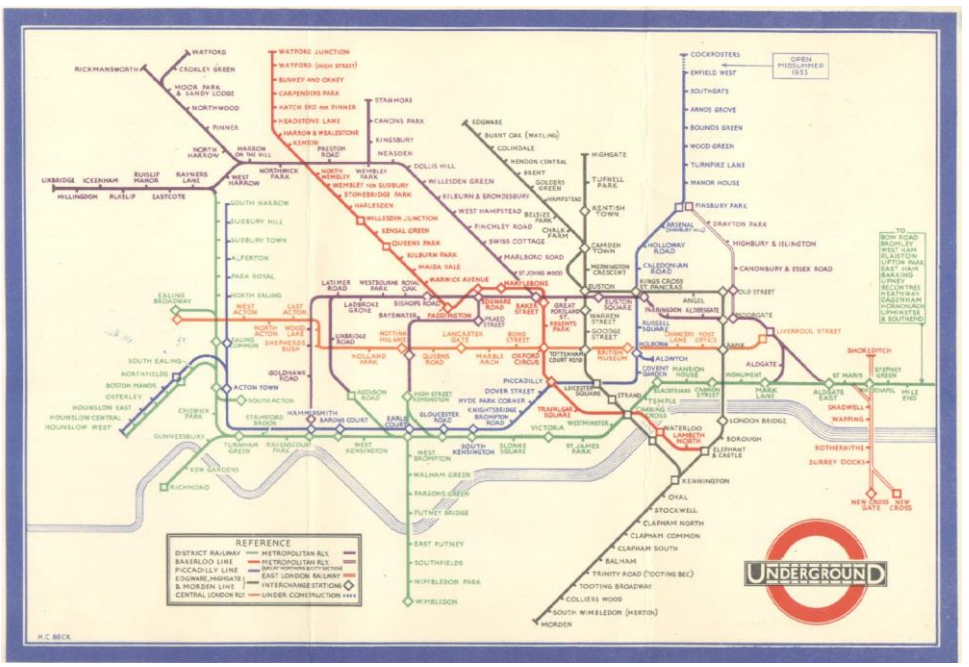
36

[Afzal et al., 2012]

37



38



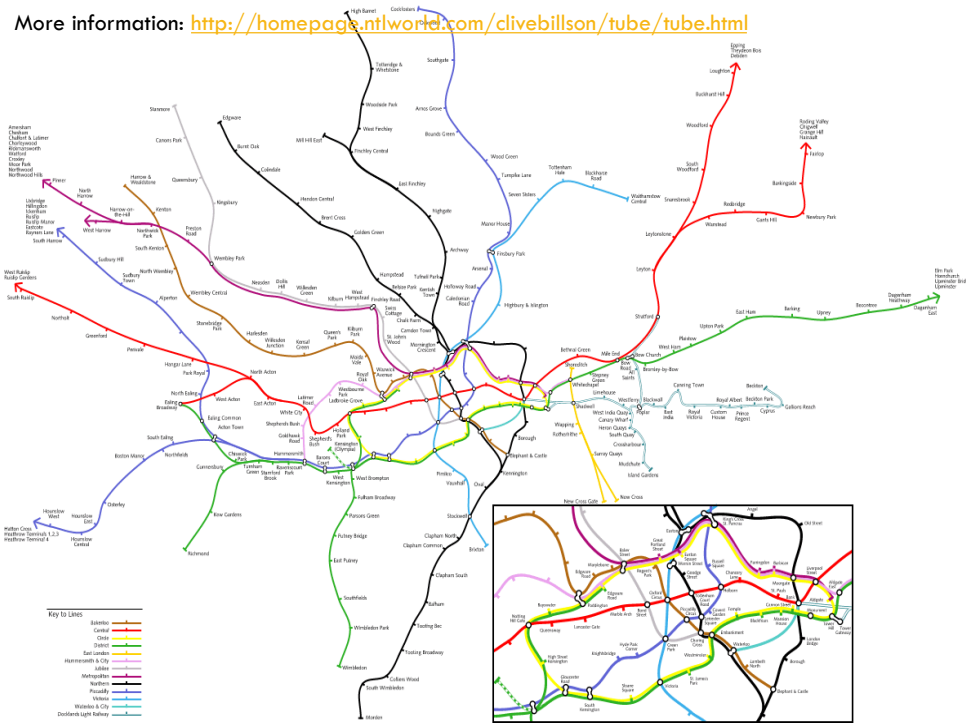
[Harry Beck, 1933]

39

London Tube Map, 2010

40

More information: http://homepages.ntlworld.com/clivebillson/tube/tube.html



41

Why do we need?

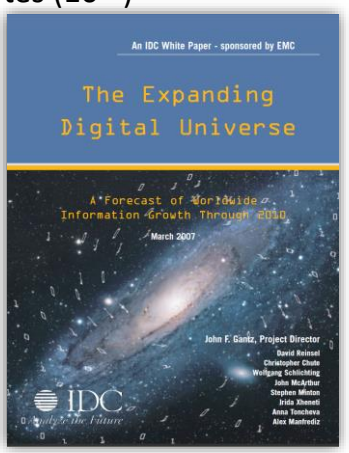
42

[Gantz et al. 2007]

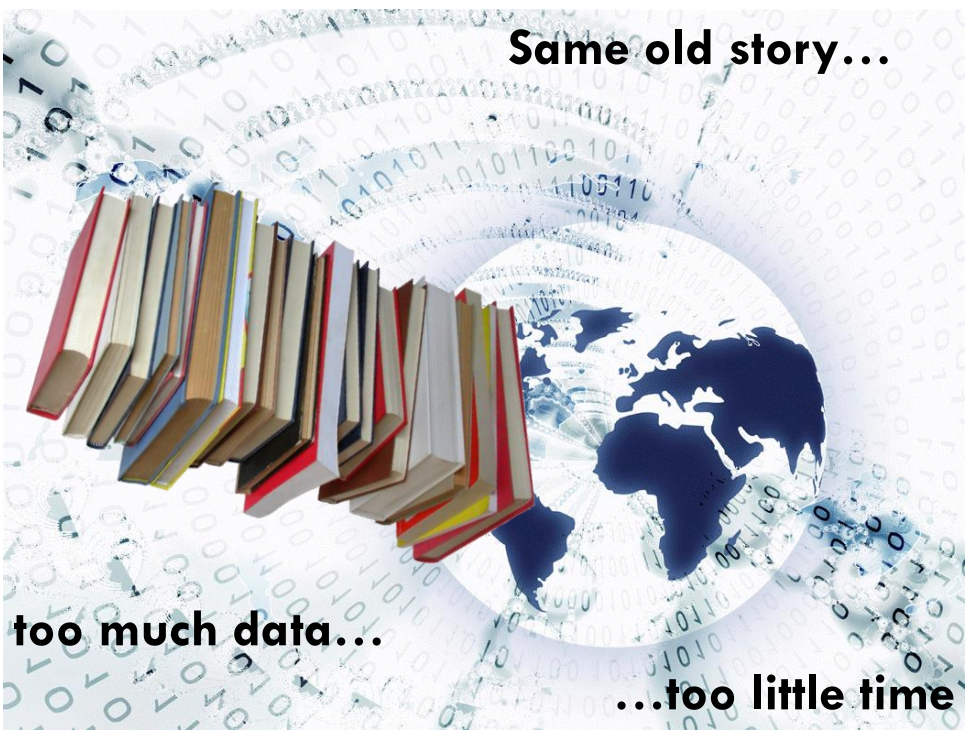
The Digital Universe…

- ~1 zettabyte of data in 2010 (988 EB)
  - 1,000,000,000,000,000,000,000 bytes (10^{21})
  - 95+% **unstructured**
    - Images, video, audio, etc
    - 1 billion digital capture devices in 2006
  - 25% original, 75% replicated

"…the digital universe will remain unstructured – meaning tools and techniques will be required to add structure […] to improve **search, discovery,** [and] **management…**"

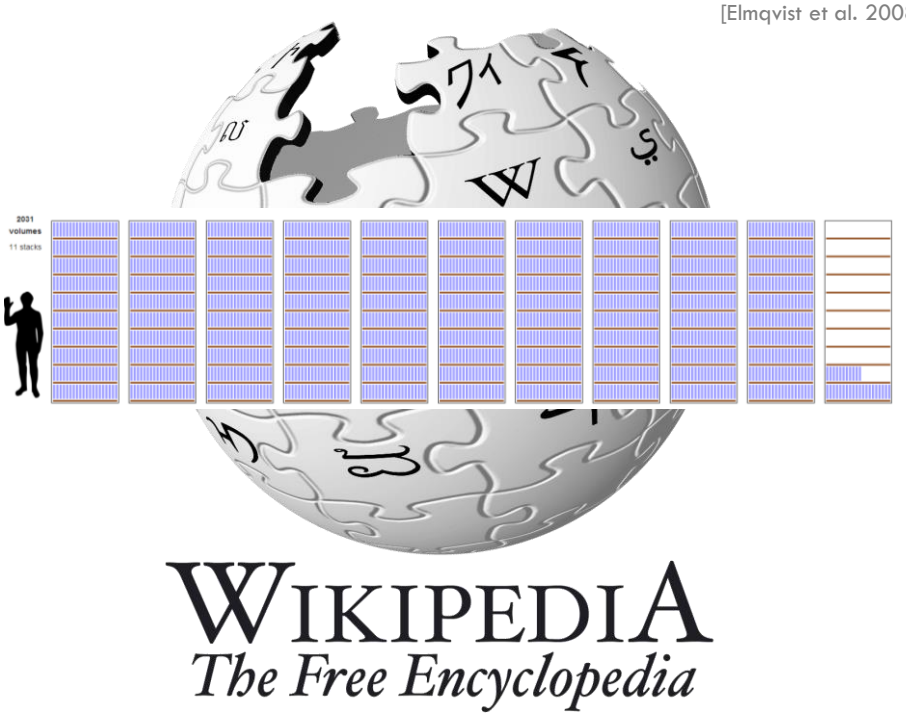


43



44

[Elmqvist et al. 2008]



45

The Ongoing Data Deluge

46

- Since 2003, digital information has accounted for 90% of all information produced[1]
- In 2009, drones from Iraq and Afghanistan recorded 24 years of video footage
- In 2010, the amount of information added annually to the digital universe was estimated to be nearly 1 ZB
- Wal-mart process > 1 million transactions per hour
- By 2013 Cisco estimates the annual internet traffic will be 667 EBs

1 – C. R. Johnson, R. Moorhead, T. Munzner, H. Pfister, P. Rheingans, and T. S. Yoo, Eds., *NIH-NSF Visualization Research Challenges Report*, IEEE Press, ISBN 0-7695-2733-7, 2006

46

The Ongoing Data Deluge

47

- Consumers carry more than 1 billion Visa cards worldwide. More than 450 million of those cards are in the United States
  - http://www.creditcards.com/credit-card-news/credit-card-industry-facts-personal-debt-statistics-1276.php

47

Data Overload

48

- Opportunity: Huge amounts of data available in digital form and ready for analysis!
- Problem: The amount of data is simply too huge for humans to analyze!
  - (Also, 95% of it is unstructured...)
  - But, how can we make sense of this data?
  - How can we harness this data in the decision making process?
  - How do we avoid being overwhelmed by all of this data?

48

[Jeffrey Heer]

The Value of Visualization?

- Answering questions
- Confirm the expected
- Discover the unexpected
- Making decisions
- Expand memory
- Find patterns
- Tell a story
- Inspire others

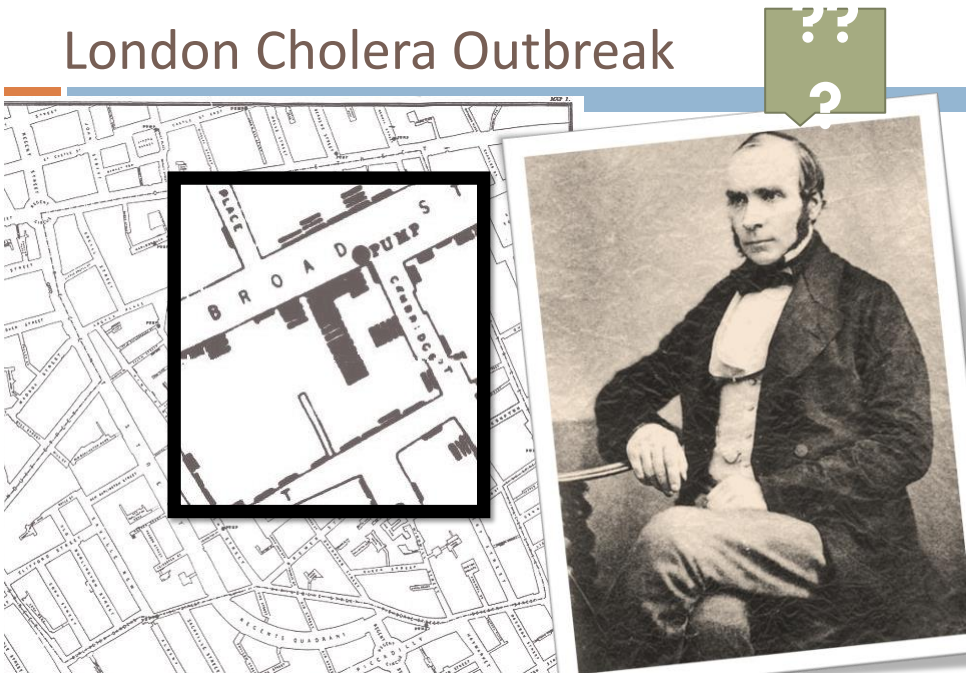
49

Answering Questions

The Value of Visualization

50

John Snow and the London Cholera Outbreak



51

Confirm the Expected

The Value of Visualization

52

53

Expand Memory

The Value of Visualization

55

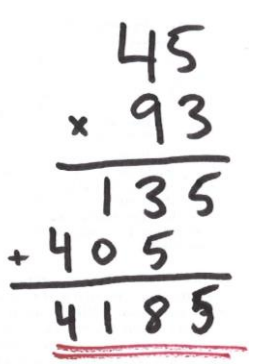
External Cognition and Memory

- **External cognition** is the use of the external world to achieve cognition
  - Scaife and Rogers (1996)
  - Explains the power of visualization
  - **Example**: post-it notes
- Three mechanisms
  - Offloading: supports memory
  - Re-representation: new form
  - Graphical constraining: utilize visual reasoning
- Don Norman: "It is things that make us smart."

56

Example: External Memory

45 × 93 = ???

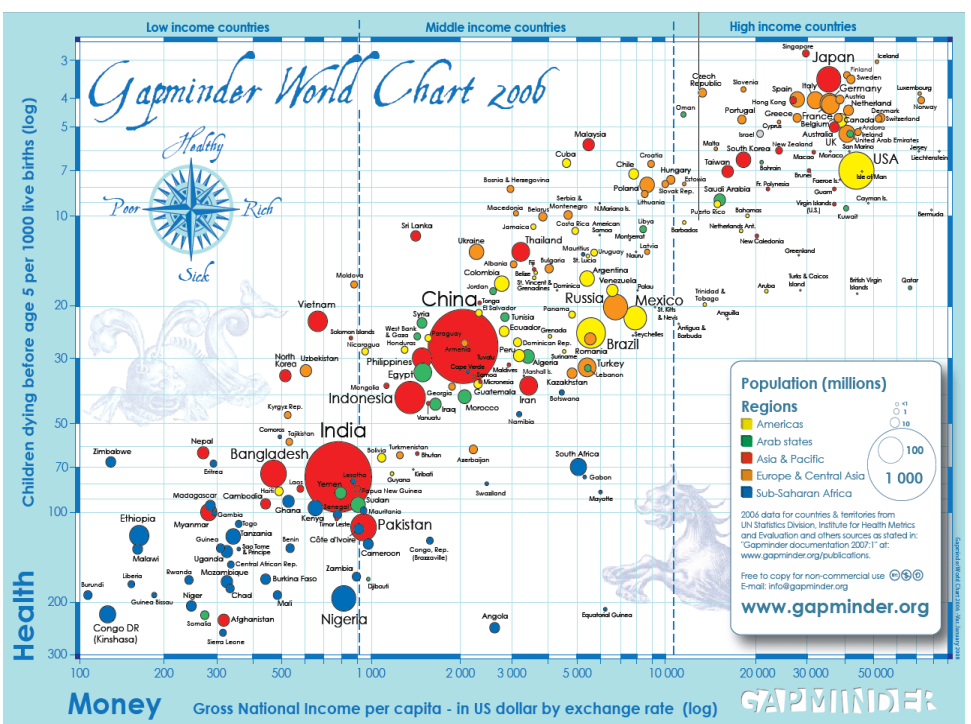


57

Discover the Unexpected

The Value of Visualization

58



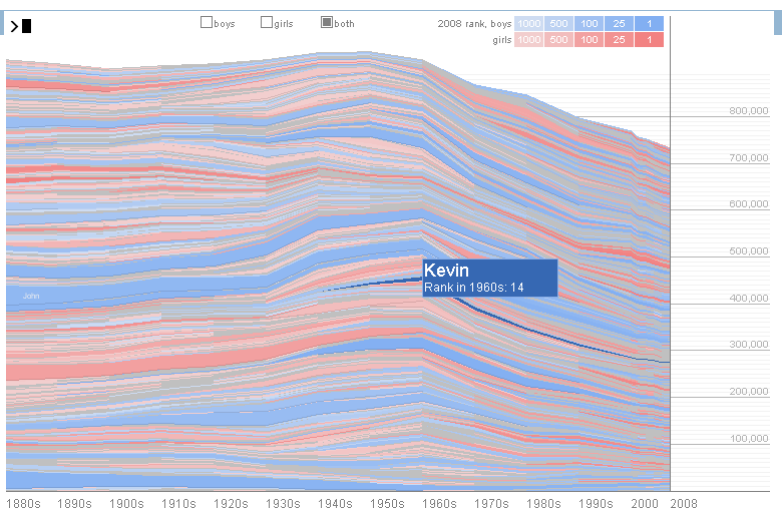
60

Making Decisions

The Value of Visualization

61

Example: BabyNameExplorer



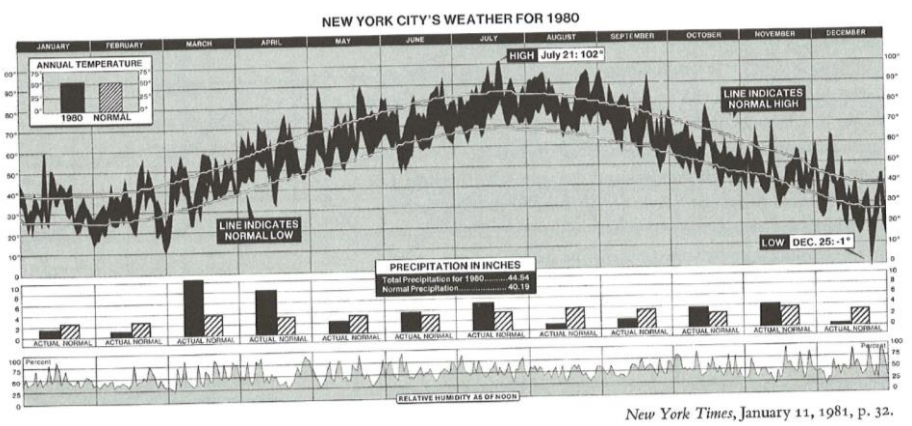
https://namerology.com/baby-name-grapher/

62

Find Patterns

The Value of Visualization

63



New York Times, January 11, 1981, p. 32.

64

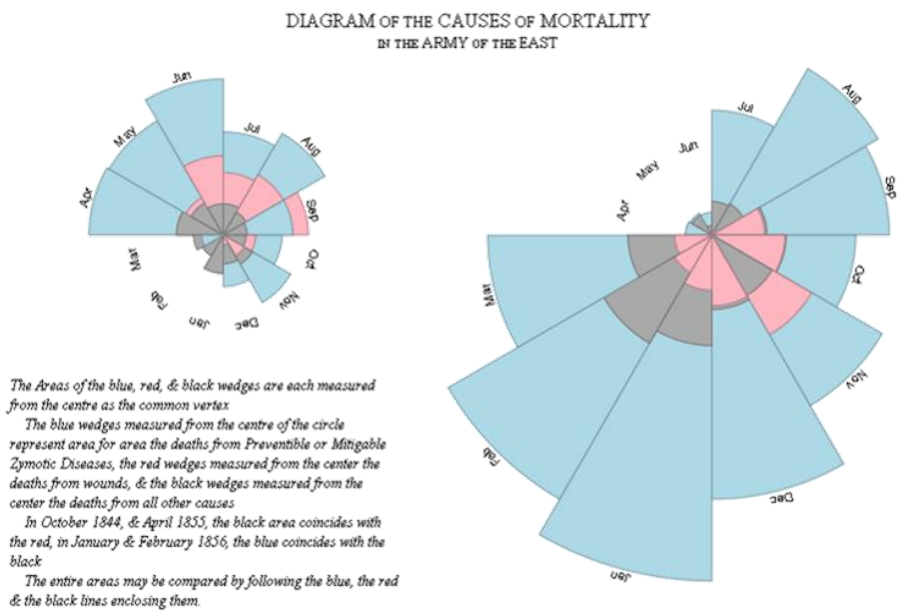
Tell a Story

The Value of Visualization

65

[Bostock and Heer, 2009]

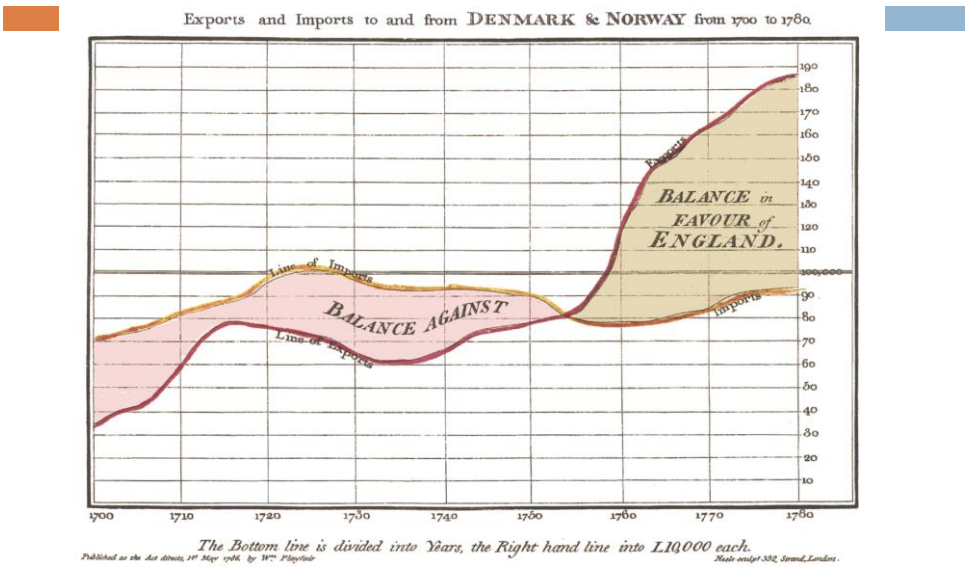
Nightingale's Roses



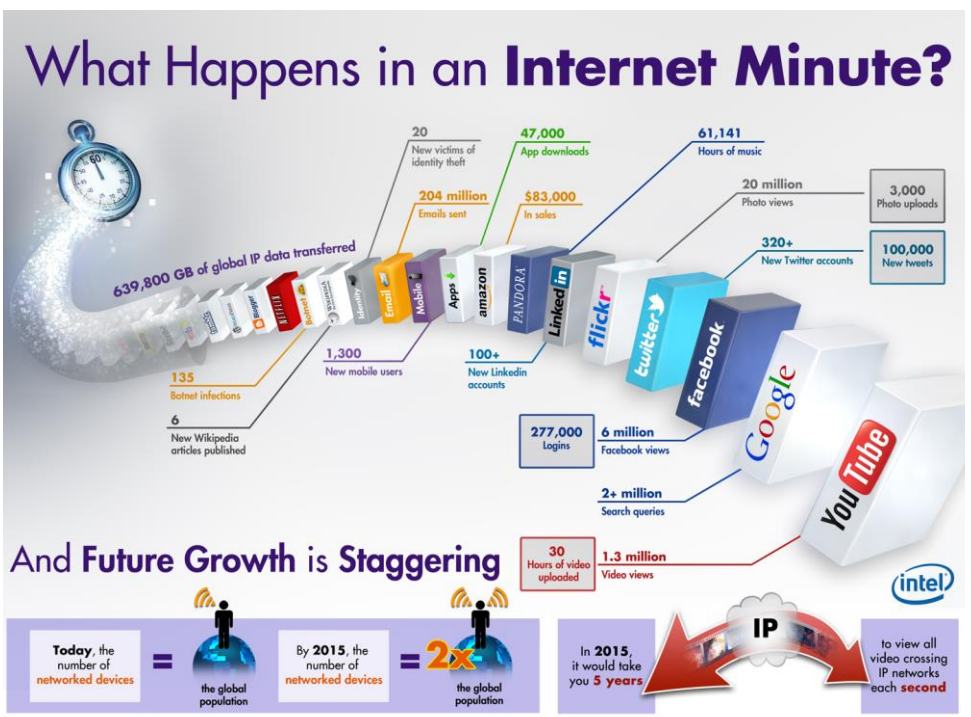
66

[Playfair, 1785]

Example: William Playfair (1759-1823)



67



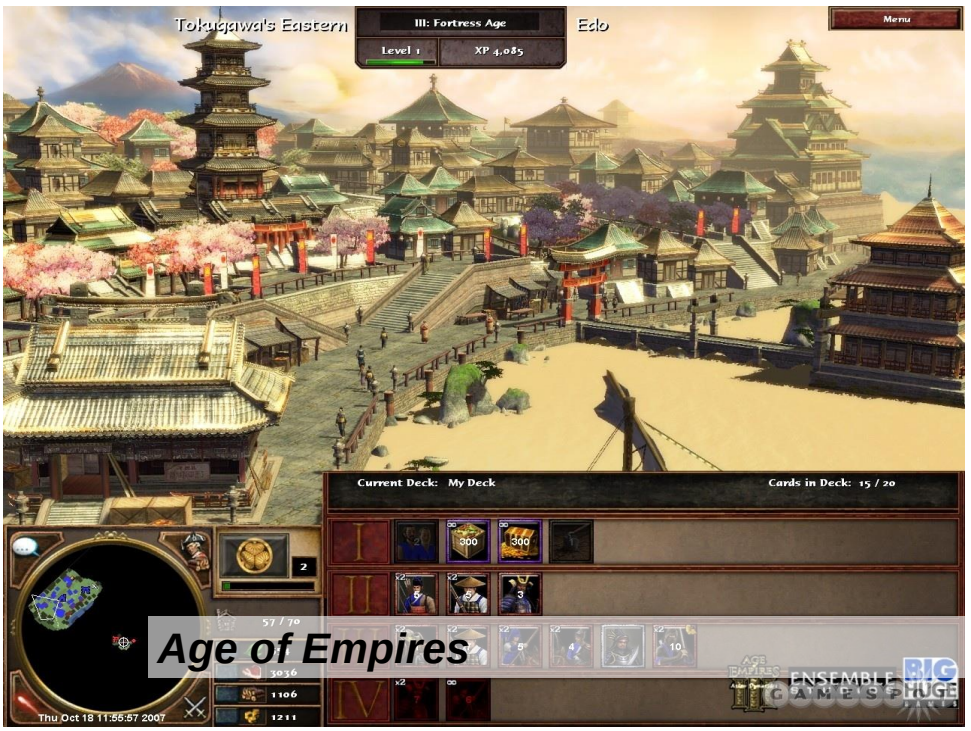
68

Visualization In Games

The Value of Visualization

69

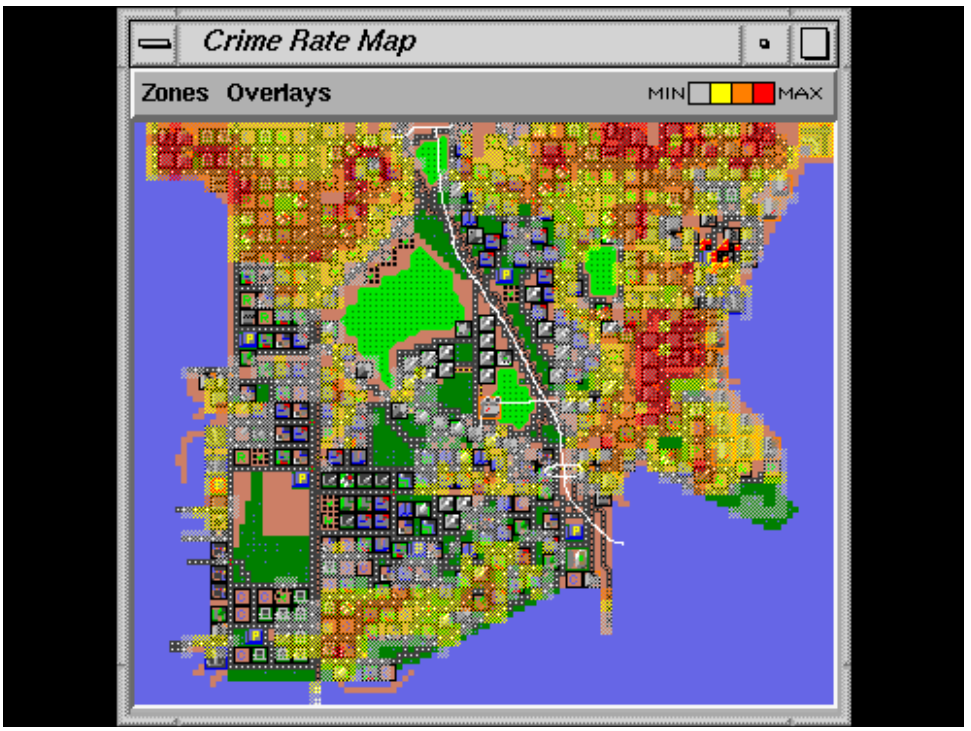
70


Tokugawa's Eastern
III: Fortress Age
Edo
Level 1
XP 4,085
Menu
Current Deck: My Deck
Cards in Deck: 15 / 20
Age of Empires
Thu Oct 18 11:55:57 2007

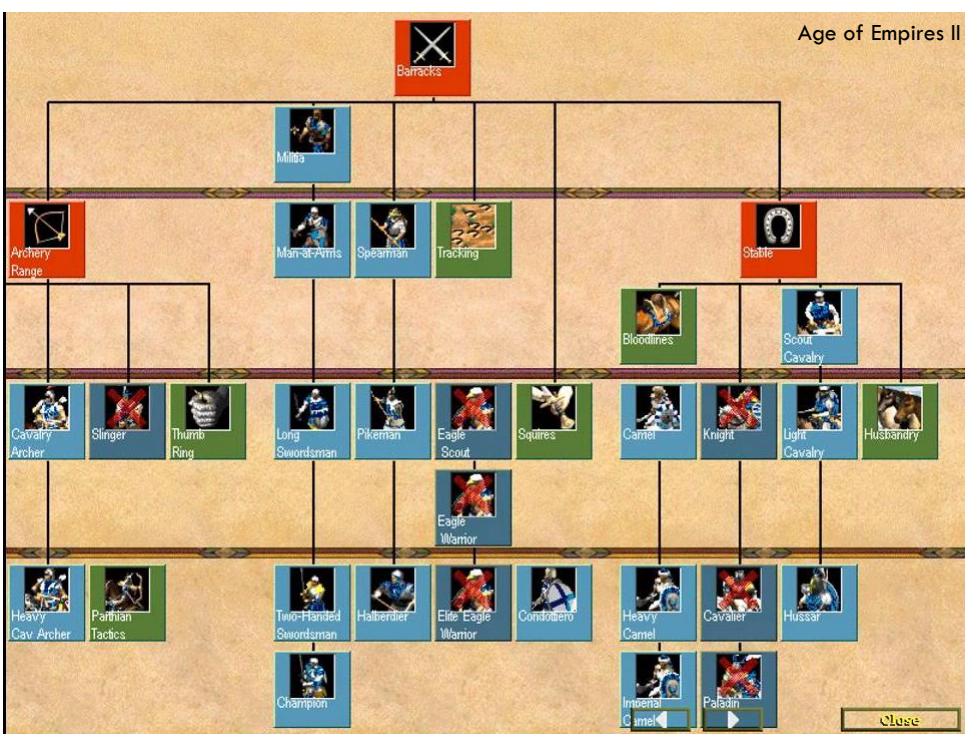
71


12787/+294
5810/+180
100/+18.1
20/20
19/20
Construction Completed
Squad Completed
Research Completed
Add-On Completed
Your enemy, Computer 1, captured a Relic!
Elapsed Time: 0:25:25
Order of the Sacred Rose
Team 1
Immolator
Order of the Sacred Rose - Team 1
Vehicle
Infantry
Morale

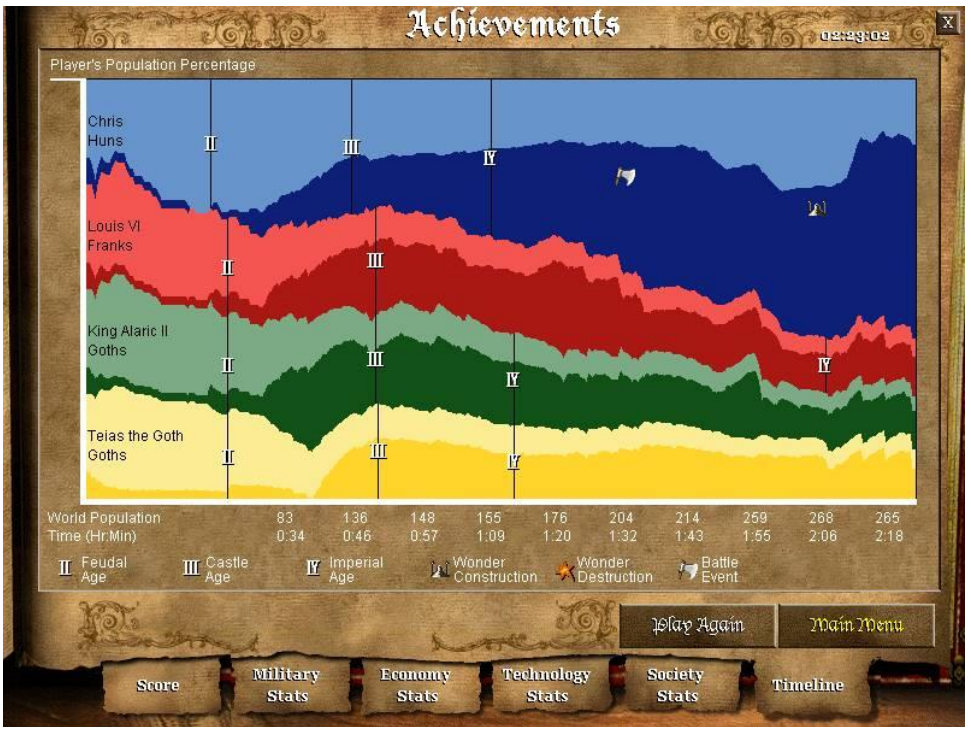
72


Crime Rate Map
Zones Overlays
MIN
MAX

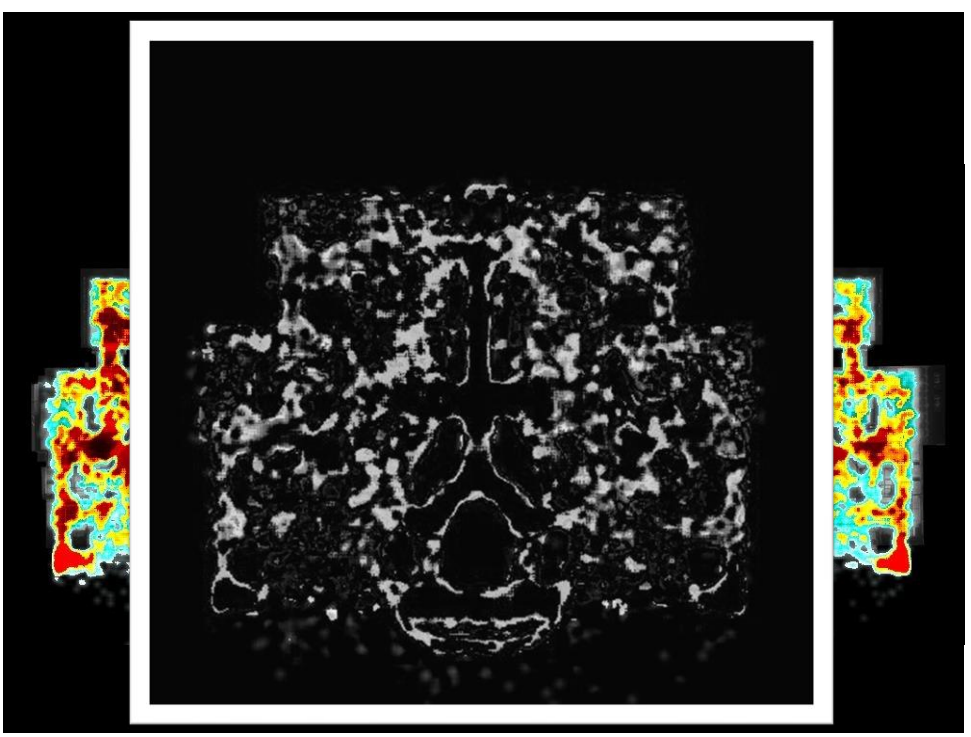
73


Age of Empires II
Barracks
Militia
Archery Range
Man-at-Arms
Spearman
Tracking
Stable
Bloodlines
Scout Cavalry
Cavalry Archer
Slinger
Thumb Ring
Long Swordsman
Pikeman
Eagle Scout
Squires
Camel
Knight
Light Cavalry
Husbandry
Eagle Warrior
Heavy Cav Archer
Parthian Tactics
Two-Handed Swordsman
Halberdier
Elite Eagle Warrior
Condottiero
Heavy Camel
Cavalier
Hussar
Champion
Imperial Camel
Paladin
Close

74


Achievements
Player's Population Percentage
Chris
Huns
Louis VI
Franks
King Alaric II
Goths
Teias the Goth
Goths
World Population 83 136 148 155 176 204 214 259 268 265
Time (Hr:Min) 0:34 0:46 0:57 1:09 1:20 1:32 1:43 1:55 2:06 2:18
II Feudal Age
III Castle Age
IV Imperial Age
Wonder Construction
Wonder Destruction
Battle Event
Play Again
Main Menu
Score
Military Stats
Economy Stats
Technology Stats
Society Stats
Timeline

75



76

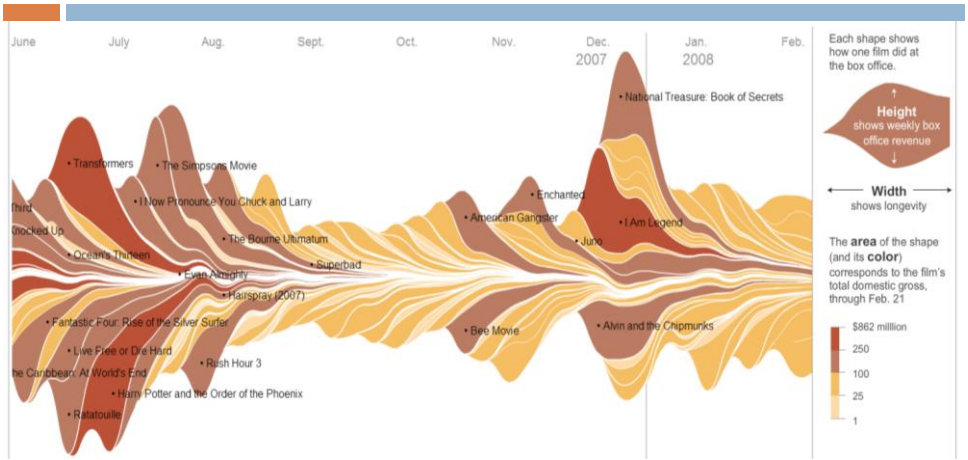
Visualization In Media

The Value of Visualization

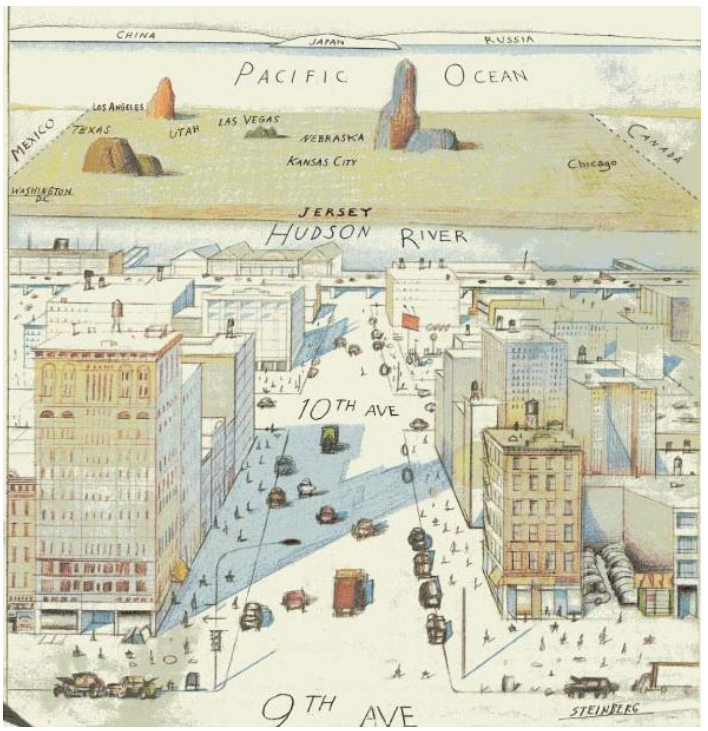
77

http://www.nytimes.com/interactive/2008/02/23/movies/20080223_REVENUE_GRAPHIC.html

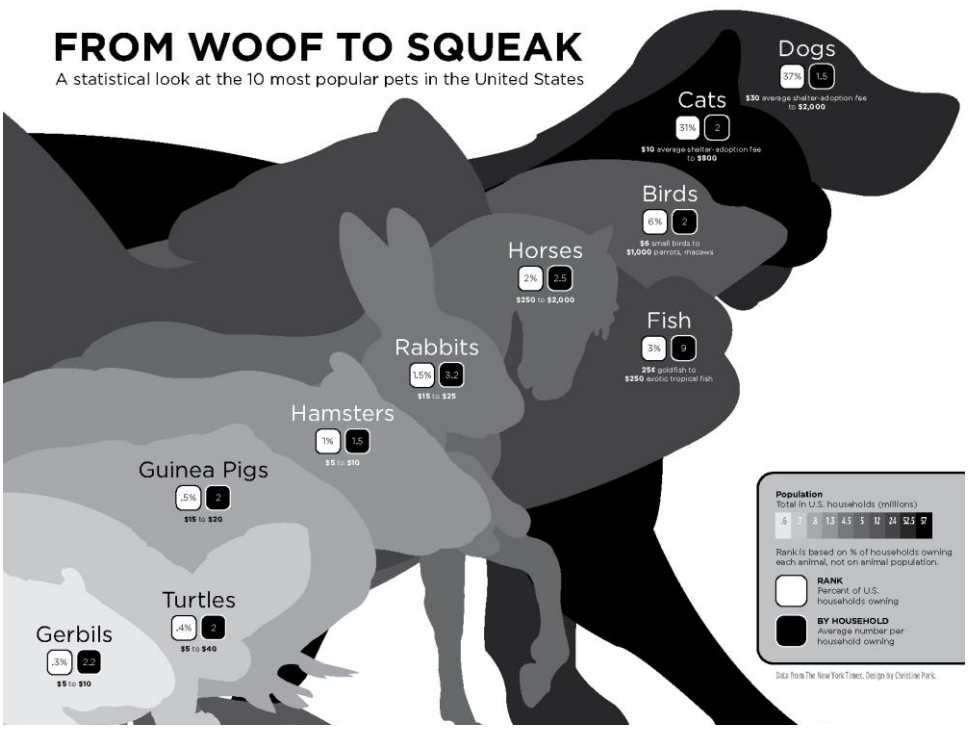
Box Office (1986-2008)



78

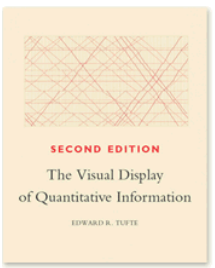

CHINA
JAPAN
RUSSIA
PACIFIC OCEAN
LOS ANGELES
MEXICO
TEXAS
UTAH
LAS VEGAS
NEBRASKA
KANSAS CITY
CANADA
Chicago
WASHINGTON D.C.
JERSEY
HUDSON RIVER
10TH AVE
9TH AVE
STEINBERG

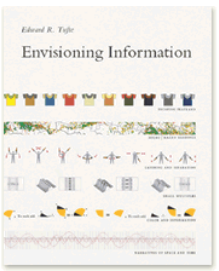
79


FROM WOOF TO SQUEAK
A statistical look at the 10 most popular pets in the United States
Dogs
37% 1.5
$30 average shelter-adoption fee to $2,000
Cats
31% 2
$10 average shelter-adoption fee to $800
Birds
6% 2
$6 small birds to $1,000 parrots, macaws
Horses
2% 2.5
$250 to $2,000
Fish
3% 9
25¢ goldfish to $250 exotic tropical fish
Rabbits
1.5% 3.2
$15 to $25
Hamsters
1% 1.5
$5 to $10
Guinea Pigs
.5% 2
$15 to $20
Turtles
.4% 2
$5 to $40
Gerbils
.3% 2.2
$5 to $10
Population
Total in U.S. households (millions)
.6 .7 .8 1.3 4.5 5 12 24 62.5 57
Rank is based on % of households owning each animal, not on animal population.
RANK
Percent of U.S. households owning
BY HOUSEHOLD
Average number per household owning
Data from The New York Times. Design by Christine Park.

80

More Examples?






Summary

A picture is worth a thousand words… an interactive visualization is worth a million!

Confucius
(Chinese philosopher)

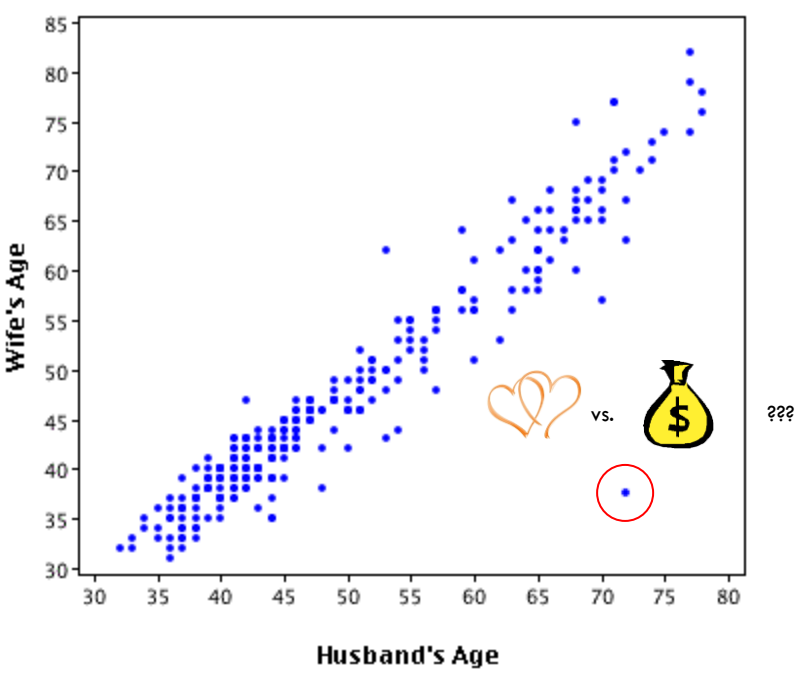
- Power of using the human visual system to see data
- Large number of examples of existing visualizations
- Efficient and well-designed graphics software at core

> The greatest value of a picture is when it forces us to notice what we never expected to see.
>
> – John W. Tukey. Exploratory Data Analysis. 1977.

The Power of Visualization

- The goal is to take all of this *data* and transform it into *information*
- How many terabytes of data we have collected doesn't matter, it's how many petaflops of *insights* we can generate from this data
- "*The purpose of computing is insight, not numbers.*" Dedication to his book: RW Hamming (1971). *Introduction to Applied Numerical Analysis*. McGraw Hill.
- We need to make the data understandable to people and a key way of doing this is through *visualization*

83



84

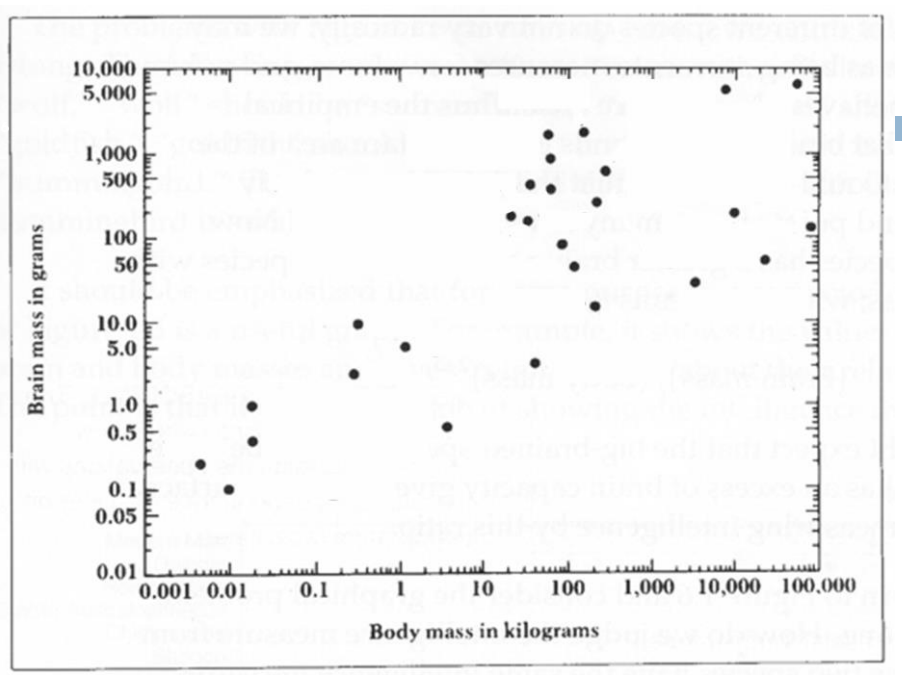
85

	A	B	C	D
1	Animal	Brain Weight (kg)	Body Weight (kg)	
2	Mountain beav	1.35	465	
3	Cow	465	423	
4	Grey wolf	36.33	119.5	
5	Goat	27.66	115	
6	Guinea pig	1.04	5.5	
7	Dipliodocus	11700	50	
8	Asian elephant	2547	4603	
9	Donkey	187.1	419	
10	Horse	521	655	
11	Potar monkey	10	115	
12	Cat	3.3	25.6	
13	Giraffe	529	680	
14	Gorilla	207	406	
15	Human	62	1320	
16	African elephar	6654	5712	
17	Triceratops	9400	70	
18	Rhesus monke	6.8	179	
19	Kangaroo	35	56	
20	Golden hamste	0.12	1	
21	Mouse	0.023	0.4	

Which animal weights the least/most?
Is there a relationship between brain weight and body weight?
If so, are there any outliers?

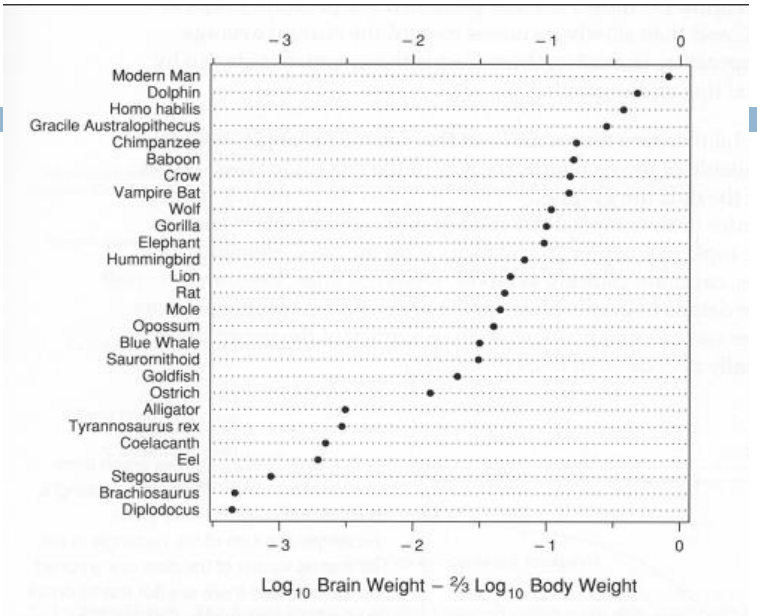
Rousseeuw, P.J. & Leroy, A.M. (1987) Robust Regression and Outlier Detection. Wiley, p. 57

85



86

87



WS Cleveland – The Elements of Graphing Data, 1994

87

Visualization Through the Ages

88

- Hand-drawn illustration[1] of water by Leonardo da Vinci from his studies to determine the processes underlying water flow (1510)

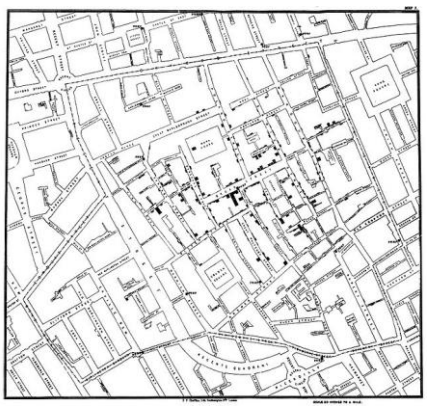
1 – Leonardo da Vinci. *OldMan Seated on Rocky Outcrop, Seen in Profile to the Right, with Water Studies*. Windsor Castle, Royal Liberty, RL 12579r, c. 1510-1513.

88

Visualization Through the Ages

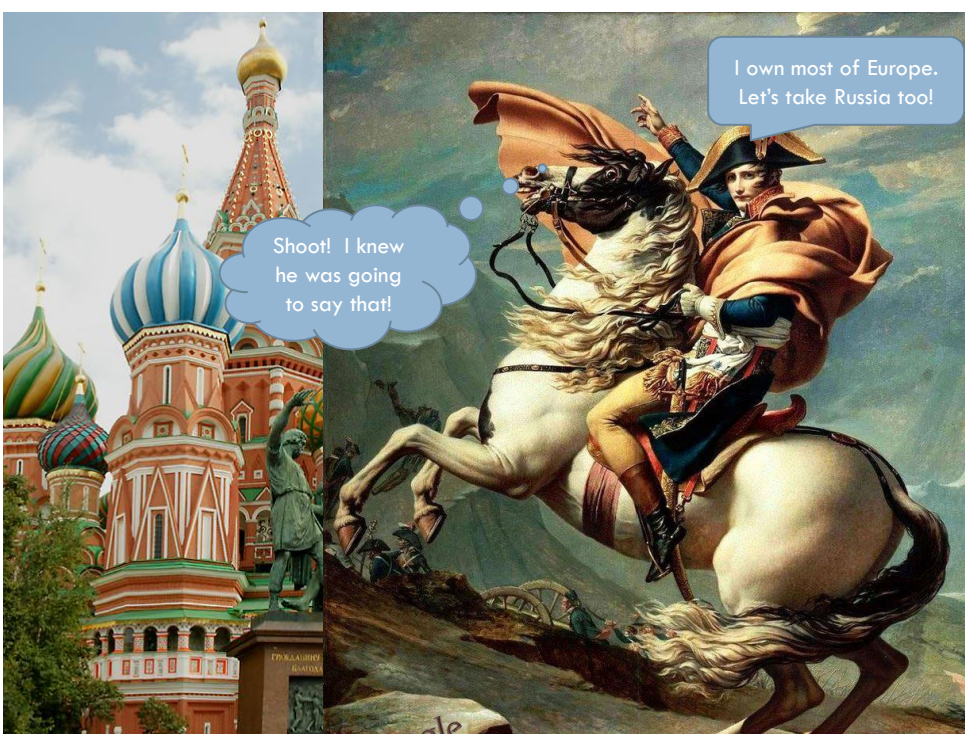
89

- John Snow's map of Cholera cases in the London epidemic of 1854[1]



1 – The Visual Display of Quantitative Information, E. R. Tufte, 1983

89

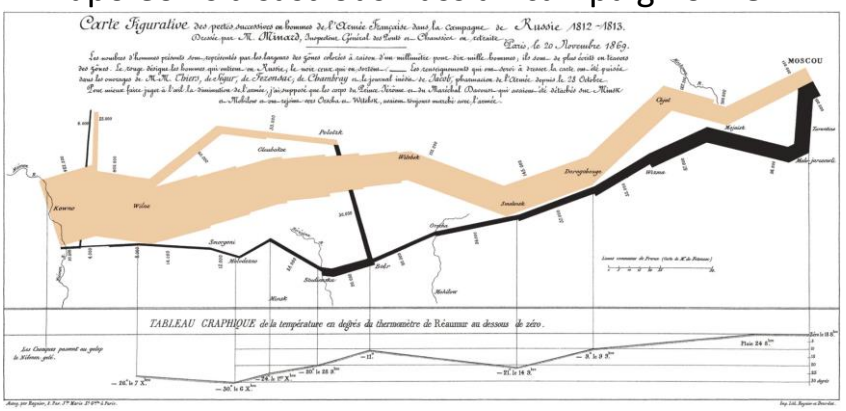


90

Visualization Through the Ages

91

- Charles Minard's 1869 flow map[1] showing Napoleon's disastrous Russian campaign of 1812.



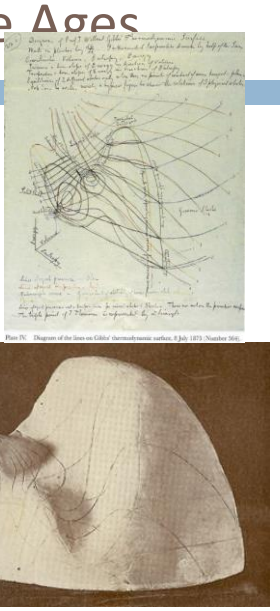
1 – Charles Joseph Minard: Mapping Napoleon's March, 1861 by John Corbett, Center for Spatially Integrated Social Science

91

Visualization Through the Ages

92

- James Maxwell's[1] thermodynamic surface sculpture (1874)
- Three-dimensional plot of the states of a fictitious water-like substance
- Coordinates are volume (x), entropy (y), and energy (z)



1 – James Clerk Maxwell and P. M. Harman (2002), The Scientific Letters and Papers of James Clerk Maxwell, Volume 3: 1874-1879, Cambridge University Press

92

Visualization Through the Ages

93

- 1936 *American Journal of Cancer XXVII*. P. 49: "The hexagonal tube … offers distinct advantages with its flat sides permitting good visualization"
- 1973 *Nature* 17 Aug. P. 410-11: "Direct visualization of biological material at this level would tell us much about the structure and mode of action macromolecules."
- Visualization in Scientific Computing ACM SIGGRAPH Computer Graphics, 21(6) – Special Issue, 1987.

1 – The first two citations on this page are borrowed from Pat Hanrahan's "The Purpose of Visualization" lecture: http://graphics.stanford.edu/courses/cs448b-04-winter/lectures/purpose/walk003.html

93

Why is Visualization Helpful?

94

- It utilizes the high bandwidth of the human visual systems
- The human mind is fast and parallel
- Humans are great at visual pattern recognition
- We have pre-attentive visual phenomena
- Visual tools can extend memory and cognitive capacity
- We think visually!
- "A picture is worth a thousand words." – *Printers Ink,* pp. 96-97 December 8, 1921

94

Is a Picture Worth a Thousand Words?

95

- Diagram have relationships defined within them (topological and geometric)
- Information can be indexed and ordered in logical sequences
- Information is processed differently when presented in textual form as opposed to diagrammatically
- Diagrams have the ability to group information spatially which can reduce the search process as well as support perceptual inferences where are difficult to make from text

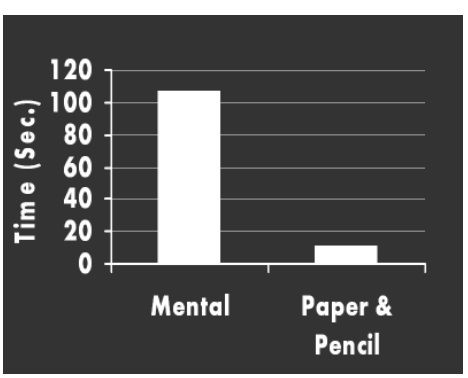
1 - Larkin, J. & Simon, H. (1987) Why a diagram is (sometimes) worth ten thousand words. Cognitive Science, 11:65-992

95

Let's Exercise Our Brain

96

207
x 52
414
10350
10764



1 – The image on this page is borrowed from Pat Hanrahan's "The Purpose of Visualization" lecture: http://graphics.stanford.edu/courses/cs448b-04-winter/lectures/purpose/walk003.html

96

Why Is Visualization So Helpful?

97

- Amplifies cognition
  - Expands our working memory by allowing us to offload results
  - Reduces the search time
  - Pattern detection and recognition can be improved through perceptual cues and inference
  - Visualizations can be designed to control attention interaction for improving cognition

Readings in Information Visualization: Using Vision to Think, SK Card, J Mackinlay and B.Shneiderman, 1999

97

Visualization: Definition

- Anyone?

- Components:
  - Data
  - Graphics
  - Interaction
  - Human
  - Computer
  - Analysis
  - Algorithms

98

Visualization – Definition?

- Wikipedia: **Visualization** is any technique for creating images, diagrams, or animations to communicate a message.
- M-W.com: the act or process of interpreting in visual terms or of putting into visible form.

99

Visualization – Definition!

- "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]

100

Visualization – Definition!

- Focus on Card, Mackinlay & Shneiderman's version…
- *Visualization* is the **graphical** representation of **data** using **interactive images** to aid **cognition**
  - Graphical + images: computer graphics
  - Interactive: human-computer interaction
  - Cognition: understanding, mental model

101

What is Visualization?

102

- "The use of computer-supported, interactive visual representations of data to amplify cognition."[1]
- This is not simply the process of making a graphic or an image, the goal is to create insight, not pretty pictures
- We want to help people form a mental image of something and internalize their own understanding
- We want to promote discovery, decision making and explanations

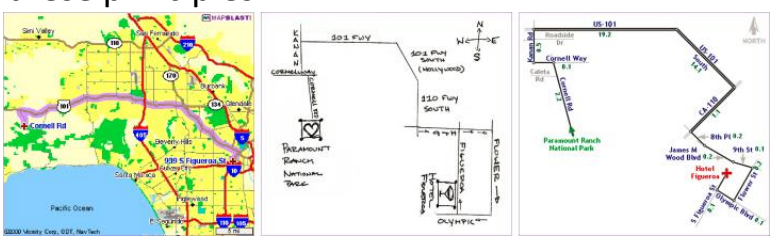
1-Readings in Information Visualization: Using Vision to Think, SK Card, J Mackinlay and B.Shneiderman, 1999

102

What is Visualization

103

- We want to find and utilize cognitive and perceptual principles
- We want to optimize our visualizations and our interactions with the visualization according to these principles



Maneesh Agrawala, Chris Stolte: Rendering effective route maps: improving usability through generalization. SIGGRAPH 2001: 241-249

103

Scientific Visualization

104

- Primarily relates to and represents something physical or geometrics
- The structure of the data is typically defined or given
- Examples
  - Air flow over a wing
  - Stresses on a girder
  - Organs in the human body
  - Molecular bonding

1 – Descriptions on this slide are borrowed from John Stasko's "InfoVis Overview" lecture: http://www.cc.gatech.edu/~stasko/7450/Notes/overview.pdf

104

Information Visualization

105

- Primarily relates to data that does not have a direct physical correspondence
- Notion of the data is abstract
- Examples
  - Baseball statistics
  - Stock trends
  - My social network

1 – Descriptions on this slide are borrowed from John Stasko's "InfoVis Overview" lecture: http://www.cc.gatech.edu/~stasko/7450/Notes/overview.pdf

105

InfoVis vs. SciVis

- If data has some natural 2D or 3D form
  - Scientific data -> **scientific visualization**
  - **Example**: air flow around space shuttle, CAT scan data, ocean temperature readings
- If data is abstract
  - Abstract data -> **information visualization**
  - **Example**: multidimensional database, text, trees, graphs
- Most differentiated by communities
  - SciVis people from computer graphics background
  - InfoVis people from HCI background
- This course -> Infovis
- Prof. Jeong's computer graphics -> Scivis

106

Purpose of Visualization

107

- Analysis – Understand your data better and act upon that understanding
  - Given a data set, compare, contrast, assess, evaluate
  - Solve a problem!
- Presentation – Communicate and inform others more effectively
- Visualization is most useful in **exploratory data analysis**[1]

1 – J. W. Tukey. Exploratory Data Analysis

107

108

"Information visualization is ideal for exploratory data analysis. Our eyes are naturally drawn to trends, patterns, and exceptions that would be difficult or impossible to find using more traditional approaches, such as tables or text, including pivot tables. When exploring data, even the best statisticians often set their calculations aside for a while and let their eyes take the lead."

S. Few

Now You See It

108

The Information Seeking Mantra

109

Overview first,
then zoom and filter,
details on demand

1 - B. Shneiderman. *The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations*. In the Proceedings of the IEEE Symposium on Visual Languages, pp. 336-343, 1996.

109

Tasks for Visualization

110

- **Searching and browsing** - find a specific piece of information, inspect data, seek information
- **Analyze** – do comparisons, differences, look for outliers, extrema and patterns
- **Monitor** – look for changes and trends

110

111

"Contained within the data of any investigation is information that can yield conclusions to questions not even originally asked. That is, there can be surprises in the data … To regularly miss surprises by failing to probe thoroughly with visualization tools is terribly inefficient because the cost of intensive data analysis is typically very small compared with the cost of data collection."

W. S. Cleveland

The Elements of Graphing Data

111

Visual Analytics

112

- Visualization is good for exploring data, but we can do more than just explore
- "Visual analytics is the science of analytical reasoning facilitated by interactive visual interfaces"[1]
- Visual analytics combines automated analysis techniques with interactive visualizations for an effective understanding, reasoning and decision making on the basis of very large and complex data sets.[2]
- "A graphic display has many purposes but it achieves its highest value when it forces us to see what we were not expecting."[3]

1 - J. J. Thomas and K. A. Cook (Ed.). *Illuminating the Path: The R&D Agenda for Visual Analytics*. National Visualization and Analytics Center, 2005.
2 – Keim et al. chapter in *Information Visualization: Human-Centered Issues and Perspectives*, 2008.
3 – H. Wainer. *A Graphic Discovery: A Trout in the Milk and Other Visual Adventures*.

112

Challenges in Visualization

113

- **Scale**
  - Challenge often arises when data sets become large
- **Diversity**
  - Data is of varying types, forms, sizes
- **Evaluation**
  - How can we prove that a visualization helped?
  - Benefits are not easily quantifiable and measured.

113

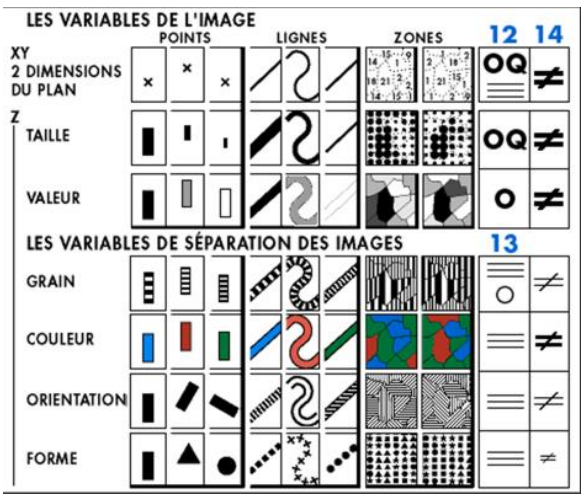
What will this course cover?

114

114

Data Representations

115

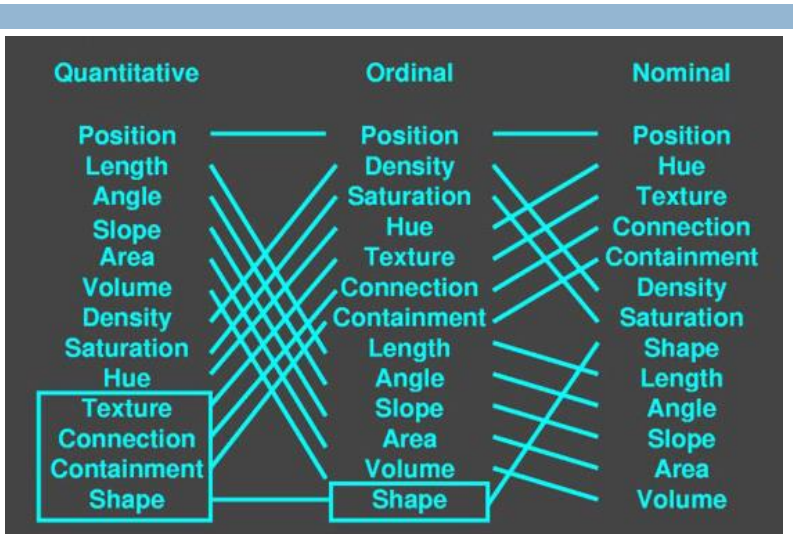


J Bertin. The Semiology of Graphics

115

Perception and Cognition

116

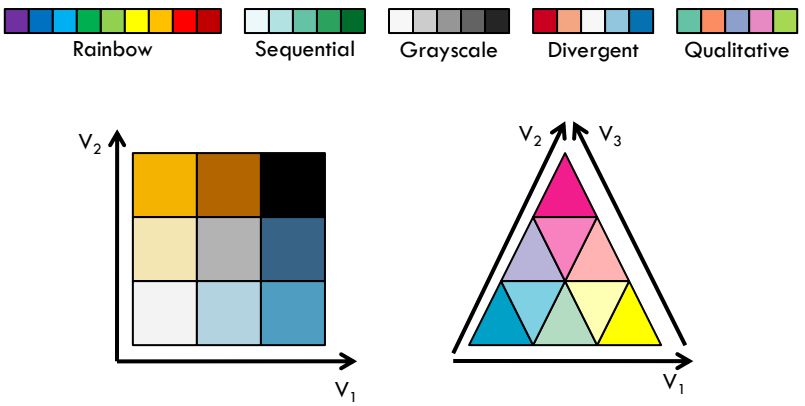


J Mackinlay. Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986.

116

Color

117



117

Interaction

118

"The capacity of vibrissae, hairs, claws, and horns **to feel things at a distance** is not different in principle from the ability of a man to use a cane or probe to detect the mechanical encounters at the end of the artificial appendage to his hand. The use of **tools**, from sticks, clubs, and rakes to more elaborate ones like screwdrivers and pliers or even fishing rods and tennis rackets, is probably based on a perceptual capacity of the body that is found in other animals. The remarkable fact is that when a man touches something with a stick he feels it at the end of the stick, not in the hand. This is a difficulty for the theory of sensation-based perception; it requires some such postulate as **the projecting of sensations outward from the body**. But we entertain the hypothesis that information for the mechanical disturbance at the end of the stick is obtained by the hand as a perceptual organ, including information about the length and direction of the stick. The sensations in the hand itself are irrelevant. The surface of an organism, it should be remembered, is actually a **boundary** between the organism and its environment, and the boundary is **not always or everywhere as clean-cut** as the hairless human philosopher tends to think."

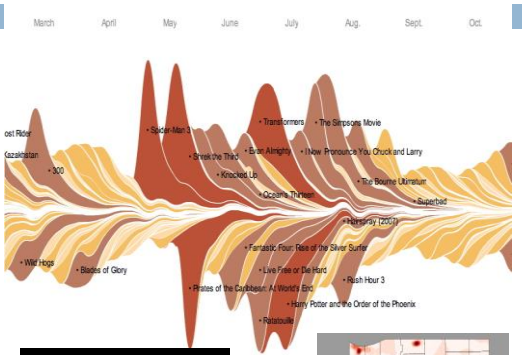
Gibson, J. J. The Senses Considered as Perceptual Systems. p.100-102]

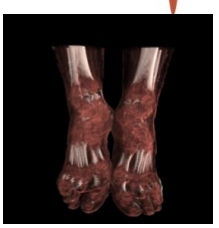
118

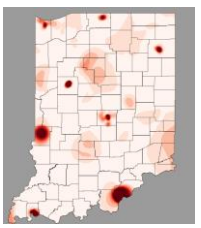
Visual Metaphors

119

http://images.fastcompany.com/upload/poster_beer_1300.jpg







* - Theme River Image from: http://www.nytimes.com/interactive/2008/02/23/movies/20080223_REVENUE_GRAPHIC.html#

119

Watch Lecture Video

120

https://www.youtube.com/watch?v=1GhZisgc6DI&list=PLT4XLHmqHJBeB5LwmRmo6ln-m7K3lGvrk&index=1

Intro (Ch 1), Visualization Analysis & Design, 2021

120