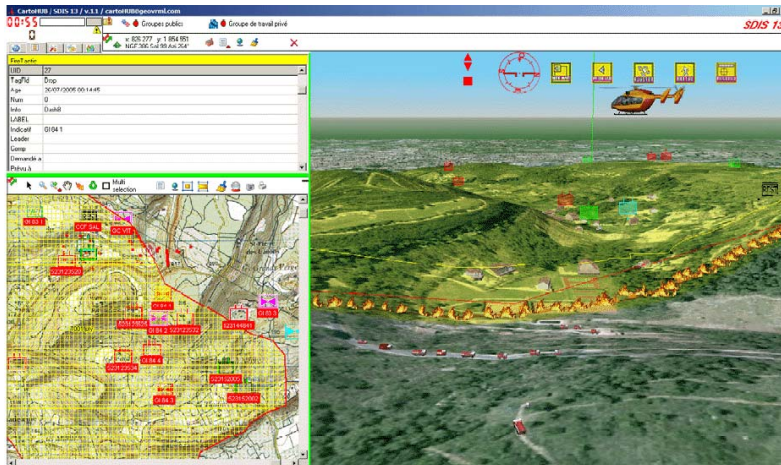


# Introduction to Visual Analytics



Week 1 Lecture 1  
IAT 355  
Lyn Bartram

# Introductions

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- Instructor
  - Lyn Bartram
  - [lyn@sfu.ca](mailto:lyn@sfu.ca)
- Visualization
  - Information visualization
  - Personal visual analytics
  - Perception, attention and visual representations
  - Visualization for sustainable living/Ambient visualization
  - Motion and Animation visual techniques
  - Affect and aesthetics





# Introductions: Maha

---

- She will introduce herself

# Data are everywhere

Table 2: Outstanding Student Loan Debt Owed as Share of Household Income and Assets, by Household Income Group, 2010

Household Income Group, 2010	% of Income
Lowest fifth (less than \$21,044)	24
Second fifth (\$21,044 - \$36,723)	10
Middle fifth (\$36,724 - \$59,623)	12
Fourth fifth (\$59,624 - \$97,585)	7
80% - 89.9% (\$97,586 - \$146,791)	7
Richest 10% (more than \$146,792)	2
All Households	6

Source: Fry (2012)

## Vancouver Average Detached Home Prices See Worst Slide In 39 Years

The Huffington Post Canada | By Jesse Ferreras



- An average-priced detached home throughout Greater Vancouver now costs \$1,470,265, compared to \$1,764,682 in July.
- An average attached home fell by 8.6 per cent to \$730,189
- apartments dropped by 7.8 per cent to \$528,808.

### Canada

#### Quarterly population estimate

(Note) (October 1, 2017)

**36,885,049**

**0.5% ↑**

(quarterly change)

#### Consumer Price Index

(November 2017)

**2.1% ↑**

(12-month change)

#### Unemployment rate

(November 2017)

**5.9%**

**-0.4 pts ↓**

(monthly change)

#### Real GDP by expenditure

(Third quarter 2017)

**1.7% ↑**

(quarterly change, annualized)

#### Industrial Product Price Index

(October 2017)

**1.0% ↑**

(monthly change)

#### Retail sales

(October 2017)

**\$49.9 billion**

**1.5% ↑**

(monthly change)

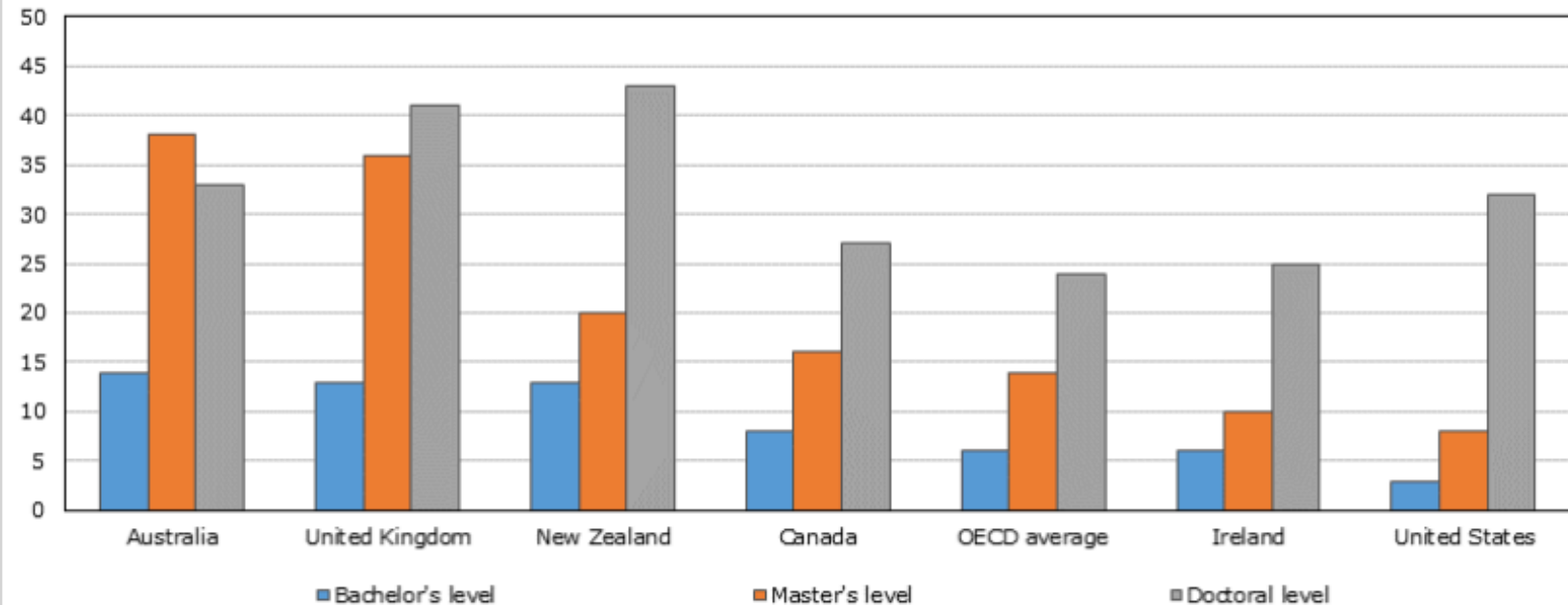
ACTIVE  
GY

# Easier when we see it

**Chart 2**

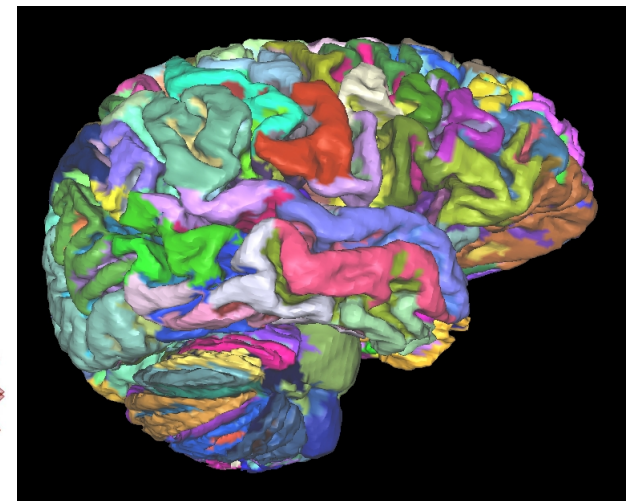
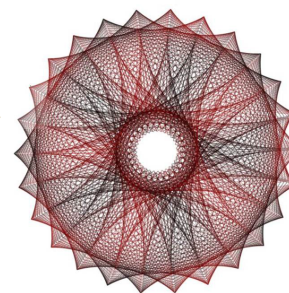
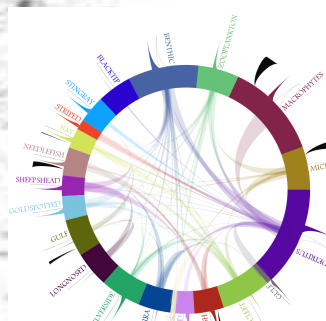
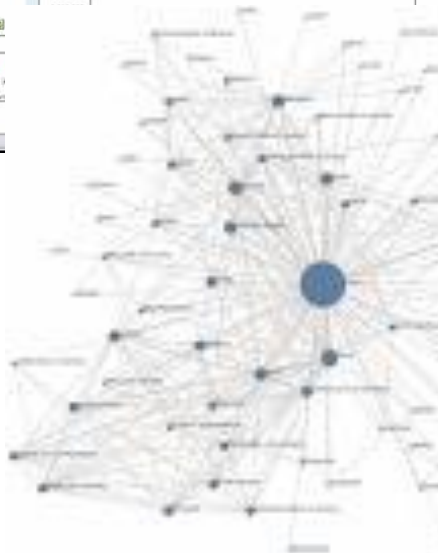
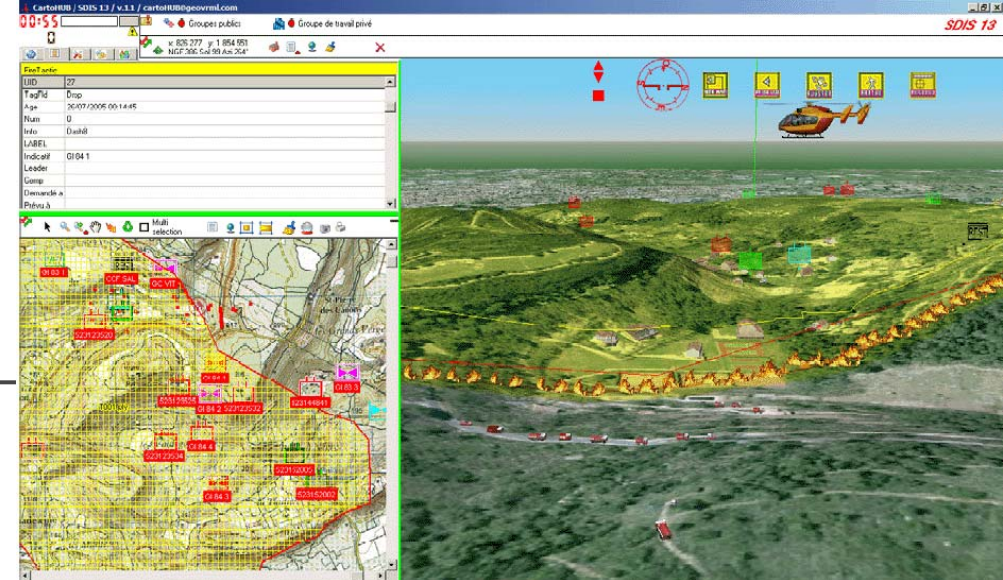
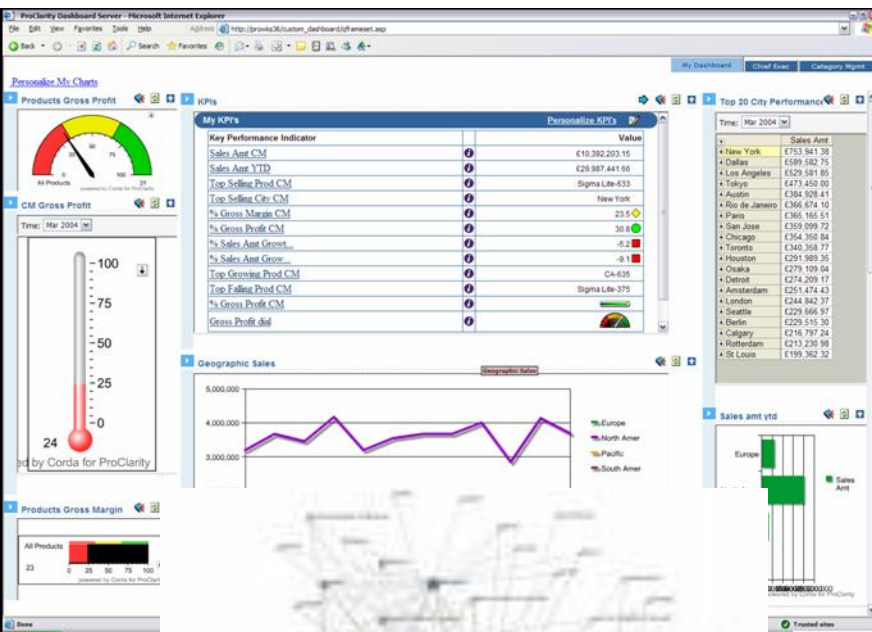
**Proportion of international students, by program level, selected OECD countries, 2012-2013**

percent



Note: To provide some context, the same reference years (2012-2013) values for Canada come directly from the Postsecondary Student Information System (PSIS).





# Visualization

Computer-based systems that provide visual representations of data designed to help people carry out tasks more effectively.

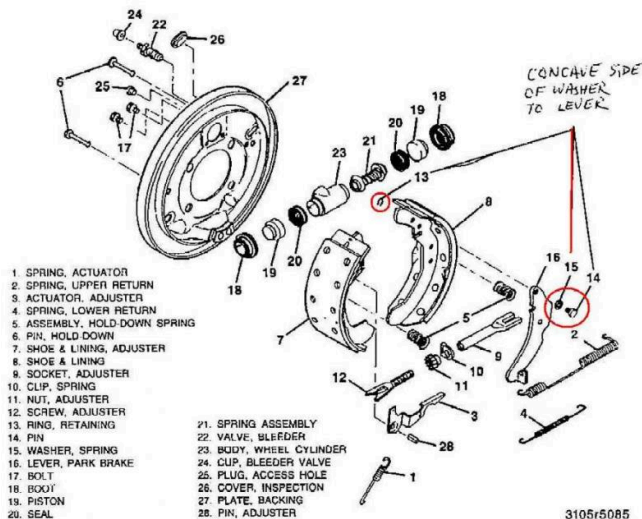
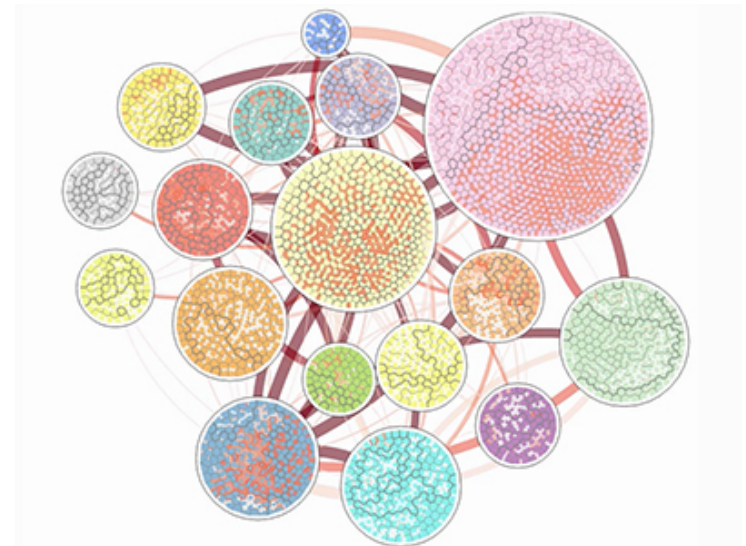


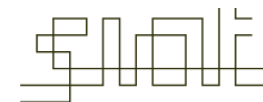
Figure 1—Leading/Trailing Drum Brake

??? or



[Brake Diagram for Chevy Malibu, justanswer.com](http://justanswer.com)

[Vorograph, IBM 2015](http://www.vorograph.com)



SCHOOL OF INTERACTIVE  
ARTS + TECHNOLOGY

# Why do we care?

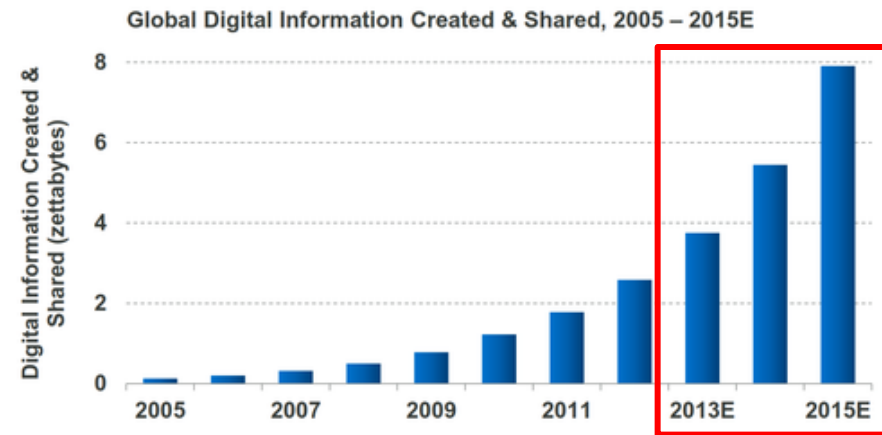




# An explosion of data

- Everyday we produce ~2.5 quintillion petabytes of data
- Amount of data produced doubles every two years
- 2013 - 4.4 zettabytes
- 2020 - 44 zettabytes
- 1 zettabyte = 44 trillion gigabytes!

*Amount of global digital information created & shared  
– from documents to pictures to tweets –  
grew 9x in five years to nearly 2 zettabytes\* in 2011, per IDC.*



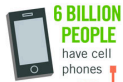
<https://www.emc.com/leadership/digital-universe/2014iview/executive-summary.htm>

# The FOUR V's of Big

## VALUE

### 40 ZETTABYTES

[ 43 TRILLION GIGABYTES ]  
of data will be created by 2020, an increase of 300 times from 2005



6 BILLION PEOPLE have cell phones

WORLD POPULATION: 7 BILLION

### Volume SCALE OF DATA

### It's estimated that 2.5 QUINTILLION BYTES

[ 2.3 TRILLION GIGABYTES ]  
of data are created each day



As of 2011, the global size of data in healthcare was estimated to be

150 EXABYTES  
[ 161 BILLION GIGABYTES ]



### Variety DIFFERENT DATA

By 2014, it's anticipated there will be  
420 MILLION WEARABLE, WIRELESS HEALTH MONITORS

4 BILLION+ HOURS OF VIDEO are watched on YouTube each month



400 MILLION TWEETS are sent per day by about 200 million monthly active users



The New York Stock Exchange captures

1 TB OF TRADE INFORMATION

during each trading session



By 2016, it is projected there will be

18.9 BILLION NETWORK CONNECTIONS

— almost 2.5 connections per person on earth

### Velocity ANALYSIS OF STREAMING DATA



100 SENSORS that monitor items such as fuel level and tire pressure



internal and external sources such as transactions, social media, enterprise content, sensors and mobile devices. Companies can leverage data to adapt their products and services to better meet customer needs, optimize operations and infrastructure, and find new sources of revenue.

By 2015  
4.4 MILLION IT JOBS will be created globally to support big data, with 1.9 million in the United States



LEADERS don't trust the information they use to make decisions



in one survey were unsure of how much of their data was inaccurate

### Veracity UNCERTAINTY OF DATA

Poor data quality costs the US economy around

\$3.1 TRILLION A YEAR



Sources: McKinsey Global Institute, Twitter, Cisco, Gartner, EMC, SAS, IBM, MEPEEC, QAS

IBM

[www.ibmbigdatahub.com](http://www.ibmbigdatahub.com)

The production of data is expanding at an astonishing pace. Experts now point to a 4300% increase in annual data generation by 2020. Drivers include the switch from analog to digital technologies and the rapid increase in data generation by individuals and corporations alike.

Size of Total Data  
Enterprise Created Data  
Enterprise Managed Data

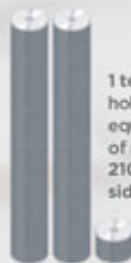
2020: MORE THAN 1/3 OF THE DATA PRODUCED WILL LIVE IN OR PASS THROUGH THE CLOUD.

2012: CUSTOMERS WILL START STORING 1 EB OF INFORMATION.



### WHAT IS A ZETTABYTE?

1,000,000,000,000	gigabytes
1,000,000,000,000	terabytes
1,000,000,000,000,000	petabytes
1,000,000,000,000,000,000	exabytes
1,000,000,000,000,000,000,000	zettabyte



1 terabyte holds the equivalent of roughly 210 single-sided DVDs.

It took roughly 1 petabyte of local storage to render the 3D CGI effects in Avatar.



In 2007, the estimated information content of all human knowledge was 295 exabytes.

### DATA PRODUCTION WILL BE 44 TIMES GREATER IN 2020 THAN IT WAS IN 2009

More than 70% of the digital universe is generated by individuals. But enterprises have responsibility for the storage, protection and management of 80% of it.\*



# Data Velocity

The Digital Universe: 50-fold Growth from the Beginning of 2010 to the End of 2020

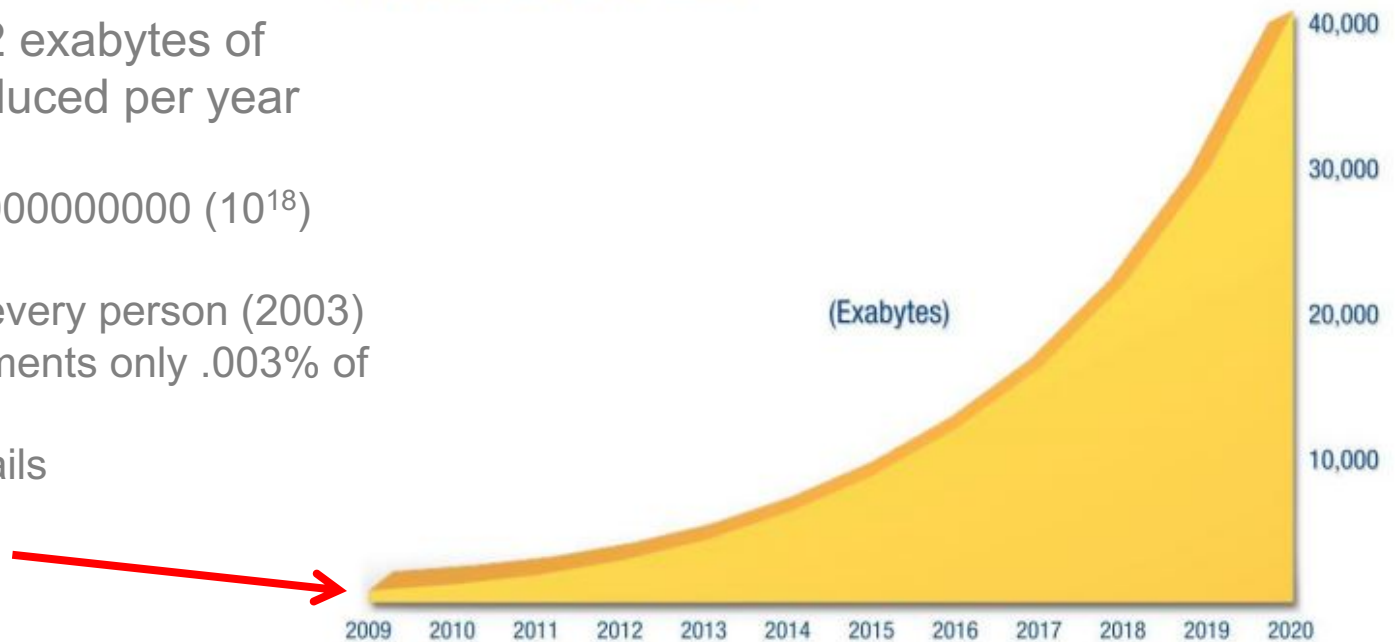
Between 1 and 2 exabytes of unique data produced per year (2009)

1000000000000000000 (10<sup>18</sup>) bytes

800 meg for every person (2003)

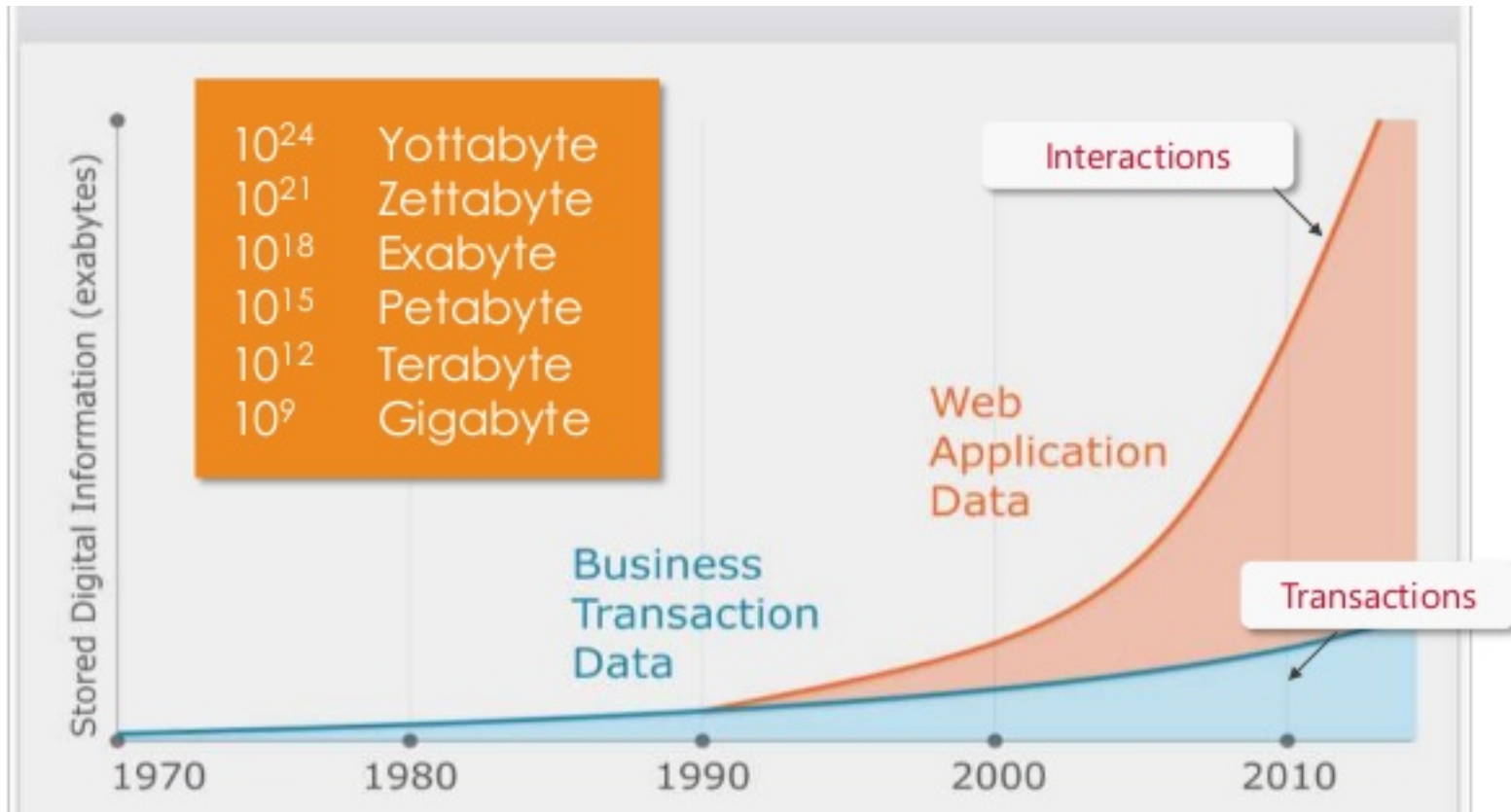
Printed documents only .003% of total

90 trillion emails



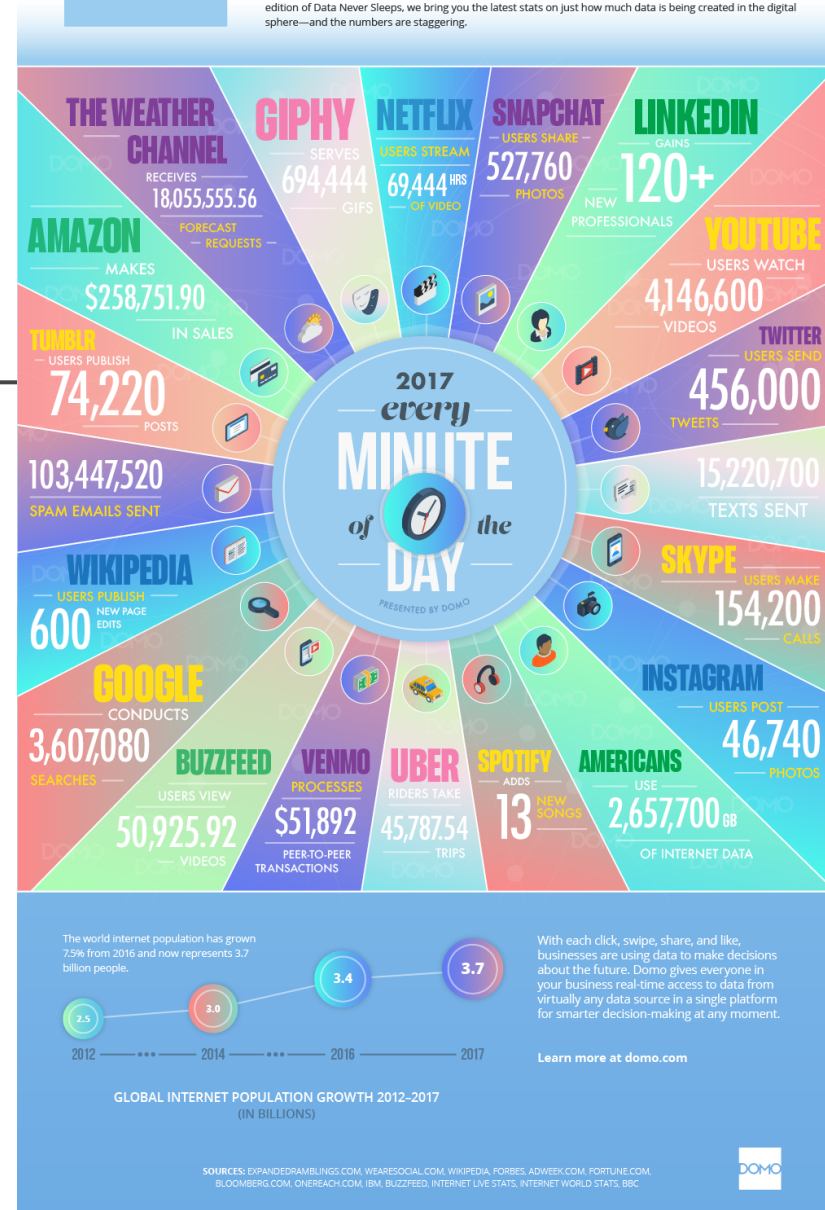
Source: IDC's Digital Universe Study, sponsored by EMC, December 2012

# Data Growth and Volume



# Volume and Variety

- How much data goes through the Internet in 1 minute  
[www.internetlivestats.com](http://www.internetlivestats.com)
- Data, documents, media, social media, sensed, ...
- > ½ from mobile activity
- Corporate, consumer, government, social, criminal, enforcement..

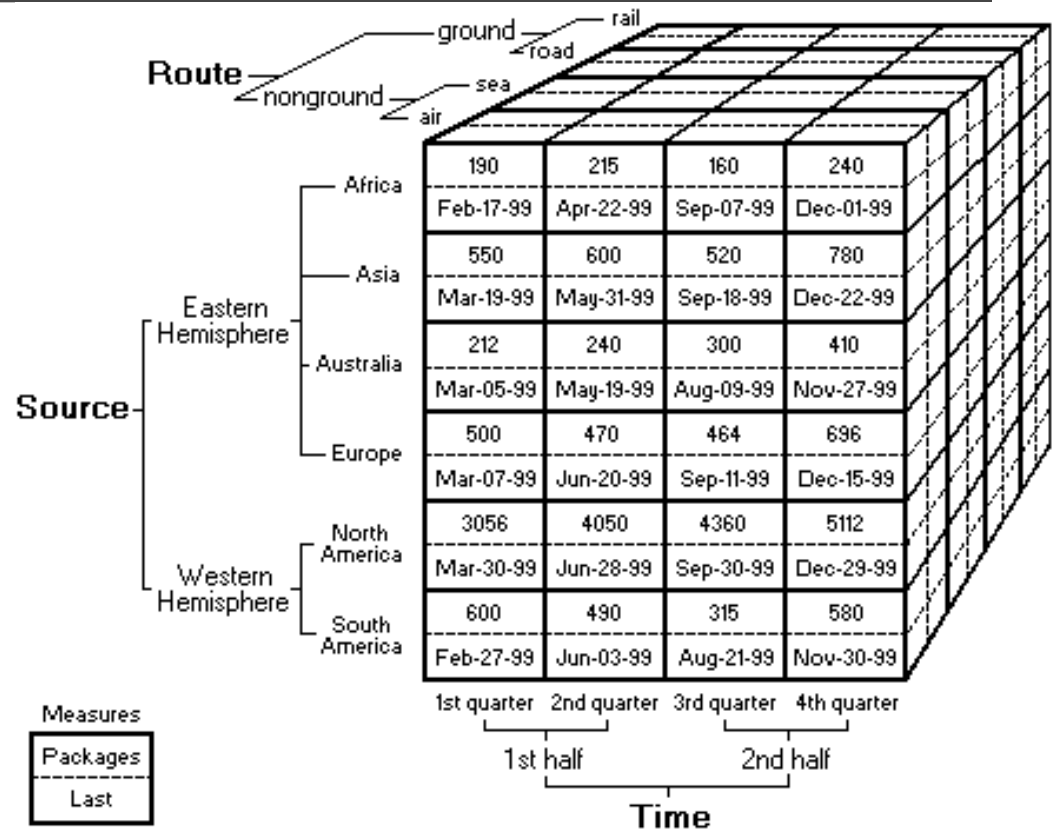


<http://www.iflscience.com/technology/this-is-how-much-data-the-internet-gets-through-in-one-minute/>



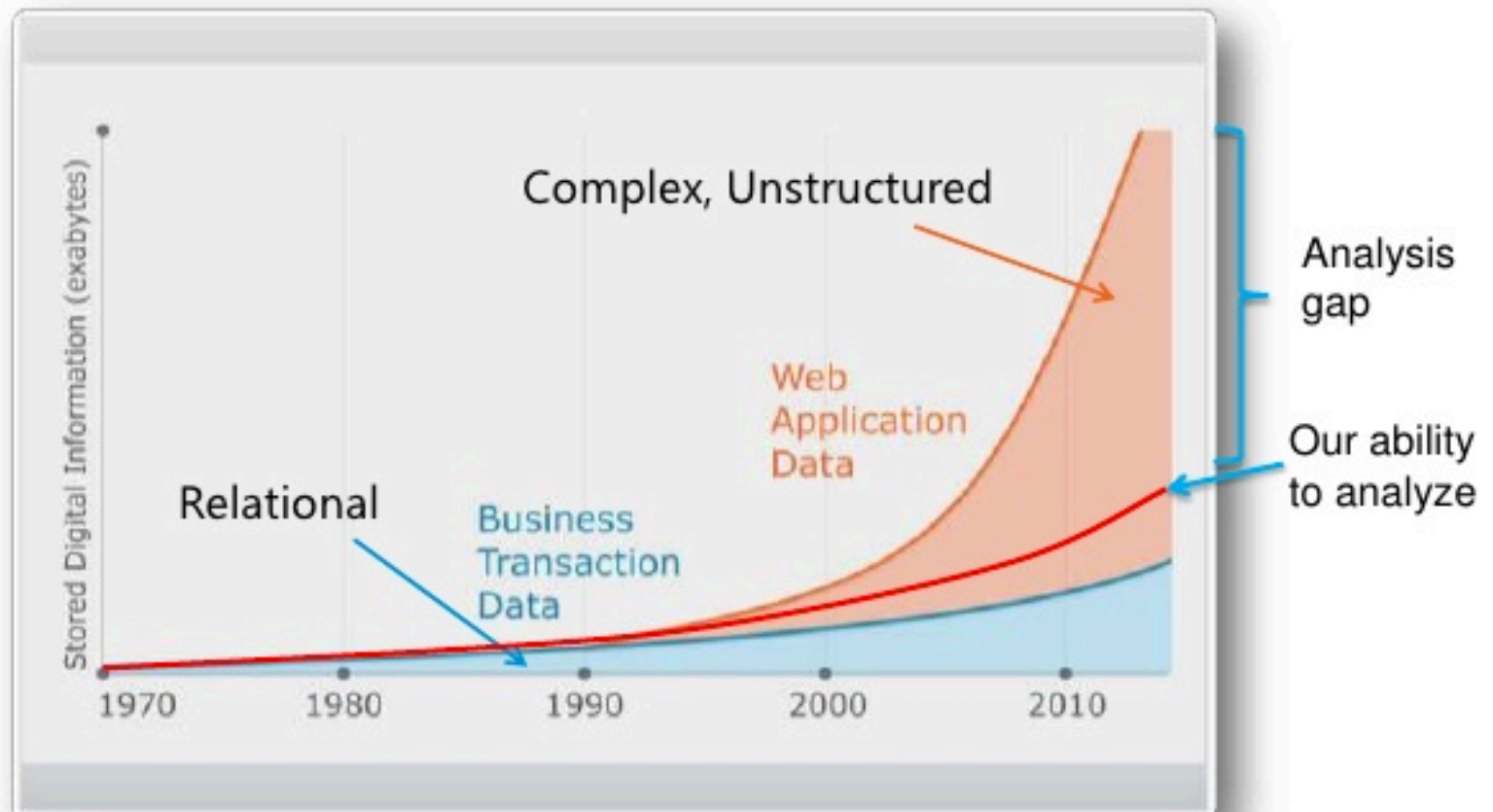
# Variety: Heterogeneous Data

- Highly multidimensional
- A data “case” has many aspects – attributes –
  - DIMENSIONS



# New kinds of data

## Structured data vs. Unstructured data growth



Source: An IDC White Paper - sponsored by EMC. As the Economy Contracts, the Digital Universe Expands. May 2009.

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# So what is Big Data??

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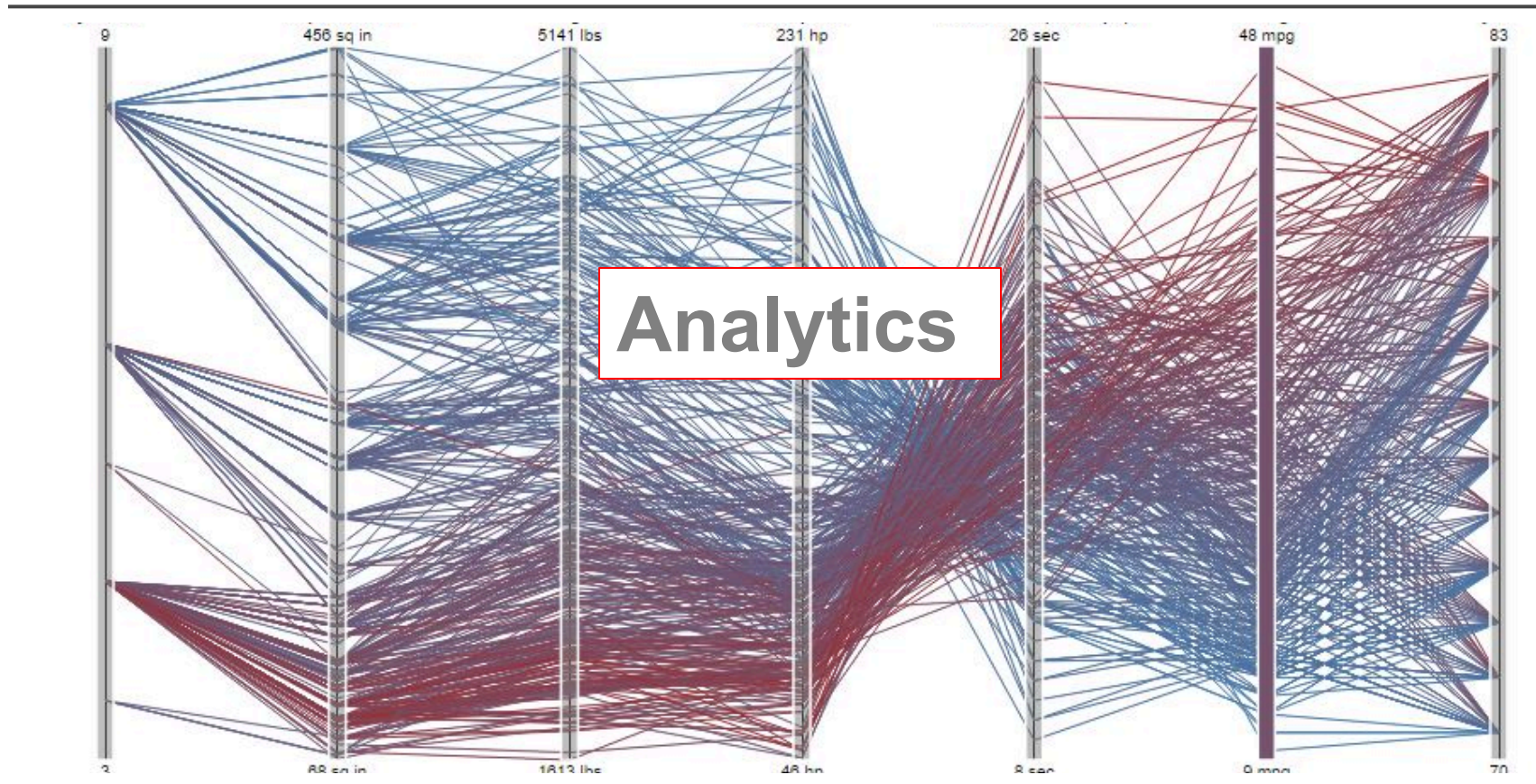


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discovery, interpretation, and communication of meaningful patterns in data





# Analytics are everywhere

- A simple problem
  - What is the best breakfast cereal to buy for your family/house?
  - What properties do you need to consider?



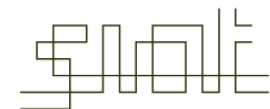
# Traditional analysis

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- Deductive
- Questions are already known
- Factors of importance are already set
- Looking for the descriptive or statistically significant answer

Or .....

- Needle in a haystack of intermediate results



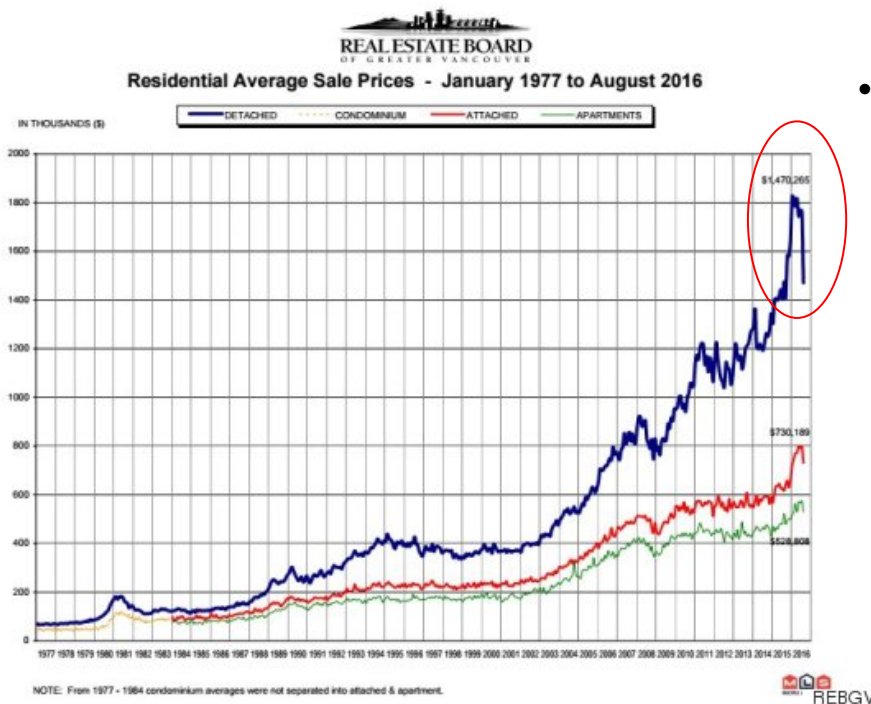
# Visualization for *analysis*

## Vancouver Average Detached Home Prices See Worst Slide In 39 Years

The Huffington Post Canada | By Jesse Ferreras

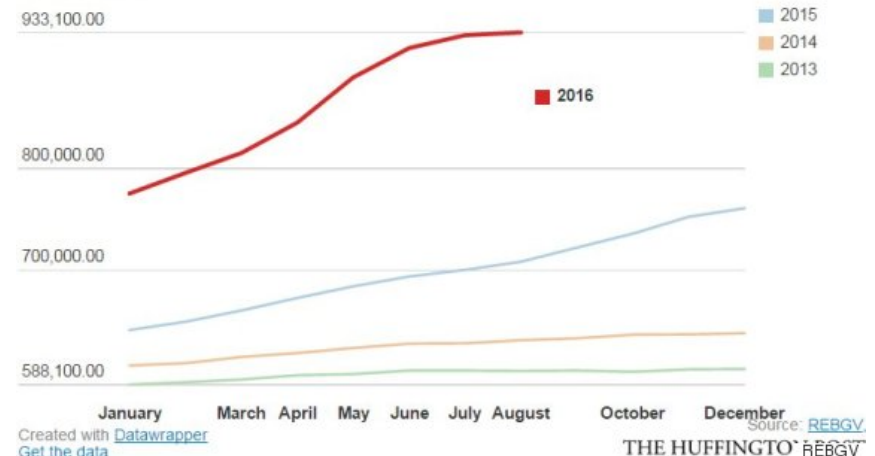


- An average-priced detached home throughout Greater Vancouver now costs \$1,470,265, compared to \$1,764,682 in July.
- An average attached home fell by 8.6 per cent to \$730,189
- apartments dropped by 7.8 per cent to \$528,808.



Greater Vancouver, Benchmark Price, 2015 to 2016

This chart shows how the benchmark price of a Greater Vancouver home has trended over the past three years. Figures in 000s.



# AN OLD FOLKTALE

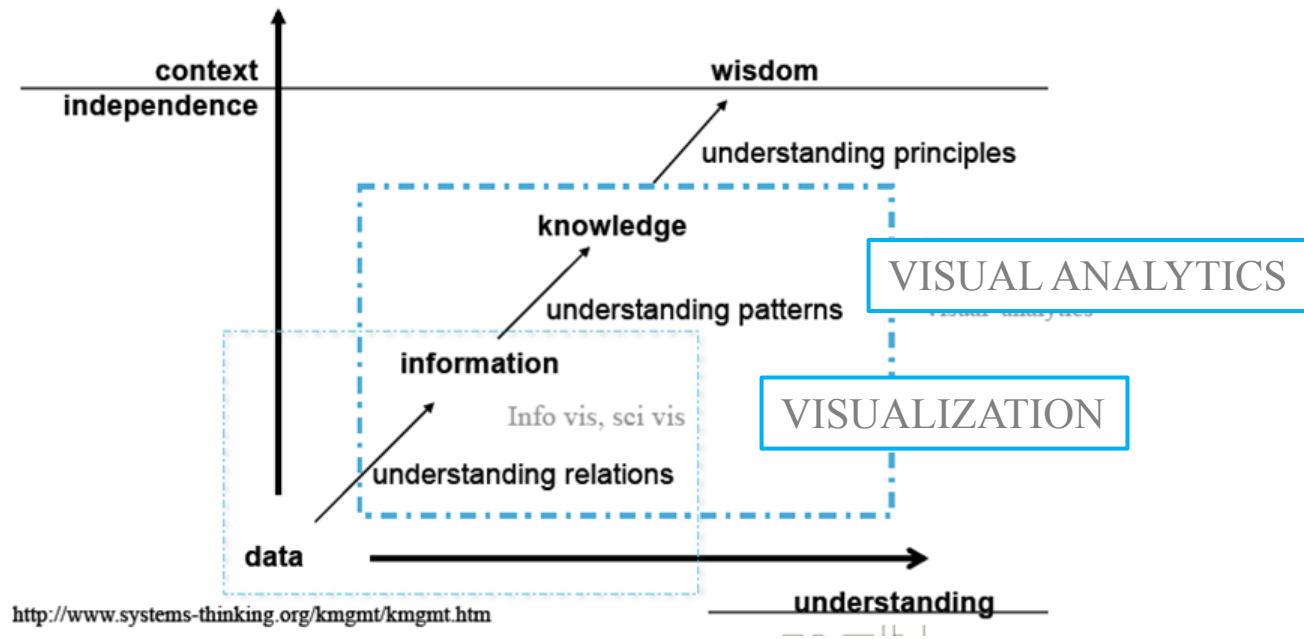
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We need to examine and analyze data from multiple perspectives



# From Data to Knowledge



# Or following our general theme ....

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**Data**



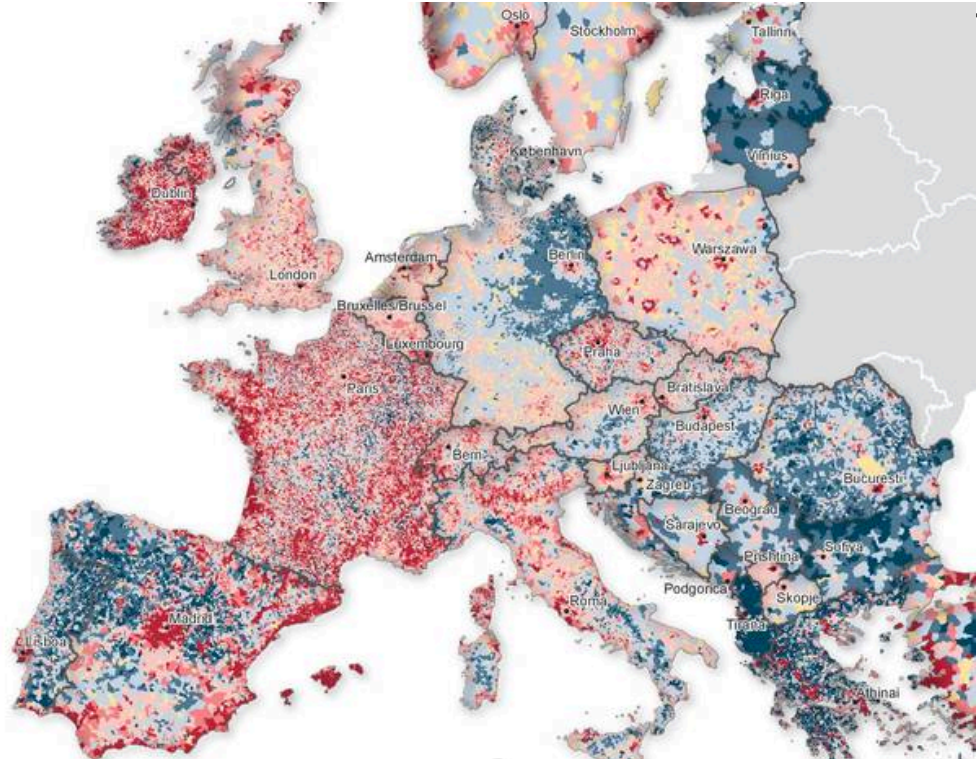
[cphicography.com](http://cphicography.com)



# Visualizations make data into information

## Why some European countries (should) love asylum seekers

*The Independent, Sept. 2015*



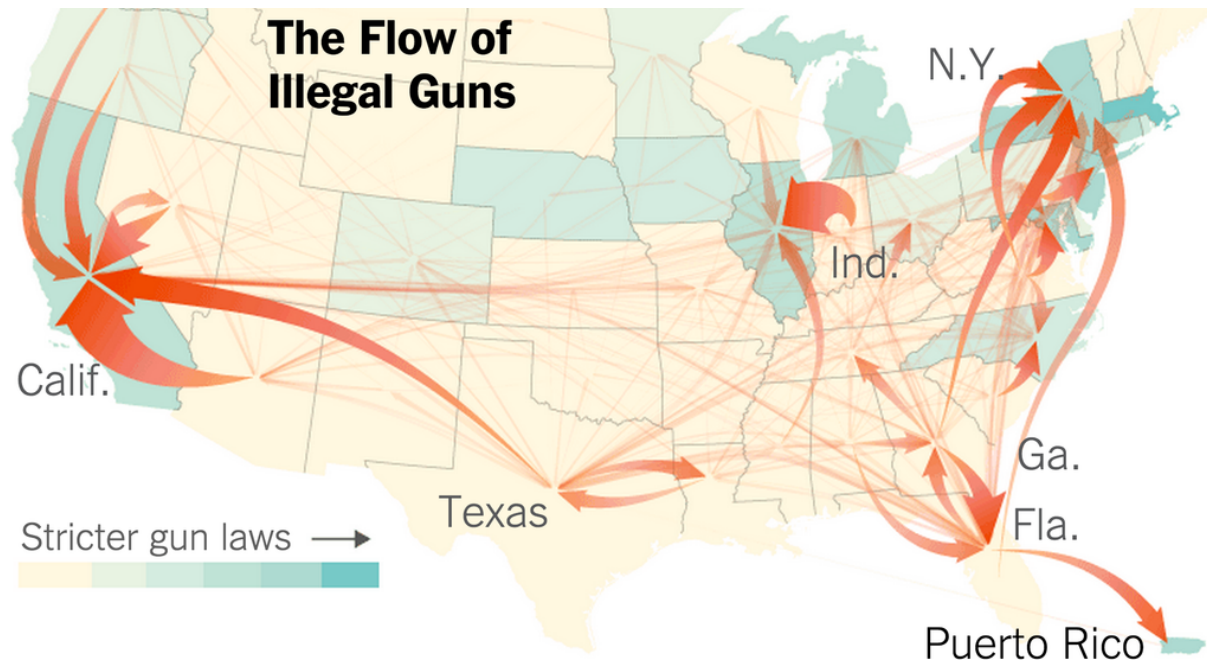
Introduction to Visual  
Analytics



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Visualization  
helps us see  
patterns that  
predefined  
analytical queries  
do not elicit

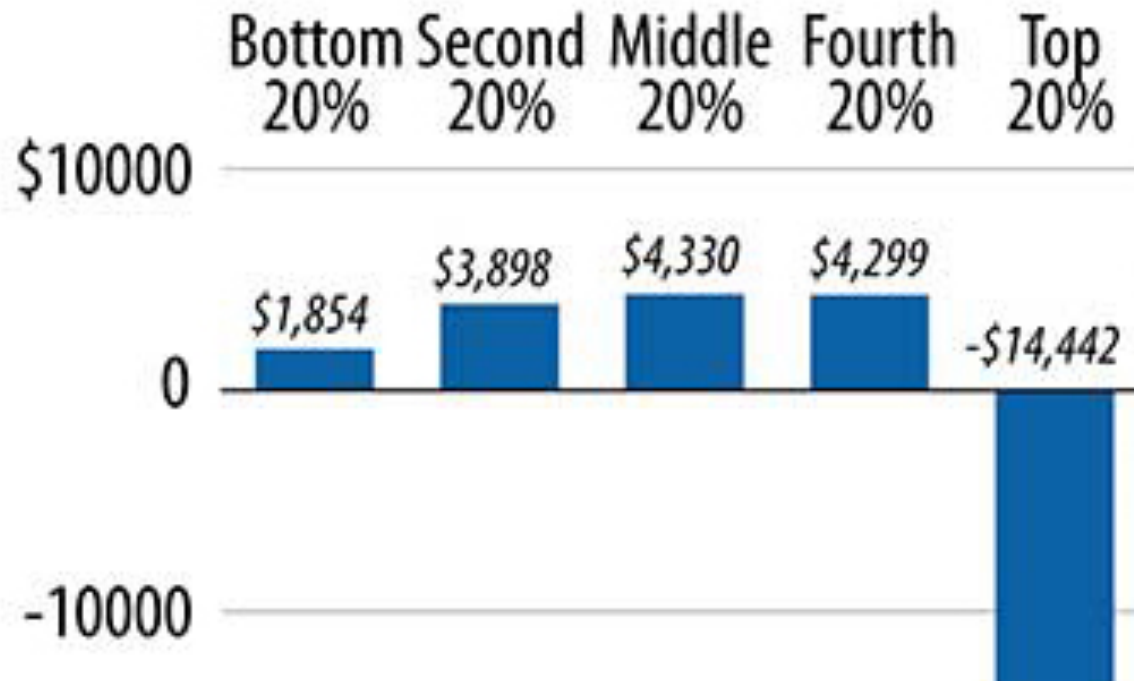


<http://www.mdpi.com/1660-4601/14/9/1056>

# At first glance: the Cain 9-9-9 tax proposal

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*Relative to current tax policy, 2013*

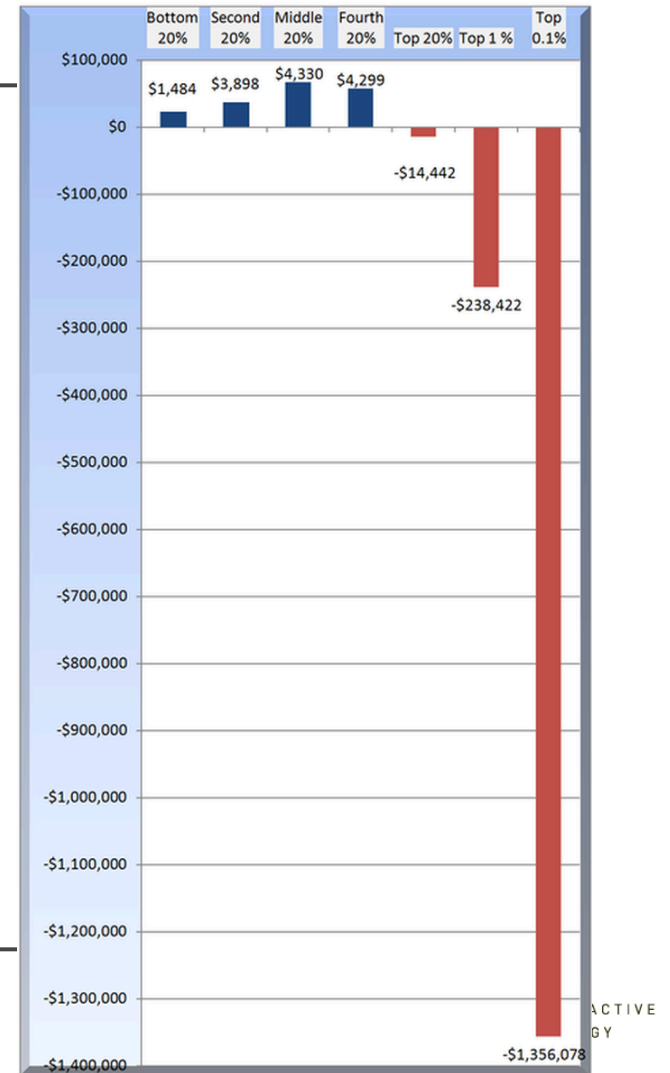


# But really: It's not just about the “data”

A different picture  
tells a very different  
story

Tax Policy Center, 2011

[http://www.rob-servations.com/1/post/2011/10/cains-9-9-9-tax-policy-explained-with-one-chart.html#.Usw0G\\_aRs70](http://www.rob-servations.com/1/post/2011/10/cains-9-9-9-tax-policy-explained-with-one-chart.html#.Usw0G_aRs70)



# Analysis is complicated by cognitive limitations

---

- Two ways our brains manage limited short term memory:
  - *Consolidate into long-term memory using rehearsal*
  - *forget it*
- Without some way to offload information:
  - Thinking and analysis are more difficult





# We use vision to think

---

- We build tools to amplify cognition.
- Example: multiplication (Card, Moran, & Shneiderman.)
  - In your head, multiply  $35 \times 95$
  - What if you did it on paper ?
  - People are 5 times faster with the visual aid

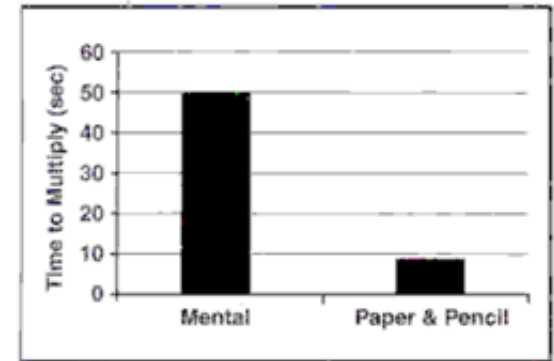


FIGURE 1.1

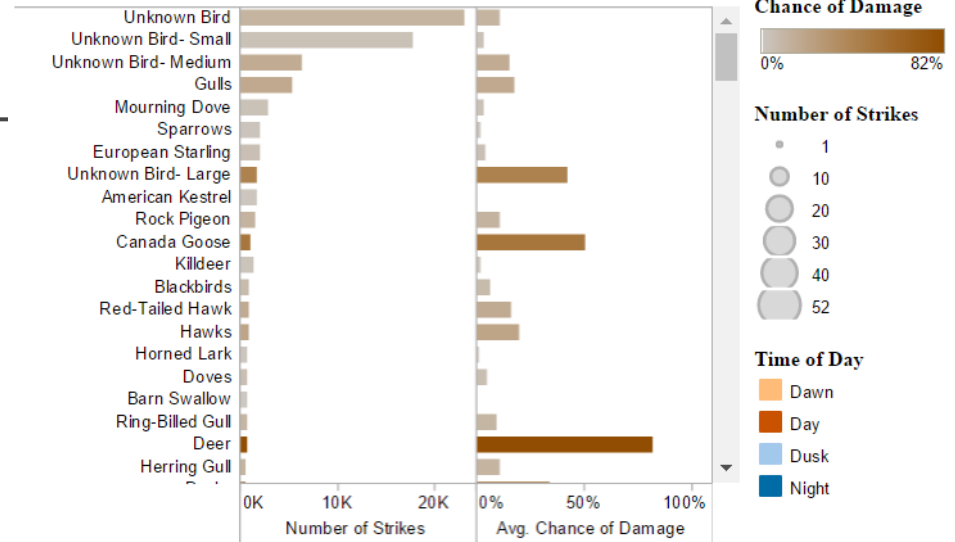
Use of external aids amplifies ability to do multiplication.

# Cognitive offloading

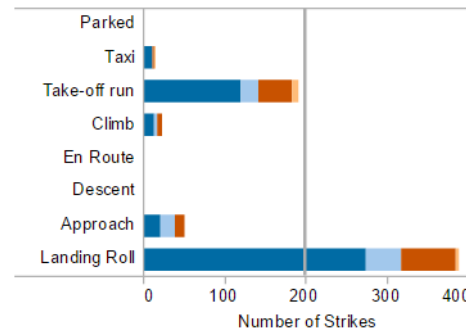
SPECIES_ID	SPECIES	BIRDS_SEEN	BIRDS_STRK	SIZE	WARNED	COMMENTS/REMARKS	AGS	COST_REPAIR	COST_OTHER	COST
UNKBM	Unknown bir	1	2 to 10	Medium		SOURCE = B/REMARKS - CROWS/RAVE	0			
UNKBM	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
L4201	Ring-necked	1	1	Medium		SOURCE = B/REMARKS - RUNWAY 17R	5600			
ZT101	Red-winged	1	1	Small		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNKBM	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
O2205	Mourning do	1	1	Small		SOURCE = B/REMARKS - FOUND BY GR	0			
ZT001	Eastern mea	1	1	Small		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNK	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNKBM	Unknown bir 2 to 10	2 to 10	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNKBM	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - BOSE AIR TER	0			
UNKBM	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNK	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNK	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
ZK	Cardinals, bu	1	1			SOURCE = B/REMARKS - AIRCRAFT -	0			
UNK	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNKBM	Unknown bir 2 to 10	2 to 10	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNKBM	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNK	Unknown bir or bat	1	1	Medium		SOURCE = B/REMARKS - FOUND ON PK	0			
YH004	Horned lark	2 to 10	1	Small		SOURCE = B/REMARKS - BLOOD MEAL	0			
ZT002	Western meadowlark	2 to 10	1	Small		SOURCE = B/REMARKS - NO REMAINS	0			
UNK	Unknown bir 2 to 10	2 to 10	1	Medium		SOURCE = B/REMARKS - FOUND ON PK	0			
YH005	Barn swallow	2 to 10	1	Small		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNK	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
K1302	Turkey vultur	1	1	Large		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNK	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
NE	Gulls/terms	1	1			SOURCE = B/REMARKS - SEAGULL AIR	0			
O2201	Rock pigeon	1	1	Small		SOURCE = B/REMARKS - POST FLIGHT	0			
UNK	Unknown bir or bat	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
ZT001	Eastern mea	1	1	Small		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNK	Unknown bir 2 to 10	2 to 10	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
K1302	Turkey vultur	1	1	Large		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNKBM	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - REFACED XL	3761			
UNK	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AC 0402 - RUP	0			
UNKBM	Unknown bir 2 to 10	2 to 10	1	Medium		SOURCE = B/REMARKS - FAA REPORT	0			
UNK	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - AIRCRAFT -	0			
UNKBM	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - FOUND ON PK	0			
UNKBM	Unknown bir	1	1	Medium		SOURCE = B/REMARKS - ROCK SPRING	0			



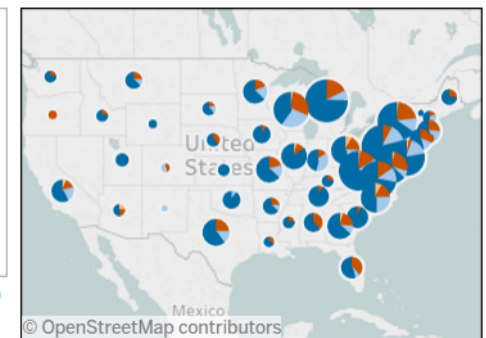
Select a species to view strikes:



Flight Phase at Strike:  
Deer



Location by Species:  
Deer

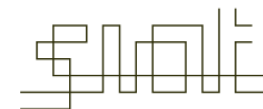


# Data thinking

1. Which state has the highest income?
2. Is there a relationship between income and education?
3. Is this consistent everywhere?

Table - StateData ()			Load	Snap
State	College Degree %	Per Capita Income		
Alabama	20.6%	11486		
Alaska	30.3%	17610		
Arizona	27.1%	13461		
Arkansas	17.0%	10520		
California	31.3%	16409		
Colorado	33.9%	14821		
Connecticut	33.8%	20189		
Delaware	27.9%	15854		
District of Columbia	36.4%	18881		
Florida	24.9%	14698		
Georgia	24.3%	13631		
Hawaii	31.2%	15770		
Idaho	25.2%	11457		
Illinois	26.8%	15201		
Indiana	20.9%	13149		
Iowa	24.5%	12422		
Kansas	26.5%	13300		
Kentucky	17.7%	11153		
Louisiana	19.4%	10635		
Maine	25.7%	12957		
Maryland	31.7%	17730		
Massachusetts	34.5%	17224		
Michigan	24.1%	14154		
Minnesota	30.4%	14389		
Mississippi	19.9%	9648		
Missouri	22.3%	12989		
Montana	25.4%	11213		
Nebraska	26.0%	12452		
Nevada	21.5%	15214		
New Hampshire	32.4%	15959		
New Jersey	30.1%	18714		
New Mexico	25.5%	11246		
New York	29.6%	16501		
North Carolina	24.2%	12885		
North Dakota	28.1%	11051		
Ohio	22.3%	13461		
Oklahoma	22.8%	11893		
Oregon	27.5%	13418		
Pennsylvania	23.2%	14068		
Rhode Island	27.5%	14981		
South Carolina	23.0%	11897		
South Dakota	24.6%	10661		
Tennessee	20.1%	12255		
Texas	25.5%	12904		
Utah	30.0%	11029		
Vermont	31.5%	13527		
Virginia	30.0%	15713		
Washington	30.9%	14923		
West Virginia	16.1%	10520		
Wisconsin	24.9%	13276		
Wyoming	25.7%	12311		

# Visual Reasoning

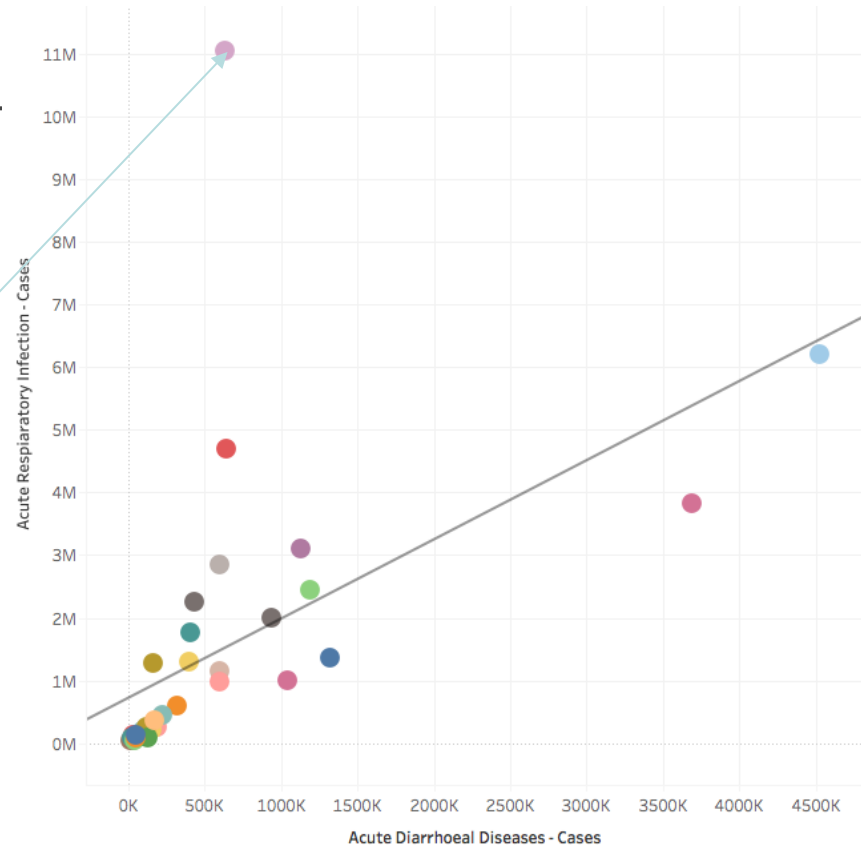


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Visualization helps  
us derive new  
questions

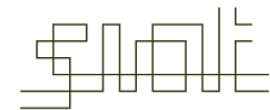
why?

beyond just  
what?



Introduction to Visual  
Analytics

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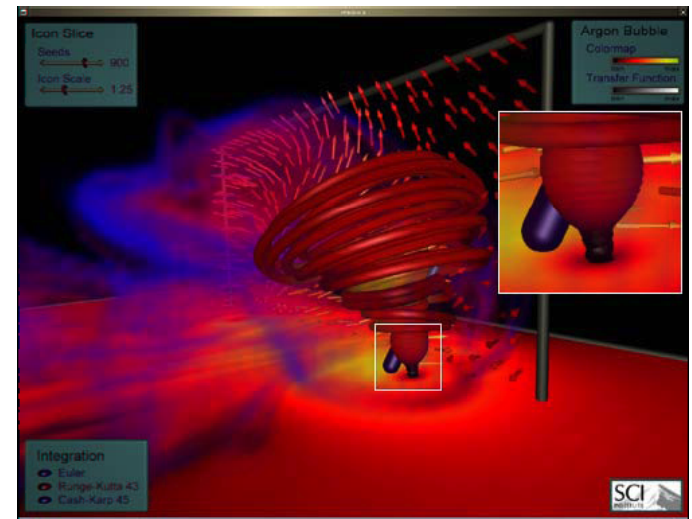
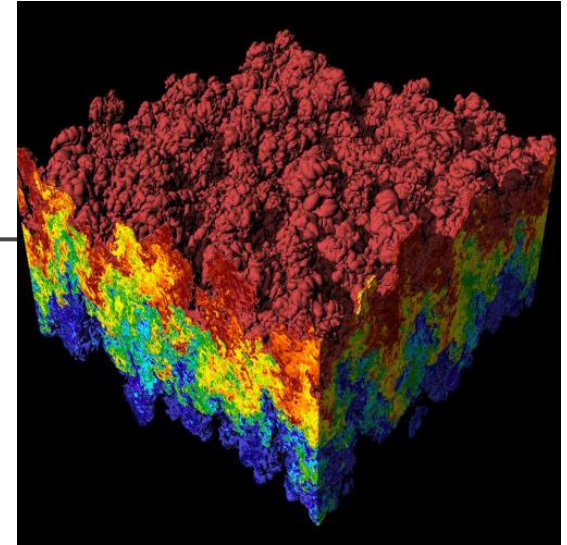


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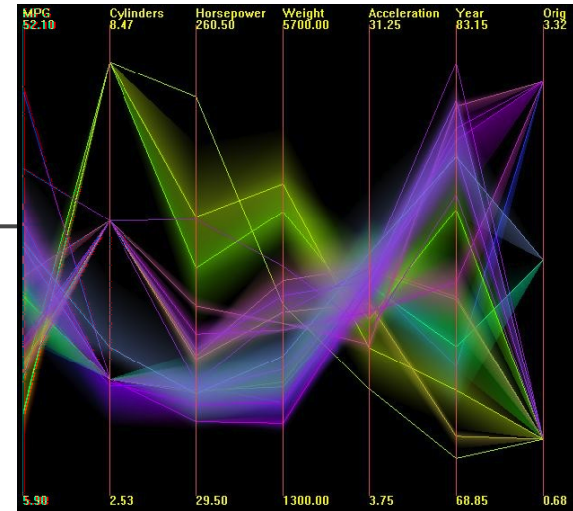
# Scientific visualization

- the visual display of spatial data associated with scientific processes (e.g., bonding of molecules)
- deals with data that has a **natural geometric structure** (e.g. chemical data or wind flows)



# Information visualization

- visual metaphors for non-inherently spatial data such as the exploration of text-based document databases.
  - More abstract
- Assign structure and position to information that has none
- Text
- Statistics
- Finance/Business
- Internet
- Software



# Information Visualization

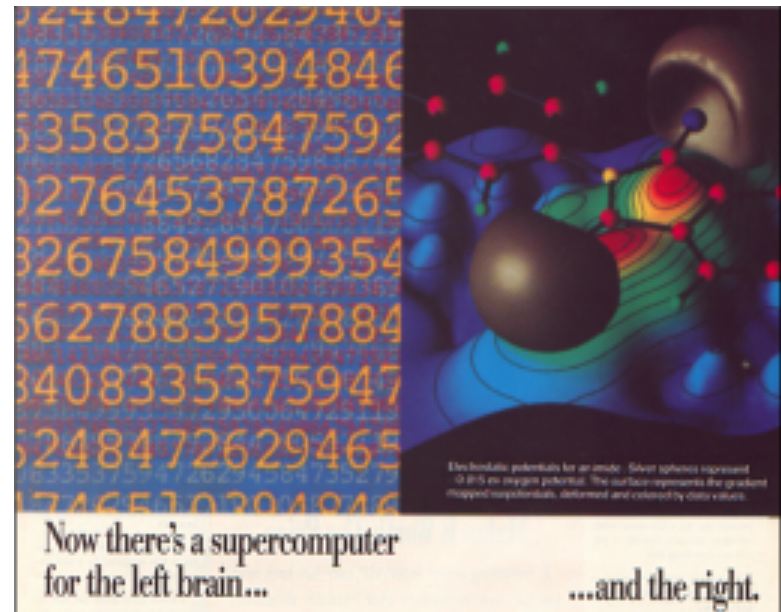
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“Transformation of the symbolic into the geometric”

(McCormick et al., 1987)

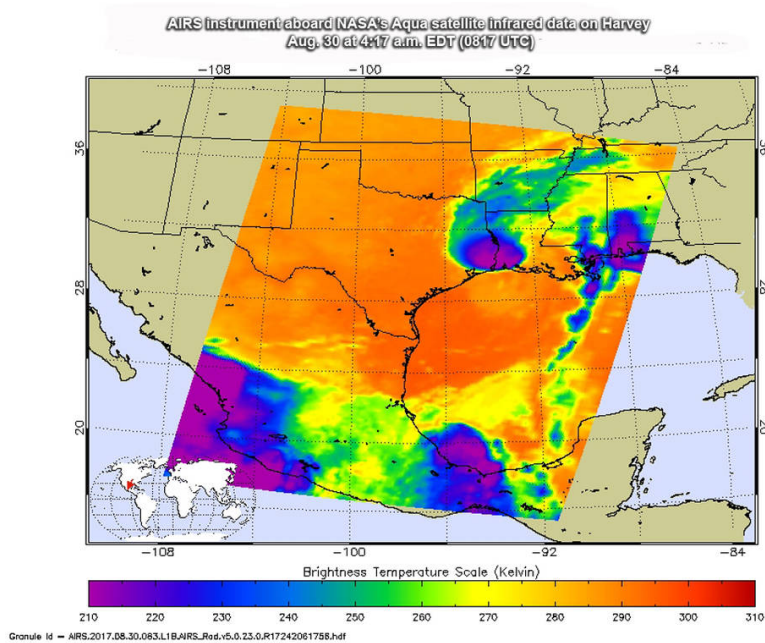
“... finding the artificial memory that best supports our natural means of perception.”

(Bertin, 1983)

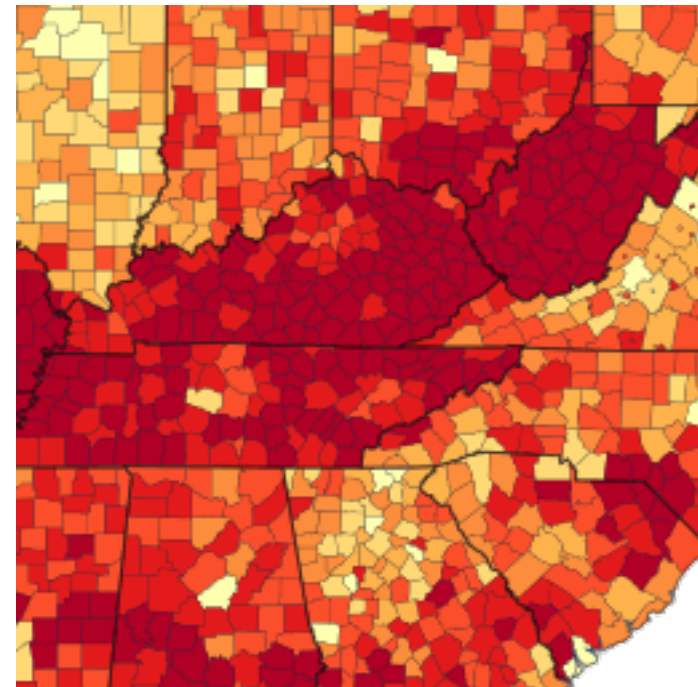


# Spatial visualization

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<https://www.nasa.gov/feature/goddard/2017/harvey-atlantic-ocean>





# Affective (experience) visualization

U.S. GUN DEATHS IN 2013 2010

DECEMBER

**11,419**  
PEOPLE KILLED

**502,025**  
STOLEN YEARS



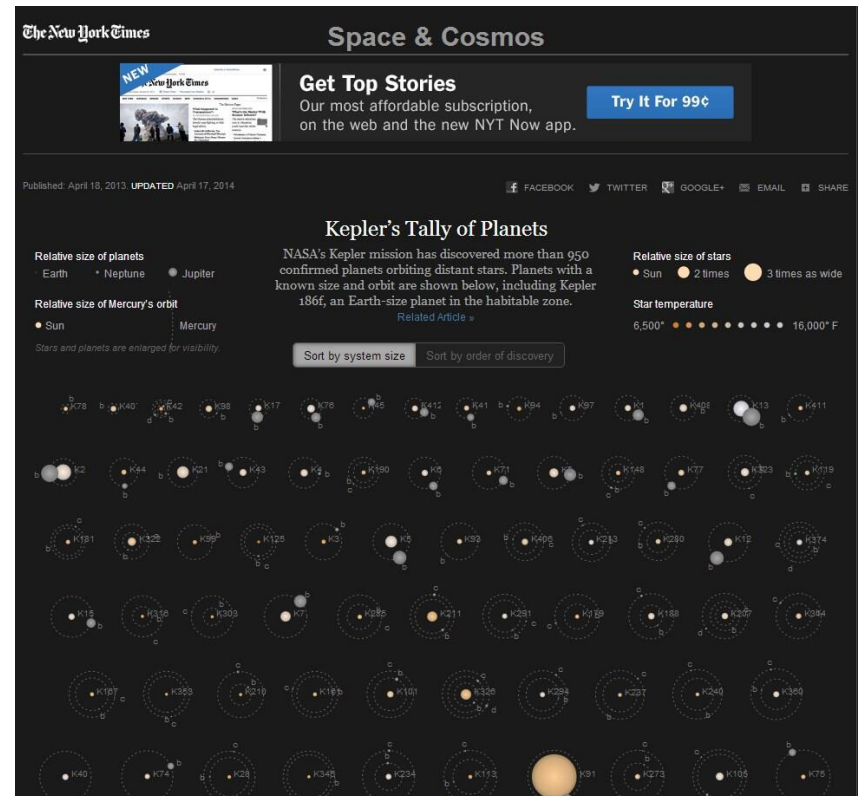
AGE 0

108

22

# The cognitive tool for analysis

- Visualization helps us derive insights and questions that even predefined analytical queries do not elicit
- *Visual analysis*



[http://www.nytimes.com/interactive/science/space/keplers-tally-of-planets.html?\\_r=0](http://www.nytimes.com/interactive/science/space/keplers-tally-of-planets.html?_r=0)



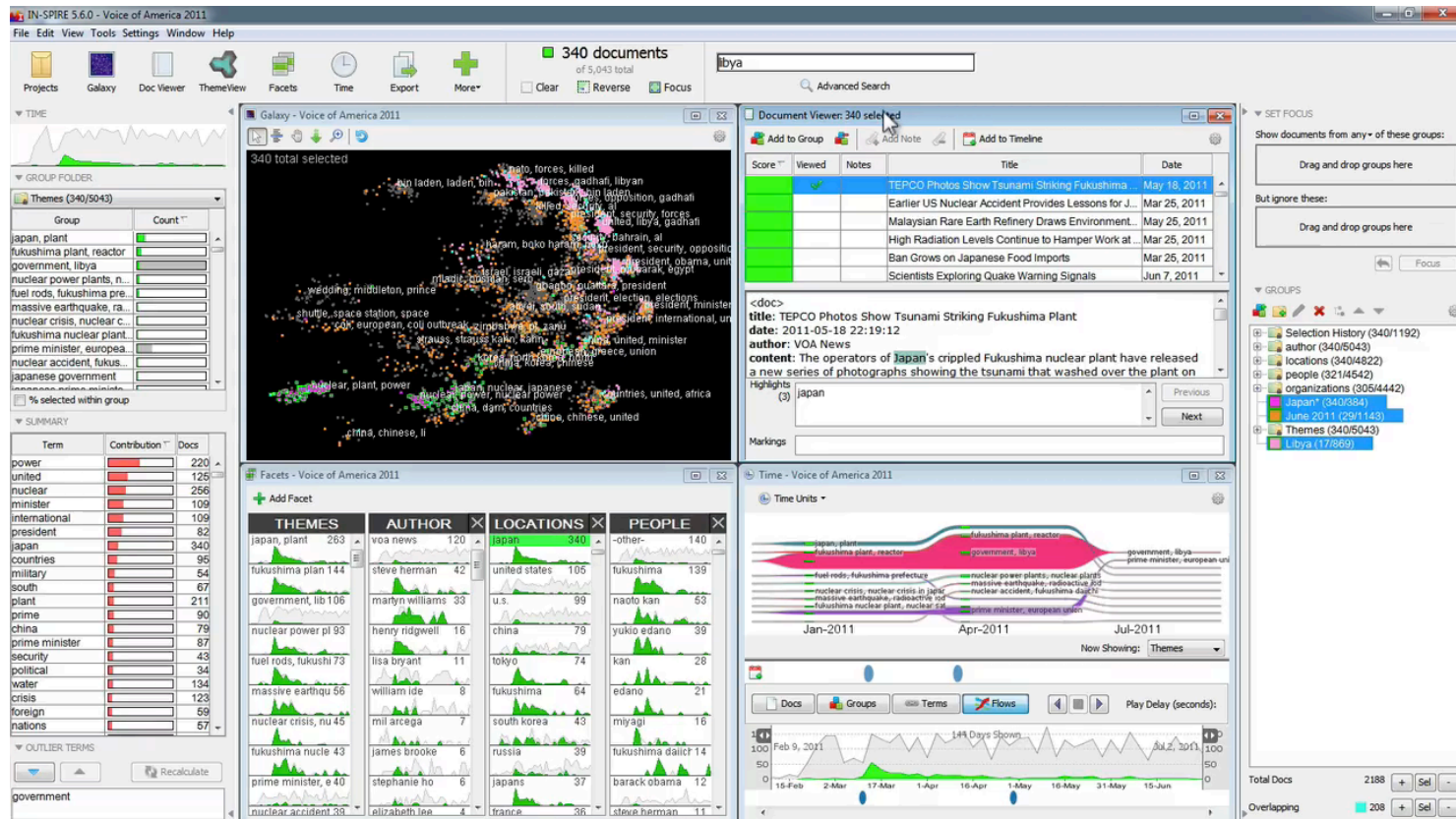
# Visual analytics

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“Visual analytics is the science of **analytical reasoning** facilitated by **interactive visual** interfaces.” - Jim Thomas, PNNL

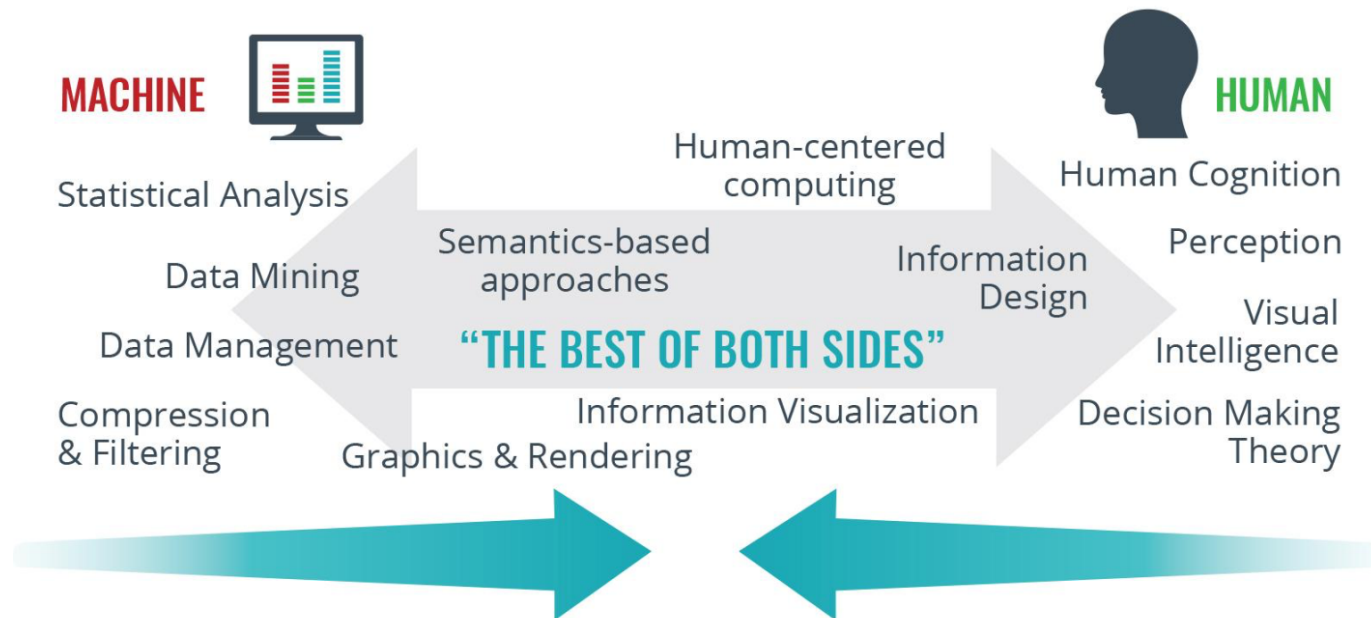
“Computers are incredibly fast, accurate but stupid; Humans are incredibly slow, inaccurate but brilliant; Together they are powerful beyond imagination.”  
- Dr. Daniel Keim, U Konstanz

# Visual Analytics



# VISUAL ANALYTICS

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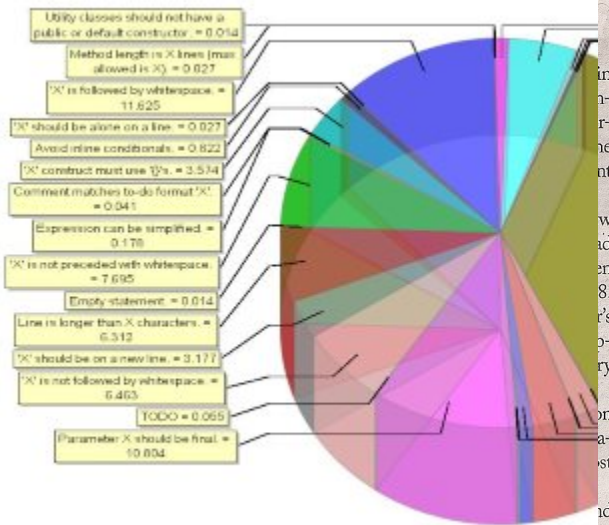
Visual Analytics: Definition, Process and Challenges in Kerren et al. (Eds.):  
Information Visualization, LNCS 4950, pp. 46 – 64, 2008. © Springer-Verlag Berlin Heidelberg 2008

# Using vision to think

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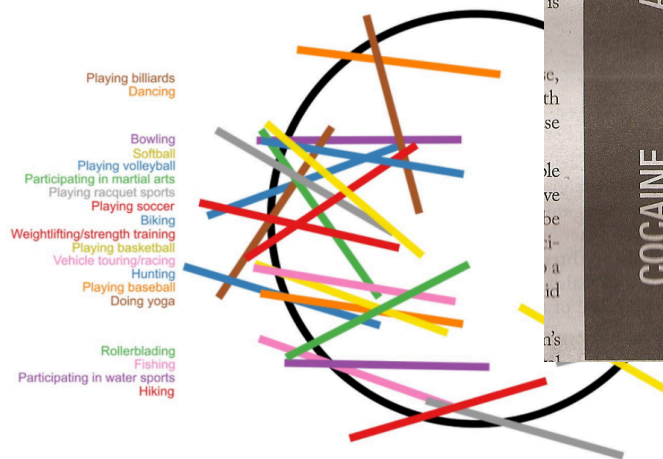
- Comprehend huge amounts of data
- Emergent properties and relations
- Detect problems and inconsistencies in data
- Facilitates understanding of large- and small-scale features of the data
- Facilitates hypothesis formation: the forming of new questions and insights





## Peak time for sports and leisure

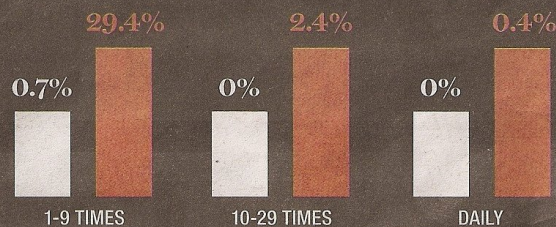
@hnrkndrbg | Source: American Time Use Survey



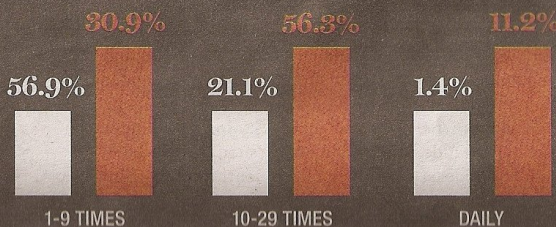
## BY THE NUMBERS

The National Collegiate Health Assessment was taken by 1,000 UCSB students in Spring 2009. Participants were asked how frequently they used substances over the past 30 days. Numbers in white reflect actual student use, while red numbers indicate perceived substance use. The average age of participants was 20 years and approximately 99 percent were full-time students.

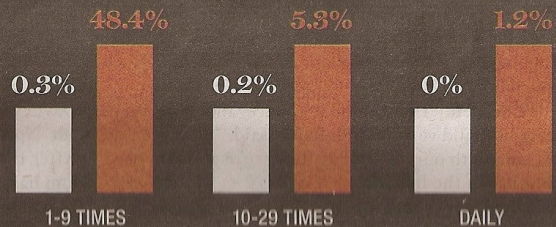
### OPIATES

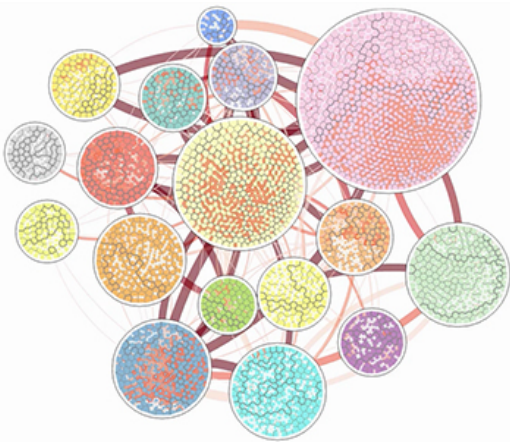


### ALCOHOL



### COCAINE





*Vorograph, IBM 2015*

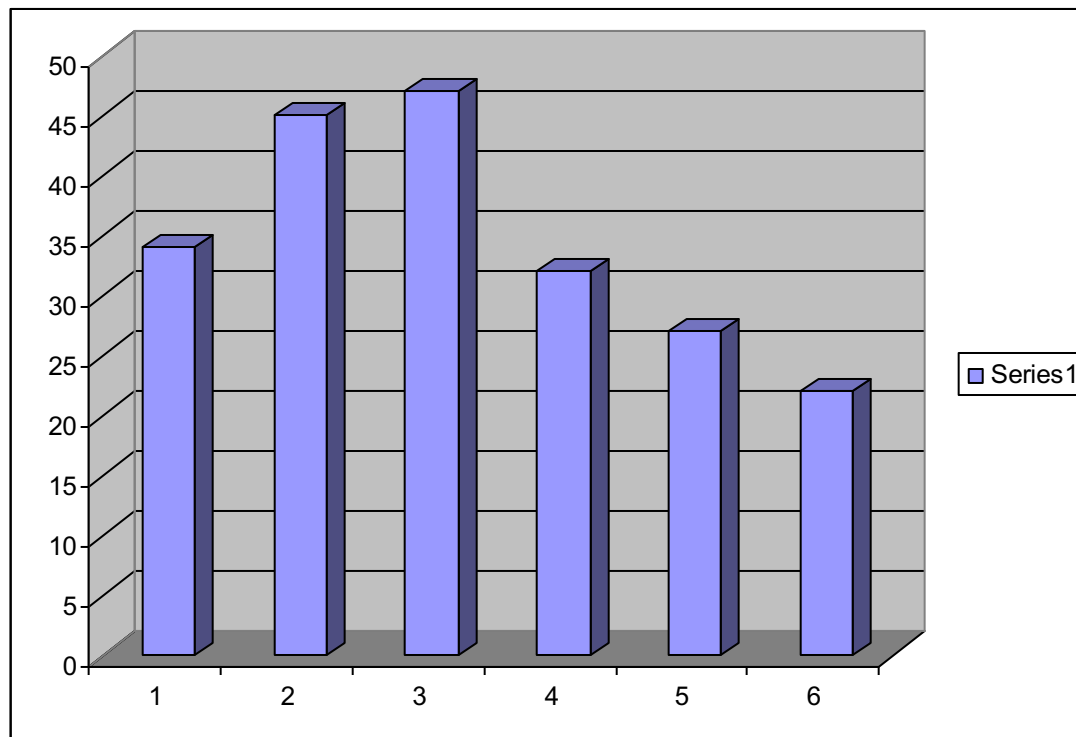
# What is visualization?

Computer-based visualization systems provide visual representations of data designed to help people carry out tasks more effectively.



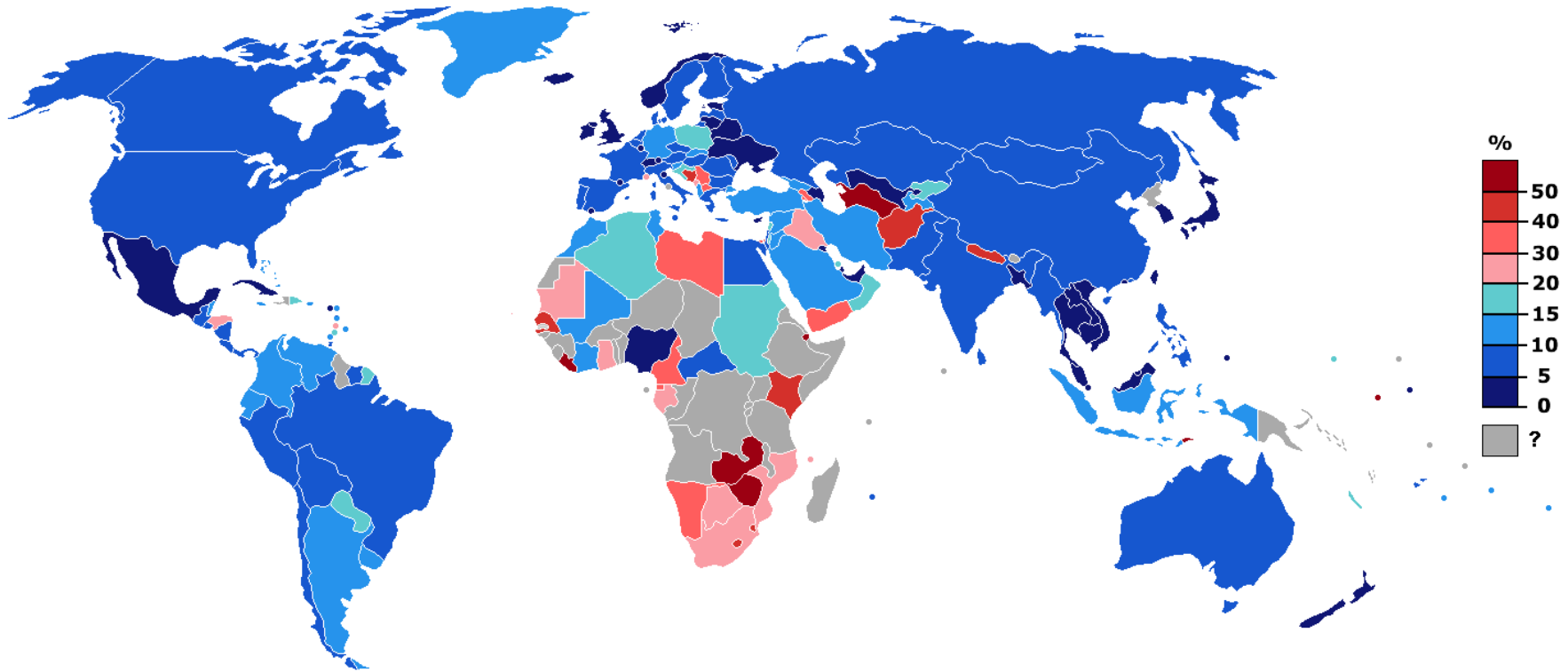
# Excel

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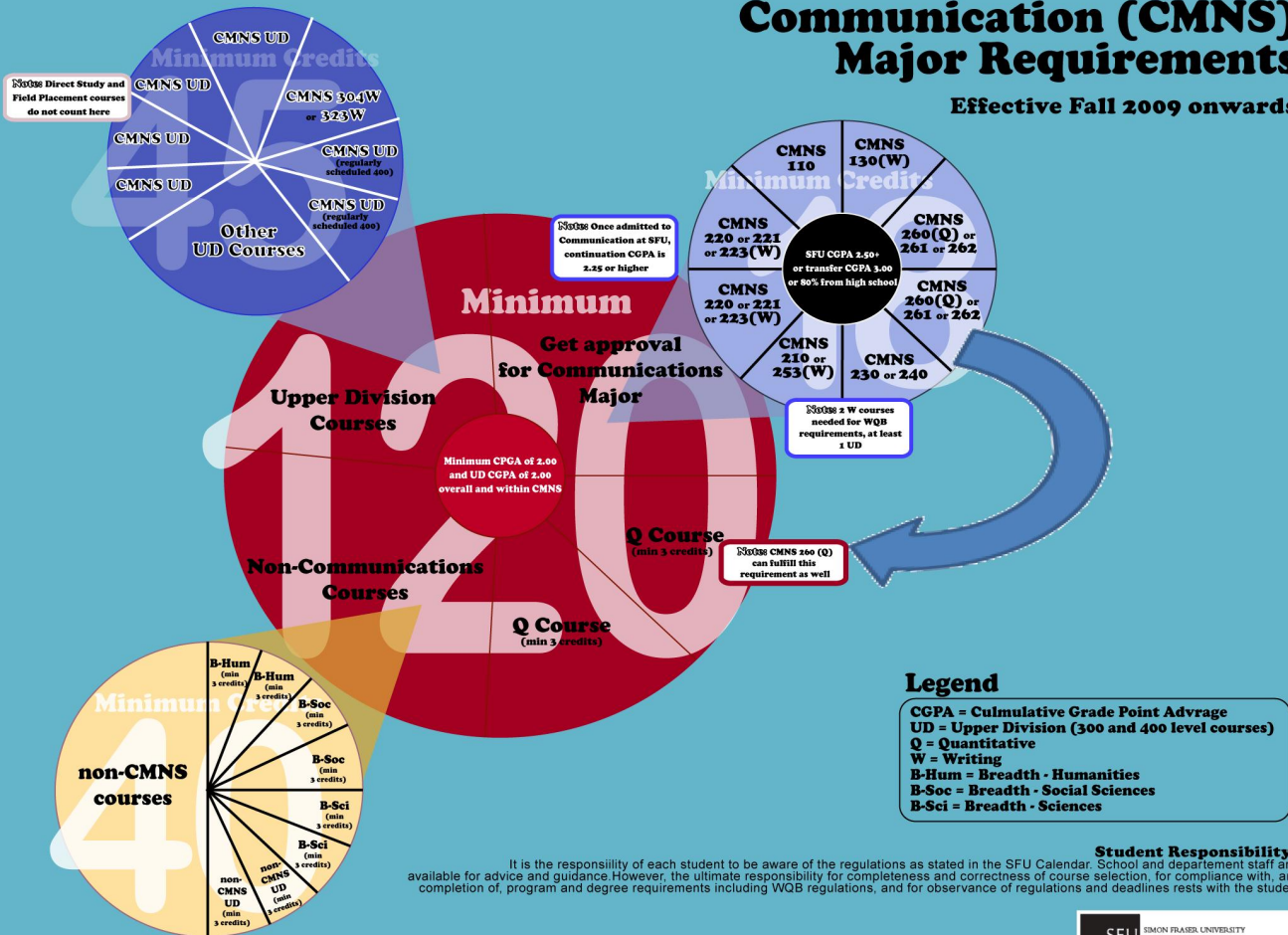
# Unemployment rates

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# Communication (CMNS) Major Requirements

Effective Fall 2009 onwards

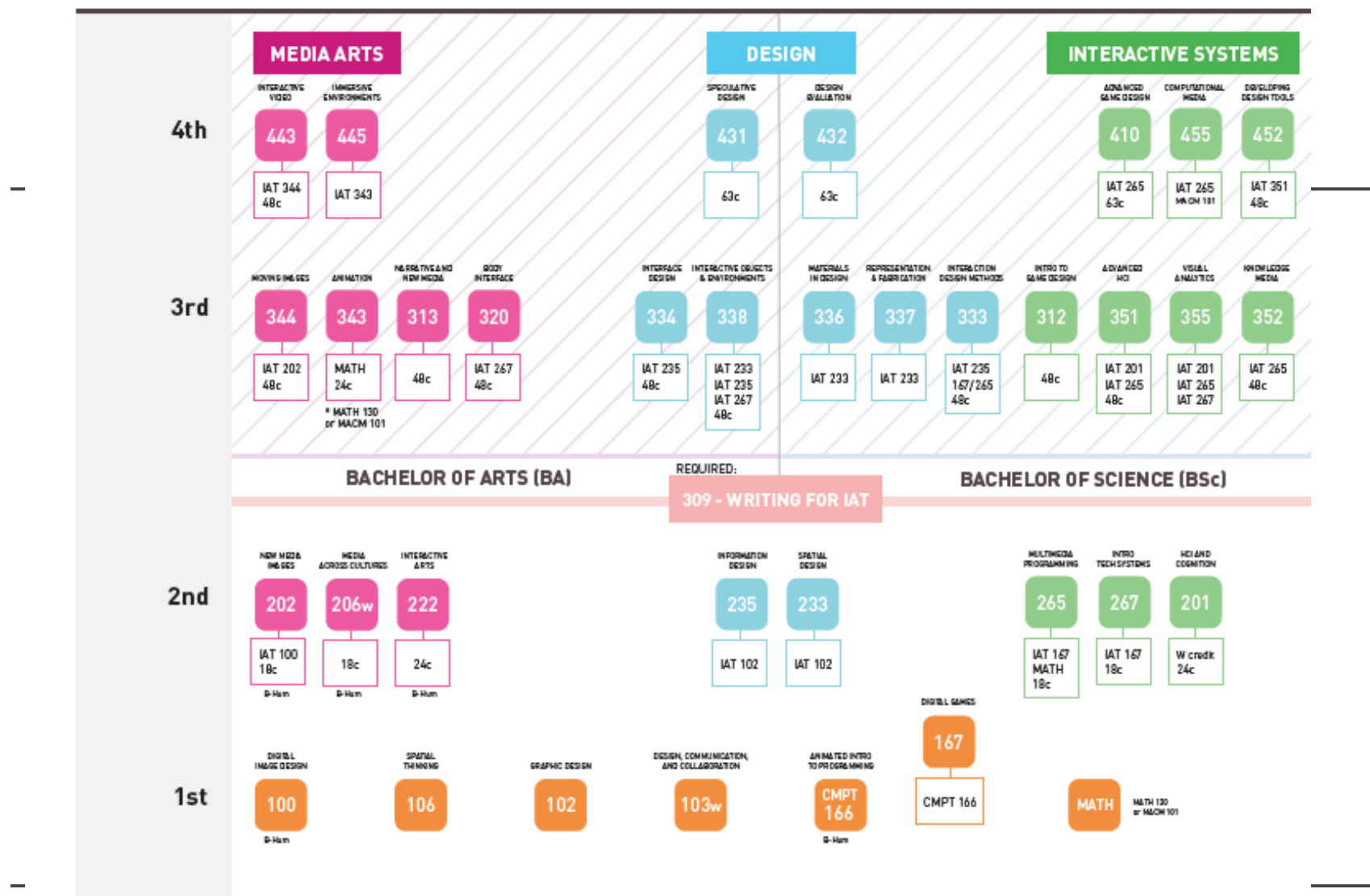


Information  
Visualization:  
Examples



SCHOOL OF INTERACTIVE  
ARTS + TECHNOLOGY

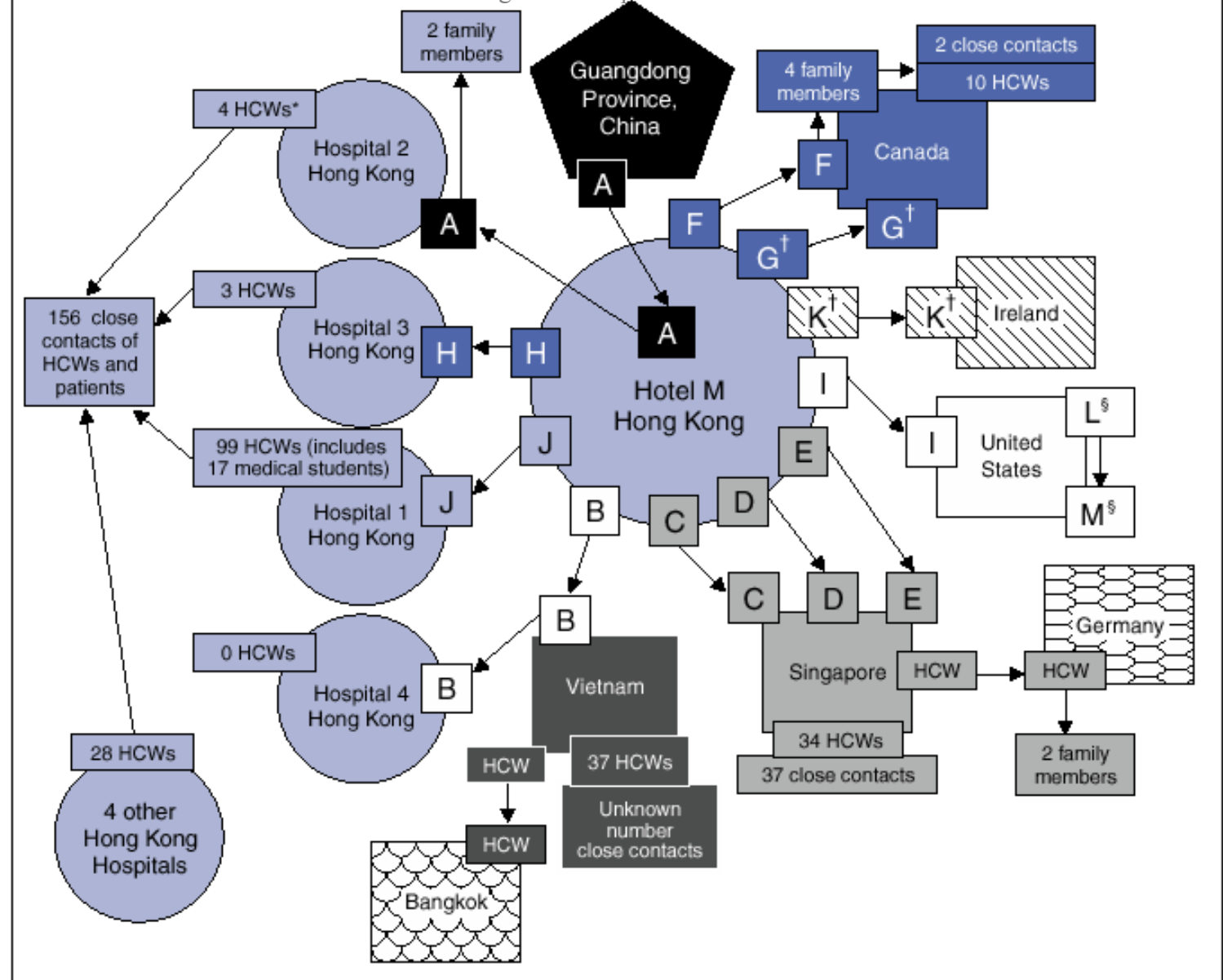
# SCHOOL OF INTERACTIVE ARTS & TECHNOLOGY PRE-REQUISITE MAP



Information  
Visualization:  
Examples

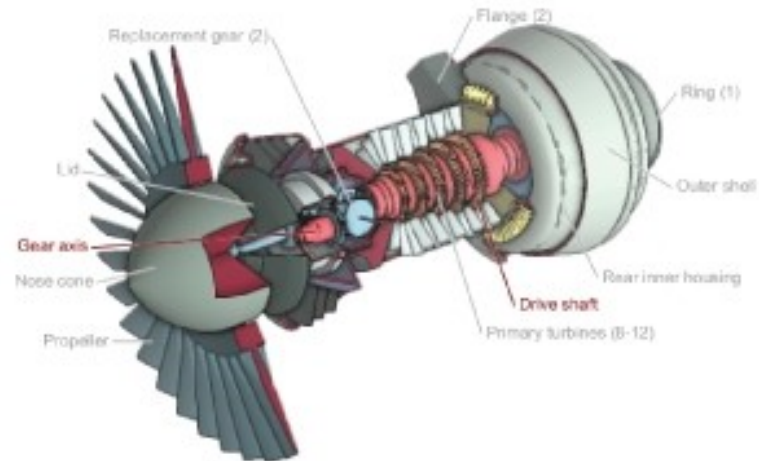


SCHOOL OF INTERACTIVE  
ARTS + TECHNOLOGY

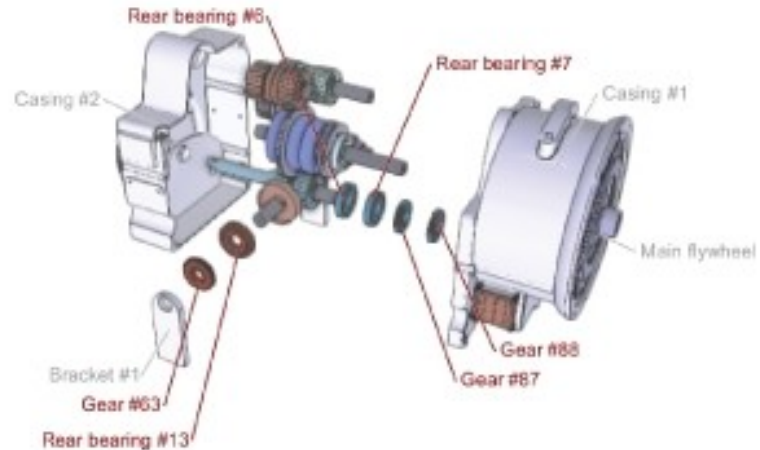


<sup>§</sup> Guests L and M (spouses) were not at Hotel M during the same time as index Guest A but were at the hotel during the same times as Guests G, H, and I, who were ill during this period.

<sup>9</sup> Guests L and M (spouses) were not at Hotel M during the same time as index Guest A but were at the hotel during the same times as Guests G, H, and I, who were ill during this period.















(a) Cutaway view of turbine



(b) Exploded view of transmission



# Train Schedule

Pied-mont	Palmetto	Caro-linian	Silver Star	Silver Meteor	Crescent	◀ Train Name ▶		Silver Meteor	Crescent	Silver Star	Caro-linian	Palmetto	Pied-mont
73	89	79	91	97	19	◀ Train Number ▶		98	20	92	80	90	74
Daily	Daily	Daily	Daily	Daily	Daily	◀ Days of Operation ▶		Daily	Daily	Daily	Daily	Daily	Daily
						◀ On Board Service ▶							
Read Down						Mile	▼	Symbol		Read Up			
67	67	95/195	93/161	93/161	93/161			Connecting Train Number		172/164	88/176	194/94	66
9 45P	9 45P	6 05A	9 35A	9 35A	0	Dp	↓	Boston, MA—South Sta. (ET)		3 15P	7 05P	9 05P	7 52A
R 9 50P	R 9 50P	R 6 10A	R 9 40A	R 9 40A	1	↓	↓	Boston, MA—Back Bay Sta.		D 3 10P	7 00P	D 9 00P	D 7 47A
R10 00P	R10 00P	R 6 20A	R 9 51A	R 9 51A	11	↓	↓	Route 128, MA		D 3 00P	6 49P	D 8 49P	D 7 30A
10 25P	10 25P	6 55A	10 16A	10 16A	43	↓	↓	Providence, RI		2 27P	6 18P	8 19P	7 04A
12 26A	12 26A	8 45A	12 11P	12 11P	156	↓	↓	New Haven, CT		12 36P	4 36P	6 33P	4 55A
1 12A	1 12A	9 28A	12 56P	12 56P	195	↓	↓	Stamford, CT		11 48A	3 48P	5 48P	4 04A
2 01A	2 01A	10 20A	1 50P	1 50P	231	Ar	↓	New York, NY—Penn Sta.		11 00A	5 00P	3 15A	3 15A
7 00A	7 00A	2 00P	5 20P	5 20P	456	Ar	↓	Washington, DC		7 25A	11 25A	1 25P	10 00P
6 15A	7 15A	11 08A	3 15P	2 15P	0	Dp	↓	New York, NY—Penn Sta.		10 30A	2 02P	3 43P	8 58P
R 6 31A	R 7 36A	R11 30A	R 3 38P	R 2 37P	10	↓	↓	Newark, NJ—Penn Sta.		D10 10A	D 1 43P	D 3 20P	D 8 37P
R 7 05A	8 13A	R12 10P	R 4 18P	R 3 15P	58	↓	↓	Trenton, NJ		D 9 30A	D 1 03P	D 2 42P	D 7 55P
R 7 36A	8 48A	R12 45P	R 4 55P	R 3 55P	91	↓	↓	Philadelphia, PA—30th St. Sta.		D 8 55A	D12 25P	D 2 07P	D 7 22P
R 8 01A	9 11A	R 1 10P	R 5 20P	R 4 19P	116	↓	↓	Wilmington, DE		D 8 30A	D12 01P	D 1 42P	D 6 57P
R 8 51A	9 58A	R 2 00P	R 6 15P	R 5 17P	185	↓	↓	Baltimore, MD—Penn Sta.		D 7 40A	D11 12A	D12 51P	D 6 05P
R 9 54A	10 55A	R 3 05P	R 7 30P	R 6 30P	225	Ar	↓	Washington, DC		Dp	D 6 32A	D10 10A	D11 53A
10 11A	11 12A	3 25P	R 7 50P	6 49P	234	↓	↓	Charlottesville—see right		D 5 41A	D 9 43A	D11 09A	4 32P
				7 22P	258	↓	↓	Alexandria, VA			8 46A		
				7 55P	293	↓	↓	Manassas, VA			8 12A		
				8 52P	338	↓	↓	Culpeper, VA			7 20A		
				10 06P	398	↓	↓	Charlottesville, VA			6 07A		
				11 14P	461	↓	↓	Lynchburg, VA			4 57A		
					260	↓	↓	Danville, VA					
		11 39A			280	↓	↓	Quantico, VA					4 01P
		11 57A			334	Ar	↓	Fredericksburg, VA					3 41P
11 49A	1 02P	5 09P	9 40P		362	Dp	↓	Richmond, VA—Staples Mill Rd.		4 00A			
11 59A	1 10P	5 19P	9 50P		460	Dp	↓	Petersburg, VA		3 50A		D 9 18A	2 46P
12 29P	1 43P	5 57P	10 24P		476	↓	↓	Rocky Mount, NC		3 07A		D 8 29A	2 39P
1 56P	3 13P	7 29P	11 56P		502	↓	↓	Wilson, NC		1 43A		D 7 01A	1 54P
2 14P	3 32P				531	↓	↓	Selma-Smithfield, NC					12 30P
2 41P	4 03P				540	↓	↓	Raleigh, NC					2 29P
7 05A	4 42P	4 50P	9 13P		557	Dp	↓	Durham, NC					11 41A
7 16A	5 03P	9 27P			591	↓	↓	Cary, NC				D 5 40A	10 58A
7 35A	5 24P				615	↓	↓	Durham, NC				5 11A	10 43A
8 11A	6 01P				628	↓	↓	Burlington, NC					10 23A
8 35A	6 32P				662	Ar	↓	Greensboro, NC					9 43A
8 52A	6 49P				677	Dp	↓	Winston-Salem—see right					9 21A
9 26A	7 26P				704	↓	↓	High Point, NC					8 58A
9 42A	7 42P				744	↓	↓	Salisbury, NC					8 25A
10 14A	8 14P				782	↓	↓	Kannapolis, NC					8 07A
	3 27P				829	Ar	↓	Charlotte, NC				D 2 03A	7 40A
	4 14P				881	Dp	↓	Fayetteville, NC					
	5 06P				603	Dp	↓	Dillon, SC					
	5 11P				633	Ar	↓	Florence, SC (Myrtle Beach)					
	5 47P				672	Ar	↓	Kingstree, SC					
	6 46P				728	↓	↓	Charleston, SC					
	7 35P				782	↓	↓	Yemassee, SC					
		10 39P			599	↓	↓	Southern Pines, NC (Pinehurst)					
		11 21P			628	↓	↓	Hamlet, NC				4 02A	
		12 50A			701	↓	↓	Camden, SC				3 25A	
		1 44A			734	↓	↓	Columbia, SC				1 53A	
		2 41A			784	↓	↓	Denmark, SC				11 12A	
					829	Ar	↓	Savannah, GA				11 57P	
					*871	Dp	↓	Jesup, GA (*mileage via Columbia)				D 10 34P	
					881	Dp	↓	Jesup, GA (Brunswick)				10 28P	

Continuation of service to/from Florida continues at right

# Visualization

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- Portray data, usually abstract data
- Use visual features to represent properties, quantities, attributes
  - Explicitly
  - derived
- Give rise to *emergent features*
- Support *visual cognition and analysis*

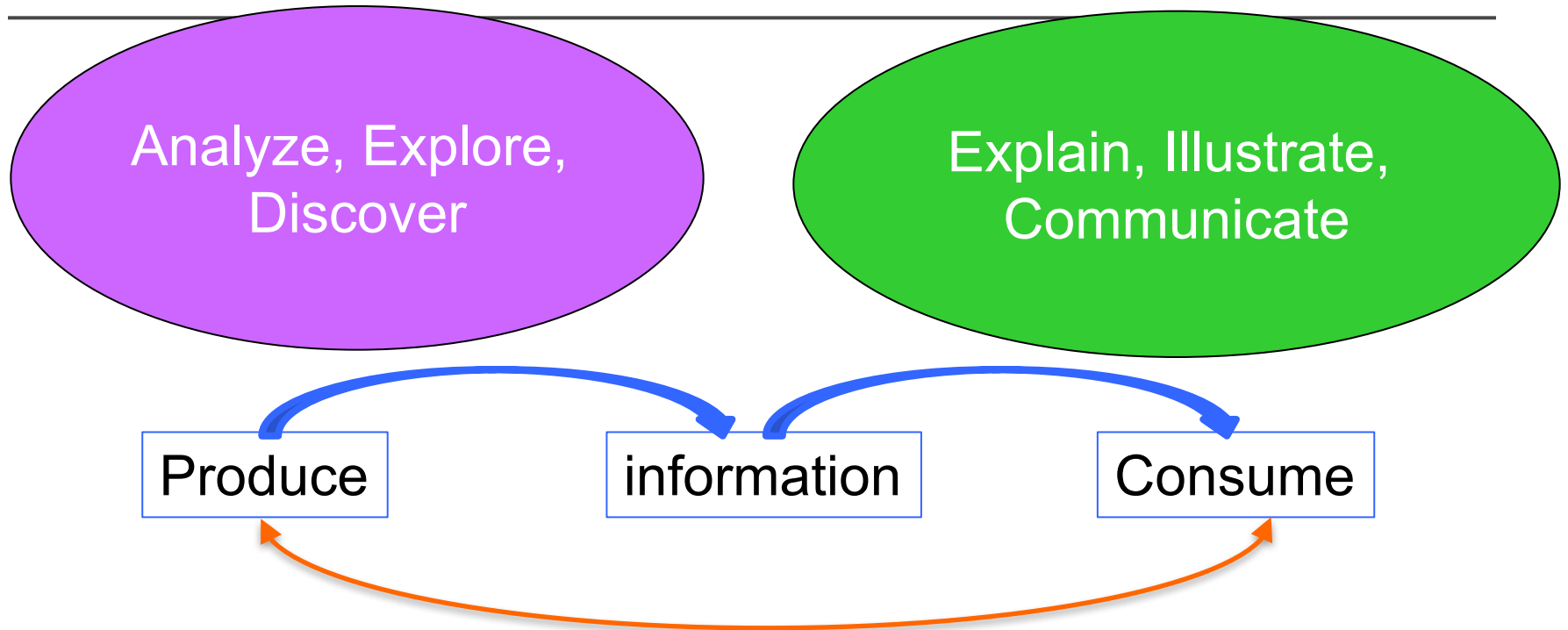
# Visualization from different lenses

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- **Geek** computer graphics and user interface design concerned with presenting data to users by means of images
  - A tool or method for generating images from complex multidimensional data fed into a computational processor
- **psychologist** The formation of mental visual images
  - The act or process of interpreting in visual terms
- **designer** The process of putting into visual form
  - The art of assigning representational “codes” and techniques to data attributes and conveying meaning
  - The practice of assembling images
- **artist** A medium
  - Representations of data to create art, to provoke and invoke

# The dyadic model of visualization

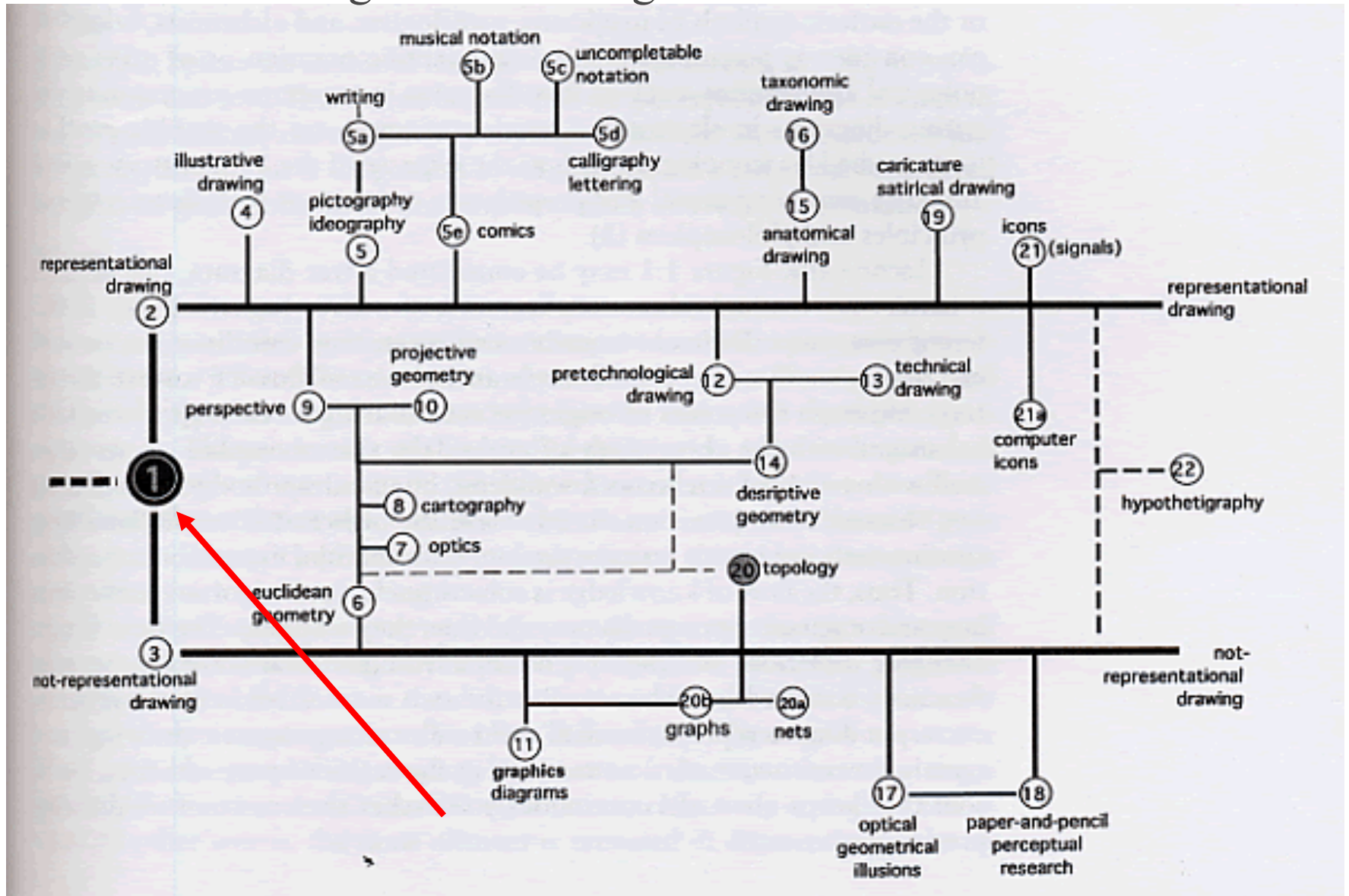
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Make the invisible visible

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We've been doing this for a long time



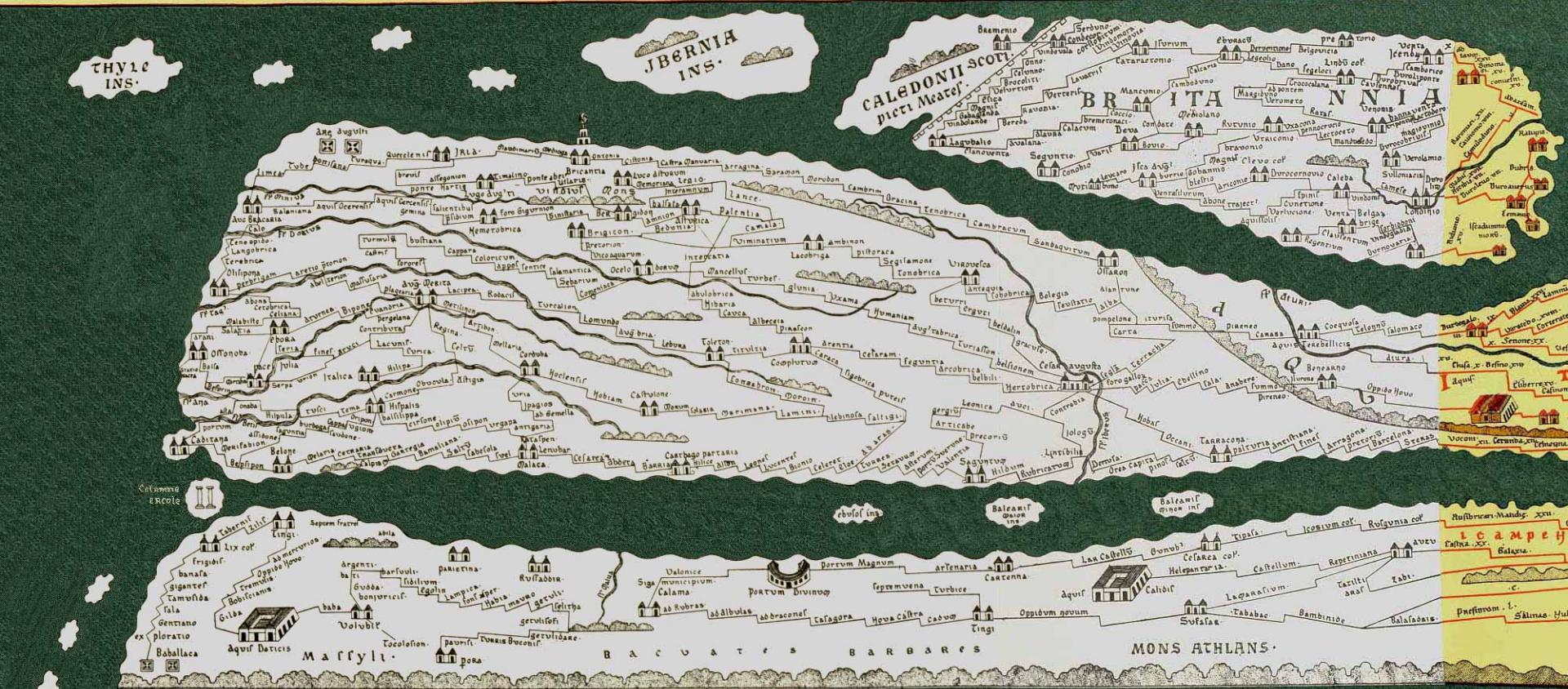
Information Visualization: Examples





# Tabula Peutingeriana, road map of ancient Rome

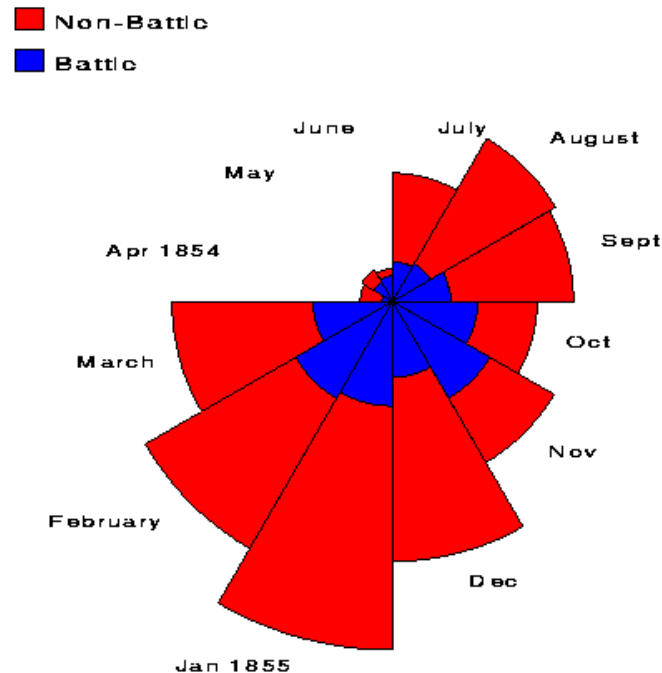
## Segmentum I





# Visualization for Communication: Nightingale's Coxcomb

Causes of Mortality in the Army in the East  
April, 1854 to March 1855



From: F. Nightingale, "Notes on Matters Affecting the Health, Efficiency and Hospital Administration of the British Army", 1858

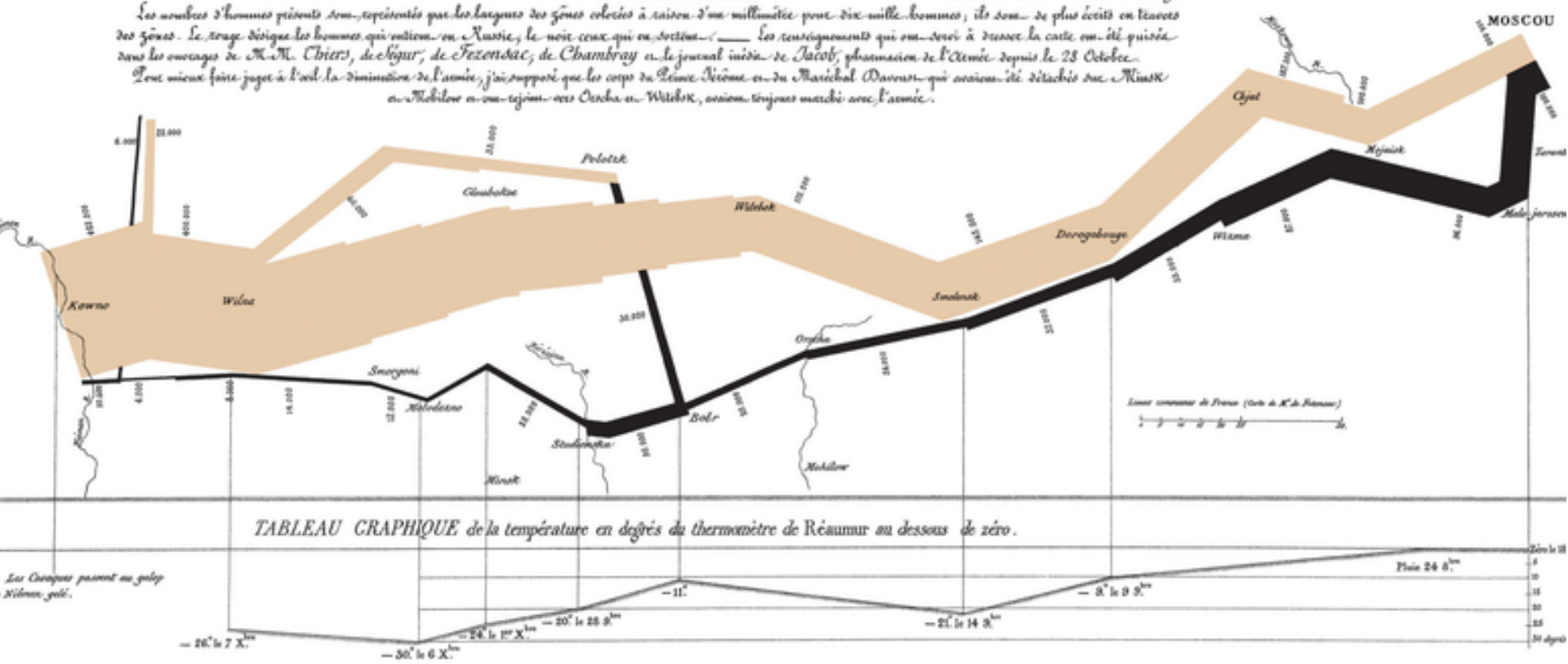
# Napoleon's Invasion of Russia

## Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.

Dessiné par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite. Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largueurs des zones colorées à raison d'une millimètre pour dix mille hommes; ils sont de plus écrits en traits des zones. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M. M. Chiers, de Schlegel, de Fozzardac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.

Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps de Prince Nèpoue et du Maréchal Davoust qui avaient été détachés sur Minsk et Mohilew en ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.



Les Cosaques passent au galop Nilous gelé.

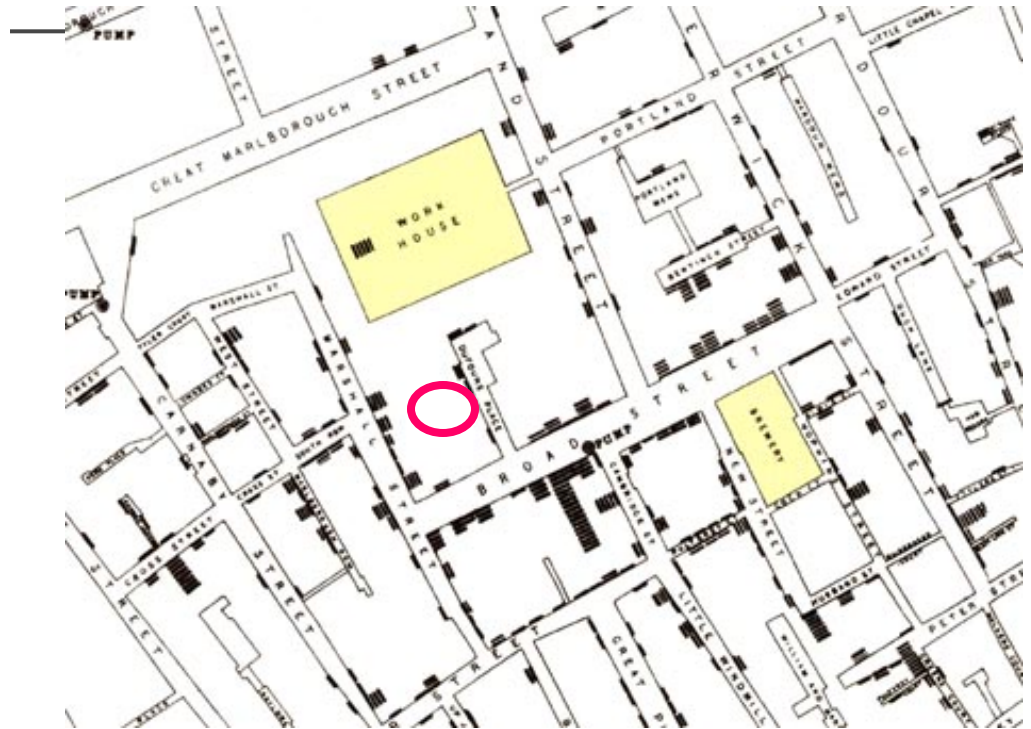
par Bignon, 8. Par 37 Mars 27 577 à Paris.

Imp. Lit. Bignon à Paris.

# Visualization for Discovery and Problem Solving: Snow's map

Illustration of John Snow's deduction that a cholera epidemic was caused by a bad water pump, circa 1854.

Horizontal lines indicate location of deaths.



*From Visual Explanations by Edward Tufte, Graphics Press, 1997*



# IAT 814 Introduction





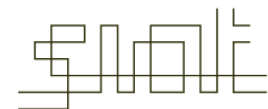
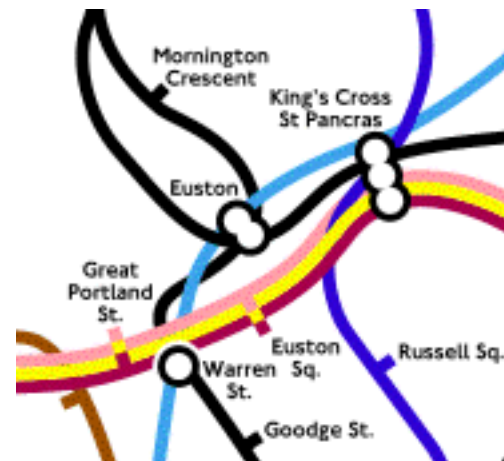
# London Underground Map 1990s



# Visualization for Clarification

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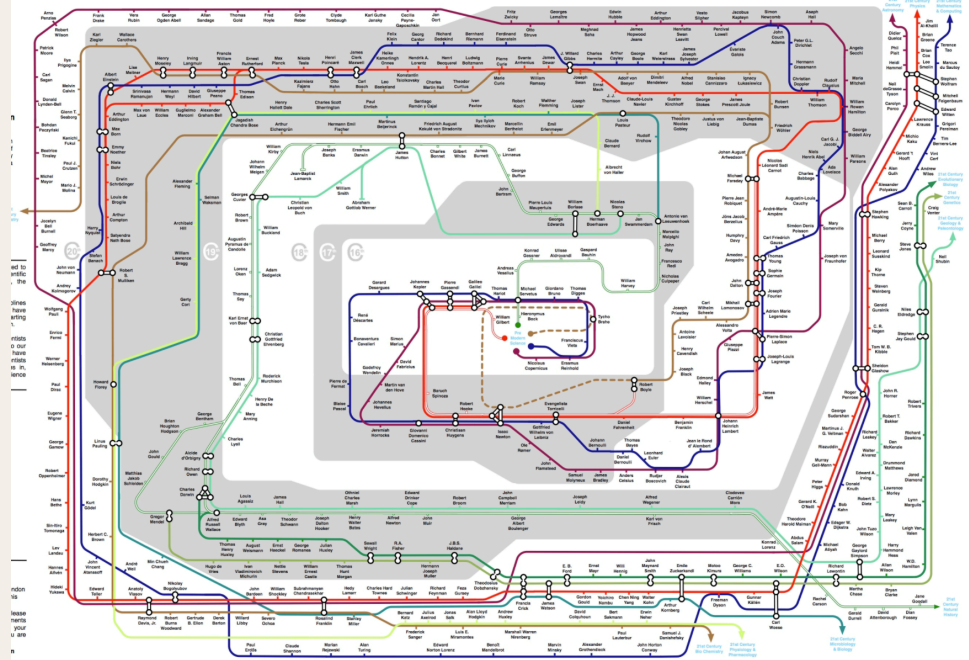
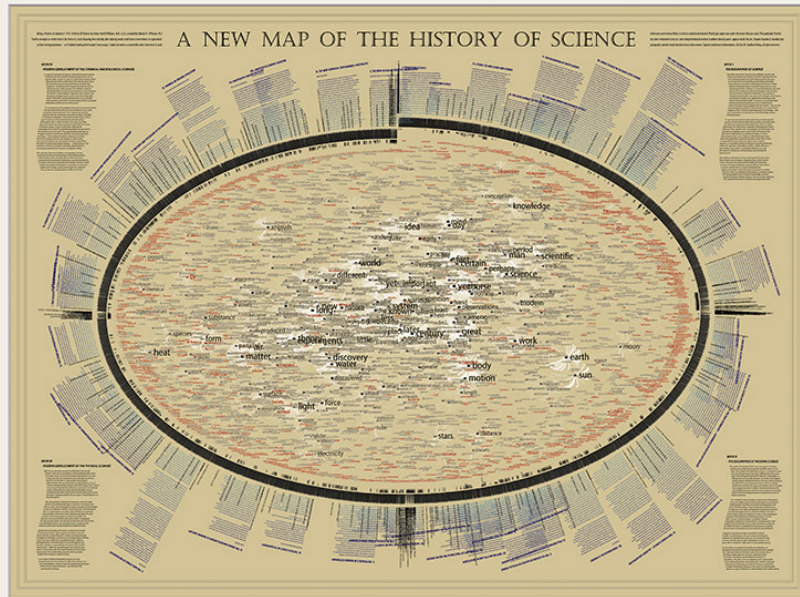
- Horizontal, vertical and 45° segments
- Key insight: topology and relative location of stations







# Many forms

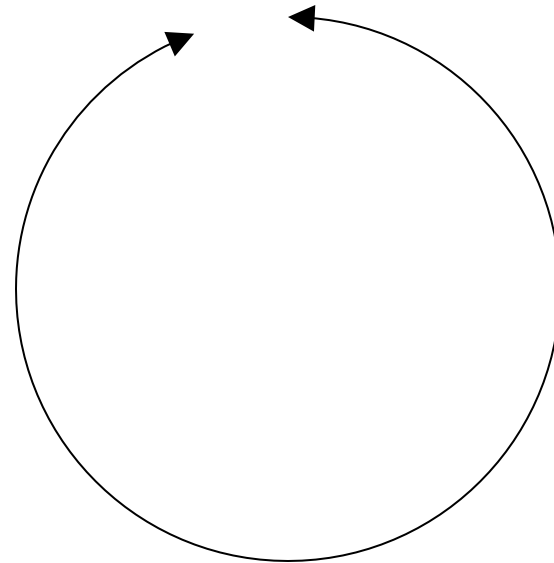




# Why do we use/create visualizations ?

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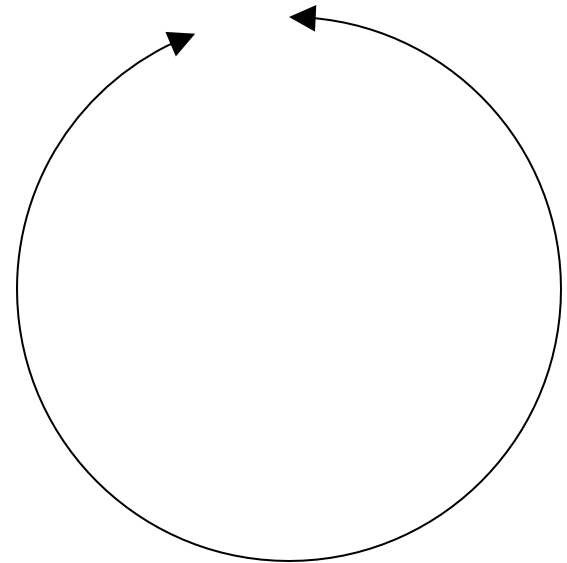
- Answer questions (or discover them)
- Make decisions
- See data in context
- Expand memory
- Support graphical calculation
- Find patterns
- Present argument or tell a story
- Inspire



# The value of visualization

---

- Capture and encode information
  - Blueprints, photographs, sensors, seismographs, maps...metadata!
- Analyse data to support reasoning
  - Develop and test hypotheses
  - Discover errors
  - Find patterns
  - Expand memory
- Communicate
  - Share, persuade, educate

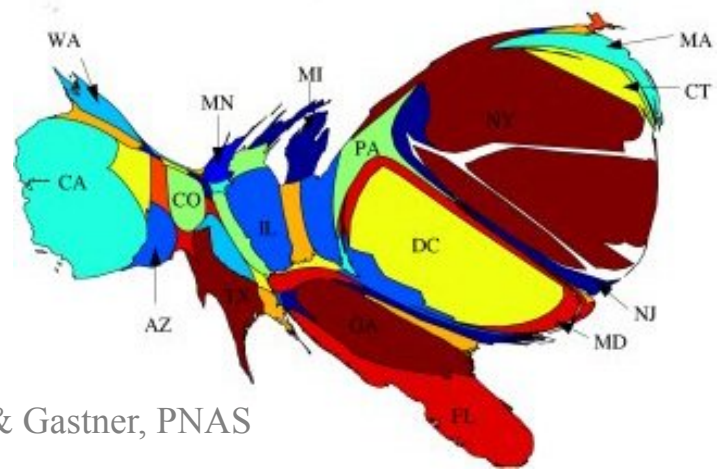




SCHOOL OF INTERACTIVE  
ARTS + TECHNOLOGY

# Answer (and discover) questions

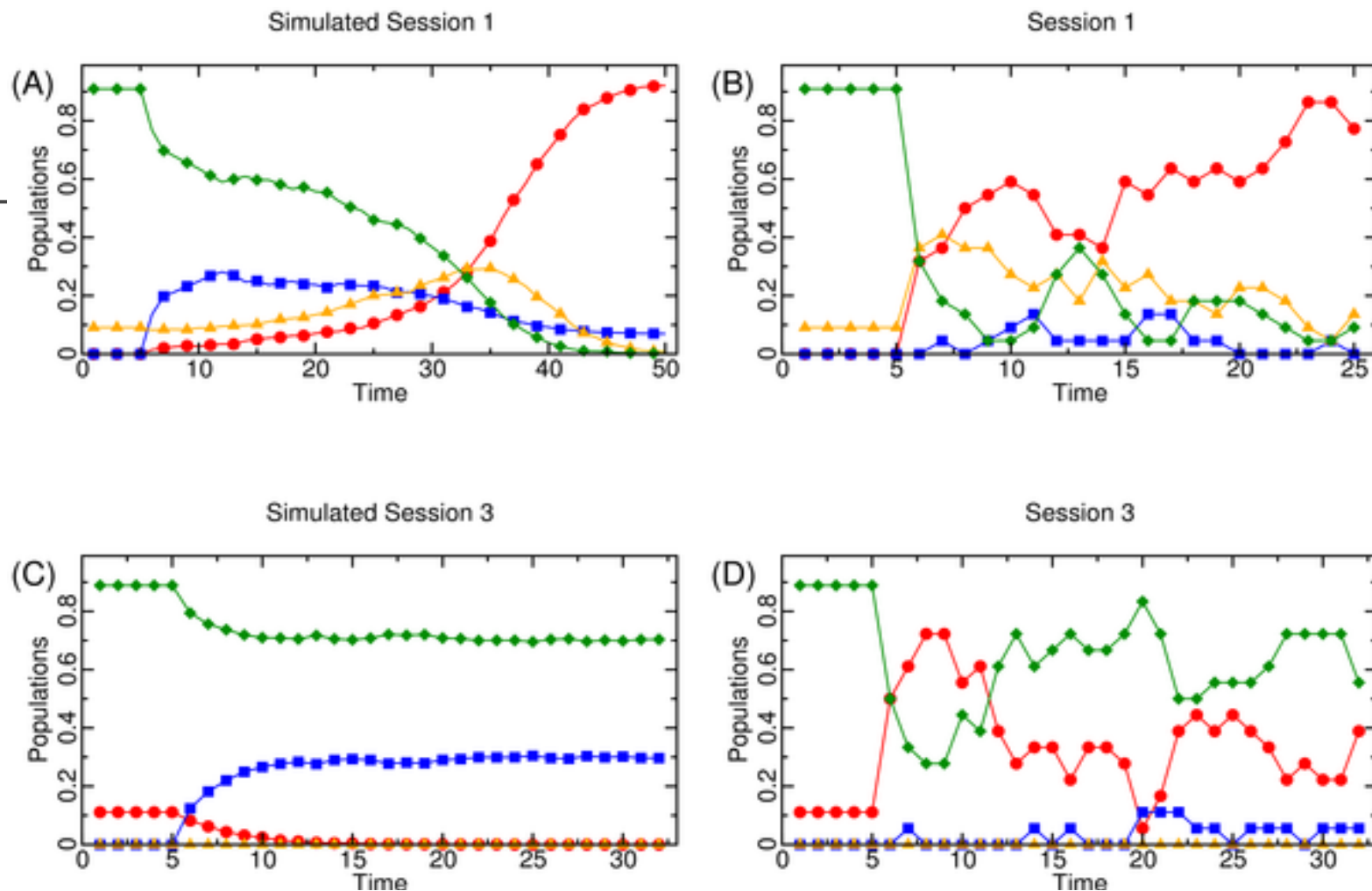
- Where do the most news stories originate?



Newman & Gastner, PNAS



**Figure 2. Comparisons of the strategy evolutions for the theoretical imitation dynamic (left figures) and two experimental sessions (right figures).**



D'Orsogna MR, Kendall R, McBride M, Short MB (2013) Criminal Defectors Lead to the Emergence of Cooperation in an Experimental, Adversarial Game. PLoS ONE 8(4): e61458. doi:10.1371/journal.pone.0061458

<http://www.plosone.org/article/info:doi/10.1371/journal.pone.0061458>

- 2 of 13 pages sent to NASA by the company that made parts for the Challenger Space shuttle

- ## Information Visualization: Examples

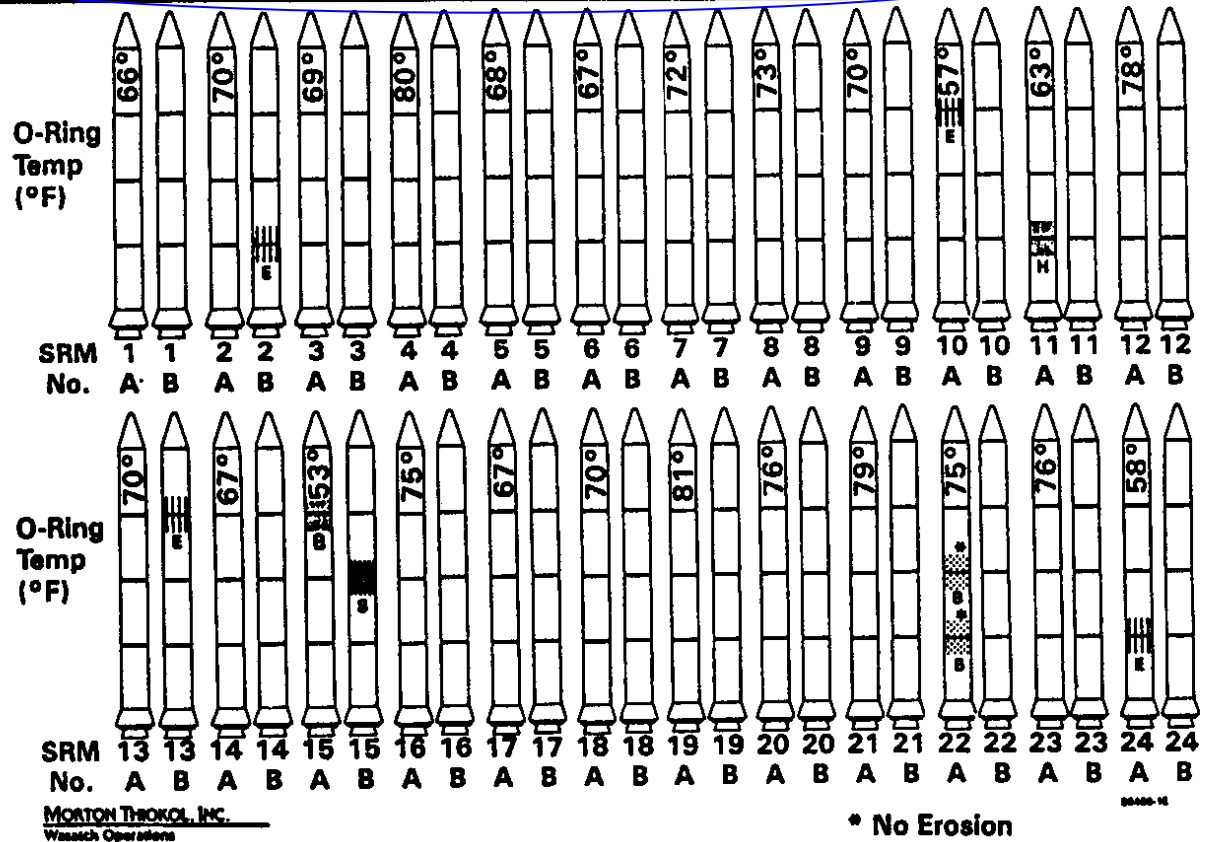


SCHOOL OF INTERACTIVE  
ARTS + TECHNOLOGY

# Challenger data

- Presented to decision makers prior to launch
  - To launch or not
  - Temp in 30s
- “Chart junk”
- Finding form of visual representation is important
  - cf. “Many Eyes”

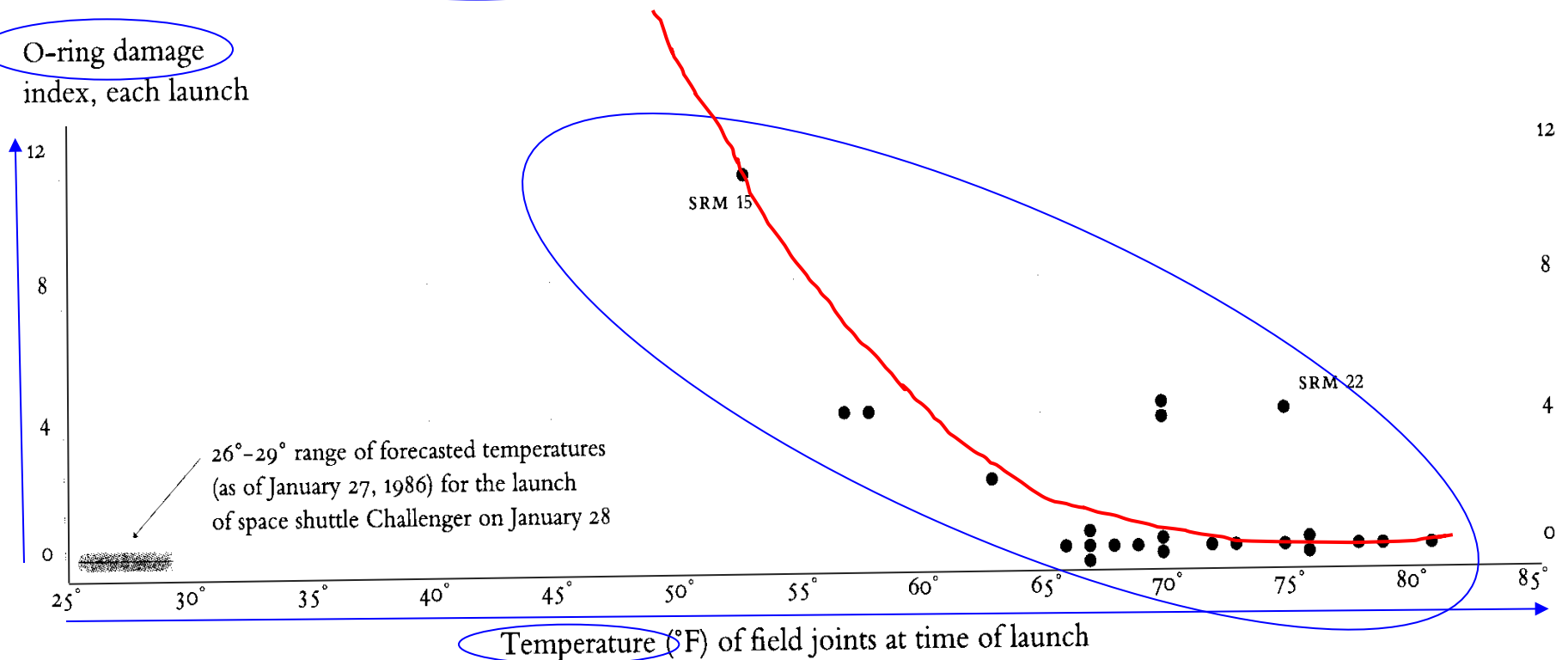
## History of O-Ring Damage in Field Joints (Cont)



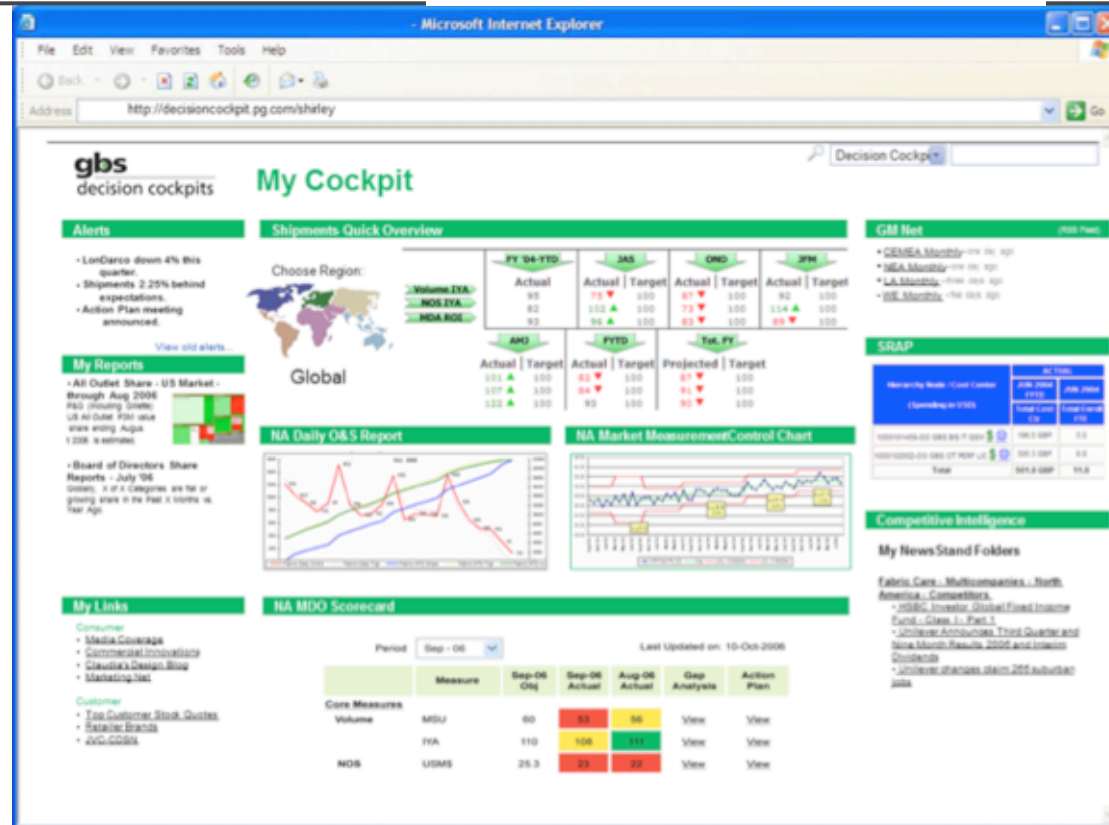
# Discover errors and insights

- With right visualization, insight (pattern) is obvious
  - Plot o-ring damage vs. temperature

O-ring damage  
index, each launch



## Dashboard, Proctor and Gamble™

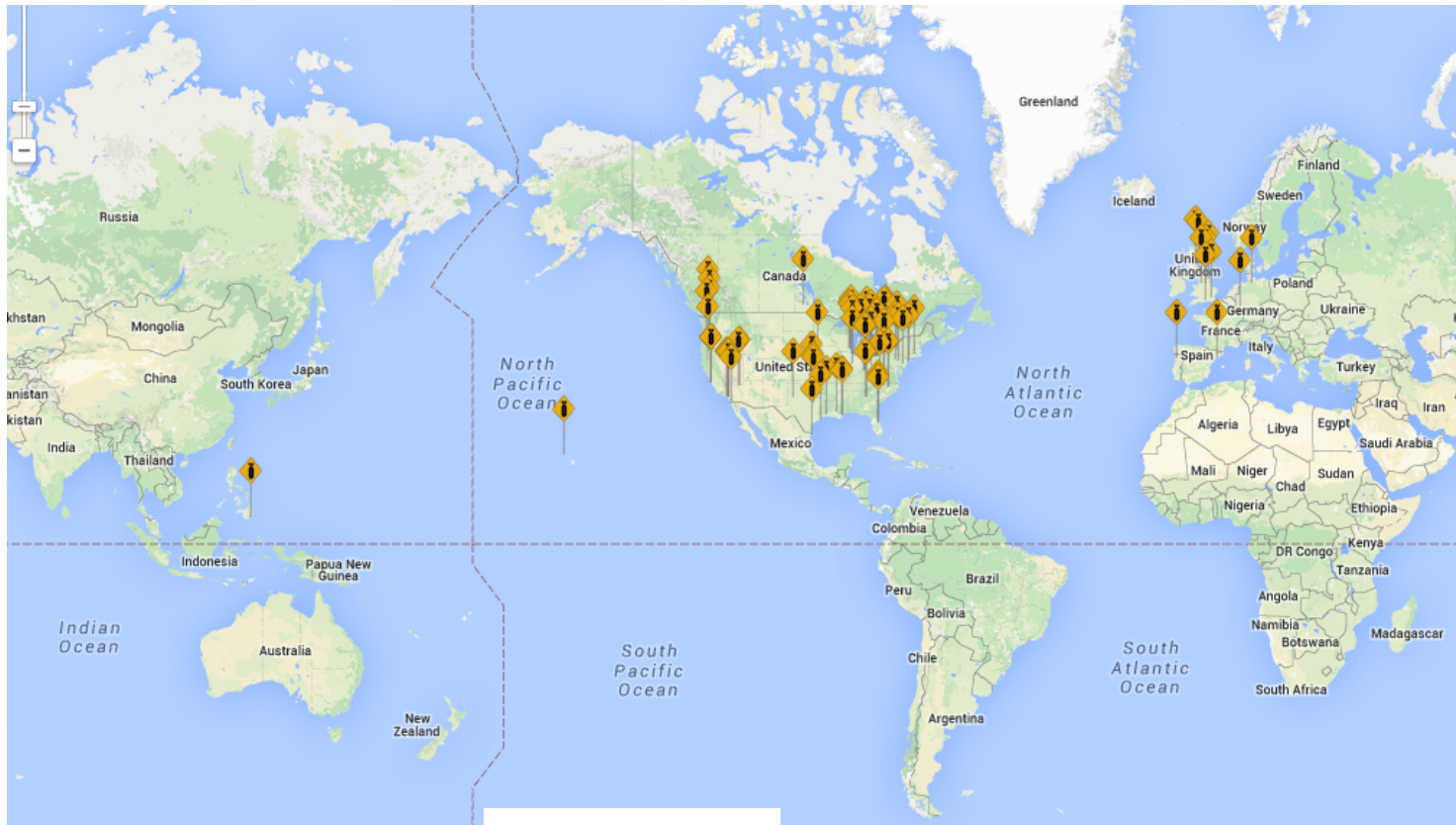


Information  
Visualization:  
Examples



SCHOOL OF INTERACTIVE  
ARTS + TECHNOLOGY

# Find patterns (in the twitterverse)



[Tweeting the FBomb](#)

Information  
Visualization:  
Examples



SCHOOL OF INTERACTIVE  
ARTS + TECHNOLOGY



# RT: Compelling and unusual



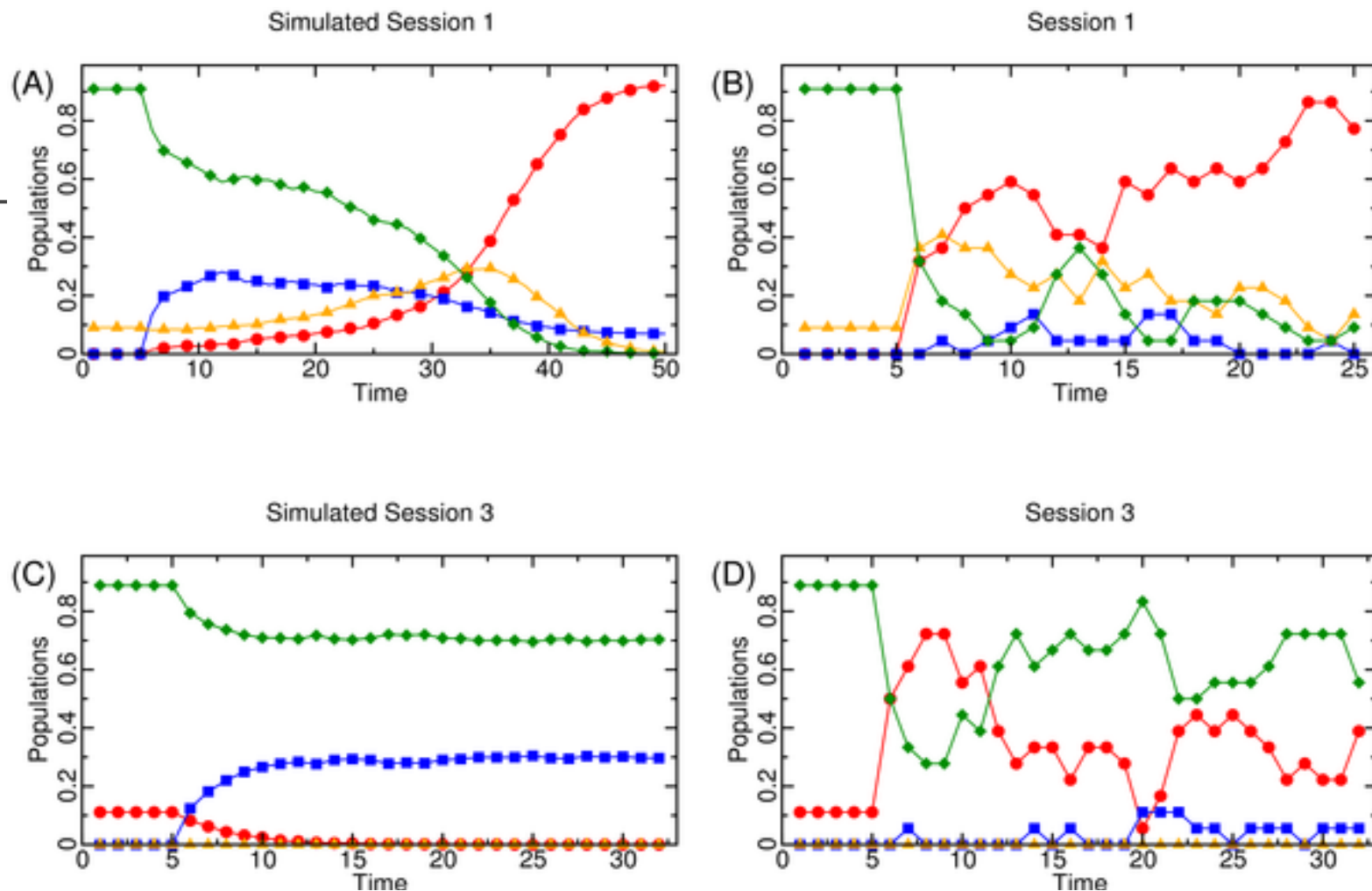
Information  
Visualization:  
Examples

<https://www.theatlantic.com/health/archive/2013/10/a-real-time-map-of-births-and-deaths/280609/>



SCHOOL OF INTERACTIVE  
ARTS + TECHNOLOGY

**Figure 2. Comparisons of the strategy evolutions for the theoretical imitation dynamic (left figures) and two experimental sessions (right figures).**



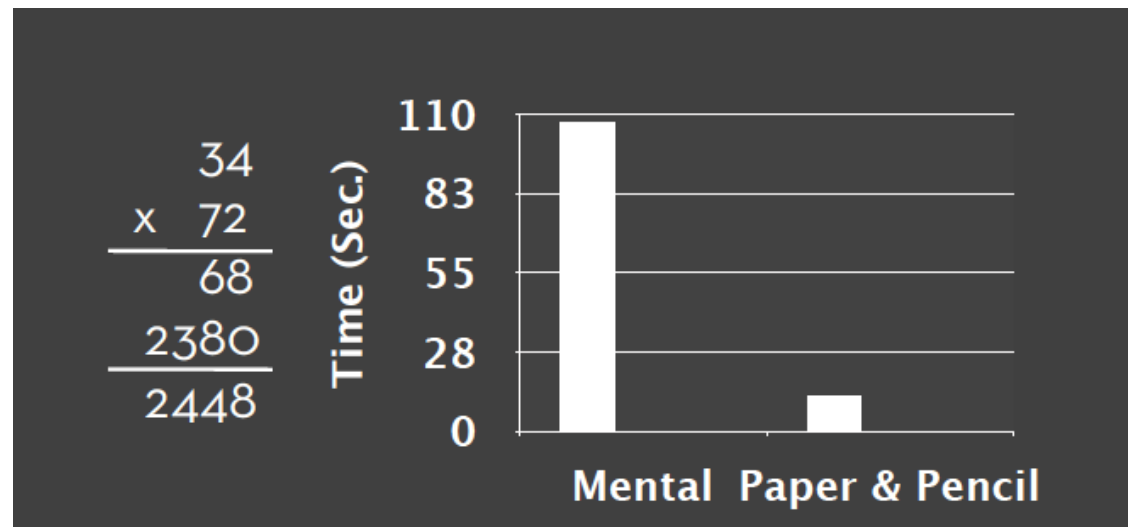
D'Orsogna MR, Kendall R, McBride M, Short MB (2013) Criminal Defectors Lead to the Emergence of Cooperation in an Experimental, Adversarial Game. PLoS ONE 8(4): e61458. doi:10.1371/journal.pone.0061458

<http://www.plosone.org/article/info:doi/10.1371/journal.pone.0061458>

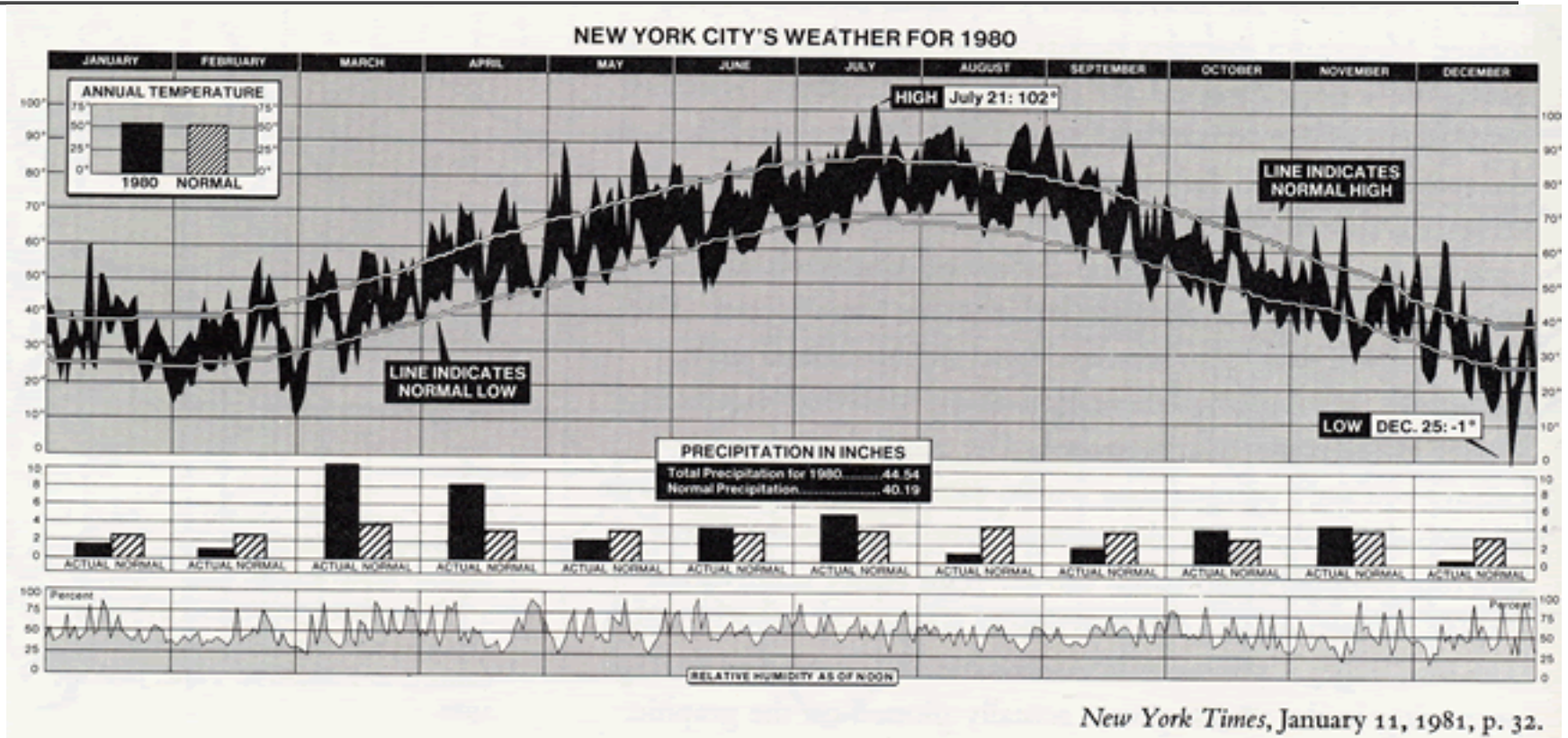
# Expand memory

- Graphical calculation example : class exercise

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



# Find Patterns

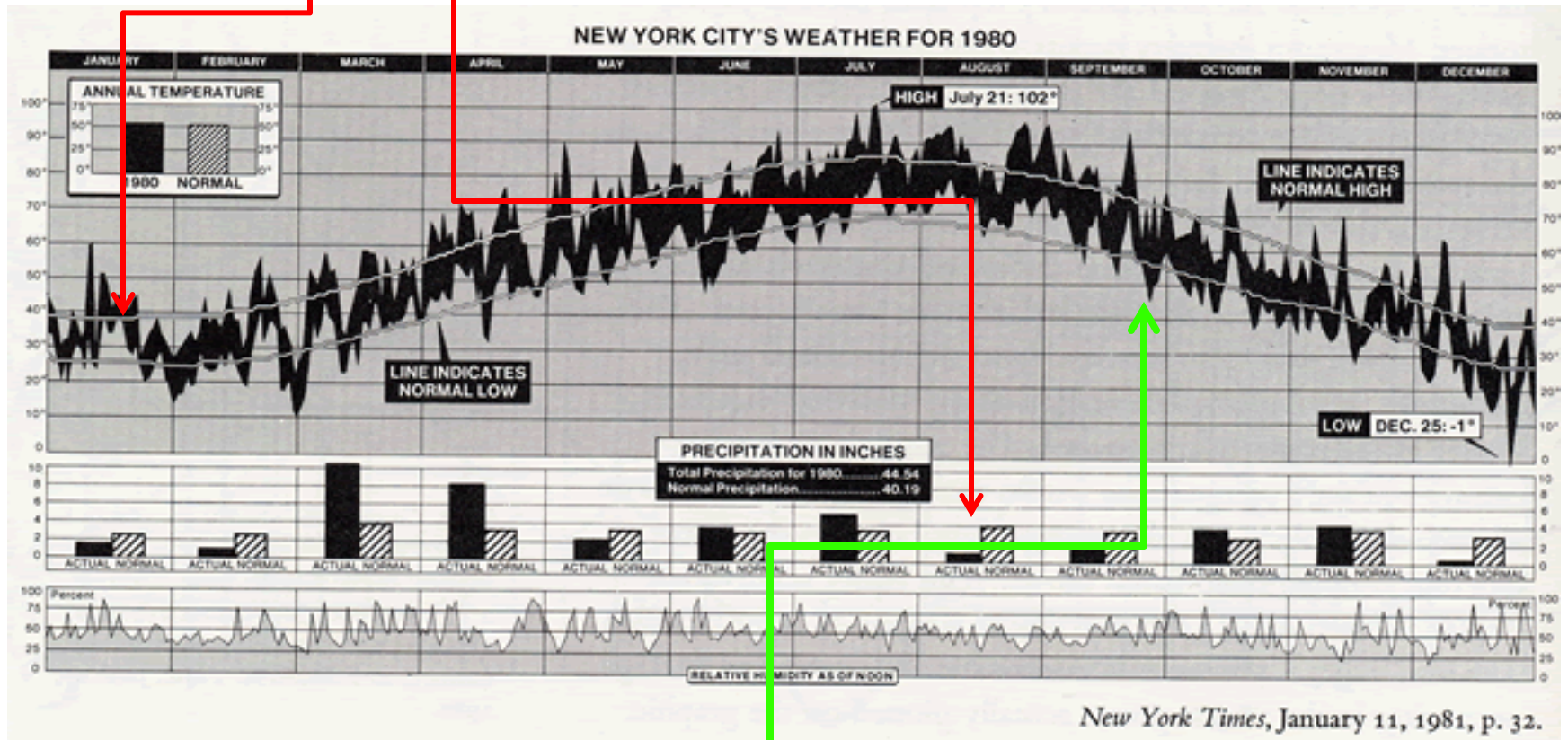


Information  
Visualization:  
Examples



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We look at the pattern(s)  
first



Focus on individual numbers? ... >2K data points!

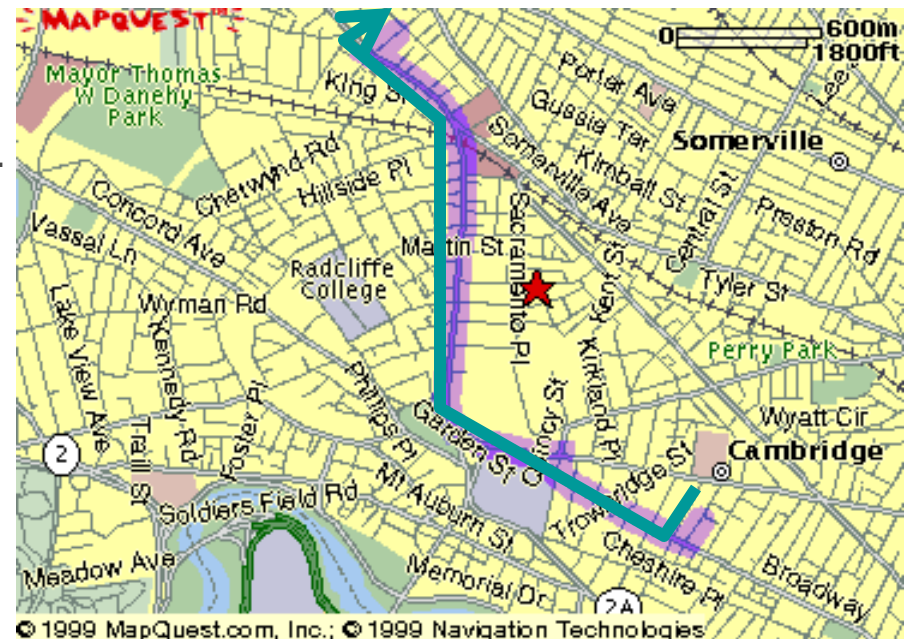




# Augment memory and reasoning

---

1. Start out going Southwest on ELLSWORTH AVE  
Towards BROADWAY by turning right.
2. Turn RIGHT onto BROADWAY.
3. Turn RIGHT onto QUINCY ST.
4. Turn LEFT onto CAMBRIDGE ST.
5. Turn SLIGHT RIGHT onto MASSACHUSETTS AVE.
6. Turn RIGHT onto RUSSELL ST.





17 Ellsworth Ave, Cambridge, MA 02139

Start address

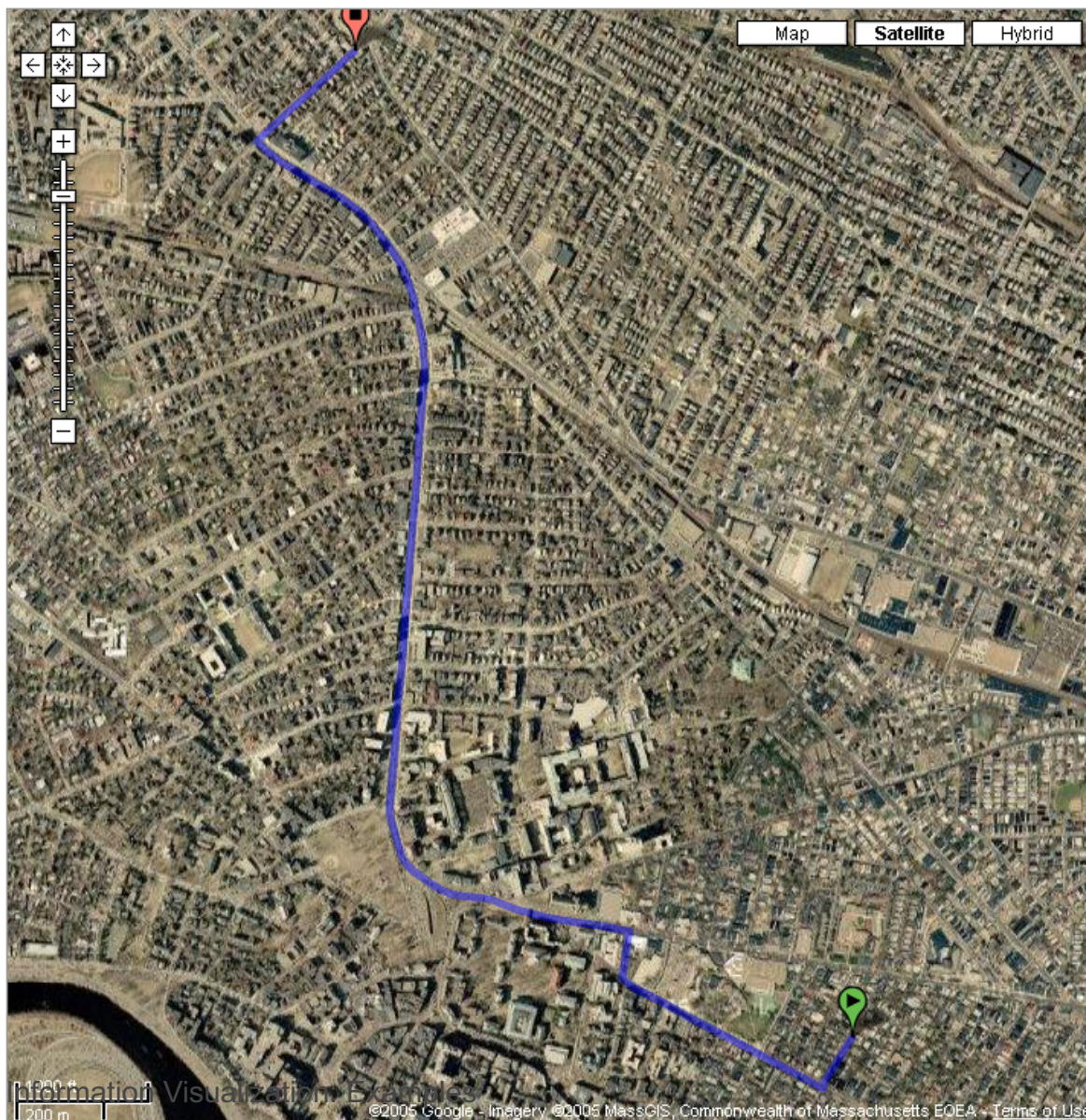
77 Russell St, Somerville, MA 02144

End address

Search

[Help](#)

## Maps



[Print](#) [Email](#) [Link to this page](#)

**Start address:** 17 Ellsworth Ave  
Cambridge, MA 02139

**End address:** 77 Russell St  
Somerville, MA 02144

**Distance:** 2.2 mi (about 3 mins)

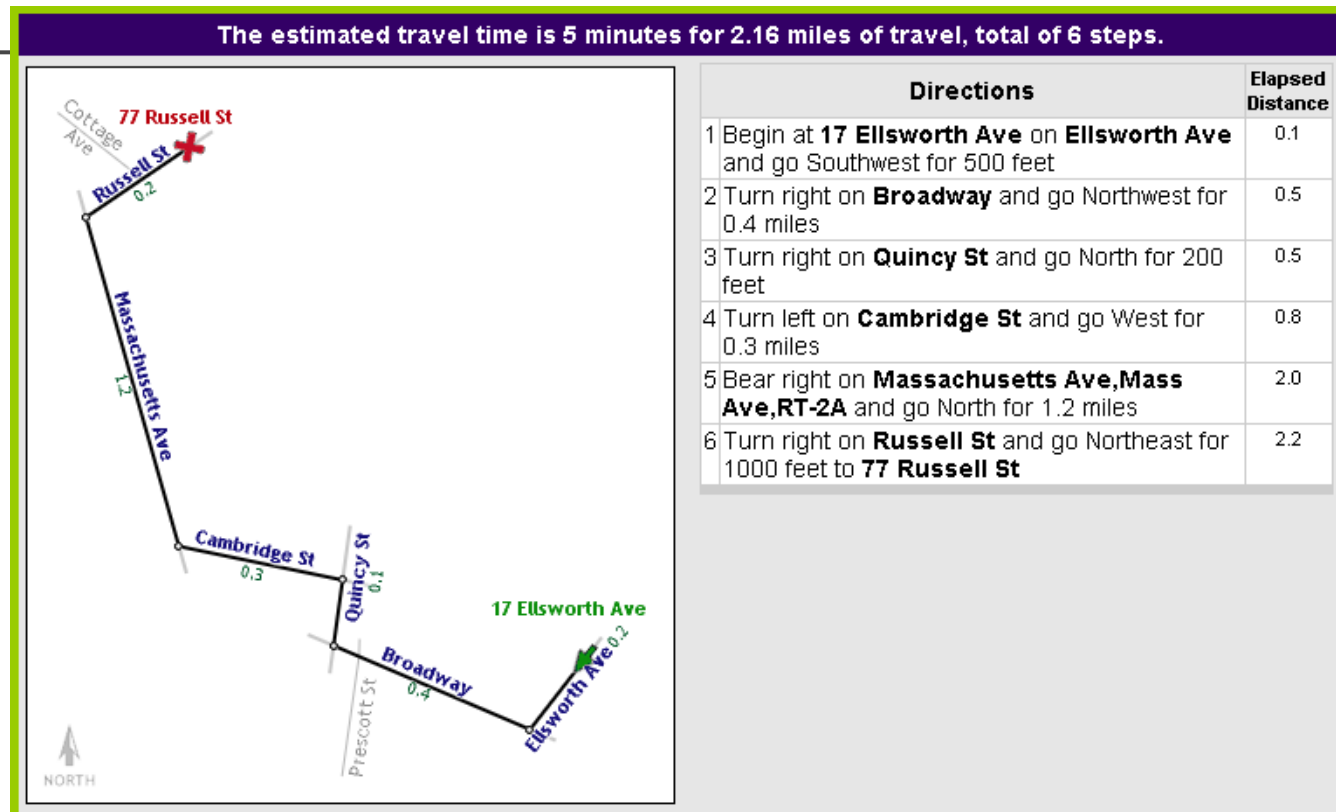
### [Reverse directions](#)

1. Head **southwest** from **Ellsworth Ave** - go **0.1 mi**
2. Turn **right** at **Broadway** - go **0.3 mi**
3. Turn **right** at **Prescott St** - go **0.1 mi**
4. Turn **left** at **Cambridge St** - go **0.3 mi**
5. Bear **right** at **Massachusetts Ave** - go **1.2 mi**
6. Turn **right** at **Russell St** - go **0.2 mi**

These directions are for planning purposes only. You may find that construction projects, traffic, or other events may cause road conditions to differ from the map results.

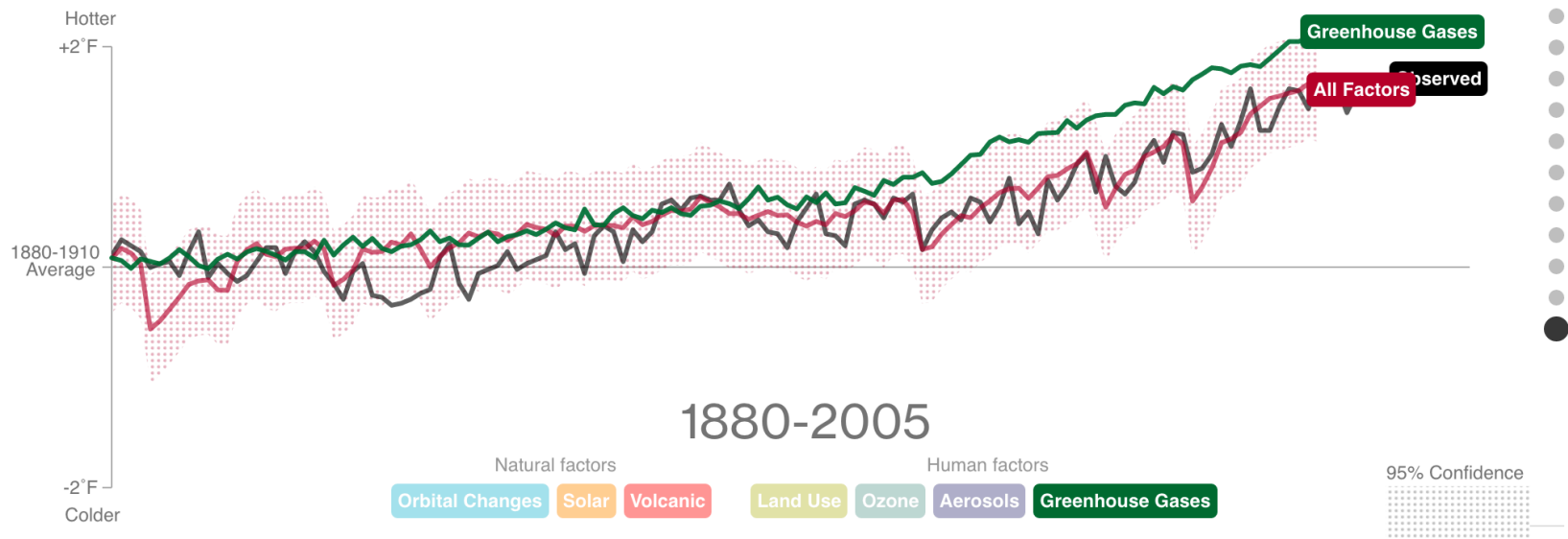
Map data ©2005 NAVTEQ™, Tele Atlas

# The Power of Visualization

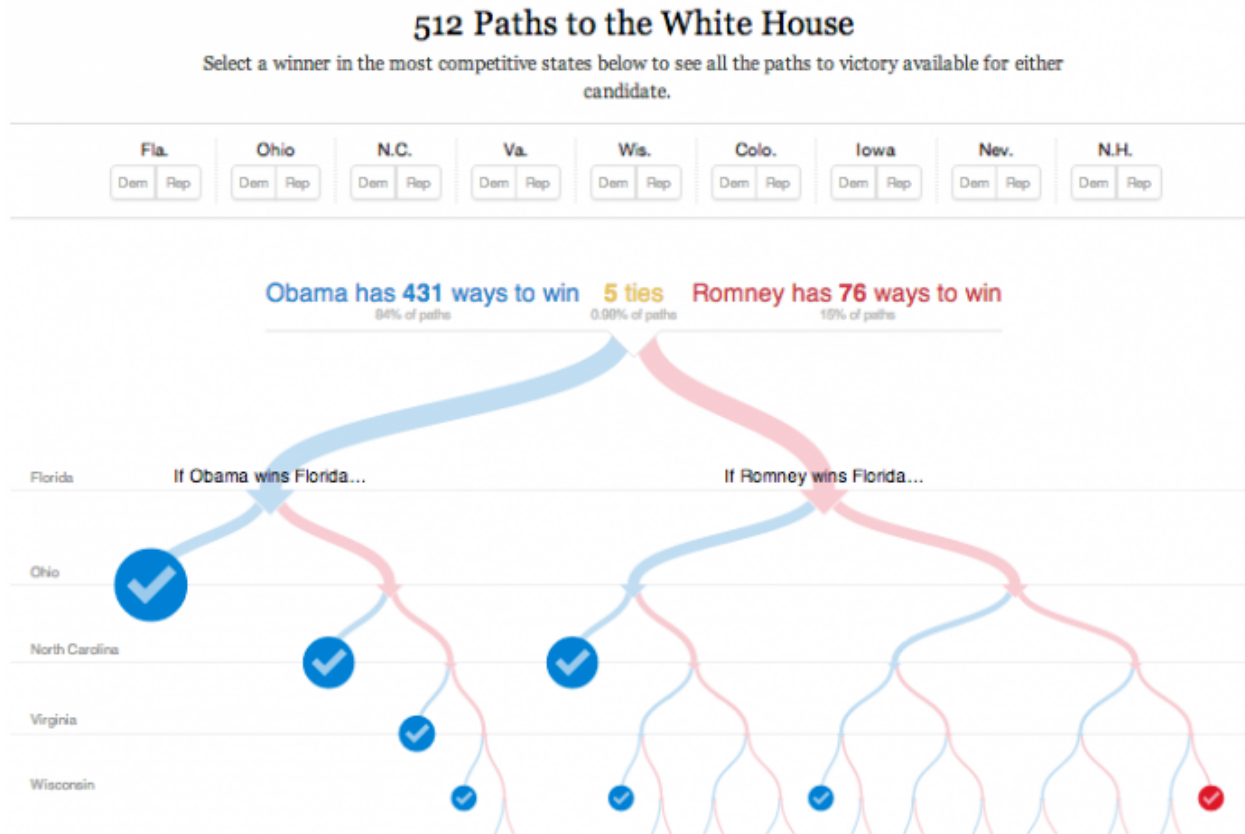


Line drawing tool by Maneesh Agrawala <http://graphics.stanford.edu/~maneesh/>

# Propose argument; tell a story

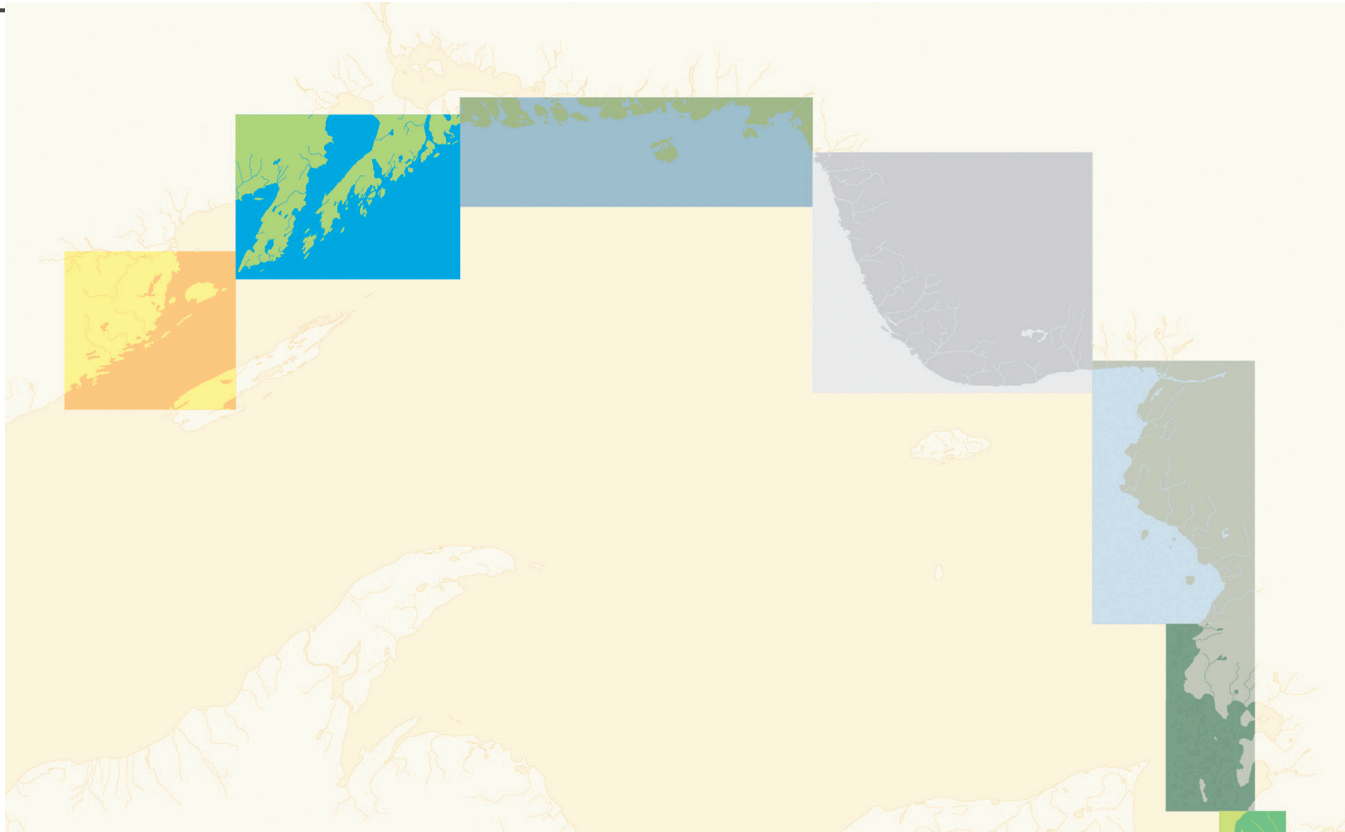


# Examine alternatives





# Visualization for telling a story



Information  
Visualization:  
Examples



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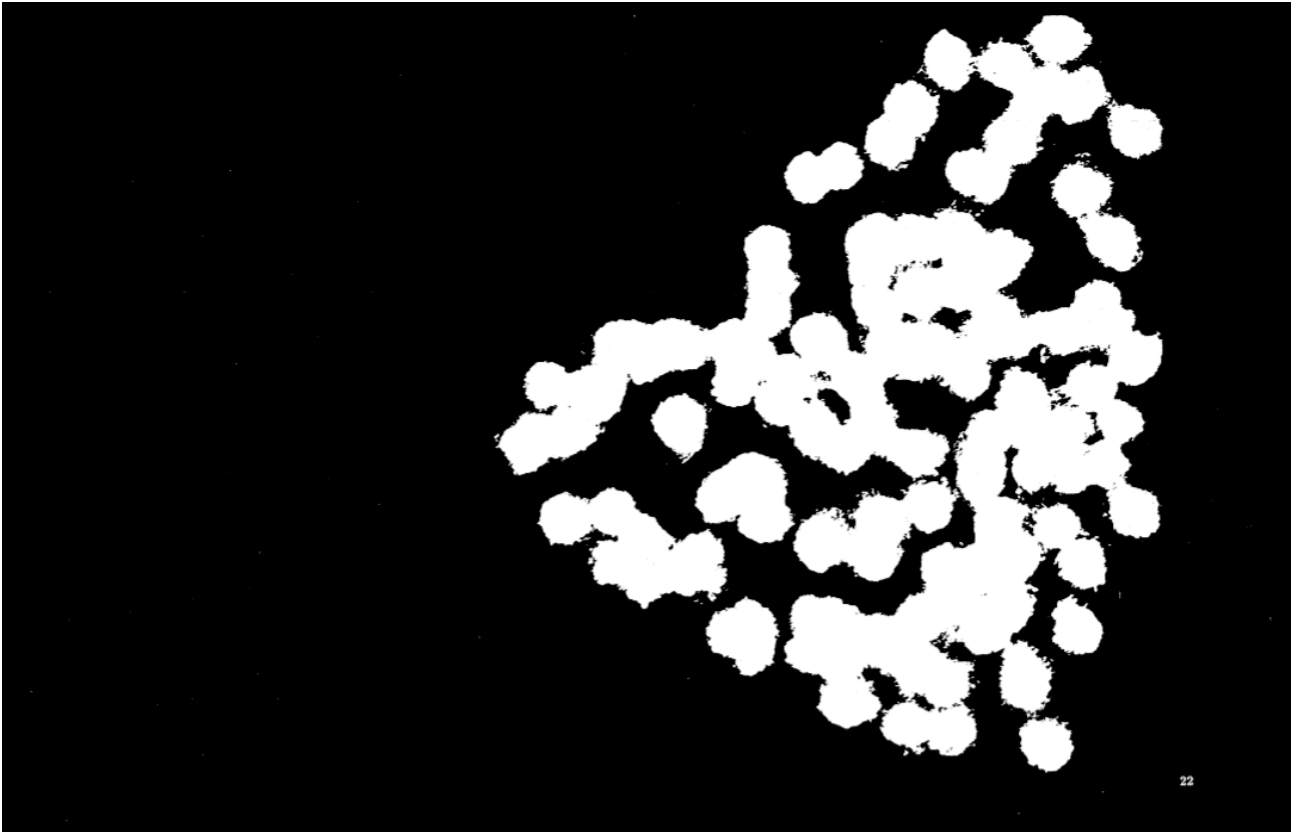
# Inspire new inquiry

What are the  
voids made  
of?

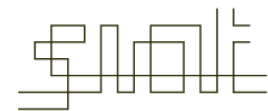


# Inspire: Experiential visualization

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# IAT 355 Course information



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ARTS + TECHNOLOGY

# Course Information

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- Course website:
- <http://www.sfu.ca/siatclass/IAT355/Spring2018/index.html>
- Updates, schedule, policies and all information are kept current on this site. Check it!
  - List of resources and articles
- Canvas submission and discussion site

# Course policies

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- Attendance
- Use of technology
- Conduct
- Plagiarism and academic honesty
- Late penalties (10% day for 2 days, 20% after)



# What you will do in this course

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- Design, Build, Use, Critique Visualizations
- Develop an understanding of tools, techniques and methods for approaching visual analytics problems
- Become familiar with some of the programming resources for making visualizations
- Determine questions
- Write code
- FIND CODE and adapt
- FIND DATA
- Design right visualizations
- Build appropriate interactions

# Evaluation

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## Assignments

- 2 Analysis and design (practice) : 20%
- 4 making (code, project): 50%
- Datavis journal: 10%
- Concept reviews: 20%

## Course Project

- **Pairs**
- **You choose, and you make**
- Real-world problems
- Data
- Visualization
- Assessment and report

# Topics

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- Visualization Tools, techniques and Programming
  - Computer Graphics
- Information Visualization
  - Representation
  - Presentation
  - Interaction
- Visual Thinking: Perception, Cognition and Information Sense-Making