

Information Visualization and Visual Analytics (M1522.000500)

Introduction to Information Visualization

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Director, Human-Computer Interaction Lab
Seoul National University

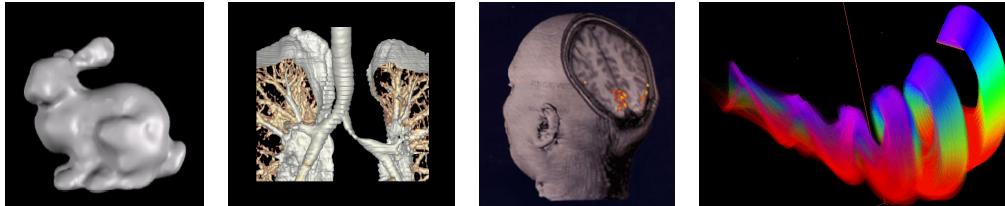
Introduction

What is it?

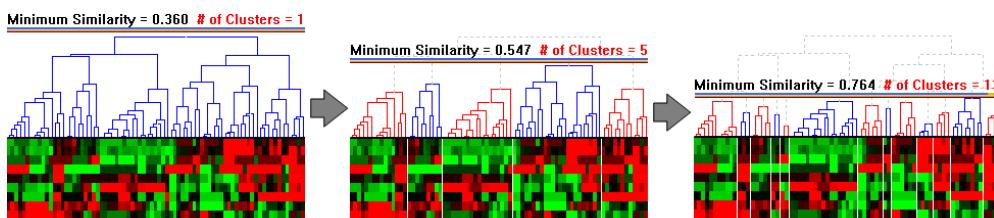
- Information Visualization vs. Scientific Visualization
- Data Visualizations – its power
- Data Visualization – definition

Visualization

- Scientific Visualization



- Information Visualization - Abstract data



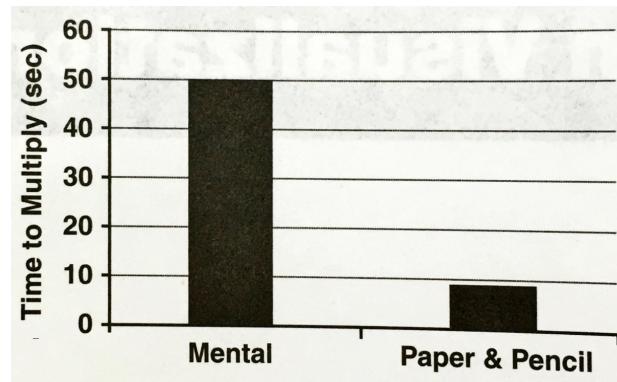
Information Visualization and Visual Analytics - Introduction

Introduction

Why Use an External Representation?

- Finding the *artificial memory* that best supports our natural means of perception
 - Bertin, 1983

$$\begin{array}{r}
 & 34 \\
 & \times 72 \\
 \hline
 & 68 \\
 238 \\
 \hline
 2448
 \end{array}$$



Information Visualization and Visual Analytics - Introduction

Introduction

Anything Interesting?

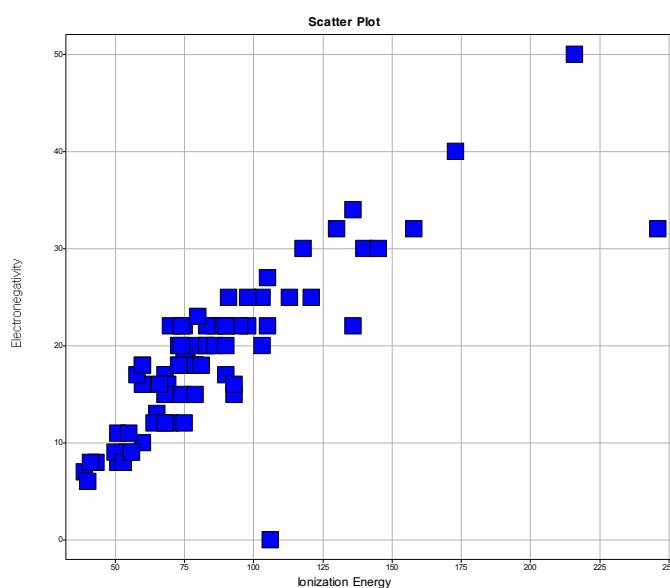
- Periodic Table Data

A	B	C	D	E	F	G	H	I	J	K
Element	P1	P2	Atomic Num	Atomic Mas	Atomic Rad	Ionic Radius	Ionization E	Electronega	C1	C2
2 Ac	140	0	89	227	200	126	51	11	62	56
3 Ag	630	80	47	107	144	129	75	18	124	40
4 Al	750	160	13	27	143	67	60	16	28	25
5 Ar	1050	160	18	39	98	154	158	32	176	51
6 As	870	120	33	75	120	72	98	22	115	33
7 At	990	40	85	210	140	76	95	22	119	22
8 Au	630	40	79	197	144	99	91	25	131	22
9 B	750	200	5	10	85	41	83	20	101	8
10 Ba	80	40	56	137	222	149	51	8	46	56
11 Be	80	200	4	9	112	59	93	15	82	15
12 Bi	870	40	83	209	150	117	73	20	140	27
13 Br	990	120	35	79	114	182	118	30	161	44
14 C	810	200	6	12	77	30	113	25	82	1
15 Ca	80	120	20	40	197	114	60	10	70	51
16 Cd	690	80	48	112	151	109	90	17	113	43
17 Cl	990	160	17	35	100	167	130	32	173	47
18 Co	500	120	27	59	125	83	79	18	120	30
19 Cr	320	120	24	52	128	75	68	17	91	28
20 Cs	20	40	55	132	265	181	39	7	7	56
21 Cu	630	120	29	63	128	87	76	19	118	32
22 F	990	200	9	19	72	119	173	40	39	1
23 Fe	440	120	26	55	126	83	79	18	115	32
24 Fr	20	0	87	223	269	194	40	6	1	56
25 Ga	750	120	31	69	135	76	60	18	89	31
26 Ge	810	120	32	72	122	87	79	20	118	33
27 H	20	240	1	1	32	0	136	22	40	1
28 He	1050	240	2	4	31	93	246	32	1	1
29 Hf	200	40	72	178	159	85	70	12	95	44
30 Hg	690	40	80	200	151	116	103	20	147	27
31 I	990	80	53	126	133	206	105	27	153	44
32 In	750	80	49	114	167	94	58	17	93	42
33 Ir	500	40	77	192	136	82	90	22	116	25
34 K	20	120	19	39	227	152	43	8	37	56
35 Kr	1050	120	36	83	112	169	140	30	163	47

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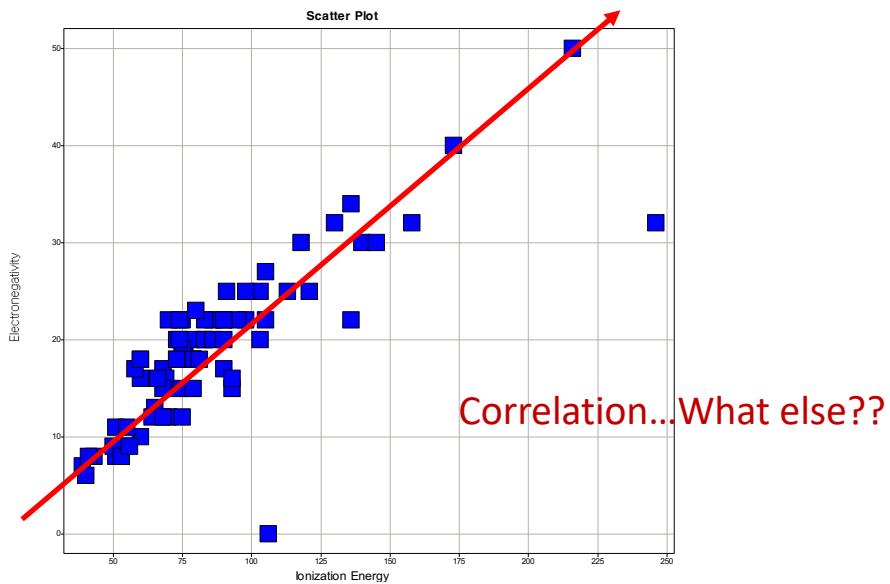
Introduction

Anything Interesting?



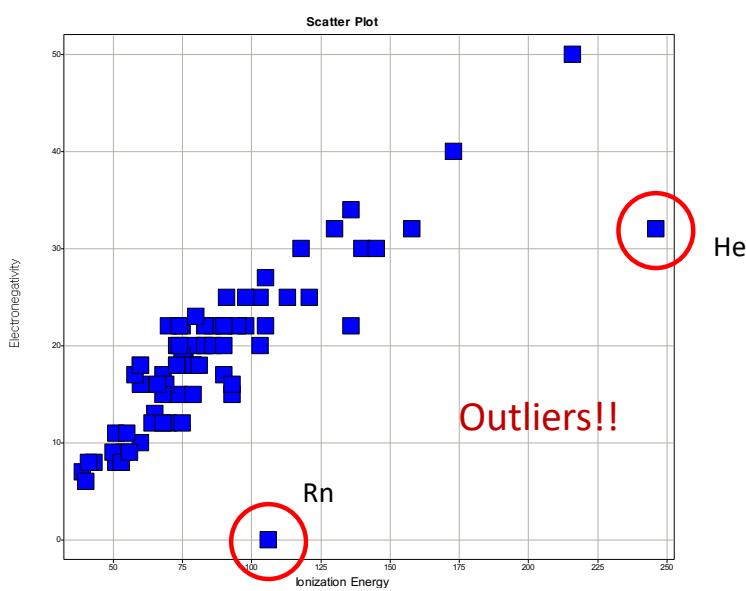
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Anything Interesting?



Information Visualization and Visual Analytics - Introduction

Anything Interesting?



Information Visualization and Visual Analytics - Introduction

Visualizations Reveal Structures

- Statistical characterization of datasets is a very powerful approach
 - losing information through summarization → hide the true structure of the dataset

Anscombe's Quartet: Raw Data

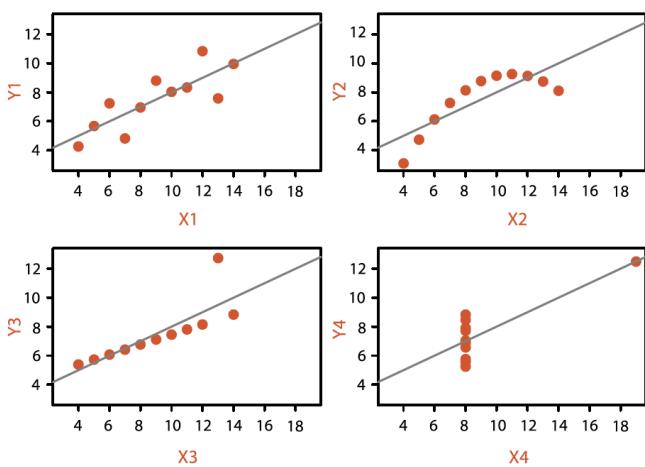
	1		2		3		4	
	X	Y	X	Y	X	Y	X	Y
	10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
	8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
	13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
	9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
	11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
	14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
	6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
	4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
	12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
	7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
	5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89
Mean	9.0	7.5	9.0	7.5	9.0	7.5	9.0	7.5
Variance	10.0	3.75	10.0	3.75	10.0	3.75	10.0	3.75
Correlation	0.816		0.816		0.816		0.816	

Descriptive statistics => Over-simplification

Introduction

Why Show the Data in Details?

- Identical descriptive statistics → very different structures
- what about features hidden in larger and/or more complex datasets?

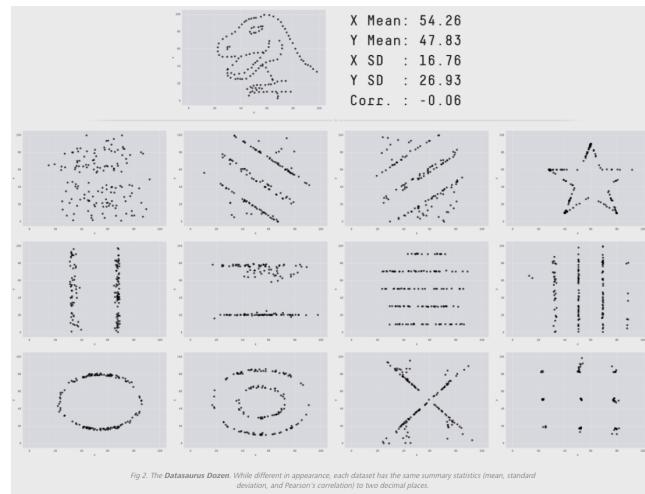


*...make **both** calculations **and** graphs.
Both sorts of output should be studied;
each will contribute to understanding.*

F. J. Anscombe, 1973

Same Stats, Different Graphs

- Generating Datasets with Varied Appearance and Identical Statistics



<https://www.autodeskresearch.com/publications/samestats>

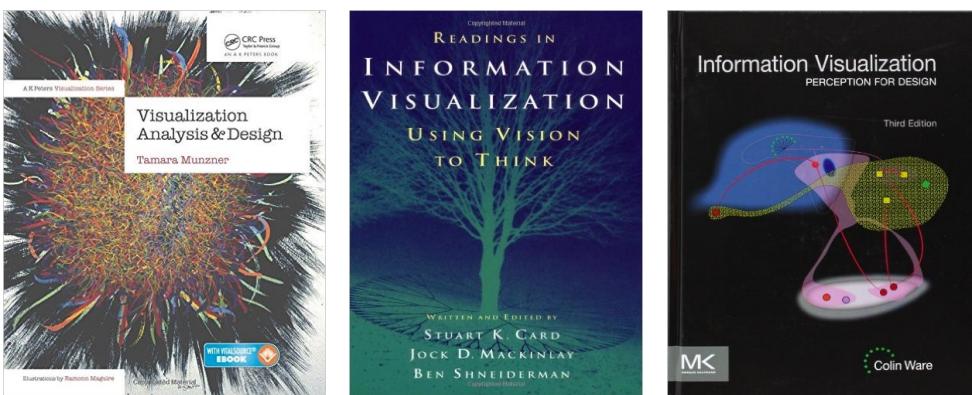
Information Visualization and Visual Analytics - Introduction

Introduction

Definition of Visualization

- The use of computer-supported, interactive, visual representations of **abstract** data to amplify **cognition**

- Stuart Card, Jock Mackinlay, Ben Shneiderman, 1999

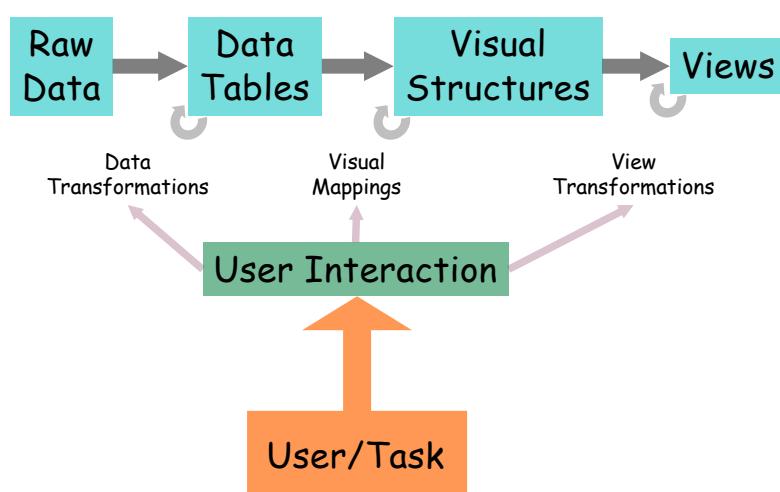


Information Visualization and Visual Analytics - Introduction

Definitions

- The use of computer-supported, interactive, visual representations of **abstract** data to amplify **cognition**
 - Stuart Card, Jock Mackinlay, Ben Shneiderman, 1999
- Finding the *artificial memory* that best supports our natural means of perception
 - Bertin, 1983
- Provide tools that present data in a way to help people understand and gain insight from it

InfoVis Reference Model



Introduction

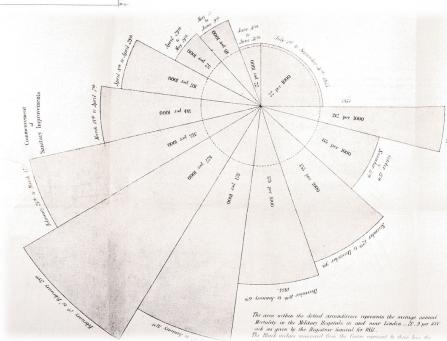
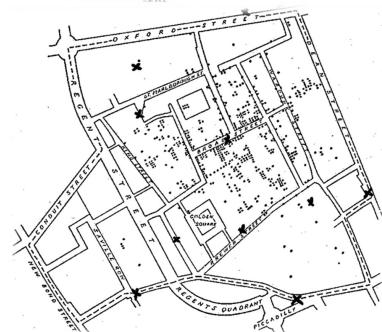
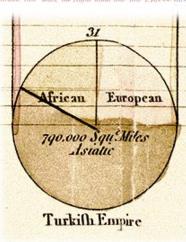
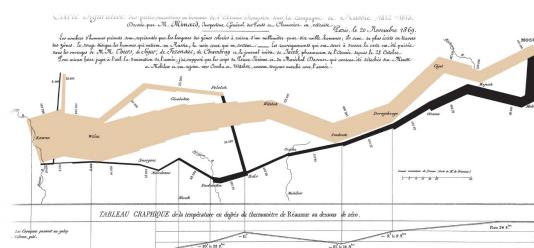
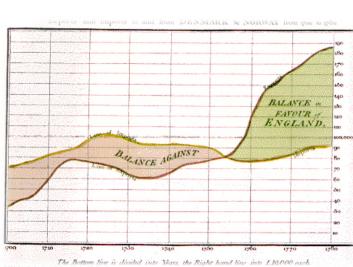
InfoVis is Interdisciplinary

- Graphics: drawing in real time (<100 ms)
 - Cognitive psychology: appropriate representation
 - HCI: using users and tasks to guide design and evaluation

Information Visualization and Visual Analytics - Introduction

Historical Aspect

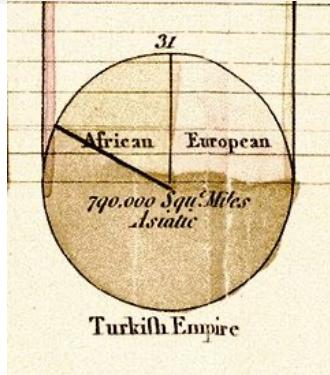
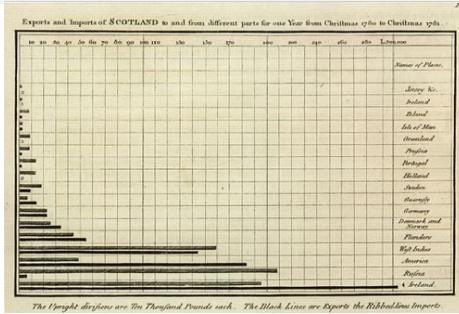
Data Visualizations – Historical Examples



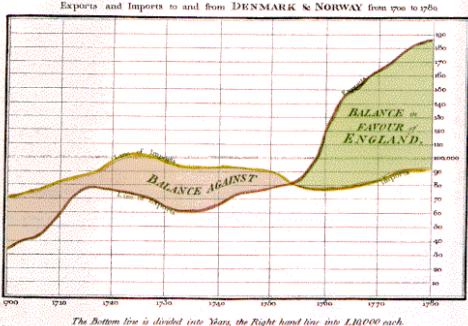
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Historical Aspect

Data Visualizations – Historical Examples



"charts communicated better than tables of data"



source: https://en.wikipedia.org/wiki/William_Playfair

Information Visualization and Visual Analytics - Introduction

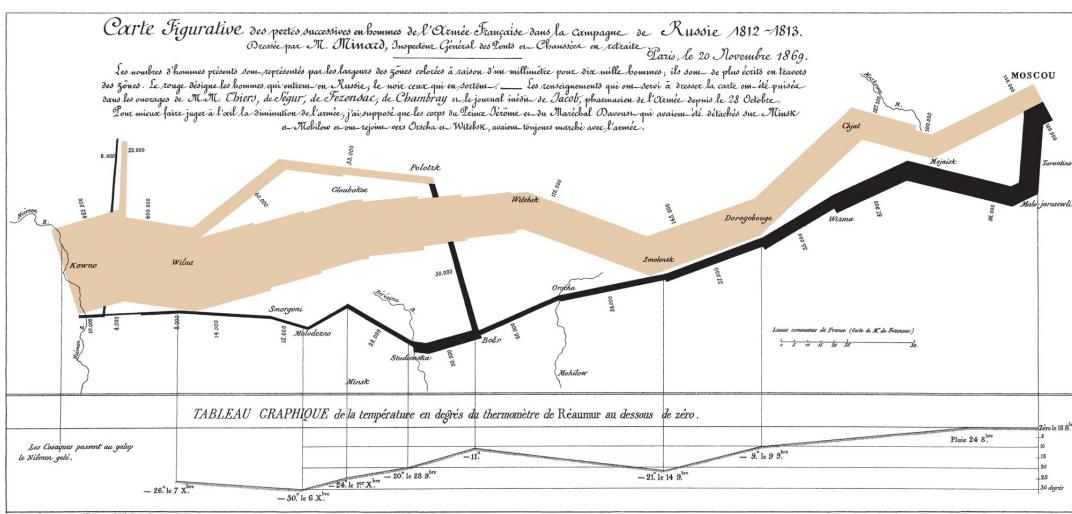
William Playfair (1759~1823)

Scottish civil engineer

Playfair has been credited with inventing the **line**, **bar**, **area**, and **pie** charts.

Historical Aspect

Data Visualizations – Historical Examples



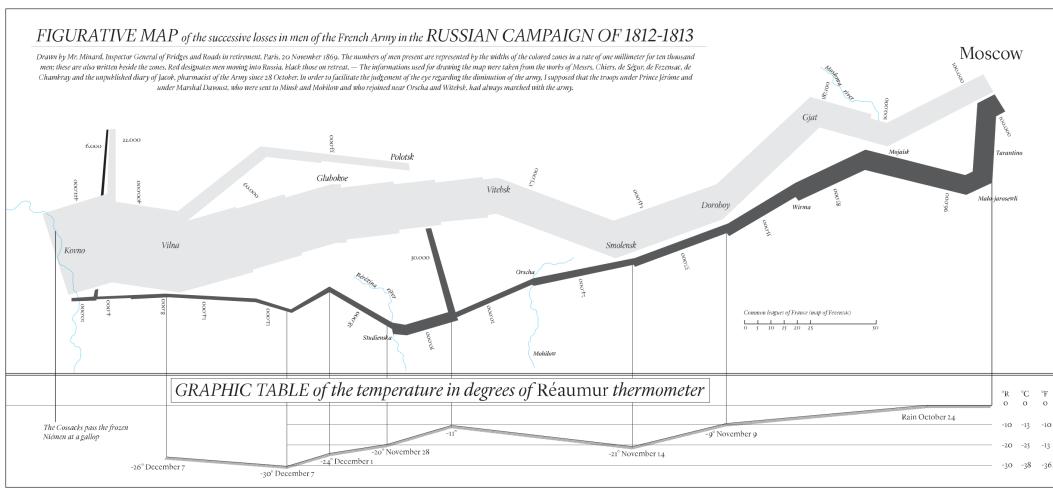
Size of army
Position
Direction of movement
Temperature
Time

Advance of Napoleon's Grande Armée into Russia in 1812
Charles Joseph Minard, 1861

Information Visualization and Visual Analytics - Introduction

Historical Aspect

Data Visualizations – Historical Examples



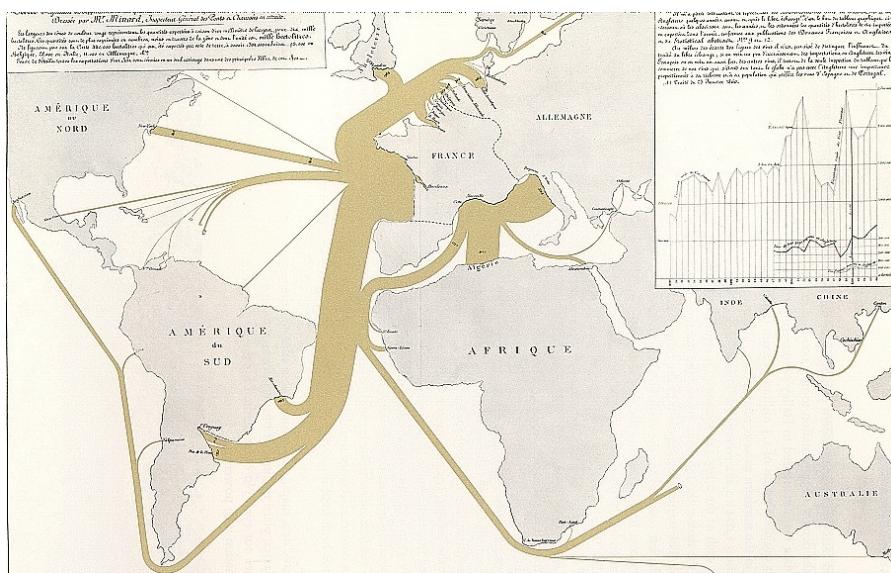
Modern redrawing of Charles Joseph Minard's figurative map of the 1812 French invasion of Russia, including a table of temperatures converting degrees Réaumur to degrees Fahrenheit and Celsius

https://en.wikipedia.org/wiki/Charles_Joseph_Minard

Information Visualization and Visual Analytics - Introduction

Historical Aspect

1864 Exports of French Wine

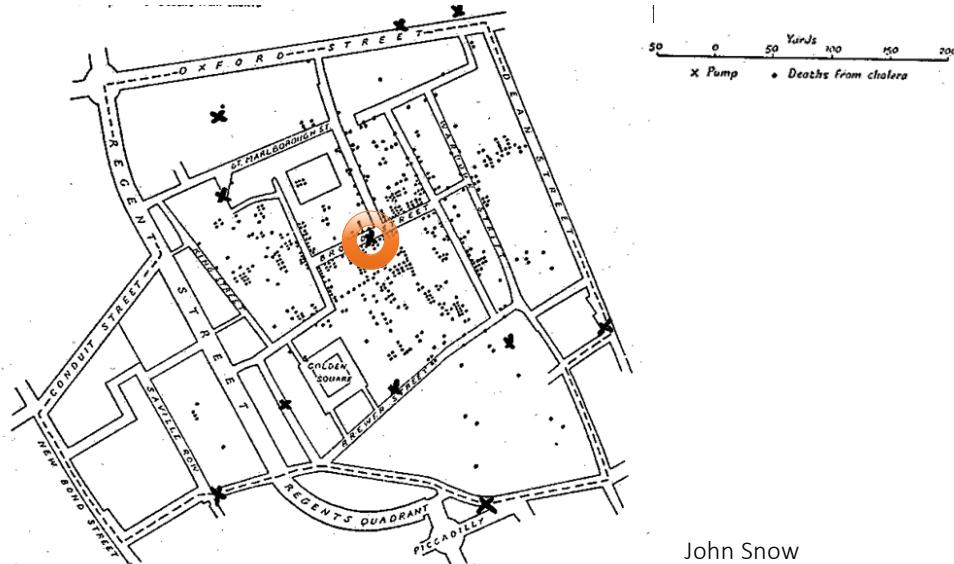


Charles Minard
(economic cartographer)

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Historical Aspect

1854 London Cholera Epidemic



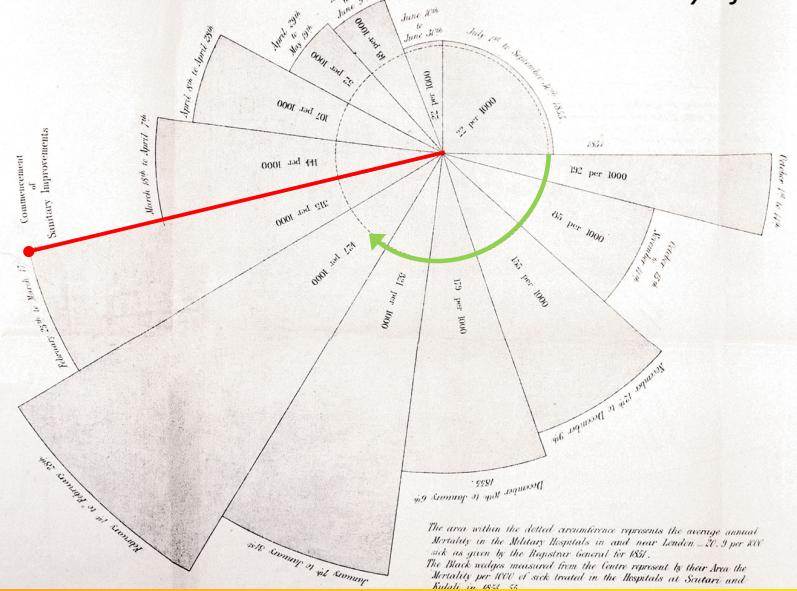
John Snow

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Historical Aspect

Rose-petal diagram

Mortality of British Army



Florence Nightingale's diagram showing the dramatic reduction in death rates in the hospitals of Scutari following the changes she introduced

Source: Nightingale (1858)

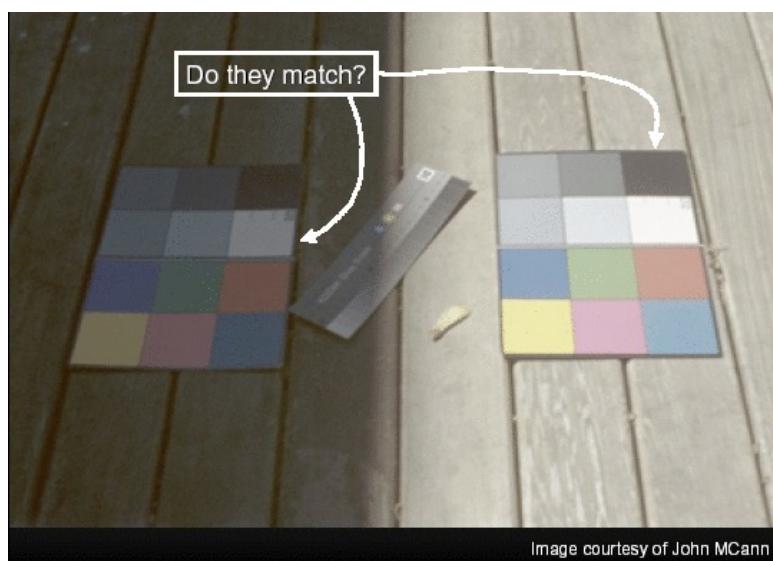
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Perception for InfoVis

- Visual Perception
- Visual Encodings of Quantitative Data
- Data Types and Tasks for InfoVis

Information Visualization and Visual Analytics - Introduction

Relative Perception



courtesy of John McCann, from Stone 2001 SIGGRAPH course graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf

Information Visualization and Visual Analytics - Introduction

Relative Perception

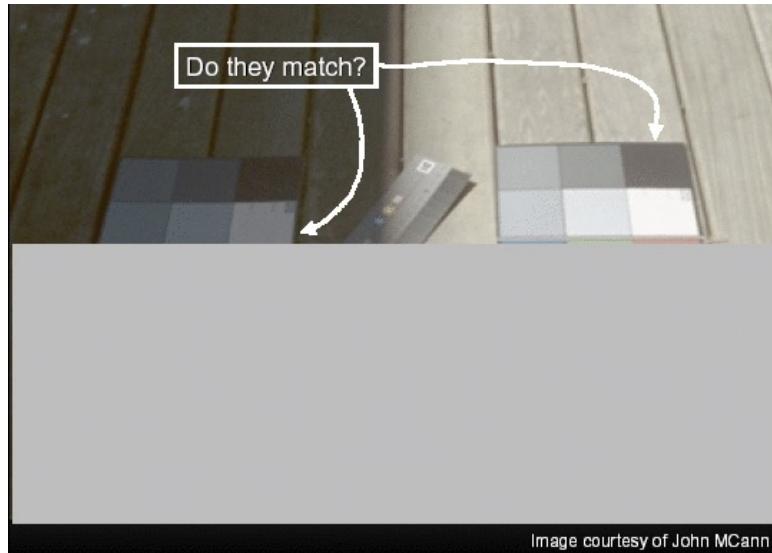


Image courtesy of John McCann

courtesy of John McCann, from Stone 2001 SIGGRAPH course graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf

Information Visualization and Visual Analytics - Introduction

Relative Perception

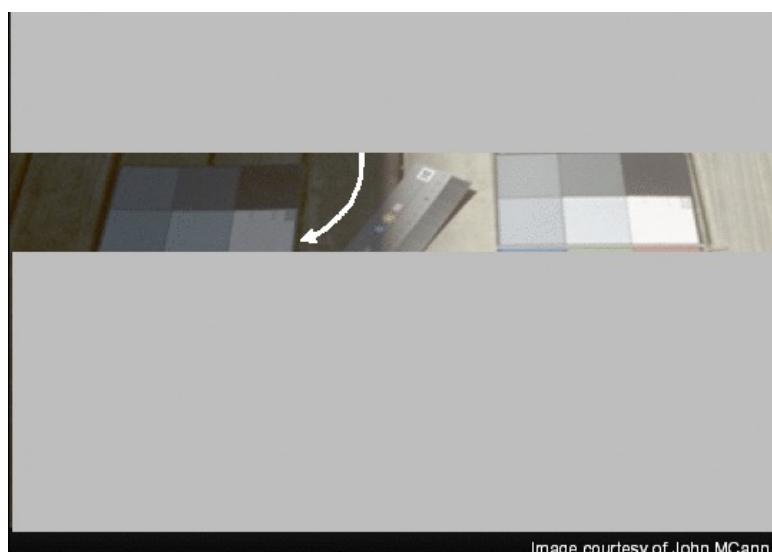


Image courtesy of John McCann

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Information Visualization and Visual Analytics - Introduction

Relative Perception

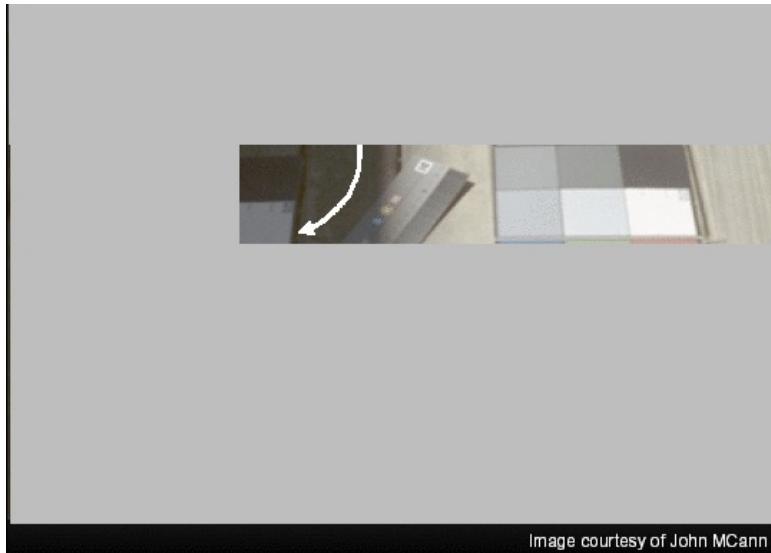


Image courtesy of John McCann

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Information Visualization and Visual Analytics - Introduction

Relative Perception

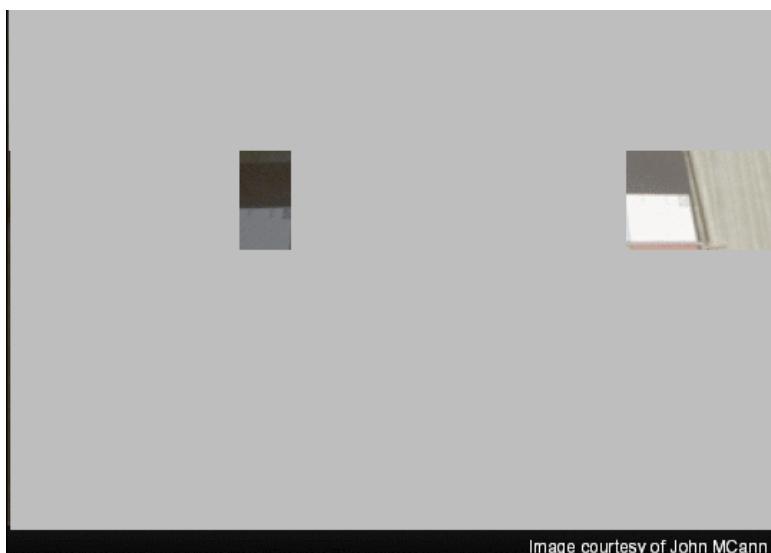


Image courtesy of John McCann

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Information Visualization and Visual Analytics - Introduction

Relative Perception

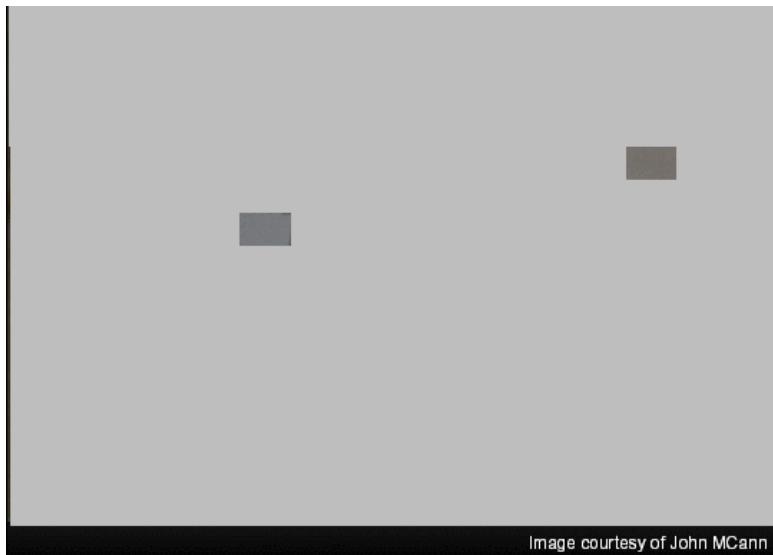


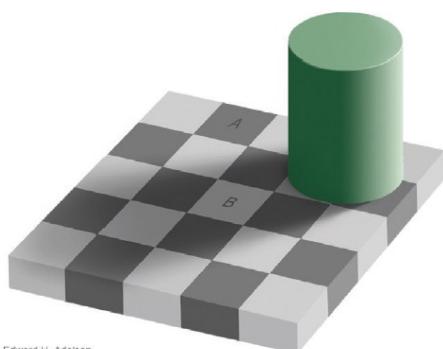
Image courtesy of John McCann

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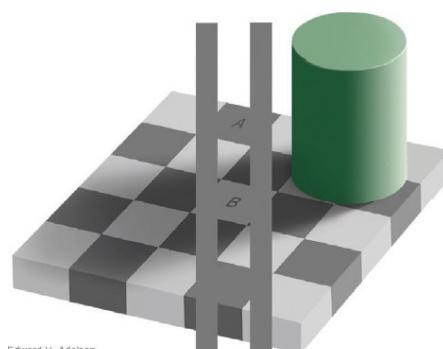
Information Visualization and Visual Analytics - Introduction

Relative versus Absolute Judgements

- Luminance contrast – Simultaneous Brightness Contrast
- Luminance perception is based on relative judgements



(a)

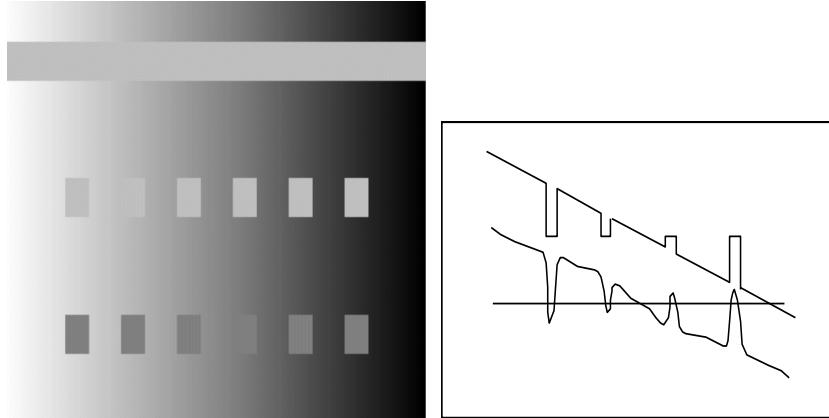


(b)

Information Visualization and Visual Analytics - Introduction

Relative versus Absolute Judgements

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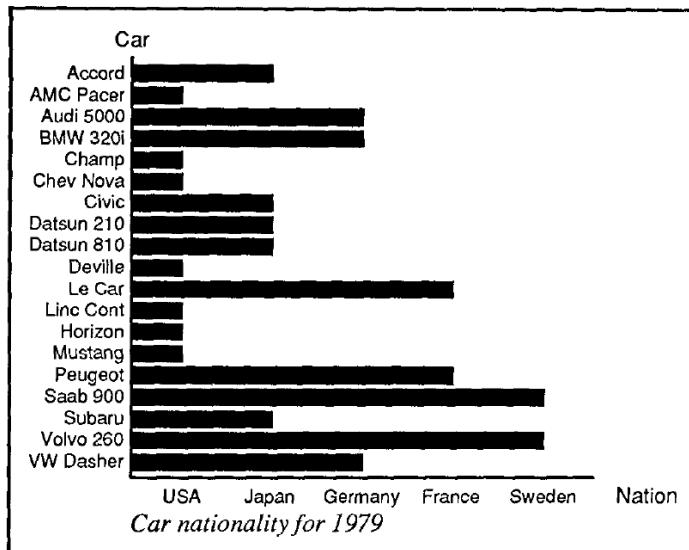
Expressiveness and Effectiveness Principles

Two criteria for evaluating graphical designs

- **Expressiveness**
 - Vis idiom should express **all of**, and **only**, the information in the dataset attributes
- **Effectiveness**
 - Most important attributes should be encoded with the most effective channels
 - ranking of channels

Expressiveness and Effectiveness Principles

Any better encodings?

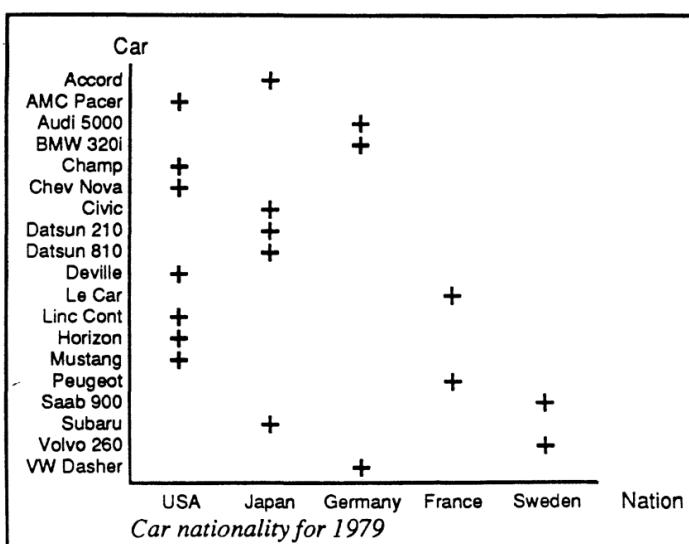


Jock Mackinlay. 1986. Automating the design of graphical presentations of relational information. *ACM Trans. Graph.* 5, 2 (April 1986), 110-141 DOI=<http://dx.doi.org/10.1145/22949.22950>

Information Visualization and Visual Analytics - Introduction

Expressiveness and Effectiveness Principles

Better Expressiveness! More Effective?



Jock Mackinlay. 1986. Automating the design of graphical presentations of relational information. *ACM Trans. Graph.* 5, 2 (April 1986), 110-141 DOI=<http://dx.doi.org/10.1145/22949.22950>

Information Visualization and Visual Analytics - Introduction

Two criteria for evaluating graphical designs

- Expressiveness

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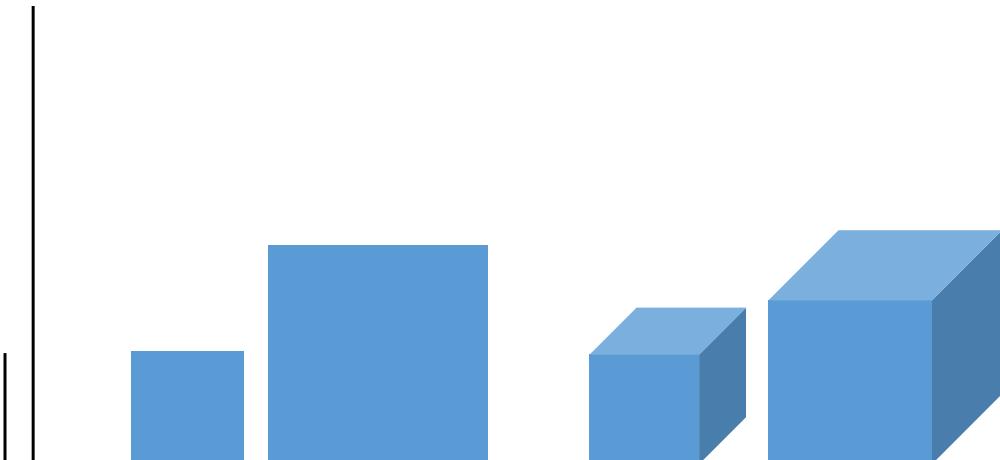
- Effectiveness

- Most important attributes should be encoded with the most effective channels
→ ranking of channels

Information Visualization and Visual Analytics - Introduction

1D, 2D, 3D

- size ratio for each pair → 1:4



INTERACTIVE DATA VISUALIZATION: FOUNDATIONS, TECHNIQUES, AND APPLICATIONS, Matthew O. Ward; Georges Grinstein; Daniel Keim, A K Peters Ltd (July 1, 2010)

Information Visualization and Visual Analytics - Introduction

Expressiveness and Effectiveness

Steven's Power Law

- p : perceived magnitude
- a : actual magnitude
- $p = ka^\alpha$
- $p_1/p_2 = (a_1/a_2)^\alpha$
- length judgment: $\alpha \approx 1$
- area judgment: $\alpha < 1$
- volume judgment: $\alpha \ll 1$

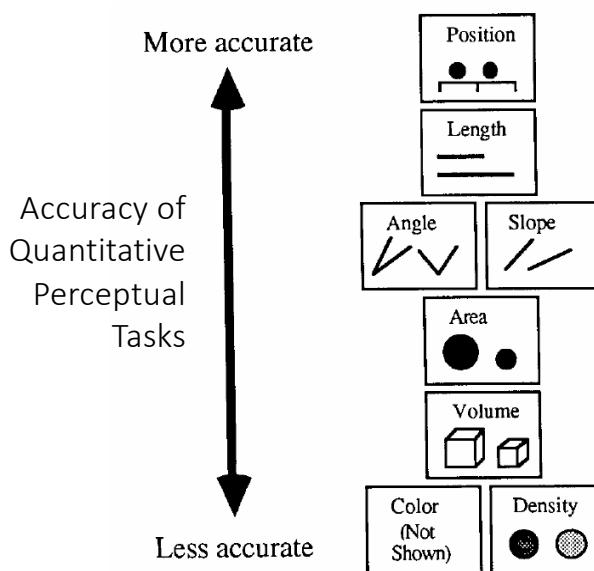
Continuum	Exponent (α)	Stimulus condition
Loudness	0.67	Sound pressure of 3000 Hz tone
Vibration	0.95	Amplitude of 60 Hz on finger
Vibration	0.6	Amplitude of 250 Hz on finger
Brightness	0.33	5° target in dark
Brightness	0.5	Point source
Brightness	0.5	Brief flash
Brightness	1	Point source briefly flashed
Lightness	1.2	Reflectance of gray papers
Visual length	1	Projected line
Visual area	0.7	Projected square
Redness (saturation)	1.7	Red-gray mixture
Taste	1.3	Sucrose
Taste	1.4	Salt
Taste	0.8	Saccharin
Smell	0.6	Heptane
Cold	1	Metal contact on arm
Warmth	1.6	Metal contact on arm
Warmth	1.3	Irradiation of skin, small area
Warmth	0.7	Irradiation of skin, large area
Discomfort, cold	1.7	Whole body irradiation
Discomfort, warm	0.7	Whole body irradiation
Thermal pain	1	Radiant heat on skin
Tactual roughness	1.5	Rubbing emery cloths
Tactual hardness	0.8	Squeezing rubber
Finger span	1.3	Thickness of blocks
Pressure on palm	1.1	Static force on skin
Muscle force	1.7	Static contractions
Heaviness	1.45	Lifted weights
Viscosity	0.42	Stirring silicone fluids
Electric shock	3.5	Current through fingers
Vocal effort	1.1	Vocal sound pressure
Angular acceleration	1.4	5 s rotation
Duration	1.1	White noise stimuli

http://en.wikipedia.org/wiki/Stevens'_power_law

Information Visualization and Visual Analytics - Introduction

Visual Encoding

Effectiveness of Visual Encoding



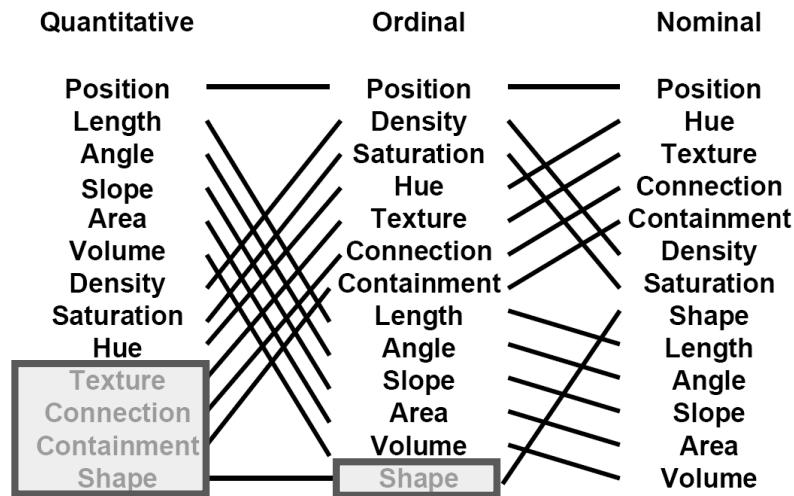
hci lab
SEOUL NATIONAL UNIVERSITY

Cleveland & McGill 1984

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Visual Encoding (Effectiveness) Principles

- Channel Ranking Varies by Data Type



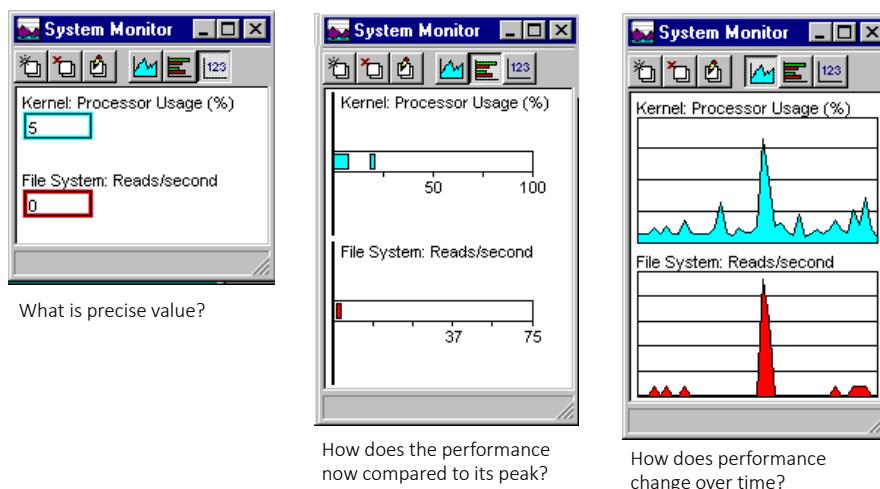
Automating the Design of Graphical Presentations of Relational Information ,Jock Mackinlay, ACM Transaction on Graphics, 1986

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Introduction

Which representation is best?

- Depends heavily on task



Information Visualization and Visual Analytics - Introduction

Introduction

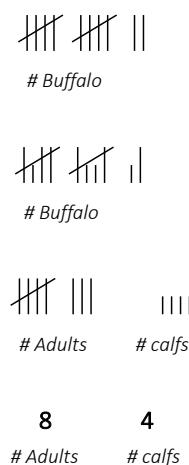
How many buffalo?



Information Visualization and Visual Analytics - Introduction

Introduction

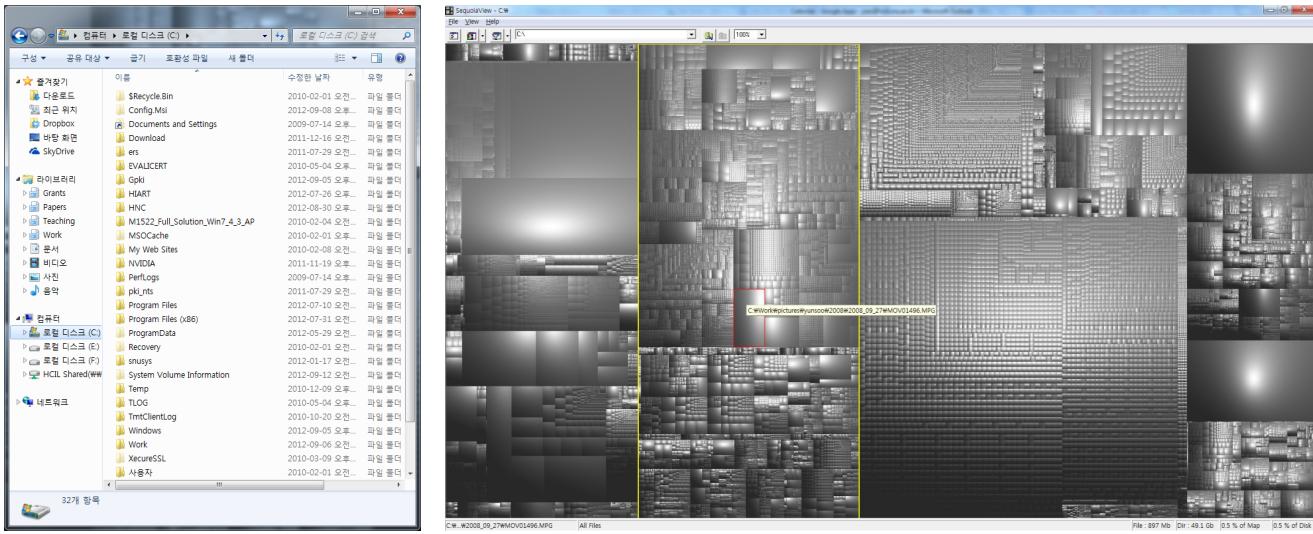
How many buffalo?



Information Visualization and Visual Analytics - Introduction

Introduction

Am I wasting my HDD space??



http://w3.win.tue.nl/nl/onderzoek/onderzoek_informatica/visualization/sequoiaview/

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Introduction

Treemap for Hierarchical Data



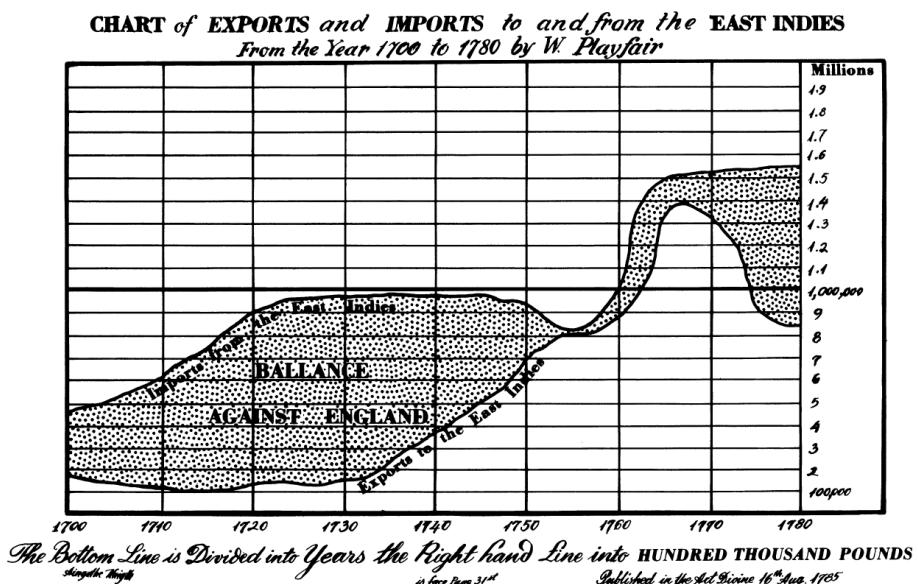
Standard & Poor's 500 index stocks categorized by sectors and industries. Size represents market cap.

<https://finviz.com/map.ashx>

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Introduction

Difference??

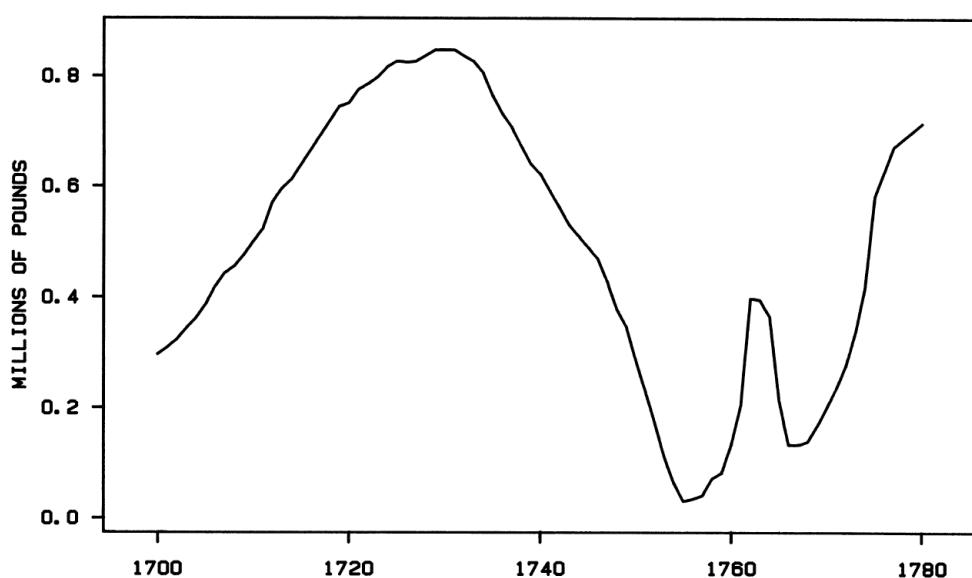


Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models. William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

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Introduction

Difference??

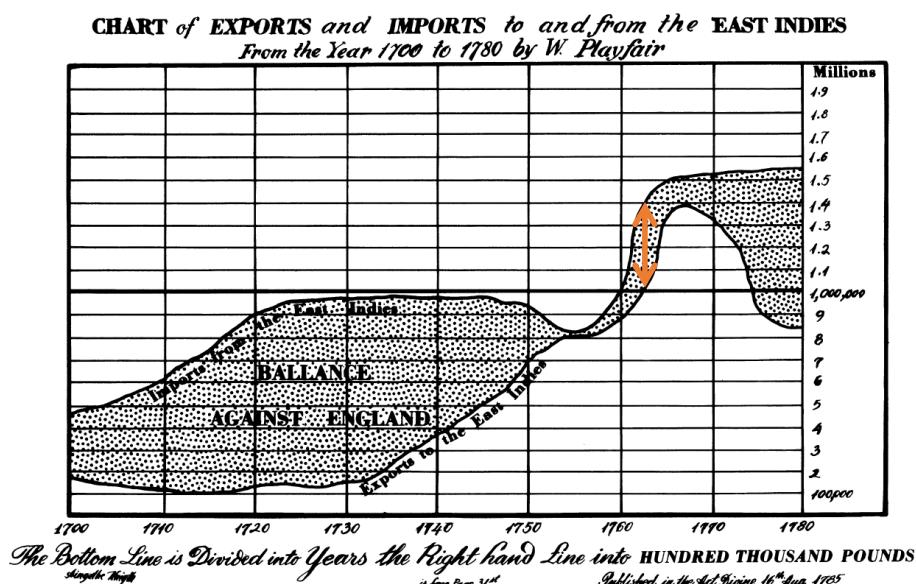


Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models. William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

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Introduction

Difference??

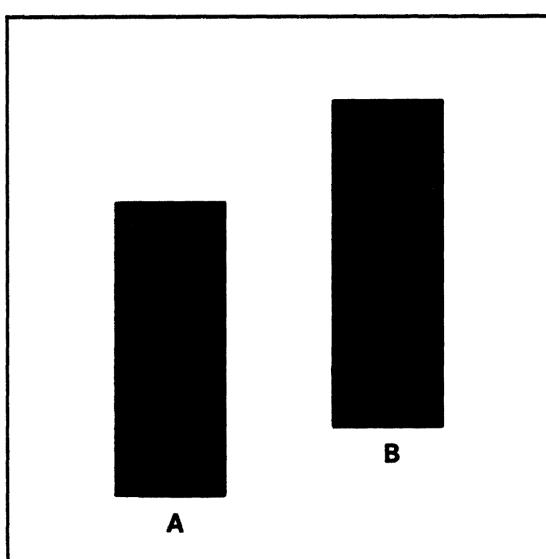


Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models. William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

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Introduction

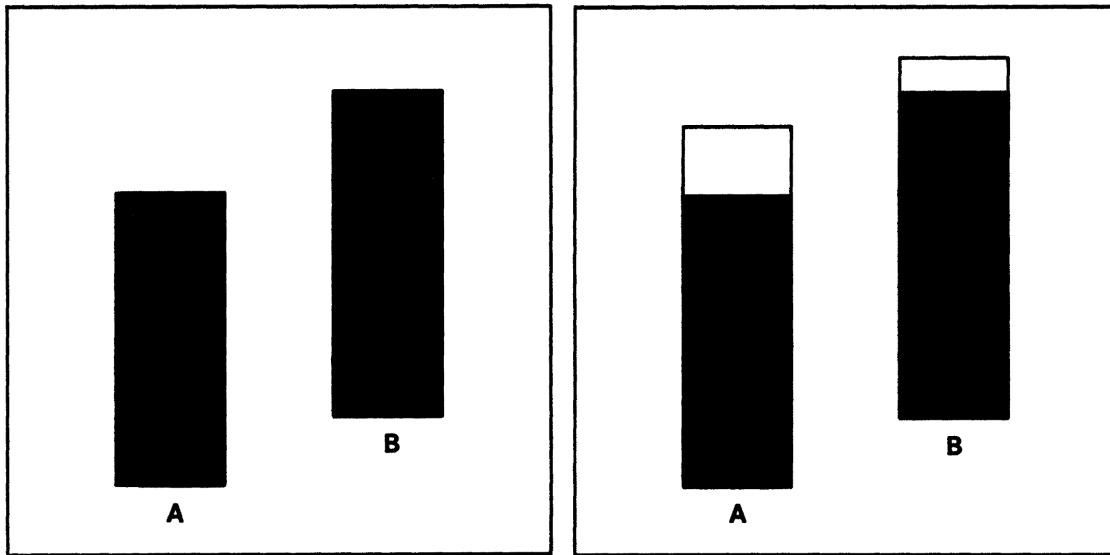
Which is Longer?



Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models. William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

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Weber's Law



Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models. William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

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Preattentive Processing

Preattentive Processing

- Cognitive operations done preattentively, without the need for focused attention
 - less than 200-250 ms
 - eye movements take 200 ms
 - minimum time to initiate eye movement
 - involves only information available in a single glance
- Popout effects
- Segmentation effects

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Preattentive tasks

- visual features that are detected very rapidly by low-level, fast-acting visual processes
- seems to precede focused attention
 - occurring within a single fixation
 - attention plays a critical role in what we see in this early stage
- “pop out” of a display
 - easily detected *regardless of the number of distractors*
 - vs. time-consuming visual search

Christopher G. Healey, James T. Enns: Attention and Visual Memory in Visualization and Computer Graphics. IEEE Trans. Vis. Comput. Graph. 18(7): 1170-1188 (2012)

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How many sevens?

2398419309213985874506209348952034809502
3984210293841909238740129384610329849238
4265293845013945594858601239480234958728
4596394058640598239485802394895029348658
4561024596234851604569828309458673049561
3045916459086130495298646658956405196809
5866304598683049561835601830459680345907
6283486510465183560241620945613045618304
5968230459630459860395620349568204385362

Slide Idea from Colin Ware

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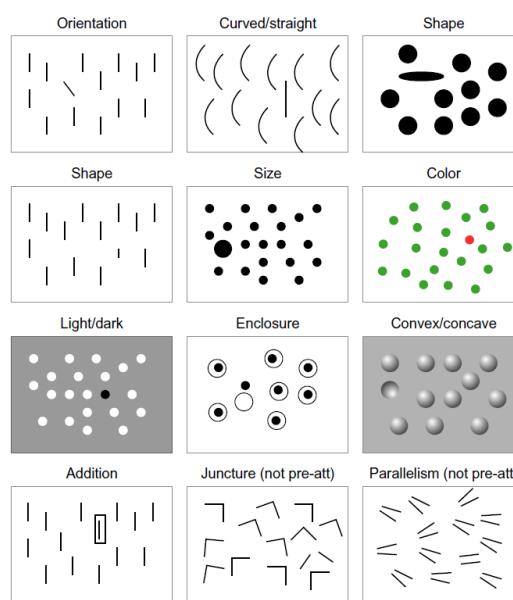
Color Makes Them Pop Out

2398419309213985874506209348952034809502
 3984210293841909238740129384610329849238
 4265293845013945594858601239480234958728
 4596394058640598239485802394895029348658
 4561024596234851604569828309458673049561
 3045916459086130495298646658956405196809
 5866304598683049561835601830459680345907
 6283486510465183560241620945613045618304
 5968230459630459860395620349568204385362

Slide Idea from Colin Ware

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Example

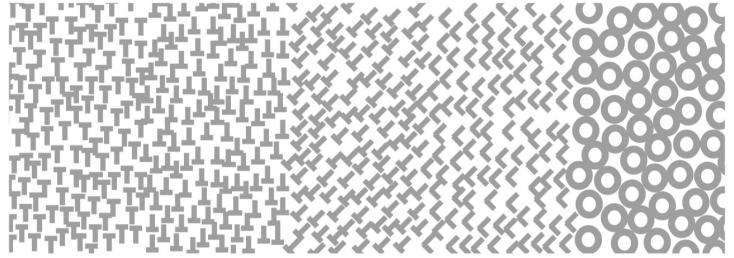


<https://www.csc2.ncsu.edu/faculty/healey/PP/>

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What Kinds of Tasks?

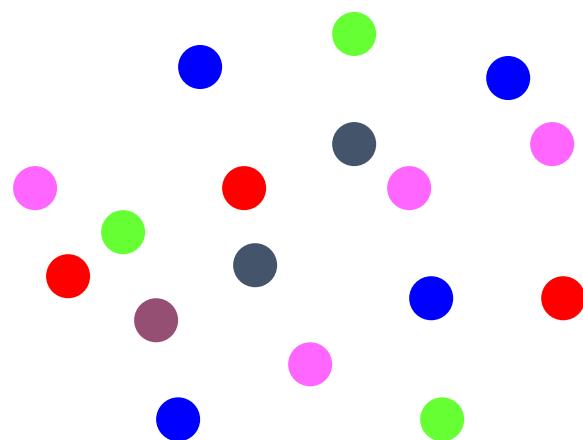
- Target detection
 - Is something there?
- Segmentation (Boundary detection)
 - Can the elements be grouped?
- Region tracking
 - Can a distinctive moving group be traced?
- Counting
 - How many elements of a certain type are present?



Jinwook Seo / John Stasko

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Surrounded colors do not pop out



Colin Ware

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Laws of Preattentive display

- Must stand out on some simple dimension
 - color,
 - simple shape = orientation, size
 - motion,
 - depth
- Lessons for highlighting – one of each

Colin Ware

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- Shneiderman's Guidelines
- Tufte's Design Principles
- The Feynman-Tufte Principle

Information Visualization and Visual Analytics - Introduction

Design Guidelines / Principles

- Visual presentation of query components
 - Visual presentation of results
 - Rapid, incremental and reversible actions
 - Immediate and continuous feedback
 - Selection by pointing (not typing)
 - Reduces errors
 - Encourages exploration
- **Visual Information Seeking Mantra**
- Overview first, zoom and filter, details on demand

Ben Shneiderman

Information Visualization and Visual Analytics - Introduction

Tufte's Design Principles

- Tell the truth
 - Graphical integrity
- Do it effectively with clarity, precision...
 - Design principles/aesthetics
- “simple design, intense content”
 - The Feynman-Tufte Principle, April 2005 *Scientific American*



E. Tufte, *The Visual Display of Quantitative Information* (1983)

E. Tufte, *Envisioning Information* (1990)

E. Tufte, *Visual Explanations* (1997)

E. Tufte, *Beautiful Evidence* (2006)

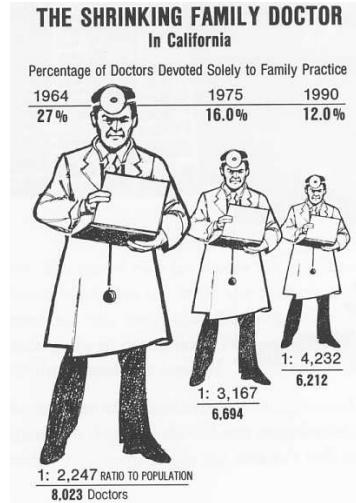
Jinwook Seo / John Stasko

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Measuring Misrepresentation

- Visual attribute value should be directly proportional to data attribute value
- Height/width vs. area vs. volume

$$\text{Lie factor} = \frac{\text{Size of effect shown in graphic}}{\text{Size of effect in data}}$$



“Lie factor” = 2.8

John Stasko

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Design Principles

- Maximize data-ink ratio

$$\text{Data-ink ratio} = \frac{\text{Data ink}}{\text{Total ink used in graphic}}$$

= proportion of graphic's ink devoted to the non-redundant display of data-information

John Stasko

Information Visualization and Visual Analytics - Introduction

Design Principles

• Avoid chartjunk

- Extraneous visual elements that detract from information



<http://nigelholmes.com/>

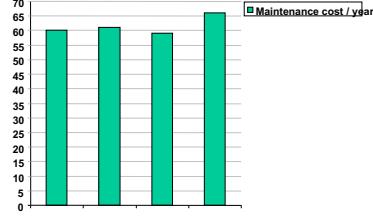
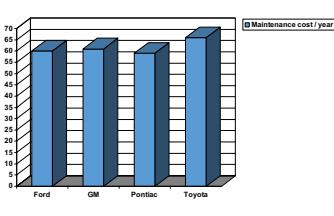
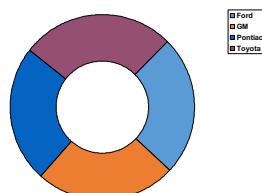
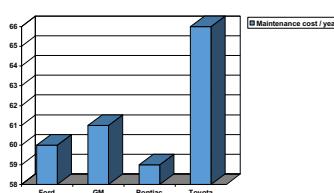
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Design Principles

Chartjunk

- All visual elements in charts and graphs that are not necessary to comprehend the information represented on the graph, or that distract the viewer from this information

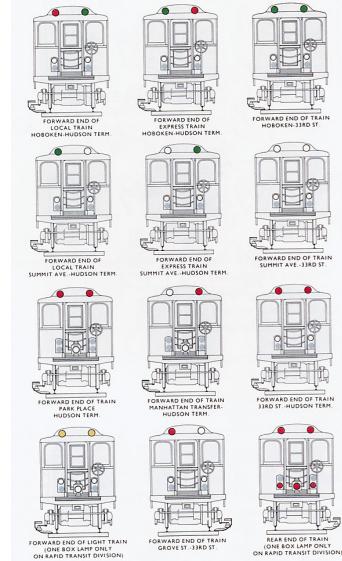


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Design Principles

- Use Small multiples

- Repeat visually similar graphical elements nearby rather than spreading far apart
- The same graphical design structure is repeated
- Learn once and compare
→ invite comparisons
- Reveal, all at once, a scope of alternatives, a range of options
→ overview



Rules and Regulations for the Government of Employees of the Operating Department of the Hudson & Manhattan Railroad Company, 1923

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Design Principles

- Utilize narratives of space and time

- Tell a story of position and chronology through visual elements

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Design Principles

Design Principles

- Utilize narratives of space and time
 - Tell a story of position and chronology through visual elements

NEW YORK TO NEW HAVEN						
MONDAY TO FRIDAY, EXCEPT HOLIDAYS						
Leave	Arrive	Leave	Arrive	Leave	Arrive	
New York	New Haven	New York	New Haven	New York	New Haven	
AM 12:35 5:40 7:05 8:45 9:05 10:45 11:45 11:55 12:05 12:25 1:05	AM 2:18 7:44 9:23 T 4:01 T 4:59 X 5:22E X 5:22E X 5:22E X 5:22E X 5:22E X 5:22E X 5:22E	PM 2:05 3:05 4:45 8:45 8:53 8:53 8:33 11:20 7:26 7:46	PM 3:45 4:45 7:05 T 8:05 8:53 10:05 8:33 11:20 7:48 7:46	PM 8:19 8:55 10:50 8:33 11:20 12:35 11:05 12:05 2:18	PM 8:25 7:05 9:05 8:33 7:08 12:35 11:05 12:35 2:18	PM 8:19 8:55 10:50 8:33 11:20 12:35 11:05 12:35 2:18

The service shown herein is operated by
Metro-North Commuter R.R.

REFERENCE NOTES
Economy off-peak tickets are not valid on
trains in shaded areas.
Check displays in G.C.T. for departure tracks.
E-Express
X-Does not stop at 125th Street.
S-Saturdays and Washington's Birthday only.
H-Sundays and Holidays only.
T-Snack and Beverage Service.
HOLIDAYS-New Year's Day, Washington's Birthday,
Memorial Day, Independence Day, Labor Day,
Thanksgiving and Christmas.

Design Principles

Design Principles - Utilize narratives of space and time

NEW YORK TO NEW HAVEN						
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Leave	Arrive	Leave	Arrive	Leave	Arrive	
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AM 12:35 5:40 7:05 8:45 9:05 10:45 11:45 11:55 12:05 12:25 1:05	AM 2:18 7:44 9:23 T 4:01 T 4:59 X 5:22E X 5:22E X 5:22E X 5:22E X 5:22E X 5:22E	PM 2:05 3:05 4:45 8:45 8:53 8:53 8:33 11:20 7:26 7:46	PM 3:45 4:45 7:05 T 8:05 8:53 10:05 8:33 11:20 7:48 7:46	PM 8:19 8:55 10:50 8:33 11:20 12:35 11:05 12:35 2:18	PM 8:25 7:05 9:05 8:33 7:08 12:35 11:05 12:35 2:18	PM 8:19 8:55 10:50 8:33 11:20 12:35 11:05 12:35 2:18

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Power of Negative space



FedEx

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Power of Negative space



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Power of Negative space



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Note

Questions?

- <http://hcil.snu.ac.kr/>

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