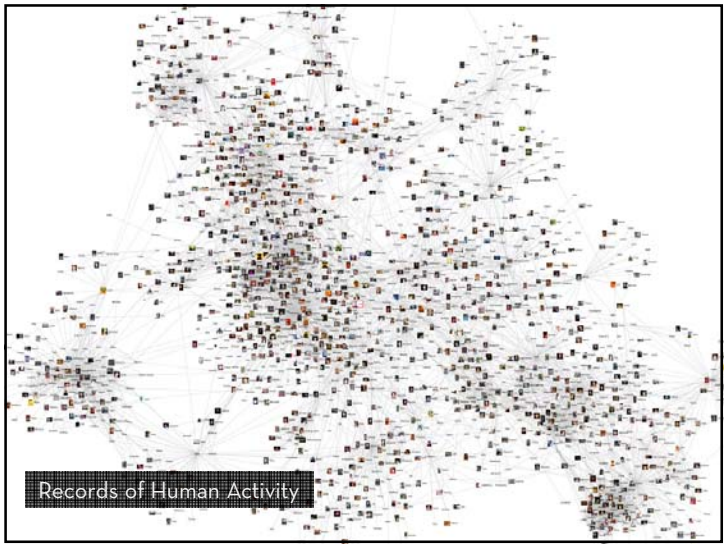
Interactive Tools for Data Transformation & Visualization

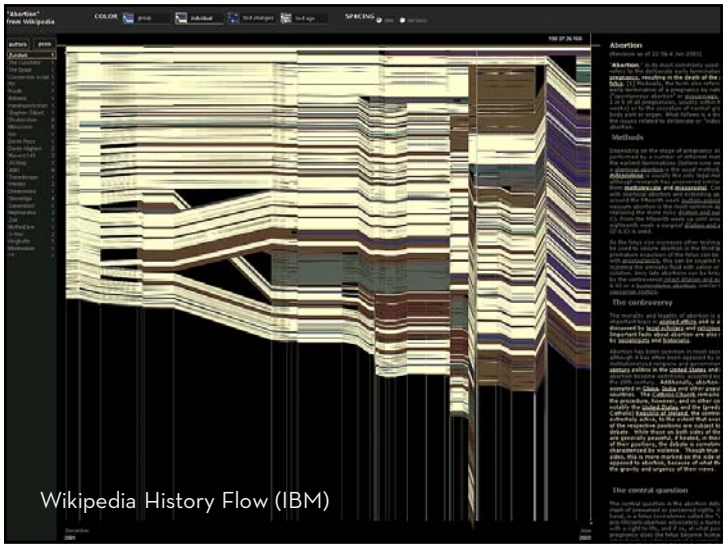
Jeffrey Heer Stanford University

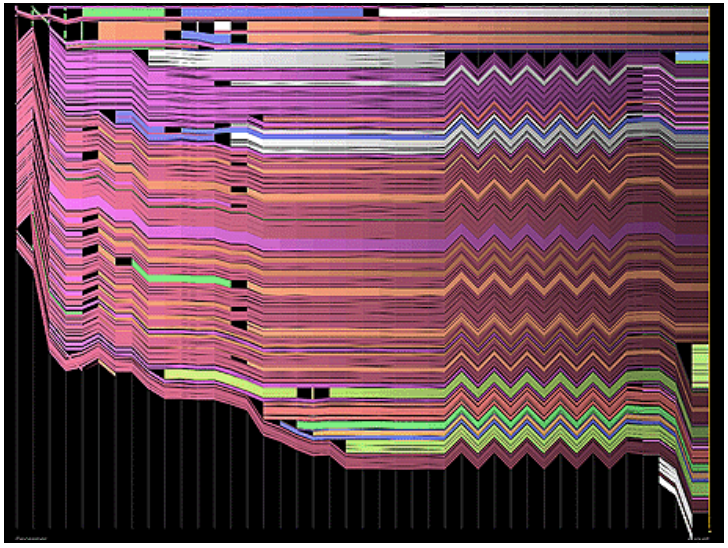
How much data (bytes) did we produce in 2010?

2010: 1,200 exabytes
10x increase over 5 years

Gantz et al, 2008, 2010

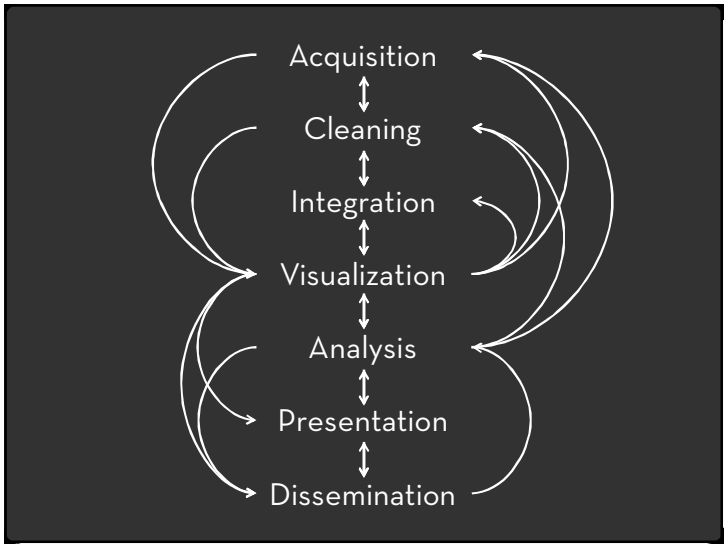


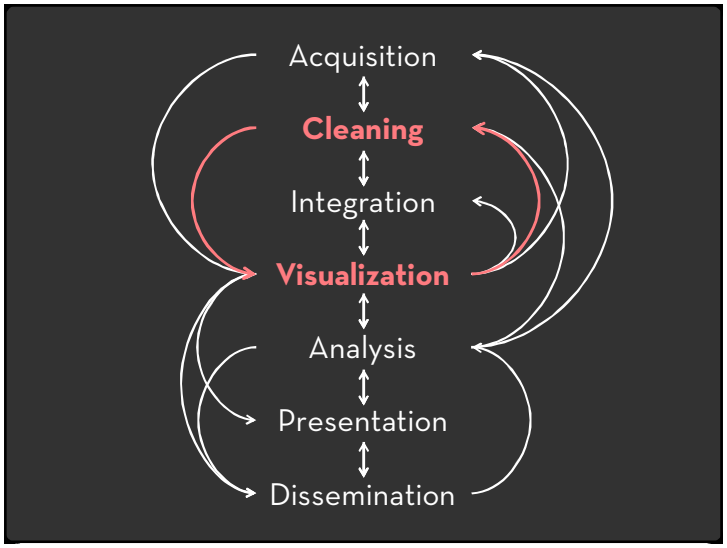




The ability to take data—to be able to **understand** it, to **process** it, to **extract value** from it, to **visualize** it, to **communicate** it—that's going to be a hugely important skill in the next decades, … because now we really do have **essentially free and ubiquitous data**. So the complimentary scarce factor is the ability to understand that data and extract value from it.

Hal Varian, Google's Chief Economist
The McKinsey Quarterly, Jan 2009





Bureau of Justice Statistics - Data Online
http://bjs.ojp.usdoj.gov/

Reported crime in Alabama

Year	Population	Property crime rate	Burglary rate	Larceny-theft rate	Motor vehicle theft rate
2004	4525375	4029.3	987	2732.4	309.9
2005	4548327	3900	955.8	2656	289
2006	4599030	3937	968.9	2645.1	322.9
2007	4627851	3974.9	980.2	2687	307.7
2008	4661900	4081.9	1080.7	2712.6	288.6

Reported crime in Alaska

Year	Population	Property crime rate	Burglary rate	Larceny-theft rate	Motor vehicle theft rate
2004	657755	3370.9	573.6	2456.7	340.6
2005	663253	3615	622.8	2601	391
2006	670053	3582	615.2	2598.5	378.3
2007	683478	3373.9	538.9	2480	355.1
2008	686293	2928.3	470.9	2219.9	237.5

Reported crime in Arizona

Year	Population	Property crime rate	Burglary rate	Larceny-theft rate	Motor vehicle theft rate
2004	5739879	5073.3	991	3118.7	963.5
2005	5953007	4827	946.2	2958	922
2006	6166318	4741.6	953	2874.1	914.4
2007	6338755	4502.6	935.4	2780.5	786.7
2008	6500180	4087.3	894.2	2605.3	587.8

Reported crime in Arkansas

Year	Population	Property crime rate	Burglary rate	Larceny-theft rate	Motor vehicle theft rate
2004	2750000	4033.1	1096.4	2699.7	237
2005	2775708	4068	1085.1	2720	262
2006	2810872	4021.6	1154.4	2596.7	270.4
2007	2834797	3945.5	1124.4	2574.6	246.5
2008	2855390	3843.7	1182.7	2433.4	227.6

Reported crime in California

Year	Population	Property crime rate	Burglary rate	Larceny-theft rate	Motor vehicle theft rate
2004	35842038	3423.9	686.1	2033.1	704.8
2005	36134147	3321	692.9	1915	712
2006	36437349	3175.2	676.9	1831.5	666.8
2007	36533215	3032.6	648.4	1784.1	600.2
2008	36756666	2940.3	646.8	1769.8	523.8

Reported crime in Colorado

Year	Population	Property crime rate	Burglary rate	Larceny-theft rate	Motor vehicle theft rate
2004	4601821	3918.5	717.3	2679.5	521.6

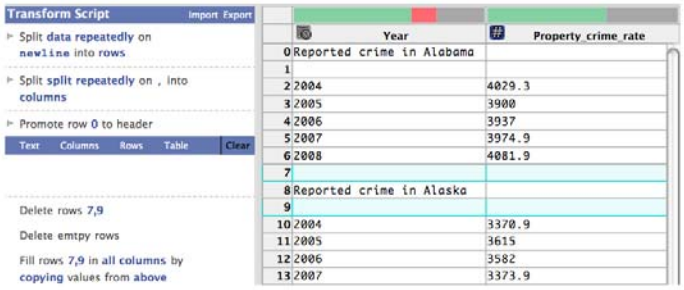
Data Wrangling (n):

A process of iterative data exploration and transformation that enables analysis.

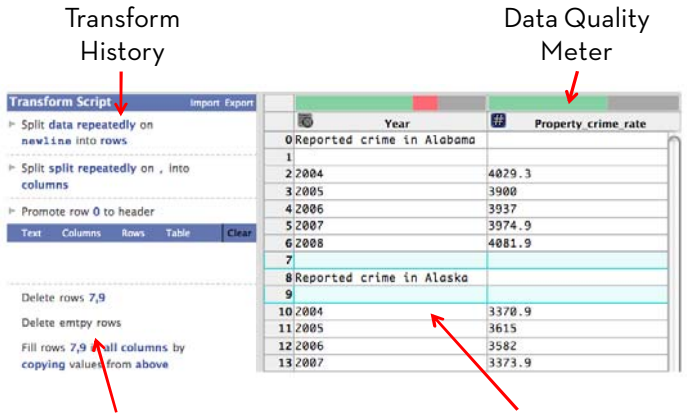
The goal of wrangling is to make data *useful*:

- Map data to a form readable by downstream tools (database, stats, visualization, ...)
- Identify, document, and (where possible) address data quality issues.

DataWrangler



with **Sean Kandel**, Andreas Paepcke & Joe Hellerstein



Data Wrangler

Declarative data transformation language

- **Tuple mapping** – split, merge, extract, delete
- **Lookups and joins** – e.g., FIPS code to US state
- **Reshaping** – e.g., cross-tabulation
- **Sorting, aggregation, etc.**

- Informed by prior work in databases, namely Potter's Wheel & SchemaSQL

Data Wrangler

Declarative data transformation language

+

Mixed-initiative interface for data transforms

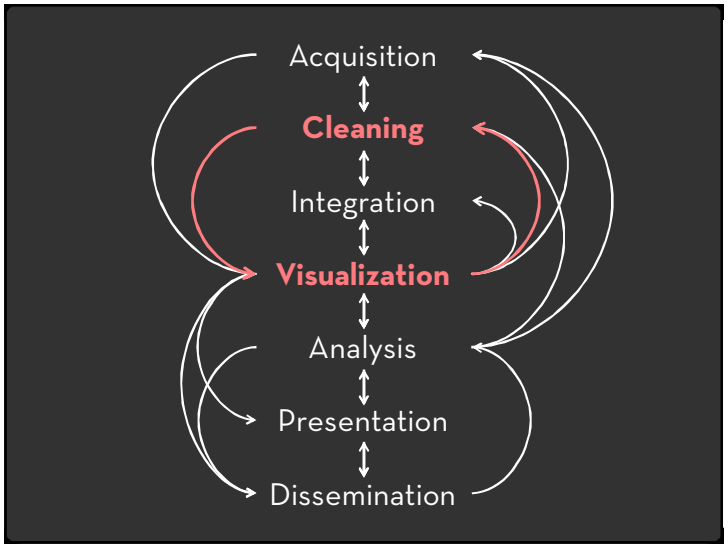
- **Select** data elements of interest
- **Suggest** applicable transforms
- Enable rapid **preview and refinement**

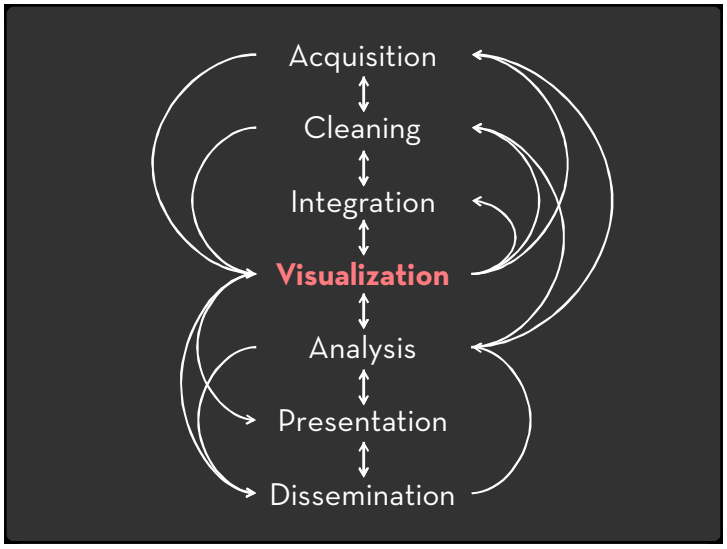
Comparative Evaluation

Compared Wrangler performance to Excel with 3 data cleaning tasks on small data sets.

Median completion time for Wrangler at least twice as fact in all tasks.

Skilled Excel users benefit proportionately!





How do people create visualizations?

Chart Typology
Pick from a stock of templates
Easy-to-use but limited expressiveness
Prohibits novel designs, new data types

Component Architecture
Permits more combinatorial possibilities
Novel views require new operators,
which requires software engineering.

Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Languages
Tableau VizQL, ggplot2, HiVE

?

Component Model Architectures
Improvise, Prefuse, Flare

Graphics APIs
OpenGL, Java2D, GDI+, Processing

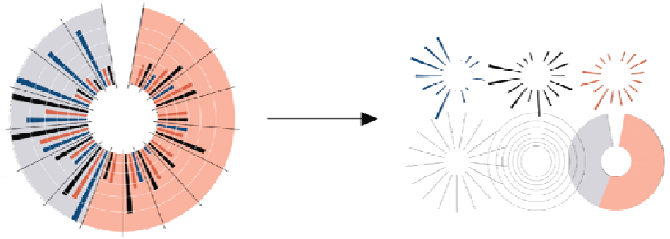
Efficiency ↑

Expressiveness ↓

Today's first task is not to invent wholly new [*graphical*] techniques, though these are needed. Rather we need most vitally to recognize and reorganize the essential of old techniques, to make easy their assembly in new ways, and to modify their external appearances to fit the new opportunities.

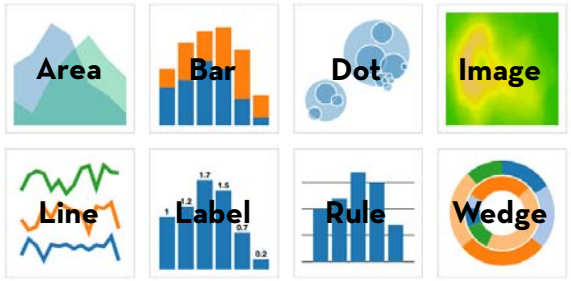
J. W. Tukey, *The Future of Data Analysis*, 1962.

Protovis: A Declarative Language for Visualization



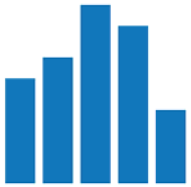
A graphic is a composition of data-representative marks.

with **Mike Bostock** & **Vadim Ogievetsky**



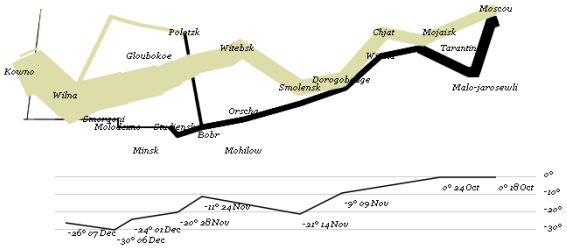
Protovis

Create customized visualizations using a declarative specification language.



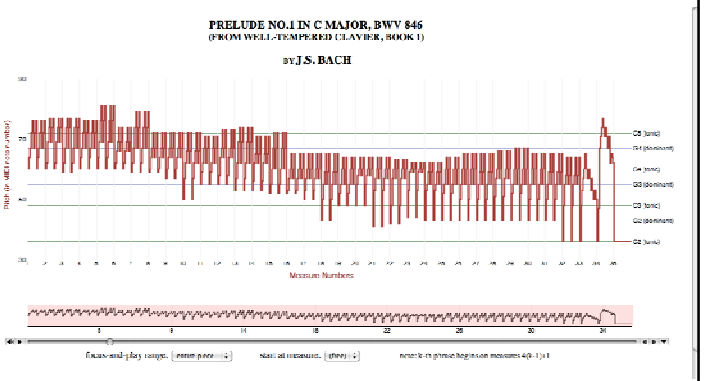
```
var vis = new pv.Panel();
vis.add(pv.Bar)
  .data([1, 1.2, 1.7, 1.5, .7])
  .bottom(10)
  .width(20)
  .height(function(d) d * 70)
  .left(function()  this.index * 25 + 20);
vis.render();
```

Protovis (http://protovis.org) – Declarative Visualization Specification

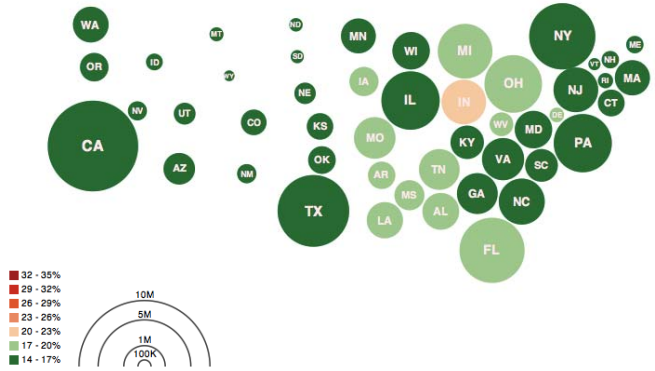



```
var army = pv.nest(napoleon.army, "dir", "group");
var vis = new pv.Panel();

var lines = vis.add(pv.Panel).data(army);
lines.add(pv.Line)
  .data(function() army[this.idx])
  .left(lon).top(lat).size(function(d) d.size/8000)
  .strokeStyle(function() color[army[panelIndex][0].dir]);

vis.add(pv.Label).data(napoleon.cities)
  .left(lon).top(lat)
  .text(function(d) d.city).font("italic 10px Georgia")
  .textAlign("center").textBaseline("middle");
```

```
vis.add(pv.Rule).data([0,-10,-20,-30])
  .top(function(d) 300 - 2*d - 0.5).left(200).right(150)
  .lineWidth(1).strokeStyle("#ccc")
  .anchor("right").add(pv.Label)
    .font("italic 10px Georgia")
    .text(function(d) d+"°").textBaseline("center");

vis.add(pv.Line).data(napoleon.temp)
  .left(lon).top(tmp) .strokeStyle("#0")
.add(pv.Label)
  .top(function(d) 5 + tmp(d))
  .text(function(d) d.temp+"° "+d.date.substr(0,6))
  .textBaseline("top").font("italic 10px Georgia");
```



Bach's Prelude #1 in C Major | Jieun Oh



Obesity Map | Vadim Ogievetsky

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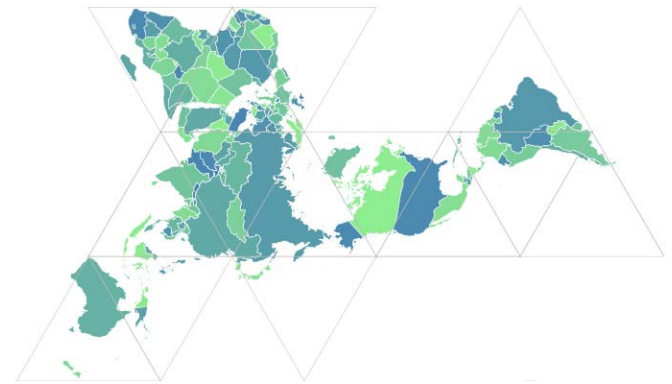
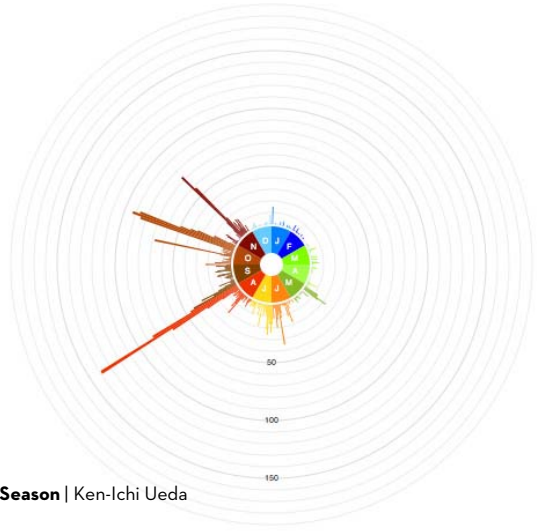


Dymaxion Maps | Vadim Ogievetsky



FlickrSeason | Ken-Ichi Ueda

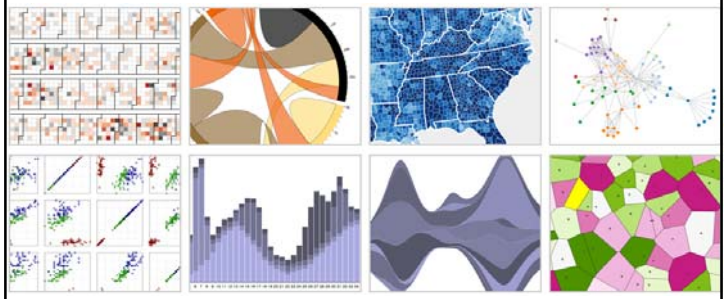
Exploiting Declarative Specification

Protovis has led to faster designs, less code
- Job Voyager: 5x less code, 10x less dev time
- Over 40,000 downloads and widely in use

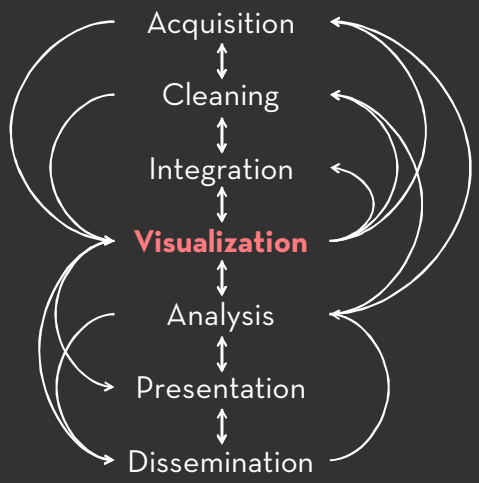
Multiple implementations: JavaScript & Java

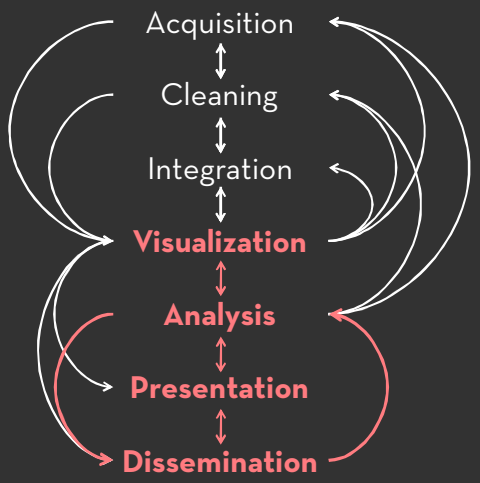
Behind-the-scenes optimization & parallelization
- 20x scalability over prior systems (in Java)

d3.js Data-Driven Documents



by **Mike Bostock**

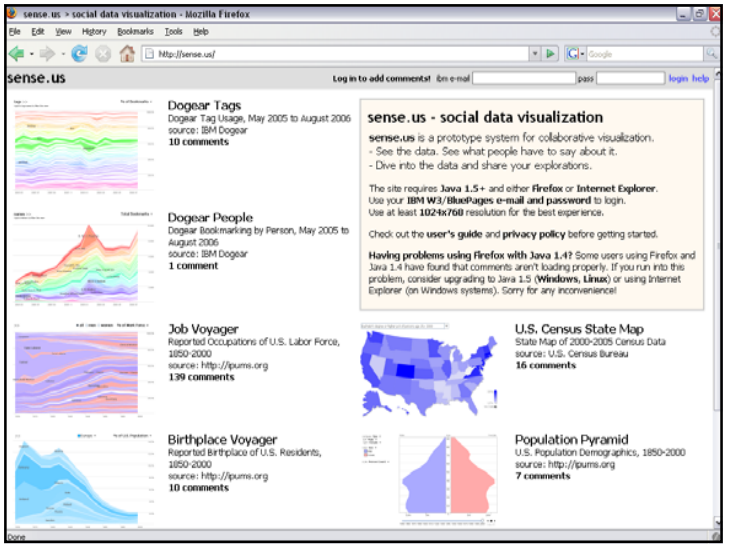


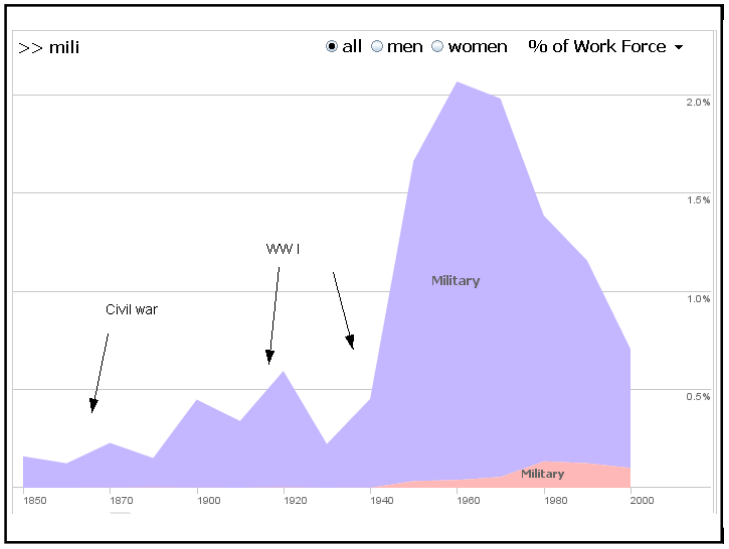


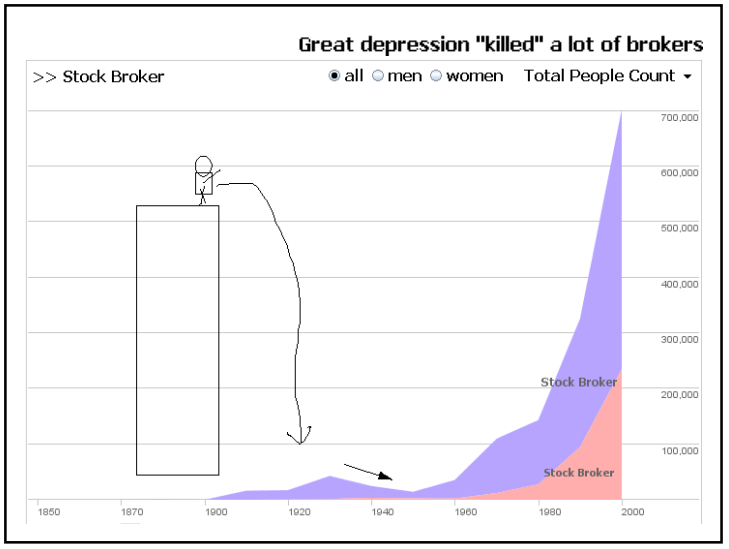
sense.us

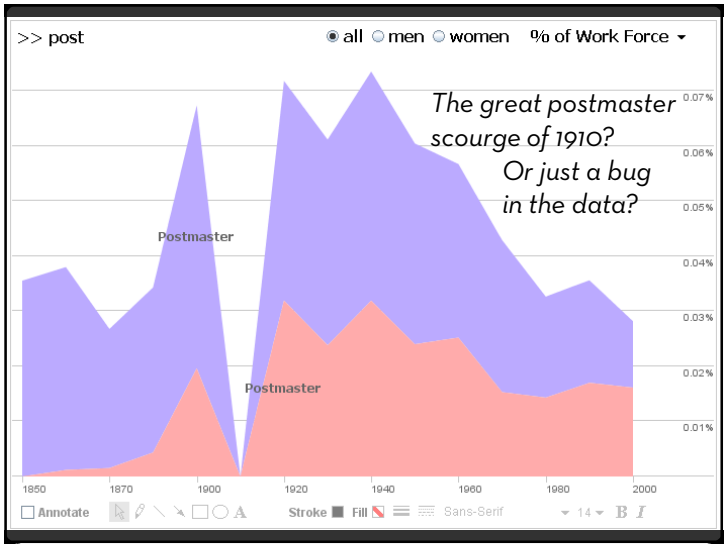
A Web Application for Collaborative Visualization of Demographic Data

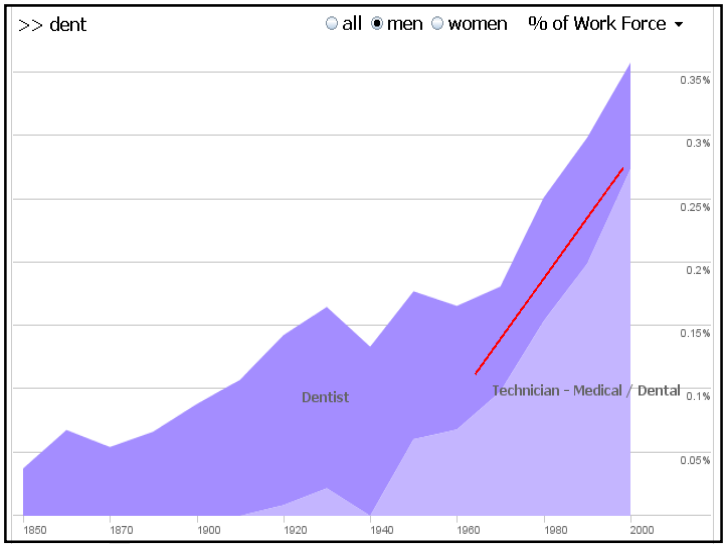
with **Fernanda Viégas** and **Martin Wattenberg**







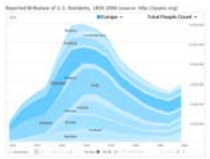




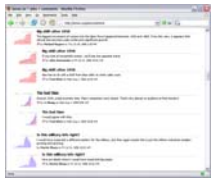
Voyagers and Voyeurs

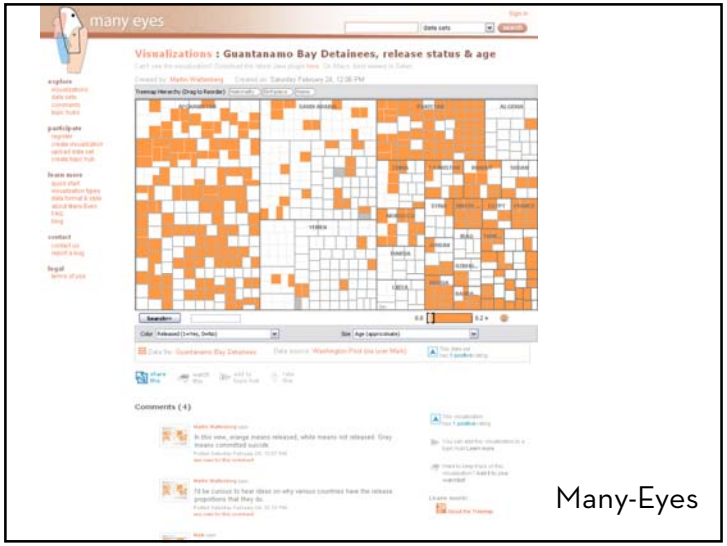
Complementary faces of analysis

Voyager – focus on visualized data
Active engagement with the data
Serendipitous comment discovery



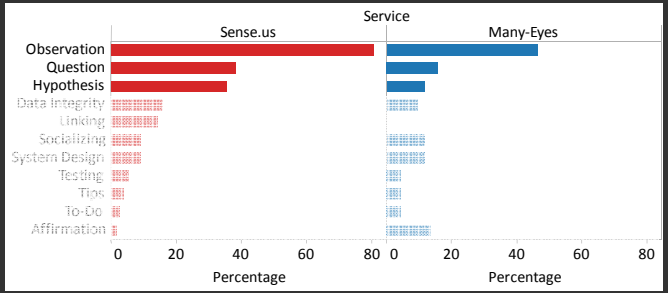
Voyeur – focus on comment listings
Investigate others' explorations
Find people and topics of interest
Catalyze new explorations





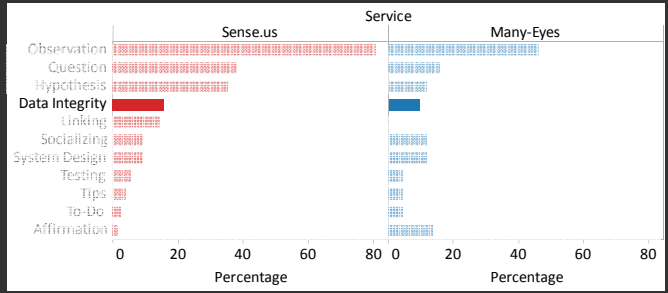
Many-Eyes

Content Analysis of Comments

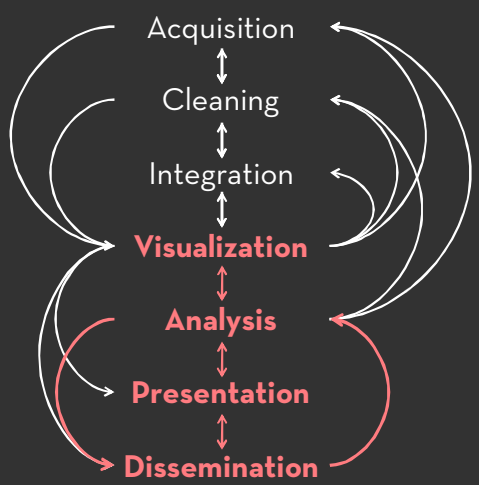


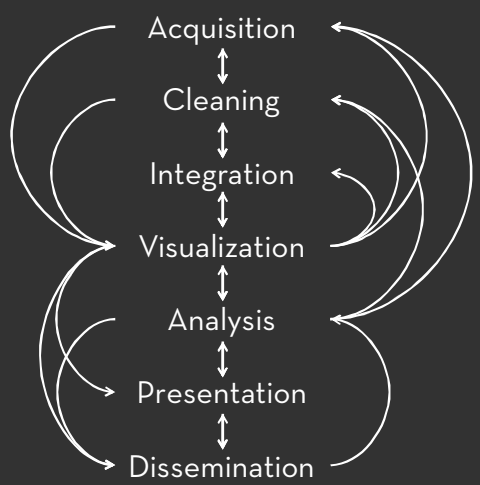
Feature prevalence from content analysis (min Cohen's $\kappa = .74$)
High co-occurrence of Observation, Question, and Hypothesis

Content Analysis of Comments



16% of sense.us comments and **10%** of Many-Eyes comments reference *data integrity* issues.





Students & Collaborators

Mike Bostock
Jason Chuang
Sean Kandel
Diana MacLean
Vadim Ogievetsky

Joe Hellerstein, Andreas Paepcke
Fernanda Viégas, Martin Wattenberg

Interactive Tools for Data Transformation & Visualization

Jeffrey Heer http://vis.stanford.edu