

# Overview of InfoVis



CS 7450 - Information Visualization  
Aug. 19, 2015  
John Stasko

## Exercise



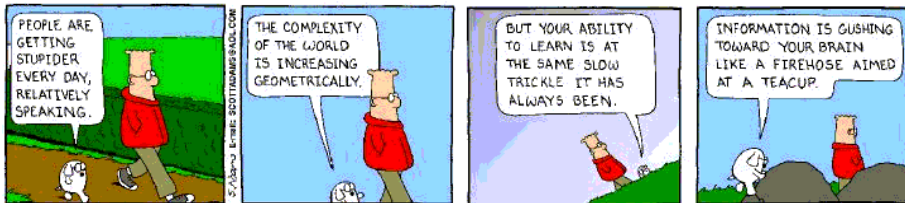
- Get out pencil and paper



# Data Overload



- Confound: How to make use of the data
  - How do we make sense of the data?
  - How do we harness this data in decision-making processes?
  - How do we avoid being overwhelmed?



Fall 2015

CS 7450

5

# The Challenge



- Transform the *data* into *information* (understanding, insight) thus making it useful to people



Fall 2015

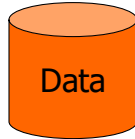
CS 7450

6

# The Problem



Web,  
Books,  
Papers,  
Game scores,  
Scientific data,  
Biotech,  
Shopping  
People  
Stock/finance  
News



Data Transfer →



## How?

Vision: 100 MB/s  
Ears: <100 b/s  
Haptic/tactile  
Smell  
Taste  
Telepathy?

Two slides courtesy  
of Chris North

Fall 2015

CS 7450

7

# Human Vision



- Highest bandwidth sense
- Fast, parallel
- Pattern recognition
- Pre-attentive
- Extends memory and cognitive capacity
- People think visually



Impressive. Lets use it!

Fall 2015

CS 7450

8

# An Example



- Why visualization helps...

Fall 2015

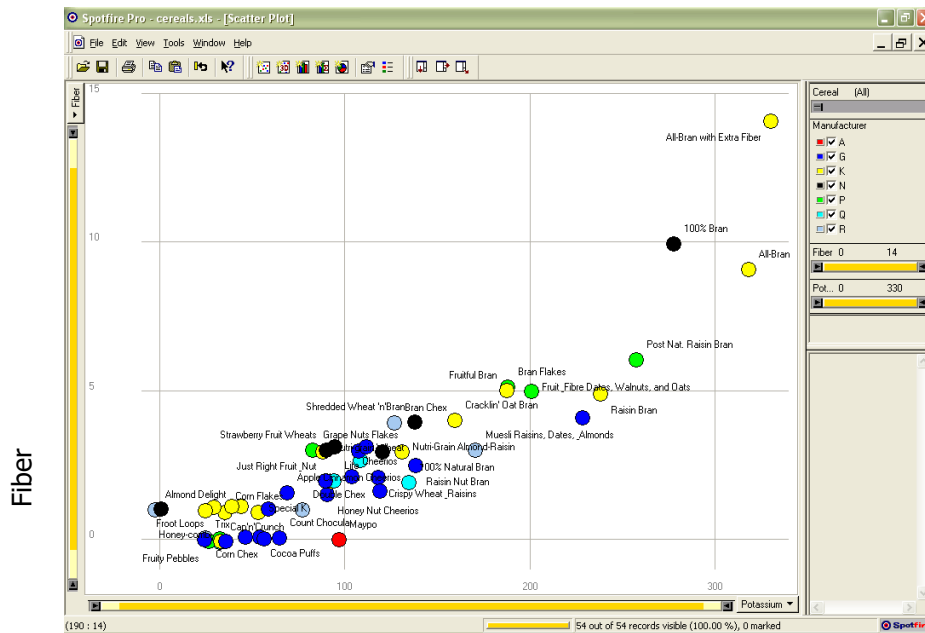
CS 7450

9

Questions: Which cereal has the most/least potassium?  
 Is there a relationship between potassium and fiber?  
 If so, are there any outliers?  
 Which manufacturer makes the healthiest cereals?



	A	B	C	D					
1	Cereal	Manufacturer	Fiber	Potassium	28	Honey-comb	P	0	35
2	100% Bran	N	10	280	29	Just Right Fruit & Nut	K	2	95
3	100% Natural Bran	Q	2	135	30	Life	Q	2	95
4	All-Bran	K	9	320	31	Lucky Charms	G	0	55
5	All-Bran with Extra Fiber	K	14	330	32	Maypo	A	0	95
6	Almond Delight	R	1	0	33	Muesli Raisins, Dates, &	R	3	170
7	Apple Cinnamon Cheerios	G	1.5	70	34	Multi-Grain Cheerios	G	2	90
8	Bran Chex	R	4	125	35	Nutri-Grain Almond-Rais	K	3	130
9	Bran Flakes	P	5	190	36	Nutri-grain Wheat	K	3	90
10	Cap'n Crunch	Q	0	35	37	Oatmeal Raisin Crisp	G	1.5	120
11	Cheerios	G	2	105	38	Post Nat. Raisin Bran	P	6	260
12	Cocoa Puffs	G	0	55	39	Product 19	K	1	45
13	Corn Chex	R	0	25	40	Quaker Oatmeal	Q	2.7	110
14	Corn Flakes	K	1	35	41	Raisin Bran	K	5	240
15	Count Chocula	G	0	65	42	Raisin Nut Bran	G	2.5	140
16	Cracklin' Oat Bran	K	4	160	43	Rice Krispies	K	0	35
17	Cream of Wheat (Quick)	N	1	0	44	Shredded Wheat	N	3	95
18	Crispy Wheat & Raisins	G	2	120	45	Shredded Wheat 'n Bran	N	4	140
19	Double Chex	R	1	80	46	Shredded Wheat spoon	N	3	120
20	Froot Loops	K	1	30	47	Smacks	K	1	40
21	Frosted Flakes	K	1	25	48	Special K	K	1	55
22	Fruit & Fibre Dates, Wal	P	5	200	49	Strawberry Fruit Wheats	N	3	90
23	Fruity Bran	K	5	190	50	Total Corn Flakes	G	0	35
24	Fruity Pebbles	P	0	25	51	Total Raisin Bran	G	4	230
25	Golden Grahams	G	0	45	52	Total Whole Grain	G	3	110
26	Grape Nuts Flakes	P	3	85	53	Trix	G	0	25
27	Honey Nut Cheerios	G	1.5	90	54	Wheaties	G	3	110
					55	Wheaties Honey Gold	G	1	60



Fall 2015

Potassium

CS 7450

11

## Even Tougher?



- What if you could only see one cereal's data at a time? (e.g. some websites)
- What if I read the data to you?

Fall 2015

CS 7450

12



## Another Illustrative Example

Fall 2015

CS 7450

13

## Four Data Sets



- Mean of the x values = 9.0
- Mean of the y values = 7.5
- Equation of the least-squared regression line is:  $y = 3 + 0.5x$
- Sums of squared errors (about the mean) = 110.0
- Regression sums of squared errors (variance accounted for by x) = 27.5
- Residual sums of squared errors (about the regression line) = 13.75
- Correlation coefficient = 0.82
- Coefficient of determination = 0.67

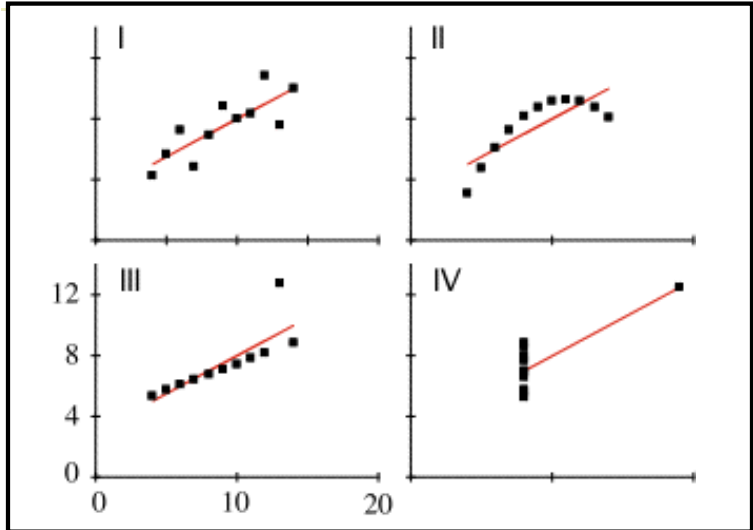
<http://astro.swarthmore.edu/astro121/anscombe.html>

Fall 2015

CS 7450

14

# The Data Sets



Fall 2015

CS 7450

15

# The Values



1	2	3	4
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

Fall 2015

CS 7450

16



## More on this Topic



- “Value of visualization” lecture later in term

Fall 2015

CS 7450

17

## Exercise Redux



- Let’s check what you did...
  
- People work differently

Fall 2015

CS 7450

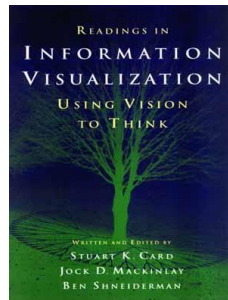
18

# Visualization



- Definition
  - “The use of computer-supported, interactive visual representations of data to amplify cognition.”

From

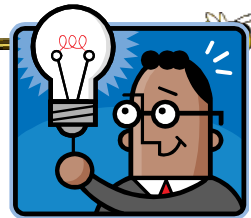


Fall 2015

CS 7450

19

# Visualization



- Often thought of as process of making a graphic or an image
- Really is a cognitive process
  - Form a mental image of something
  - Internalize an understanding
- “The purpose of visualization is insight, not pictures”
  - Insight: discovery, decision making, explanation

Fall 2015

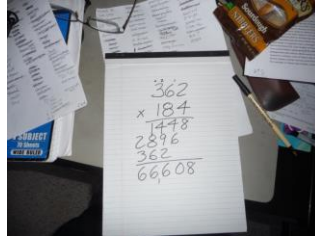
CS 7450

20

# Visuals Help Us Think



- Provide a frame of reference, a temporary storage area
- Cognition → Perception
- Pattern matching
- External cognition aid
  - Role of external world in thinking and reason



Larkin & Simon '87  
Card, Mackinlay, Shneiderman '98

Fall 2015

CS 7450

21

# Expressed Well



"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. Cleveland  
*The Elements of Graphing Data*

Fall 2015

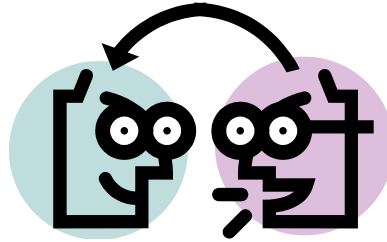
CS 7450

22

## Part of our Culture



- “I see what you’re saying”
- “Seeing is believing”
- “A picture is worth a thousand words”



Fall 2015

CS 7450

23

## Admin Intermission



- Overloads
- Surveys
- More...

Fall 2015

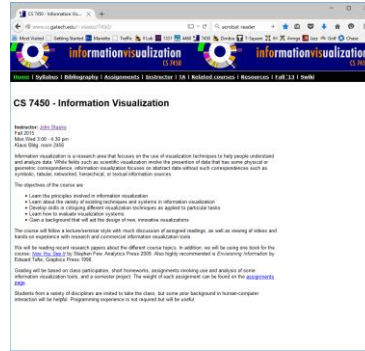
CS 7450

24

# Administratia



- Get it all from class website
  - Syllabus & Biblio
  - Assignments
  - Instructor & TA
  - Related Courses
  - InfoVis Resources



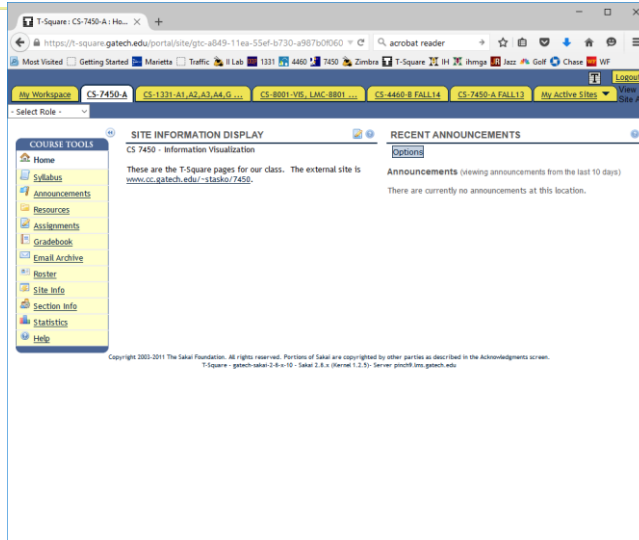
<http://www.cc.gatech.edu/~stasko/7450>

Fall 2015

CS 7450

25

# T-Square Site



Fall 2015

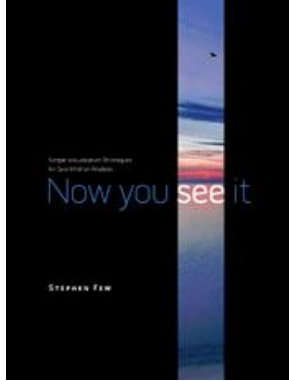
CS 7450

26

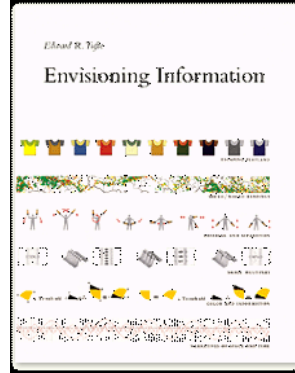
# Books



## Required



## Recommended



Fall 2015

CS 7450

27

# Syllabus



Info central

The screenshot shows the syllabus for CS 7450, Information Visualization. It includes a navigation bar with links to Home, Syllabus, Bibliography, Assignments, Instructor, TA, Related courses, Resources, Fall '13, and Swiki. The main content is titled 'Syllabus' and includes an 'Overview' section with a table of weekly topics and dates.

Week	Dates	Topic	Topic	HW
1	Aug 17, 19	Introduction	InfoVis overview	HW 1
2	Aug 24, 26	Multivariate data & table/graph design	St. Francis design guidance	
3	Aug 31, Sep 2	Multivariate visual representations.1	Multivariate visual representations.2	
4	Sep 7, 9	No Class - Labor Day	InfoVis systems & toolkits	
5	Sep 14, 16	Vis programming tutorial	Commercial systems demo	
6	Sep 21, 23	Interaction	Overview & detail	
7	Sep 28, 30	Tasks and analysis	Storyboarding	
8	Oct 5, 7	Poster session	Tufte's design principles	
9	Oct 12, 14	No Class - Fall break	Causal models	
10	Oct 19, 21	Text & documents.1	Text & documents.2	
11	Oct 26, 28	No Class - VIS Conference	No Class - VIS Conference	
12	Nov 2, 4	Hierarchies & trees.1	Hierarchies & trees.2	
13	Nov 9, 11	Graphs and networks.1	Graphs and networks.2	
14	Nov 16, 18	Time series data	Visual analytics	
15	Nov 23, 25	Visual perception	No Class - Thanksgiving break	
16	Nov 30, Dec 2	Evaluation	Review	

Below the table is a 'Detail' section with a note: 'Below are summaries of all the materials for each class. Lecture slides, references for readings and articles, videos shown, and software demonstrated are listed for each topic. Also available is a more general, alphabetical bibliography.'

The 'Aug. 17 -- Introduction' section lists 'Readings' including 'Tufte Shuttle recap'.

Fall 2015

CS 7450

28

# Grading



- Participation
- Assignments
  - HWs (about 7)
- Project
- Final Exam
  
- (Details still being finalized)

Fall 2015

CS 7450

29

## \*\*\* **CAVEAT** \*\*\*



- This course is a lot of work. If you're just looking for some easy grade, I would advise you to drop now.
  
- If you are sincerely interested in this topic, I hope you will enjoy the course and learn a lot

Fall 2015

CS 7450

30

# Purpose



- Two main uses of infovis
  - Analysis – Understand your data better and act upon that understanding
  - Communication – Communicate and inform others more effectively

Fall 2015

CS 7450

31

## 1. Analysis



- Given all the data, then
  - understand, compare, decide, judge, evaluate, assess, determine, ...
- Ultimately, about solving problems



Fall 2015

CS 7450



# When to Apply?



- Many other techniques for data analysis
  - Statistics, DB, data mining, machine learning
- Visualization most useful in **exploratory data analysis**
  - Don't know what you're looking for
  - Don't have a priori questions
  - Want to know what questions to ask

"A graphic display has many purposes but it achieves its highest value when it forces us to see what we were not expecting."

H. Wainer

Fall 2015

CS 7450

33

# EDA Example 1



- Business
  - Why has Hyundai made such great strides in the US market?
  - How influential was their "Lose your job, we'll buy the car back" campaign?
  - Have their cars improved in quality? If so, in what major ways?
  - Is the Genesis as good of a car as the Lexus ES?

Fall 2015

CS 7450

34

## EDA Example 2



- Airlines
  - What are the key factors causing flight delays in the US?
  - Are delays worse in the summer or winter?
  - Is the seasonal effect influenced by geographic location?
  - How does competition at an airport affect flight delays?

Fall 2015

CS 7450

35

## More on EDA



“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*

Fall 2015

CS 7450

36

# Tasks for Info Vis?



- Search (OK)
  - Finding a specific piece of information
    - How many games did the Braves win in 1995?
    - What novels did Ian Fleming author?
- Browsing (Better)
  - Look over or inspect something in a more casual manner, seek interesting information
    - Learn about crystallography
    - What has Jane been up to lately?

Fall 2015

CS 7450

37

# Tasks in Info Vis



- Analysis
  - Comparison-Difference
  - Outliers, Extremes
  - Patterns
- Assimilation
- Monitoring
- Awareness

More to come in a future class...

Fall 2015

CS 7450

38

## 2. Communication

---



- Use visualization to communicate ideas, present, influence, explain, persuade
- Visuals can serve as evidence or support



Fall 2015

CS 7450

## When to Apply?

---



- Visuals can frequently take the place of many words
- Visuals can summarize, aggregate, unite, explain, ...
- Sometimes words are needed, however

Fall 2015

CS 7450

40

# Key Benefits of Visualization



- Facilitating awareness and understanding
- Helping to raise new questions and supply answers
- Generating insights
- Telling a story and making a point

Fall 2015

CS 7450

41

# Key Challenge

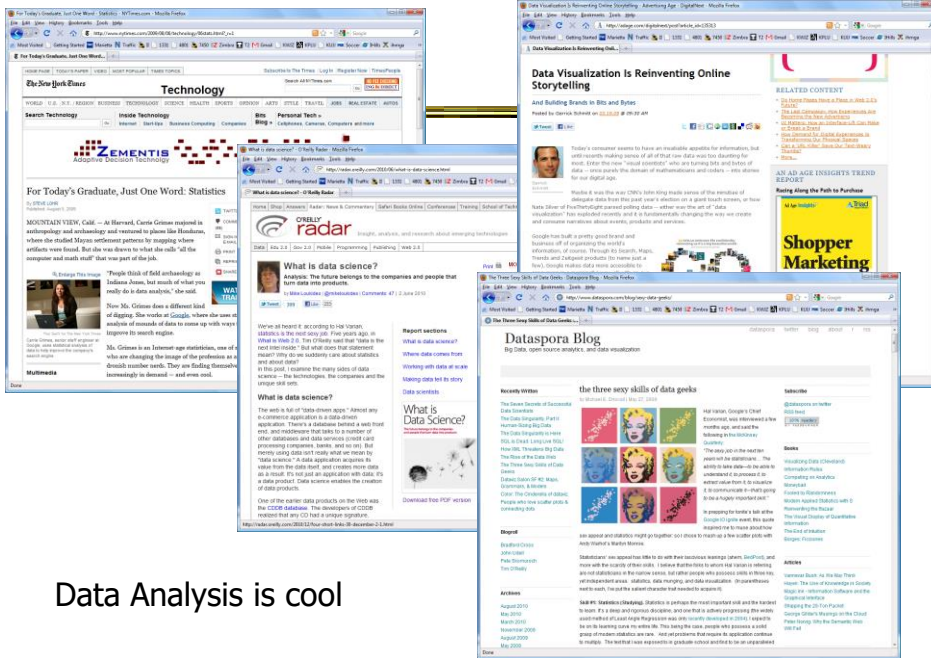


- How to measure and prove?
  - All those benefits are not easily quantifiable and measured
- Evaluation is perhaps primary open research challenge for visualization

More to come later in term

Fall 2015

CS 7450



## Data Analysis is cool

Fall 2015

CS 7450

43

# Academic Areas



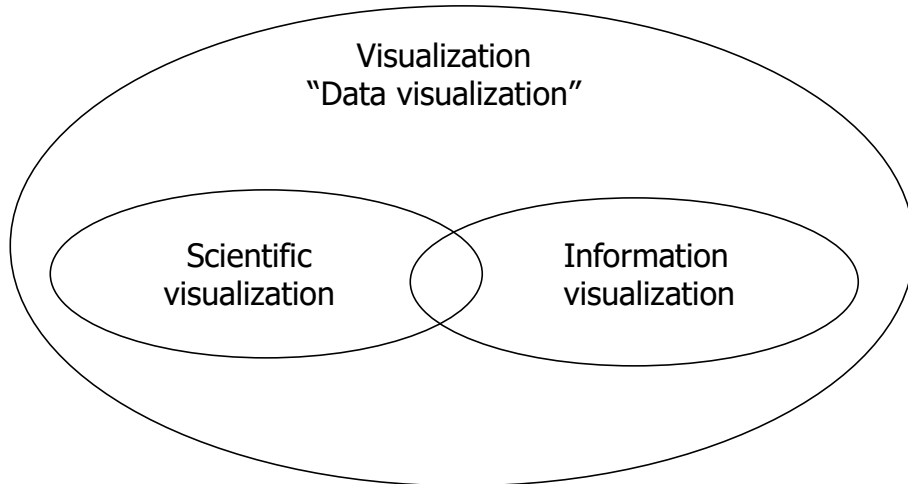
- Where does InfoVis fit in the academic world?

Fall 2015

CS 7450

44

# Overview



Fall 2015

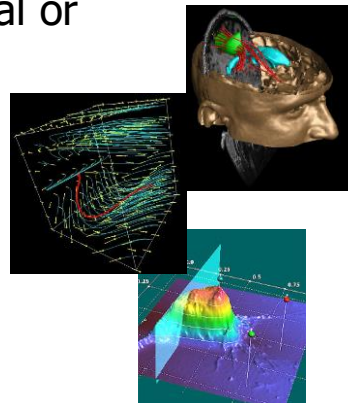
CS 7450

45

# Scientific Visualization



- Primarily relates to and represents something spatial, physical or geometric
  - Often 3-D
  - Examples
    - Air flow over a wing
    - Stresses on a girder
    - Torrents inside a tornado
    - Organs in the human body
    - Molecular bonding



Not the focus of this class

Fall 2015

CS 7450

46

# Information Visualization



- 1. What is “information”?
  - Non-spatial data: Items, entities, things which do not have a direct physical correspondence
  - Notion of abstractness of the entities is important too
  - Examples: baseball statistics, stock trends, connections between criminals, car attributes...

Fall 2015

CS 7450

47

# Information Visualization



- 2. What is “visualization”?
  - The use of computer-supported, interactive visual representations of data to amplify cognition.  
From [Card, Mackinlay Shneiderman '98]

Fall 2015

CS 7450

48



# Information Visualization



- Characteristics:
  - Taking items without a direct physical correspondence and mapping them to a 2-D or 3-D physical space.
  - Giving information a visual representation that is useful for analysis and presentation
  - “A key challenge in information visualization is designing a cognitively useful spatial mapping of a dataset that is not inherently spatial and accompanying the mapping by interaction techniques that allow people to intuitively explore the dataset. Information visualization draws on the intellectual history of several traditions, including computer graphics, human-computer interaction, cognitive psychology, semiotics, graphic design, statistical graphics, cartography, and art.”

<http://conferences.computer.org/infovis/>

Fall 2015

CS 7450

49

## Constituents



- Two key aspects of infovis
  - Representation
  - Interaction (too often overlooked)

“The effectiveness of information visualization hinges on two things: its ability to clearly and accurately represent information and our ability to interact with it to figure out what the information means.”

*S. Few, Now you see it*

Fall 2015

CS 7450

50

# Two Key Challenges



- Scale
  - Challenge often arises when data sets become large
- Diversity
  - Data of data types, forms, sizes

Fall 2015

CS 7450

51

# Example Domains for Info Vis



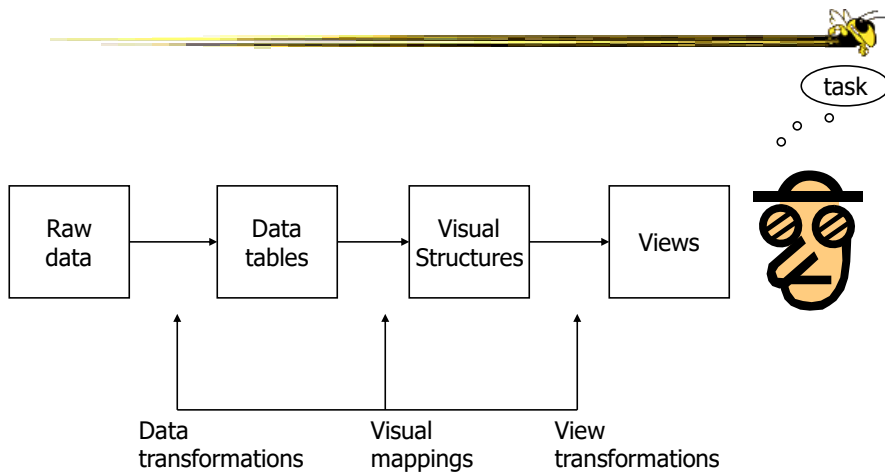
- Text
- Statistics
- Financial/business data
- Internet information
- Software
- ...

Fall 2015

CS 7450

52

# InfoVis Process Model



From: Card, Mackinlay, Shneiderman '99

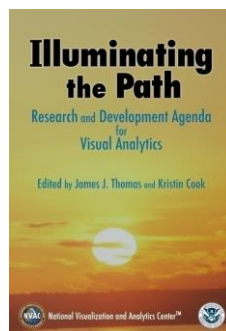
Fall 2015

CS 7450

53

## New Area Emerging: Visual Analytics

Visual analytics is the science of analytical reasoning facilitated by interactive visual interfaces



Available at <http://nvac.pnl.gov/>  
in PDF form

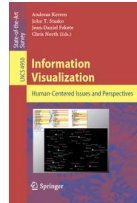
Fall 2015

CS 7450

# Alternate Definition



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

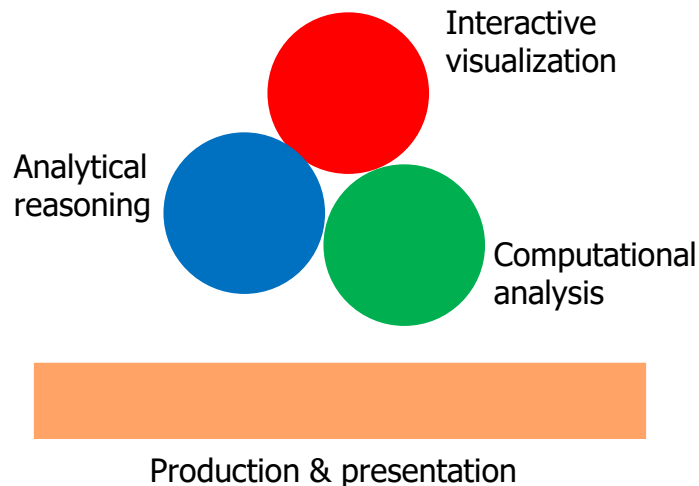


Keim et al  
chapter in *Information Visualization: Human-Centered Issues and Perspectives*, 2008

56 | 2015

CS 7450

# Main Components



56 | 2015

CS 7450

# Back to InfoVis (Examples)



- Start with static pictures (InfoGraphics)
  - Very popular on the web
  - But are they information visualizations?

Fall 2015

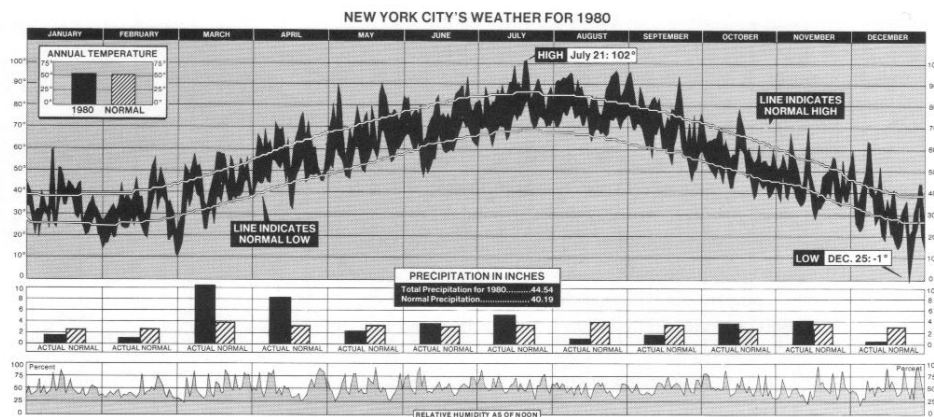
CS 7450

57

## NYC Weather



2220 numbers



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

Tufte, Vol. 1

Fall 2015

CS 7450

58

# Data Values



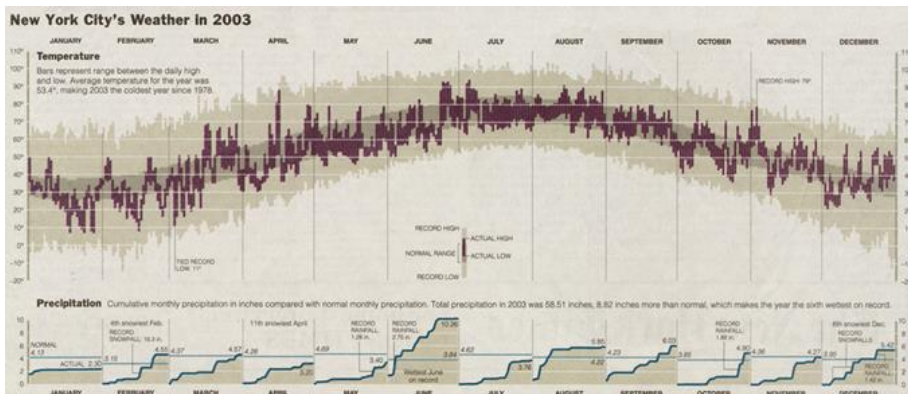
- 365 High temp for each day
- 365 Low temp for each day
- 365 Avg high temp for each day
- 365 Avg low temp for each day
- 365 Precipitation for each day
- 365 Humidity for each day
- 12 Precipitation for each month
- 12 Avg precipitation for each month
- 1 Precipitation for the year
- 1 Avg precipitation per year
- 1 Highest temp (& day) for the year
- 1 Lowest temp (& day) for the year
- 1 Avg daily temp for the year
- 1 Avg daily temp per year

Fall 2015

CS 7450

59

# Updated Version

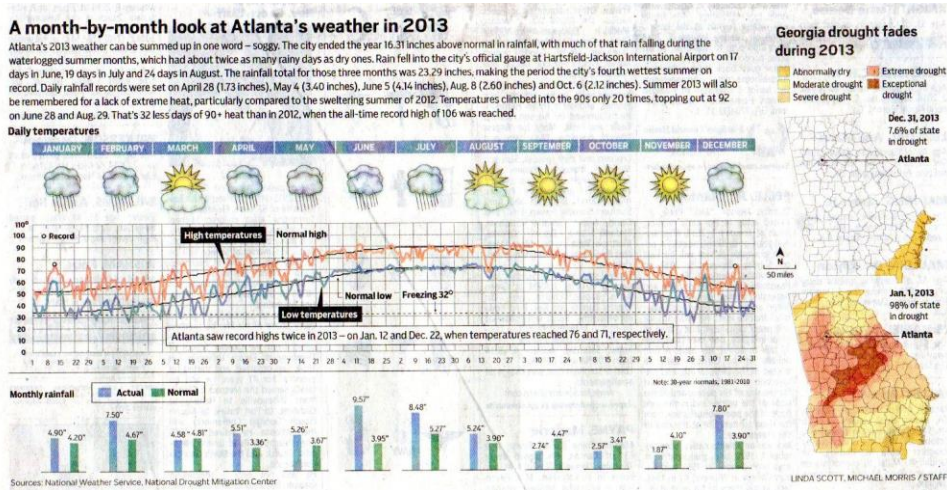


[http://www.edwardtufte.com/bboard/q-and-a-fetch-msg?msg\\_id=00014g](http://www.edwardtufte.com/bboard/q-and-a-fetch-msg?msg_id=00014g)

Fall 2015

CS 7450

60



## Atlanta Journal Constitution Jan. 3, 2014

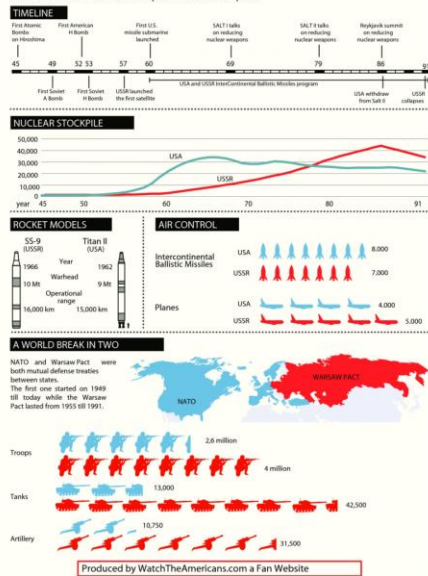
Fall 2015

CS 7450

61

### THE NUCLEAR ARMS RACE

It was the main issue in the Cold War when both America and Russia challenging each other to increase their stockpiles of nuclear weapons.



<http://visual.ly/nuclear-arms-race>

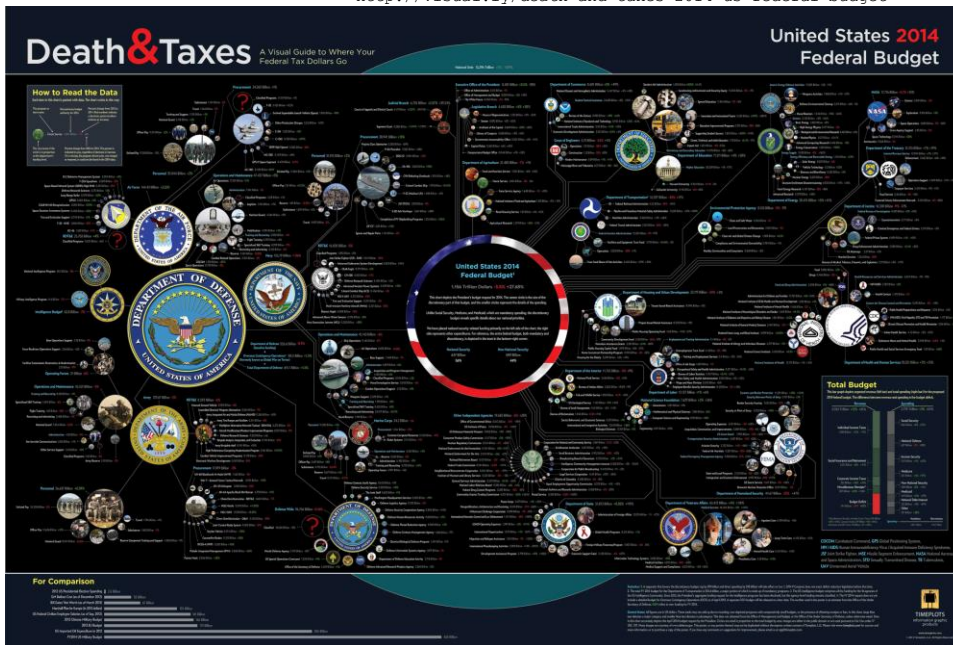
Fall 2015

CS 7450

62



<http://visual.ly/death-and-taxes-2014-us-federal-budget>



Fall 2015

CS 7450

63

<http://www.mikewirthart.com/?cat=3>

## Beer



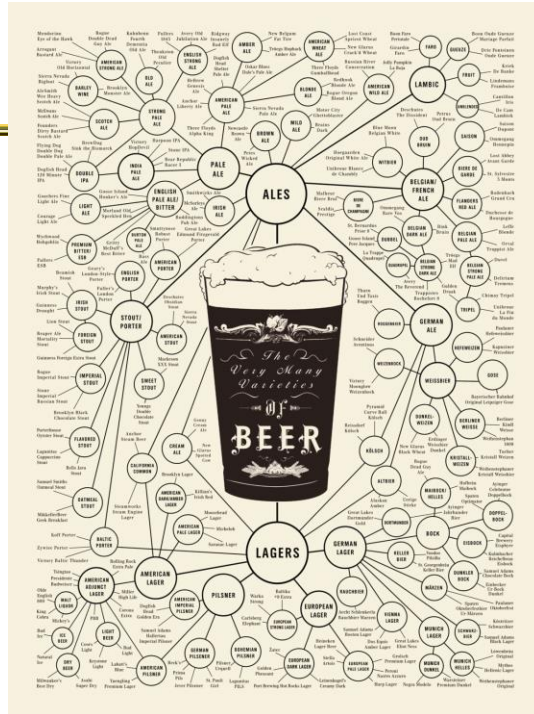
Fall 2015

CS 7450

64



# Beer!



[http://images.fastcompany.com/upload/poster\\_beer\\_1300.jpg](http://images.fastcompany.com/upload/poster_beer_1300.jpg)

Fall 2015

# More Beer!

Home | Events | **Beers** | Contact us

Click on any image below to see full description

## The Beerionic Table

ALE
HYBRID
LAGER

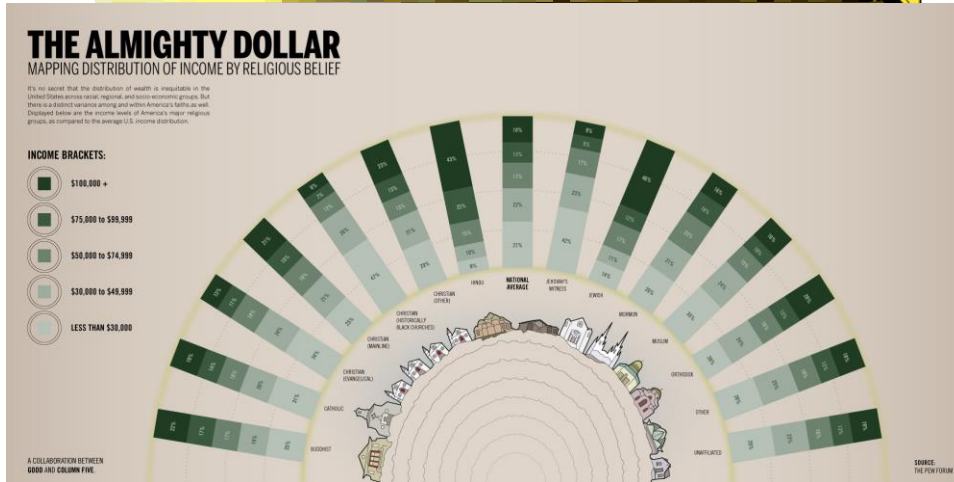
<http://thebeermongers.com/beers/>

Fall 2015

CS 7450

66

# Income and Religion

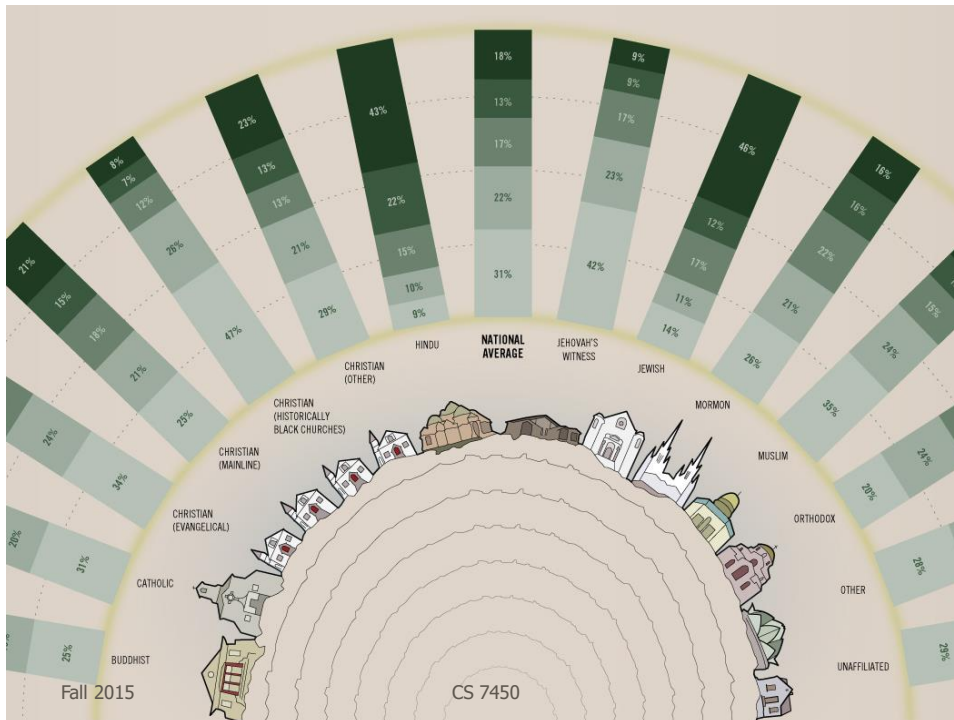


<http://awesome.good.is/transparency/web/1002/almighty-dollar/transparency.jpg>

Fall 2015

CS 7450

67



# Population

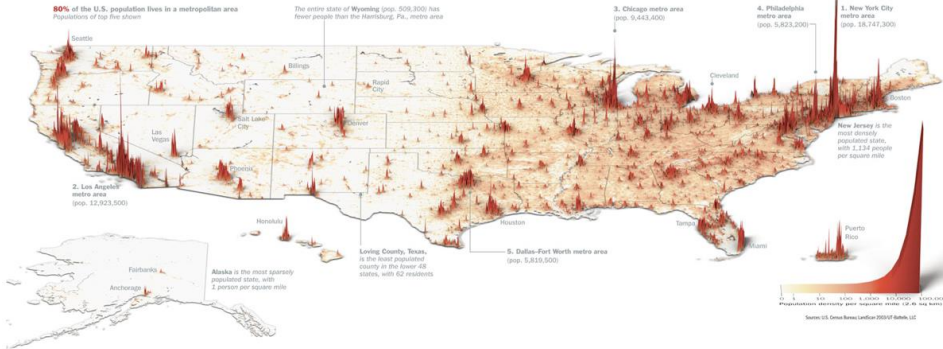


## Where We Live...

Unlike many developed countries, the U.S. keeps growing. We are also moving south and west. But compared with China or India, the nation is a vast prairie

Our families are getting smaller—with one vital exception. Compared with those of Europe and Japan, the U.S. population is younger and more colorful because of the continued arrival of immigrants and their higher-than-average birthrates. Of the 300 million Americans who will join us in the next 27 years, half will be immigrants or their children. In the next few decades, 97% of the world's population growth will occur in the developing world; the U.S. is the largest developed country in the world that is still growing at a healthy clip. That matters, strategically, economicall-

Ala.: Primm, Tenn. Ky.; or Louisville, N.Y. But they are all probably close to someone's idea of paradise. —By Henry Jones



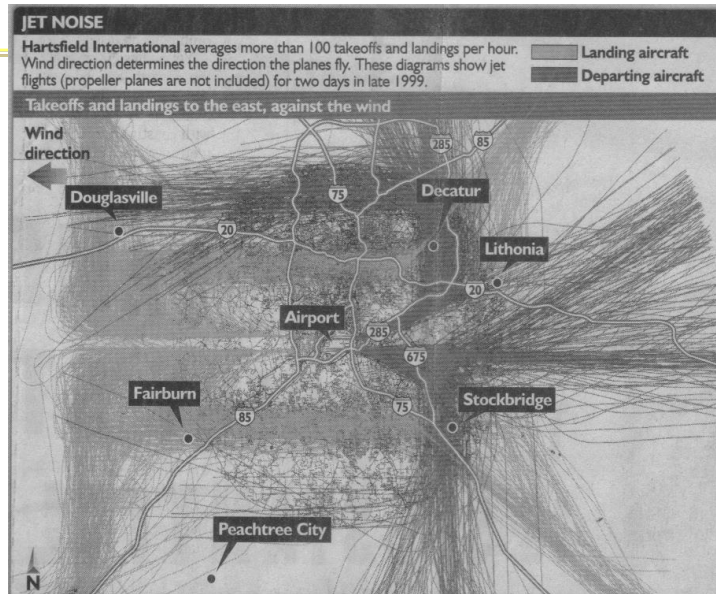
<http://infographicsnews.blogspot.com/2009/04/mantras-joe-lertolas-maps.html>

Fall 2015

CS 7450

69

# Atlanta Flight Traffic



Atlanta Journal  
April 30, 2000

Fall 2015

CS 7450

70

# Country Music



**Figure 14.** States Mentioned in Country-Music Lyrics  
 Source: Ben Marsh, "A Rose-Colored Map," *Harper's*, July 1977, 80. Used by permission.  
 Note: The size of each state is proportional to the number of times it is mentioned.

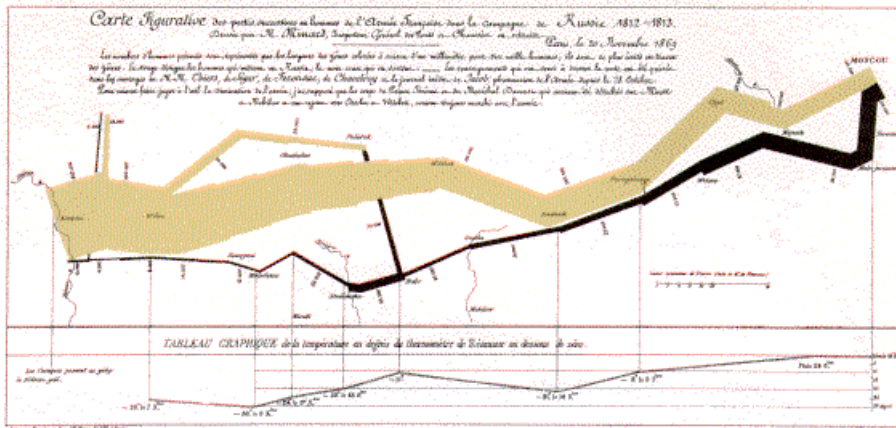
Fall 2015

CS 7450

71

# Napoleon's March

From E. Tufte  
*The Visual Display of Quantitative Information*



Minard graphic

size of army  
 direction

latitude  
 longitude

temperature  
 date

Fall 2015

CS 7450

72



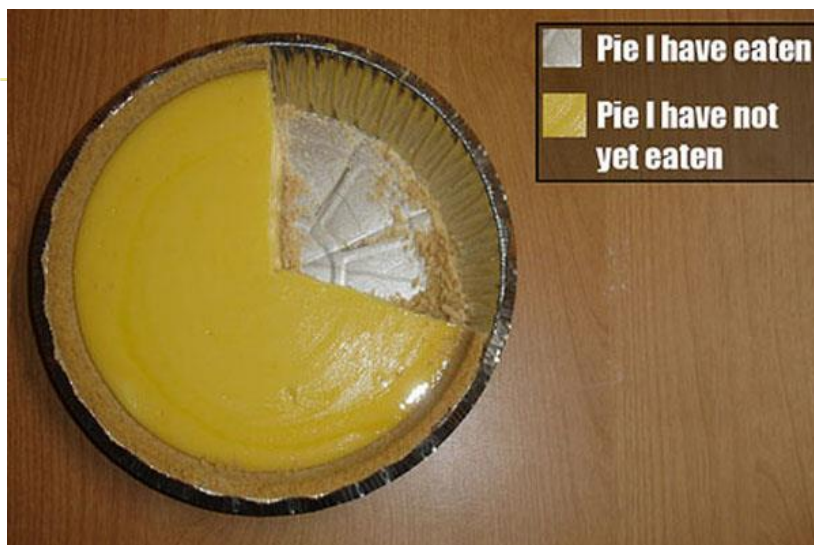


# Or, for fun...

Fall 2015

CS 7450

73



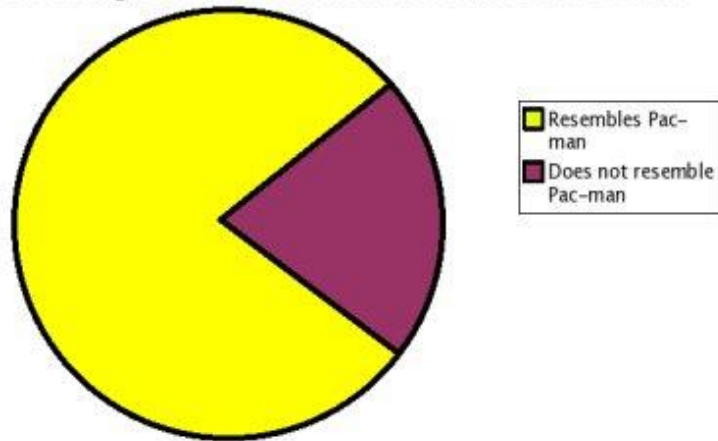
[http://infosthetics.com/archives/2008/09/funniest\\_pie\\_chart\\_ever.html](http://infosthetics.com/archives/2008/09/funniest_pie_chart_ever.html)

Fall 2015

CS 7450

74

## Percentage of Chart Which Resembles Pac-man

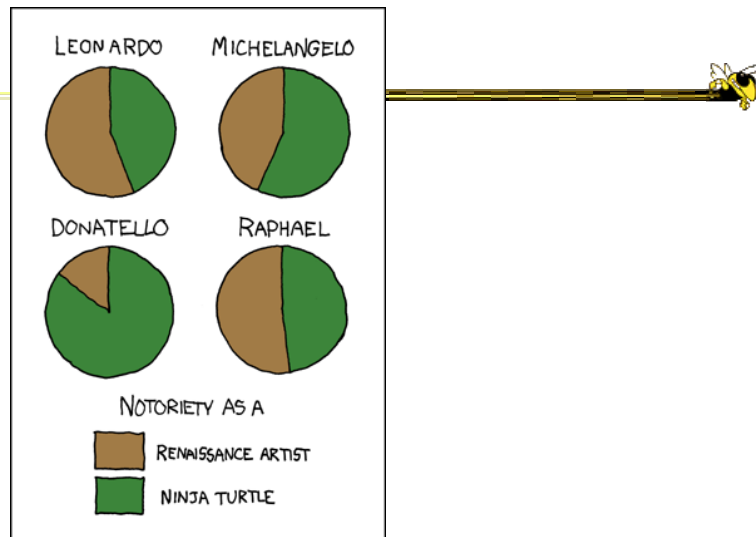


<http://www.boingboing.net/2006/11/02/hilarious-piechartvi.html>

Fall 2015

CS 7450

75

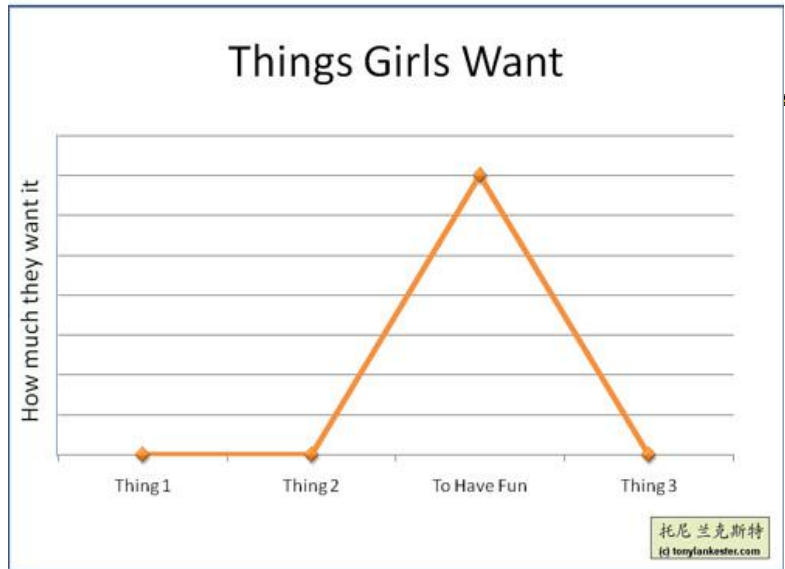


<http://xkcd.com/197/>

Fall 2015

CS 7450

76



<http://www.flickr.com/photos/91884218@N00/3108768440/in/pool-songchart>





# But Don't Do This

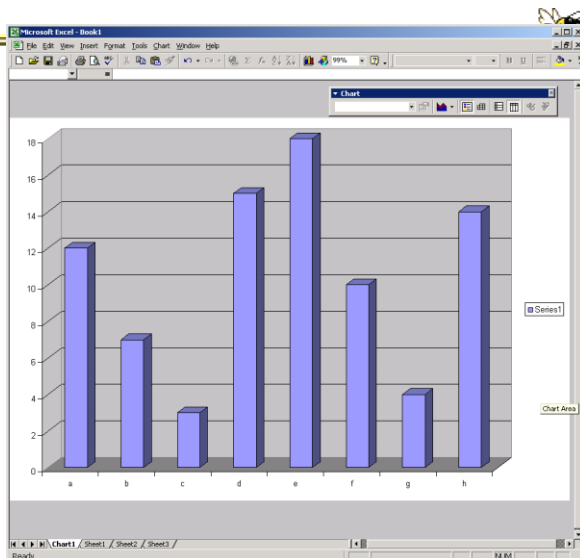
Fall 2015

CS 7450

79

## Excel

Get rid of those darn 3D bars!



Fall 2015

CS 7450

80



# USA Today Graphics



Or worse yet...



Fall 2015

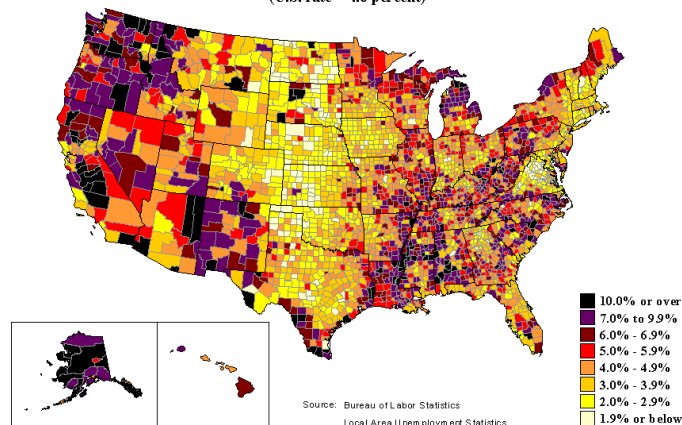
CS 7450

81

# Unemployment Rates



Unemployment rates by county,  
December 2000 - November 2001 averages  
(U.S. rate = 4.6 percent)

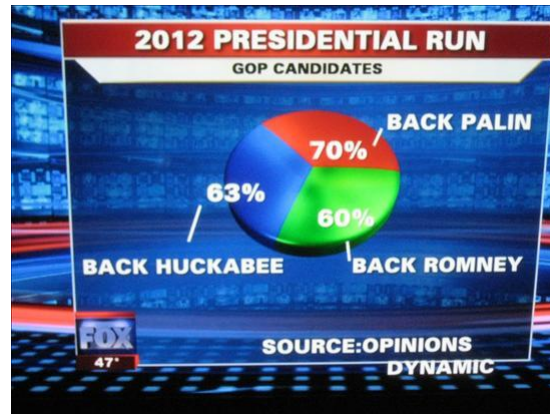


Fall 2015

CS 7450

82

# FOX "News"



<http://wonkette.com/412361/all-193-of-republicans-support-palin-romney-and-huckabee>

Fall 2015

CS 7450

83

## Examples



- Tools/Systems
  - Now interaction becomes important...

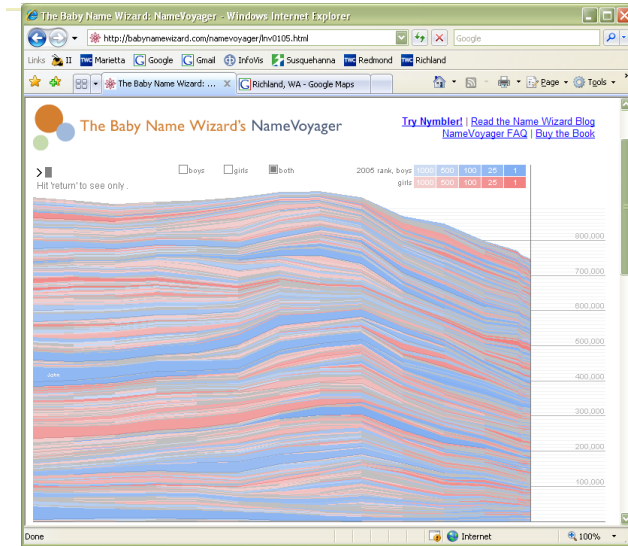
Fall 2015

CS 7450

84

http://babynamewizard.com/namevoyager/

# Baby Name Wizard



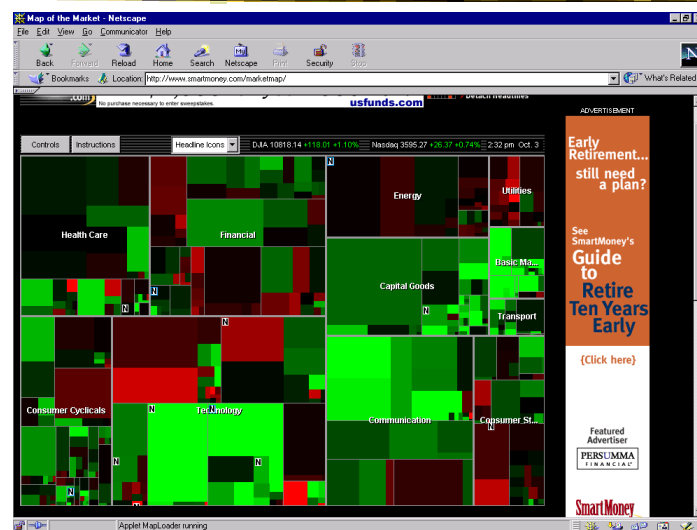
Fall 2015

CS 7450

85

www.smartmoney.com/marketmap

# Map of the Market



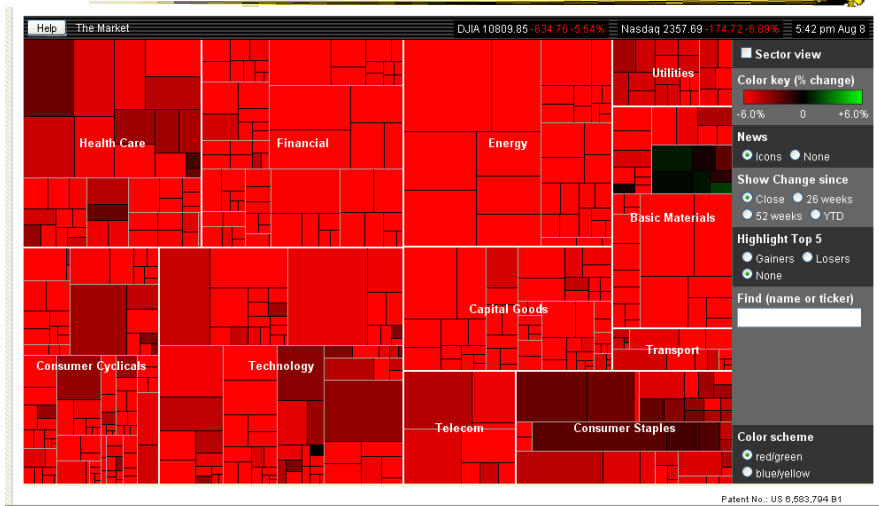
Fall 2015

CS 7450

86

Demo

# Some Days It Looks Like This...



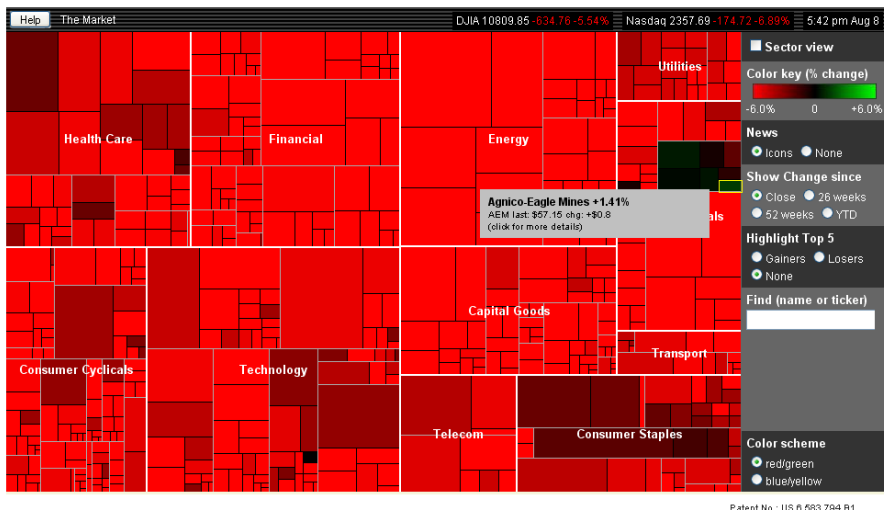
Fall 2015

CS 7450

Aug. 8, 2011

87

# Some Days It Looks Like This...



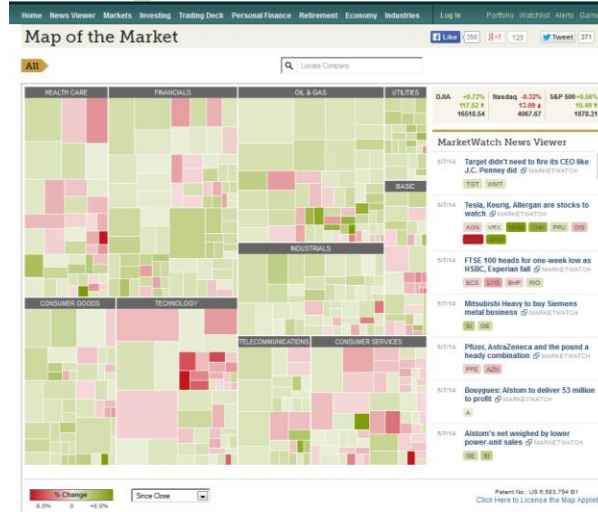
Fall 2015

CS 7450

Aug. 8, 2011

88

# Current Version



Fall 2015

CS 7450

89

# NY Times

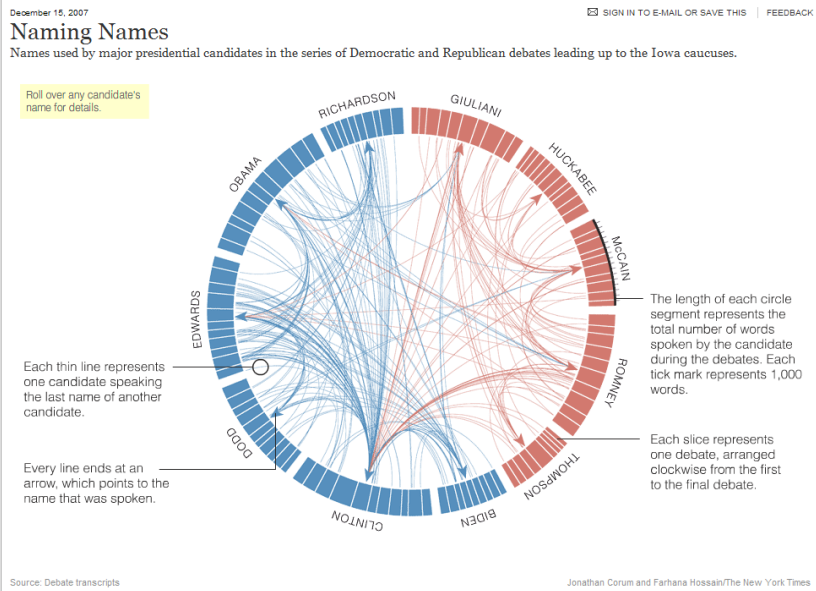


- Has been a wonderful source of interactive data visualizations
- Some examples...

Fall 2015

CS 7450

90



Fall 2015

CS 7450

91

Published: January 10, 2010

## A Peek Into Netflix Queues

Examine Netflix rental patterns, neighborhood by neighborhood, in a dozen cities. Some titles with distinct patterns are *Mad Men*, *Obsessed* and *Last Chance Harvey*. [Comments \(121\)](#)

100 titles that were frequently rented from Netflix in 2009

Change how movies are sorted: **Most rented** | Alphabetical | By metascore

◀ Previous | Next ▶

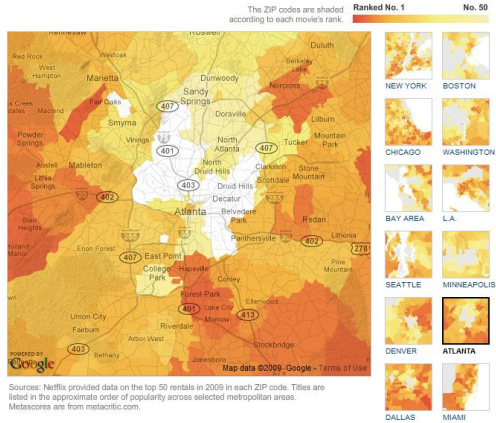
### Knowing

Nobody requires plausibility from a movie like "Knowing," which features slender blond aliens, intimations of apocalypse, clairvoyant children and Nicolas Cage as an astrophysicist. If the thing manages to avoid complete preposterousness, the audience can still have a good time.

Metascore: 41

100+ loved by critics. Detailed

[Read Rest of NYT Review](#)



Fall 2015

CS 7450

92

# Good Resources



- Some places to look for more information

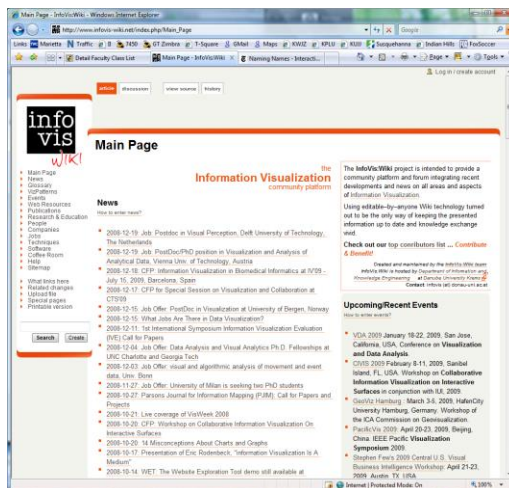
Fall 2015

CS 7450

93

<http://www.infovis-wiki.net>

# InfoVis Wiki



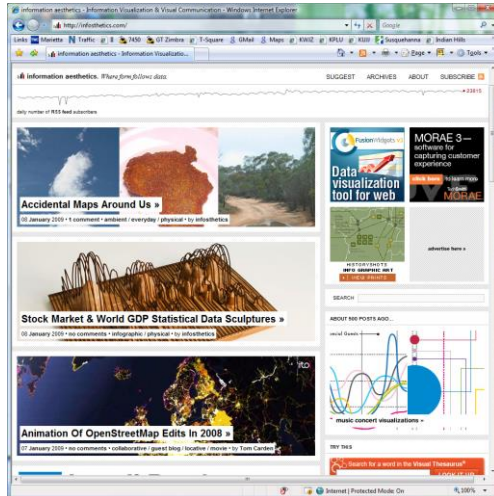
Fall 2015

CS 7450

94

# Infosthetics Blog

<http://infosthetics.com/>



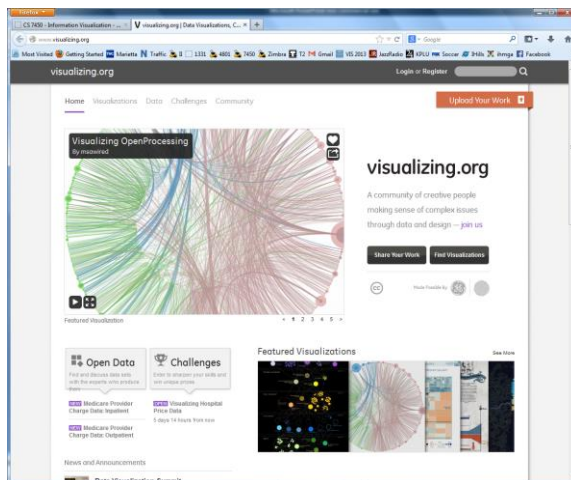
Fall 2015

CS 7450

95

# Visualizing.org

<http://www.visualizing.org>



Fall 2015

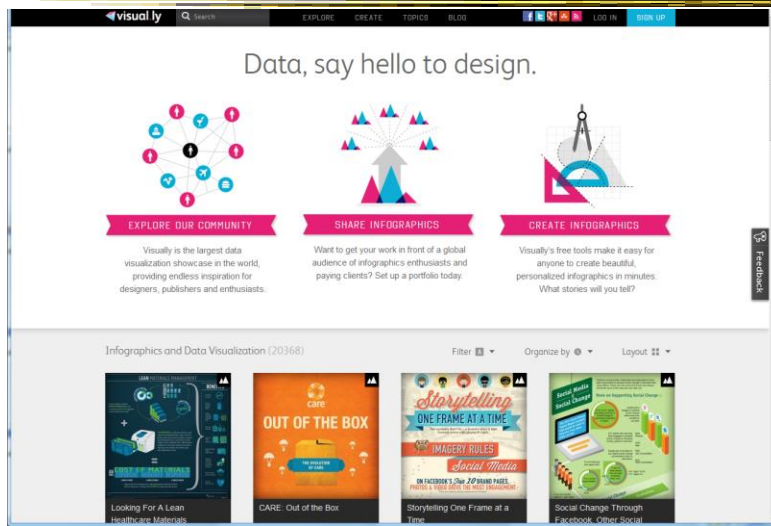
CS 7450

96



# Visual.ly

<http://visual.ly/>



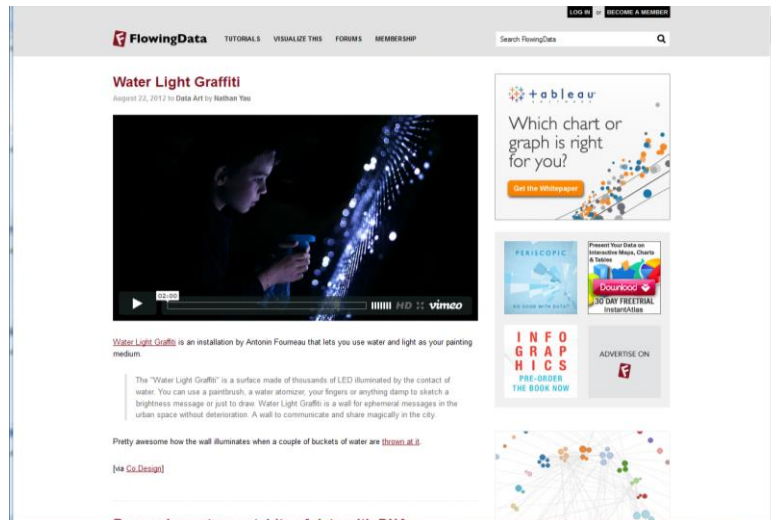
Fall 2015

CS 7450

97

# Flowing Data

<http://flowingdata.com/>

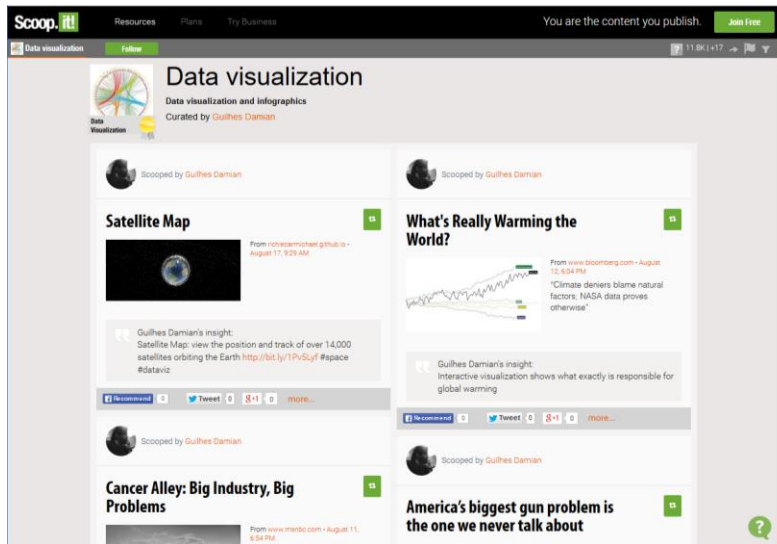


Fall 2015

CS 7450

98

# Scoop.It!

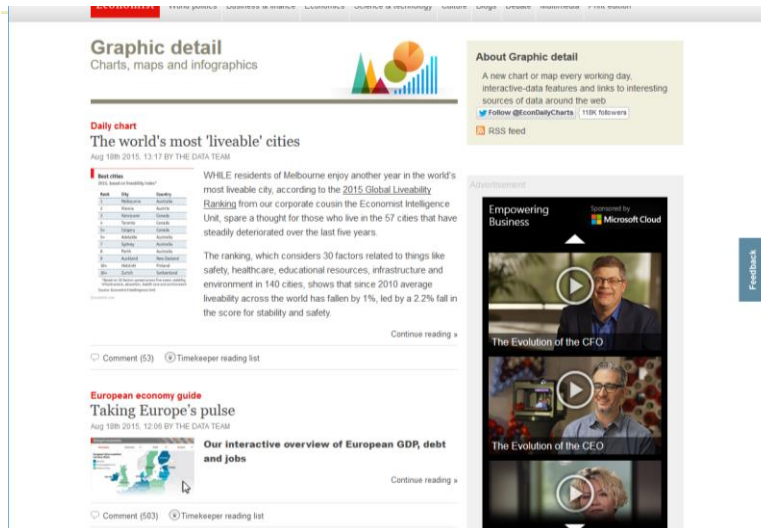


Fall 2015

CS 7450

99

# Graphic Detail - Economist

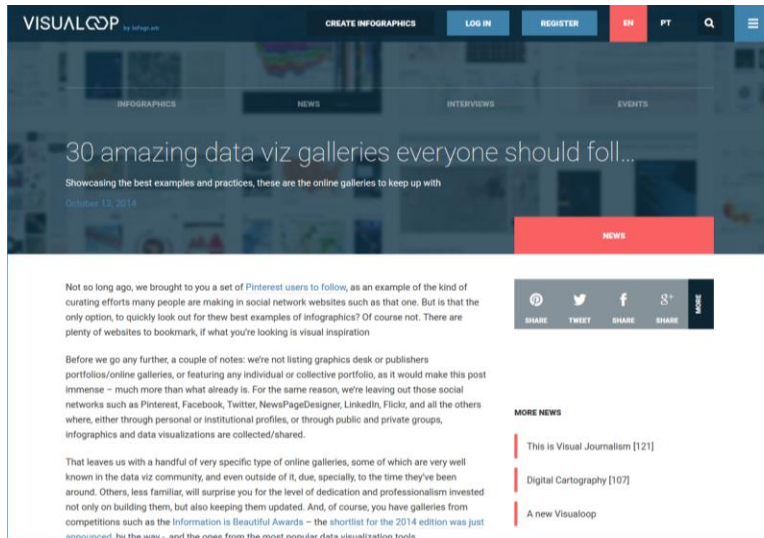


Fall 2015

CS 7450

100

# A Compendium



Fall 2015

CS 7450

101

# S. Few Book

- Chapters 1-3 read



Fall 2015

CS 7450

102

# HW



- HW1 due next Monday
  - Data Exploration and Analysis
  - Bring 2 hardcopies

Fall 2015

CS 7450

103

# Upcoming



- Multivariate data & charts
  - Reading:  
S. Few – web article
- S. Few's Design Guidance
  - Reading:  
Few book, chapters 5-12

Fall 2015

CS 7450

104