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Week 11

Modeling Interaction / Information Visualization

HCI 연구방법론 2019 Fall

Human-Computer Interaction+Design Lab _ Joonhwan Lee

오늘 다룰 내용

- Description Models
- Predictive Models

- Information Visualization

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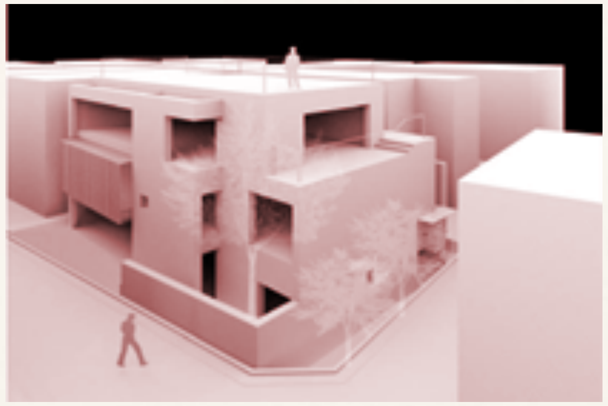
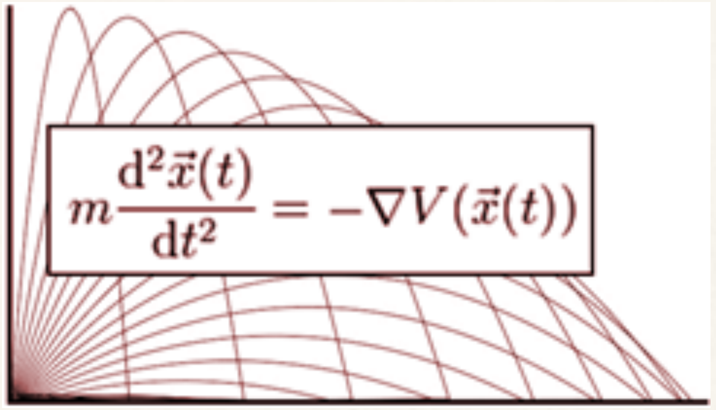
Model

- A *model* is a simplification of reality
- Consider…

Architect's scale model of a building





Physicist's model for the trajectory of a tossed ball

- Both are simplifications of complex phenomena
- The architect's model is a **description** → provides insight into space usage, movement of people, light, shade, etc.
- The physicist's model is a **prediction** → gives the ball's position as a function of time

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Descriptive Models

Descriptive Models

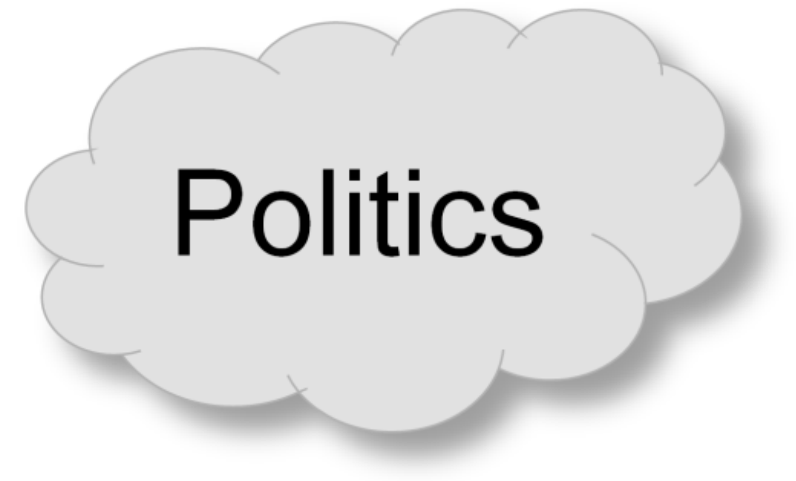
- Descriptive models are everywhere
- Descriptive modeling is at times so simple, the process barely seems like modeling
- Other names:
  - Design space, framework, taxonomy, classification, and often without a name given
- As a partitioned domain, we are empowered to think differently – and critically – about the problem

Descriptive Model Examples

- **<u>Politics</u>**
- Groupware
- Keyboards
- Two-handed input
- Graphical input

Big Fuzzy Cloud Model of Politics

- Let's consider a topic we all know a little about
- Below is a *big fuzzy cloud* model for politics:



- How do we go about making a descriptive model of politics?
- Break it down; partition the topic into parts
- What are the things that make up politics?
- How can they be labeled, presented, and organized?

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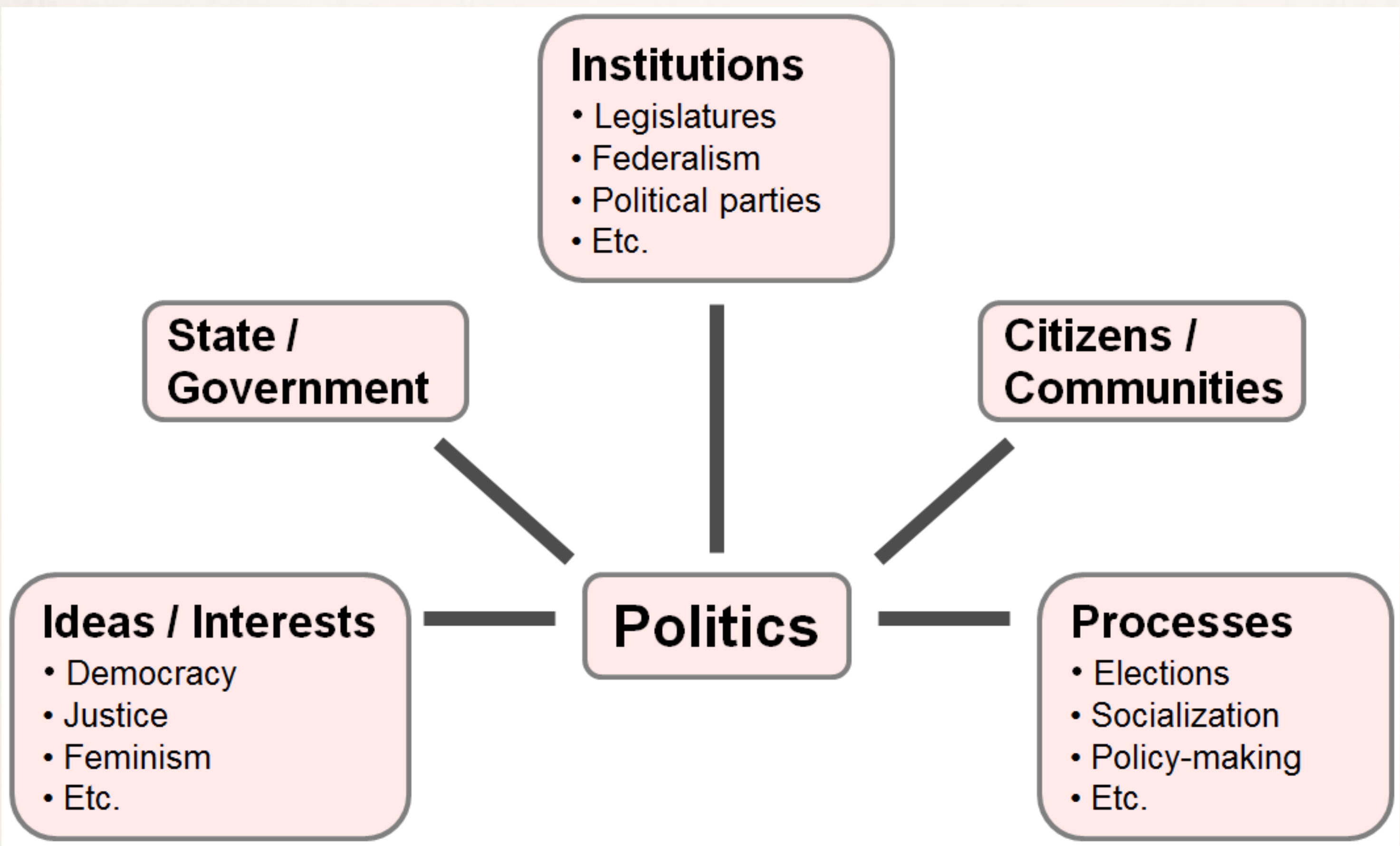
Descriptive Model of Politics

- With Johnston's model of politics, we are empowered to think differently about politics



Questions:

- Is the model correct?
- Is there a different organization that might work better?
- Is it correct to mirror citizens/communities with state/government?
- Are the five perimeter items sufficient?
- Is federalism an institution (or an idea)?
- <u>Is the model useful?</u>

Johnston, L. (2007). Politics: An introduction to the modern democratic state (3rd ed.). Peterborough, Ontario: Broadview Press.

Descriptive Model Examples

- Politics
- **<u>Groupware</u>**
- Keyboards
- Two-handed input
- Graphical input

CSCW (Groupware)

- A research topic within HCI is **CSCW** (computer supported cooperative work)
- Concerned with people working collaboratively using computing technology
- Aka groupware
- Same challenge:
  - How do we go about making a descriptive model of groupware?
  - Break it down; partition the topic into parts
  - What are the things that make up groupware?
  - How can they be labeled, presented, and organized?

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Quadrant Model of Groupware

- A descriptive model
- Groupware partitioned into a 2 × 2 space
  - Location → same place | different places
  - Time → same time | different times

	Same Time	Different Times
Same Place	Copy boards PC Projectors Facilitation Services Group Decision Room Polling Systems	Shared Files Shift Work Kiosks Team Rooms Group Displays
Different Places	Conference Calls Graphics and Audio Screen Sharing Video Teleconferencing Spontaneous Meetings	Group Writing Computer Conferencing Conversational Structuring Forms Management Group Voice Mail

Johansen, R. (1991). Groupware: Future directions and wild cards. Journal of Organizational Computing and Electronic Commerce, 1(2), 219-227.

Critiquing the Model

- The quadrant model of groupware was introduced in 1991
- The same questions apply:
  - Is the model correct? Is there a different organization that might work better? Is the model useful? Etc.
- Many of today's methods of collaborating didn't exist in 1991
- Contemporary groupware activities include
  - Sharing photos using camera phones, web cams, Skype, social media, blogging, tweeting
- Can these be positioned in the quadrant model of groupware?

Descriptive Model Examples

- Politics
- Groupware
- **<u>Keyboards</u>**
- Two-handed input
- Graphical input

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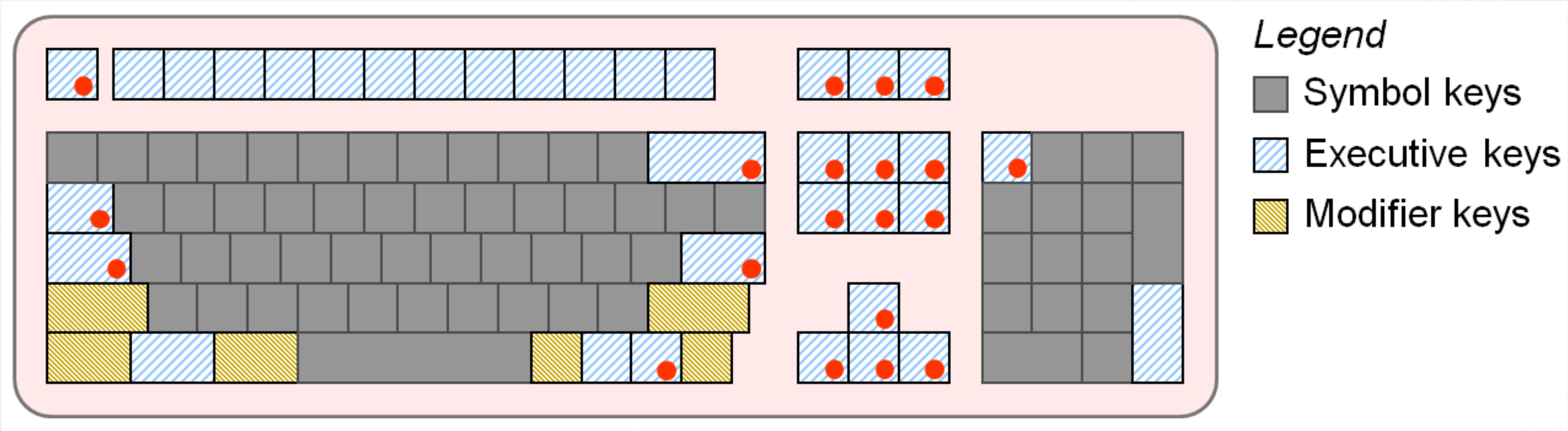
Keyboards

1874

- Keyboards date at least to the 1870s with the introduction of the Scholes-Glidden typewriter keyboard
- Today's keyboards retain the same core letter arrangement (qwerty), but have many extra keys
- 100+ keys can produce a wide variety of letters, symbols, commands, etc.
- Same challenge:
  - How do we go about making a descriptive model of keyboards?
  - Break it down; partition the topic into parts
  - What are the things that make up keyboards?
  - How can they be labeled, presented, and organized?

Key-Action Model (KAM)

- A descriptive model
- Three categories of keys:
  - Symbol keys → produce graphic symbols (e.g., A)
  - Executive keys → invoke actions (e.g., ESC)
  - Modifier keys → modify effect of other keys (e.g., CTRL)



MacKenzie, I. S. (2003). Motor behaviour models for human computer interaction. In J. M. Carroll (Ed.), HCI models, theories, and frameworks: Toward a multidisciplinary science (pp. 27-54): San Francisco: Morgan Kaufmann.

Critiquing the Model

- Nice visualization
  - Reveals organization of the keyboard in terms of symbol, executive, and modifier keys
- Questions:
  - Is the model correct? Do all keys fit the model? Are there additional categories to improve the model? Do some keys fit more than one category? Can the model be applied to other keyboards, such as mobile phone keyboards or soft keyboards? Is the model useful? Etc.
- Note: Red dots on previous slide identify executive keys that are not mirrored (excluding function keys)
- There seems to be a 3:18 right-side bias!

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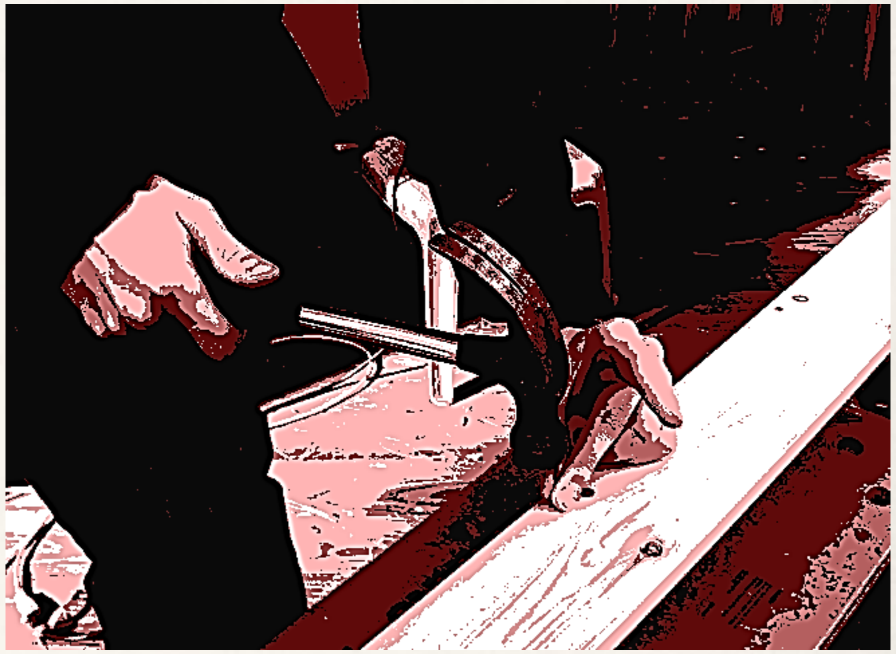
Descriptive Model Examples

- Politics
- Groupware
- Keyboards
- **Two-handed input**
- Graphical input

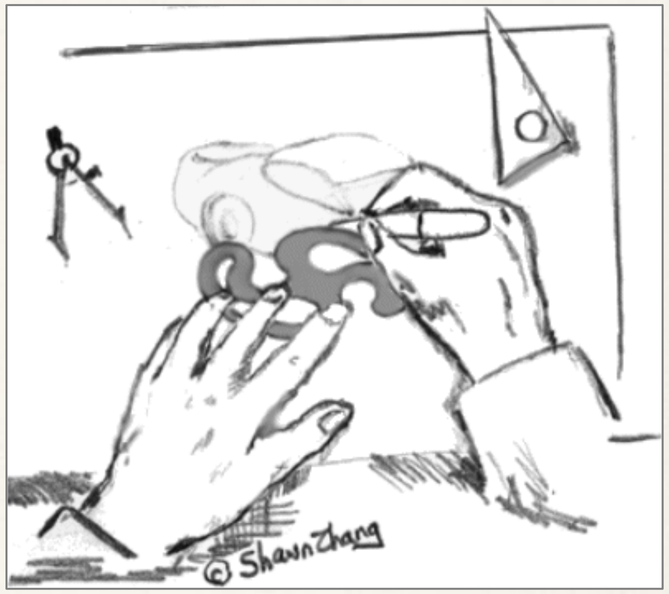
Two-handed Input



- Humans not only have two hands, they use their hands differently
- Most people have a hand preference
- Study of hand usage is called **laterality or bimanual control**
- Guiard undertook such a study, examining the roles of the preferred and non-preferred hands in common tasks
- The result is a descriptive model

Guiard’s Model of Bimanual Control

Hand	Role and Action
Non-preferred	• Leads the preferred hand • Sets the spatial frame of reference for the preferred hand • Performs coarse movements
Preferred	• Follows the non-preferred hand • Works within established frame of reference set by the non-preferred hand • Performs fine movements



- Consider the bulleted points above in terms of the sketch on the right.

Guiard, Y. (1987). Asymmetric division of labor in human skilled bimanual action: The kinematic chain as a model. Journal of Motor Behavior, 19, 486-517.

Critiquing the Model

- Guiard’s model was not developed using examples from computing
- Paul Kabbash, a graduate student at the University of Toronto in the 1990s, came across Guiard’s model as part of his research in two-handed computer input
- Guiard’s model provided insight to more fully understand the roles of the preferred and non-preferred hands for computer input
- Widely used since for analysing and understanding two-handed computer input, for example, *scrolling (next slide)*

Scrolling

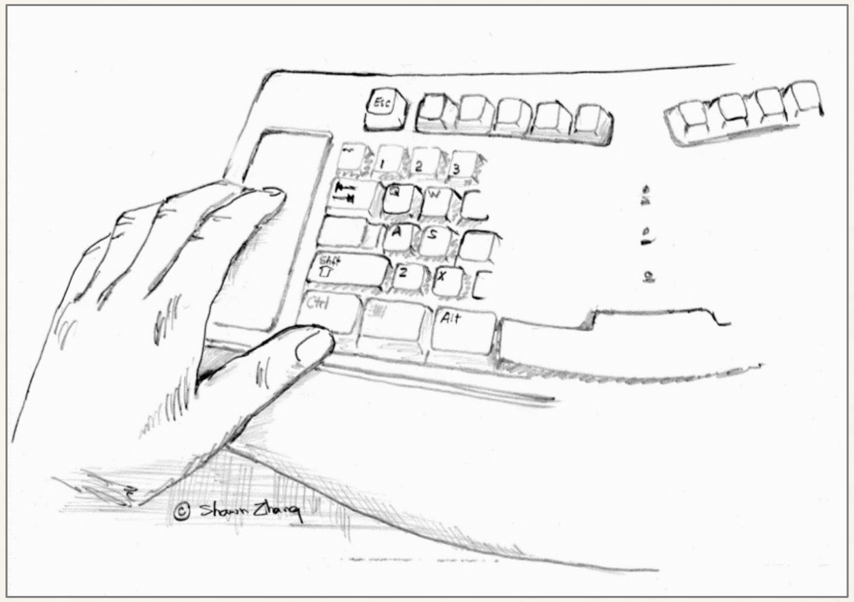
- The table below deconstructs scrolling as it relates to other common computing tasks that coexist with scrolling

Task	Characteristics
Scrolling	• Precedes/overlaps other tasks • Sets the frame of reference • Minimal precision needed (coarse)
Selecting, editing, reading, drawing, etc.	• Follows/overlaps scrolling • Works within frame of reference set by scrolling • Demands precision (fine)

- Do you see the similarity with Guiard's model of bimanual control?
- What does this suggest?

Non-preferred Hand Scrolling

- Guiard’s model of bimanual control suggests that scrolling is a task well suited to the non-preferred hand:



- But, what about the wheel mouse, introduced in 1996 by Microsoft as the *Intellimouse*?
- How to get scrolling into the non-preferred hand?

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Re-engineered *Intellimouse*

- A presentation rationalizing non-preferred hand scrolling (in view of Guiard's model of bimanual control) was given at Microsoft in Feb 1998 using a **re-engineered *Intellimouse***:

- The case for scrolling via the non-preferred hand was persuasive

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Re-engineered *Intellimouse*

- A presentation rationalizing non-preferred hand scrolling (in view of Guiard's model of bimanual control) was given at Microsoft in Feb 1998 using a **re-engineered *Intellimouse***:

Two-years later

- The case for scrolling via the non-preferred hand was persuasive

Microsoft Office Keyboard

- Includes left-side wheel (roller) for scrolling via the non-preferred hand (for right-handed users):

- The left-side scroll wheel was eventually discontinued in later releases of Microsoft keyboards
- Momentum and popularity of the wheel mouse were too much to overcome

Post Script

- Guiard's model for bimanual control remains widely used in human-computer interaction
- Google Scholar returns 230 citations "since 2008" to Guiard's 1987 paper ("Asymmetric division of labor in…")
- Most citations are from research papers in HCI

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Descriptive Model Examples

- Politics
- Groupware
- Keyboards
- Two-handed input
- **Graphical input**

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Graphical Input

- Considerable research on GUIs followed the successful introduction of the Apple Macintosh in 1984
  - Common interactive techniques (tasks):
    - pointing, dragging, selecting, inking, rubber-banding, texting
  - Common technologies (devices):
    - mouse, trackball, touch panel, joystick, stylus, finger
- How can the tasks and devices be reconciled and understood to promote better designs?

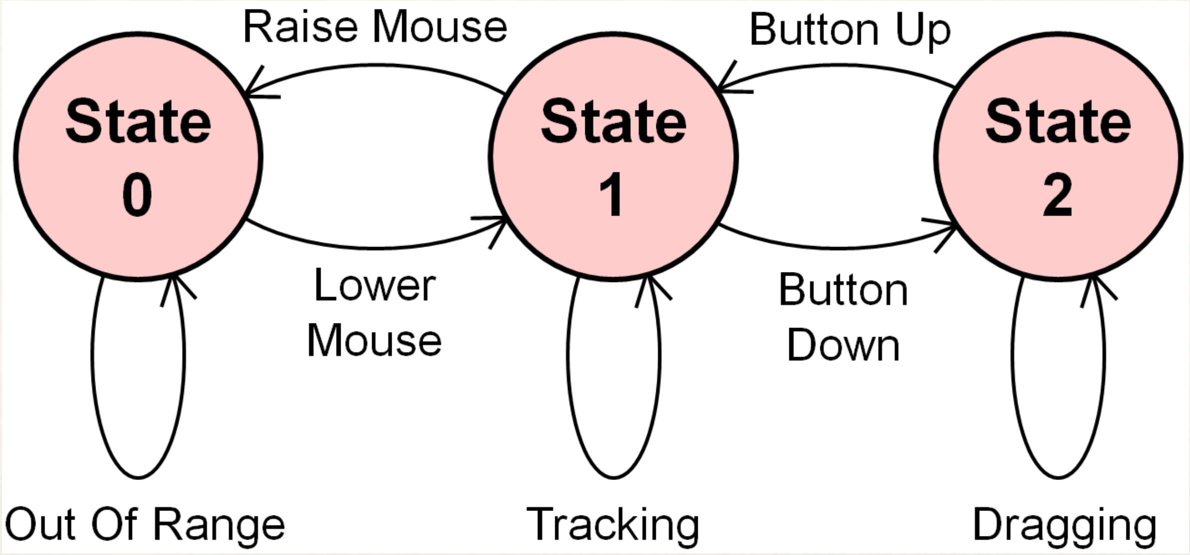
Graphical Input

- Buxton commented on…
  - "…the lack of a vocabulary that is capable of capturing salient features of interactive techniques and technologies in such a way as to afford finding better matches between the two"
- To address this, Buxton developed a **three-state model** of graphical input

Buxton, W. (1990). A three-state model of graphical input. Proceedings of INTERACT '90, 449-456, Amsterdam: Elsevier.

Buxton's Three State Model of Graphical Input

- A descriptive model
- Expresses GUI interaction in terms of three states
- Mouse example: (expressed differently for other devices)
    - State 0 → out of range
    - State 1 → tracking
    - State 2 → dragging



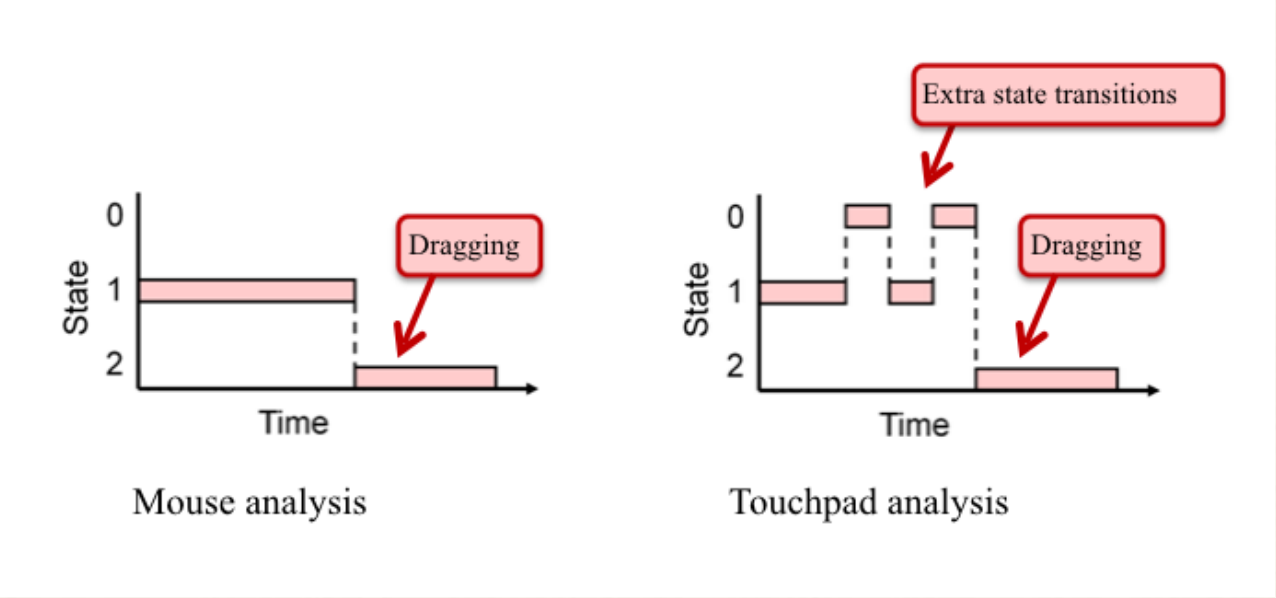
Application of Buxton's Model

- In 1994 Apple introduced the **Trackpad** on its *Powerbook 500* series notebook computer
- Soon after, the Trackpad (usually called a touchpad) became the standard pointing device on notebook computers
- Besides physical buttons to mimic mouse buttons, a touchpad includes "lift and tap" to implement button down/up actions with the fingers only

- But, lift-and-tap actions are error prone → during a tap, if the finger moves before lifting, a dragging action is sometimes invoked, instead of a click

Analysis Using Buxton's Three-state Model

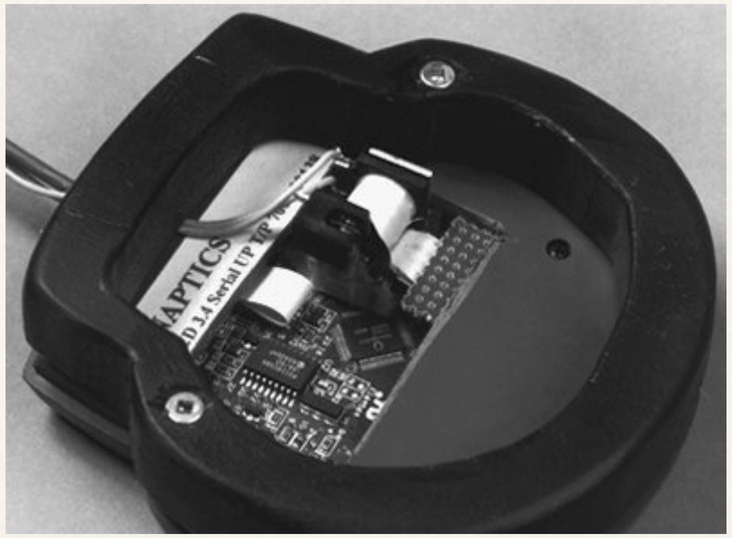
- An analysis and comparison of common touchpad and mouse interactions is possible, guided by Buxton's three-state model
- Below is an example for dragging



- but touchpads are capable of sensing finger pressure (like the pressure of a finger on a mouse button)

The Tactile Touchpad

- Uses absolute x-y-z mode (z = finger pressure)
- Implements button down (state 2) by “pressing harder”
- Button click feedback provided by relay below touchpad
- Design guided by Buxton’s three-state model



MacKenzie, I. S., & Oniszczak, A. (1997). The tactile touchpad. Extended Abstracts of the ACM SIGCHI Conference on Human Factors in Computing Systems - CHI '97, 309-310, New York: ACM.

Post Script

- Buxton’s three-state model remains widely used in human-computer interaction
- Google Scholar returns 77 citations “since 2008” to Buxton’s 1990 paper (“A three state model”)
- Contemporary applications include
  - Models for preview and undo
  - Puck and stylus input for two-handed interaction
  - Docking tasks for tabletop displays
  - Camera control for navigating animated scenes
  - Modeling multi-touch on touchscreens
  - Modeling panning and zooming on touchscreen
  - Modeling selection of moving targets
  - Modeling the rotation mode of a 3 DOF mouse

Predictive Models

Predictive Models

- A predictive model is an *equation*
- Predicts the outcome on a *criterion variable* (aka *dependent variable* or *human response*) based on the value of one or more *predictor variables* (aka *independent variables*)
  - Note: the predictor variables must be ratio-scale attributes
- Predictive models, like descriptive models, allow a problem space to be explored
- However, predictive models deal with numbers, not concepts

Why Use Predictive Models

- Card et al. presented perhaps the first predictive model in HCI. In many respects, their work was straight-forward experimental research; but they went further:
  - "While these empirical results are of direct use in selecting a pointing device, it would obviously be of greater benefit if a theoretical account of the results could be made. For one thing, the need for some experiments might be obviated; for another, ways of improving pointing performance might be suggested."
- This is a call for the use of predictive models in HCI by presenting predictive models using Fitts' law

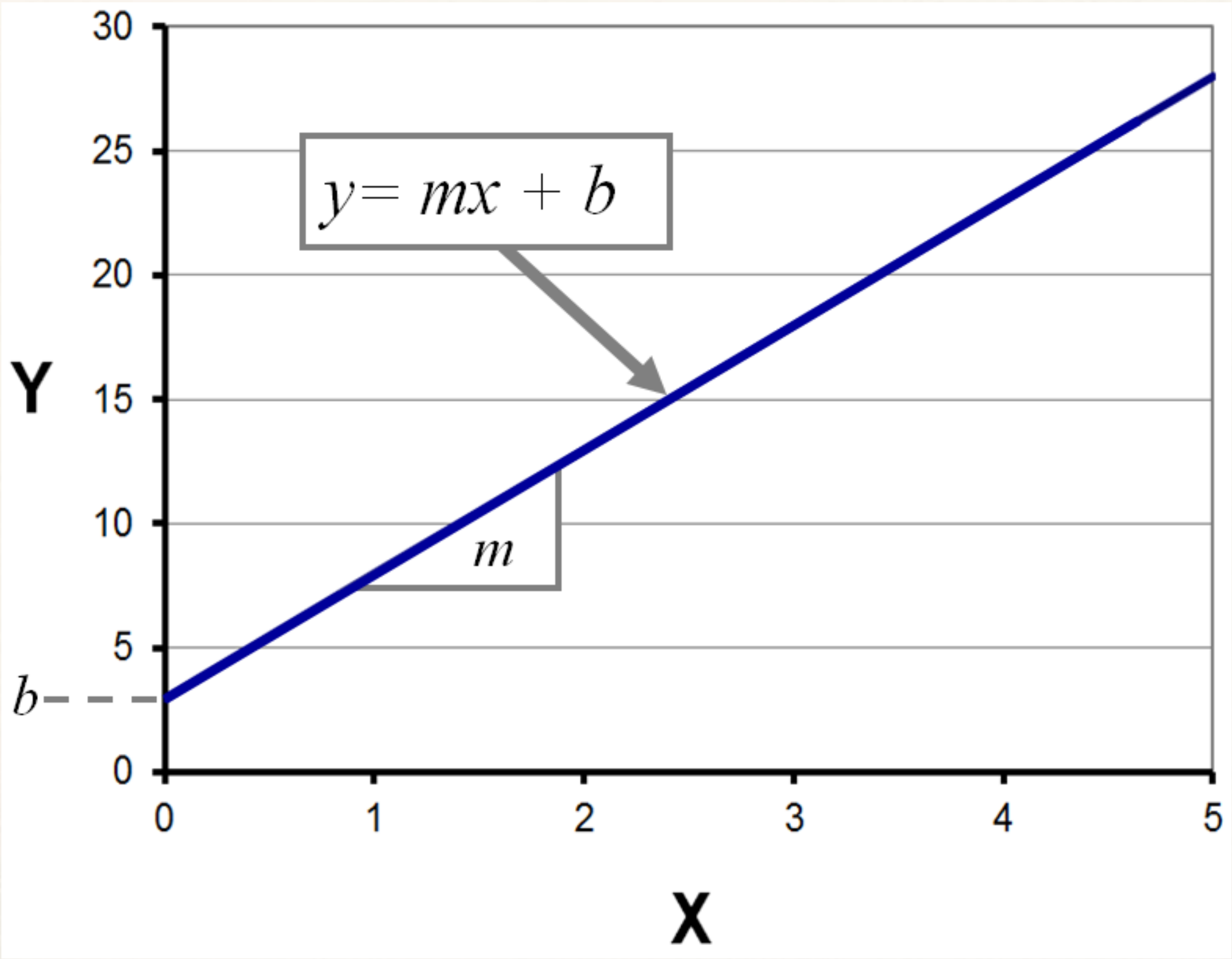
Card, S. K., English, W. K., & Burr, B. J. (1978). Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT. Ergonomics, 21, 601-613.

Predictive Model Examples

- **Linear prediction equation**
- Fitts' law
- Choice reaction time
- Keystroke-level model (KLM)

Linear Prediction Equation

- The basic prediction equation expresses a linear relationship between a predictor variable (x) and a criterion variable (y):



Linear Regression

- A linear prediction equation is built using a statistical procedure know as **linear regression**
- Goal:
  - Given a set of x-y sample points, **find the coefficients m and b** (previous slide) for the line that minimizes the squared distances (least squares) of the points from the line
- The result is a prediction equation that gives the best estimate of y in terms of x
- The assumption, of course, is that the relationship is linear

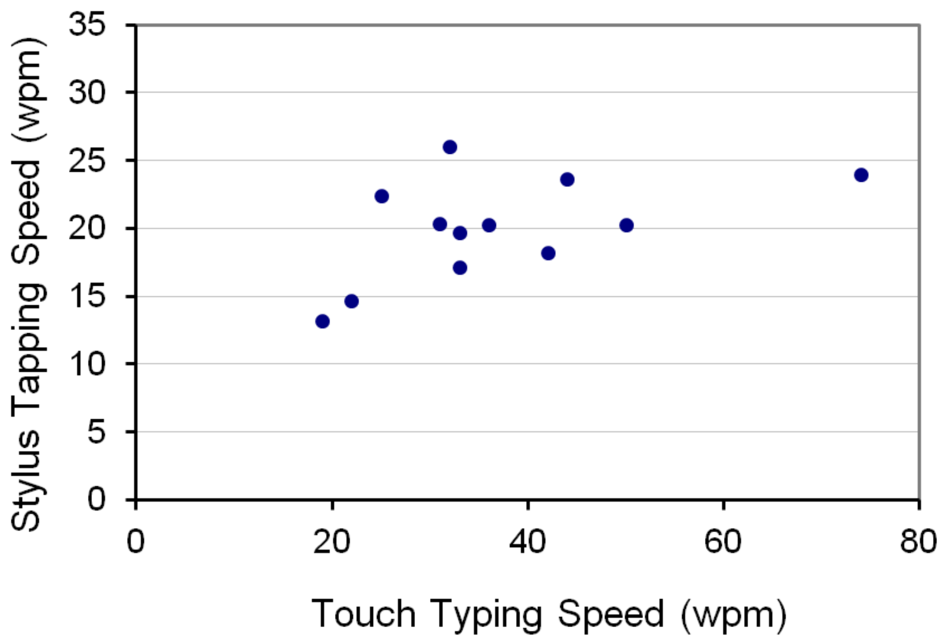
Example

- A research project investigated text entry on **soft keyboards**
- The research also asked…
  - Can stylus tapping entry speed be predicted from touch typing entry speed?
- Touch typing speed is the predictor variable (x - measured in a pre-test)
- Stylus typing speed is the criterion variable (y - measured experimentally)

MacKenzie, I. S., & Zhang, S. X. (2001). An empirical investigation of the novice experience with soft keyboards. Behaviour & Information Technology, 20, 411-418.

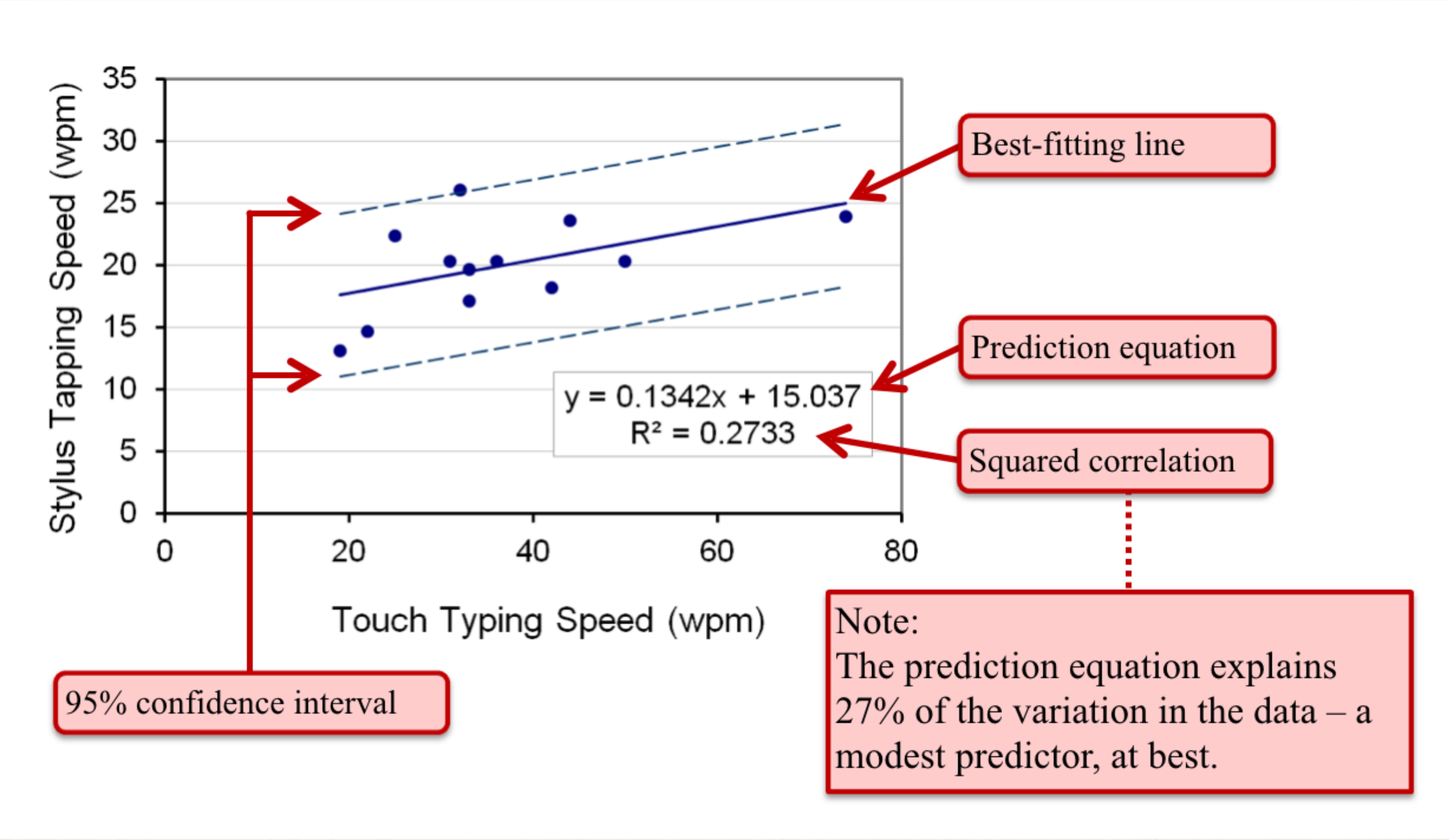
Data and Scatter Plot

Participant	Stylus Tapping Speed (wpm)	Touch Typing Speed (wpm)
P1	18.2	42
P2	23.6	44
P3	26.0	32
P4	20.3	50
P5	20.3	36
P6	17.1	33
P7	24.0	74
P8	14.7	22
P9	20.3	31
P10	19.7	33
P11	22.4	25
P12	13.1	19



- There seems to be a relationship: Faster touch typists seem to be faster at stylus tapping.
- Questions:
  - What is the prediction equation?
  - How strong is the relationship?

Prediction Equation



Predictive Model Examples

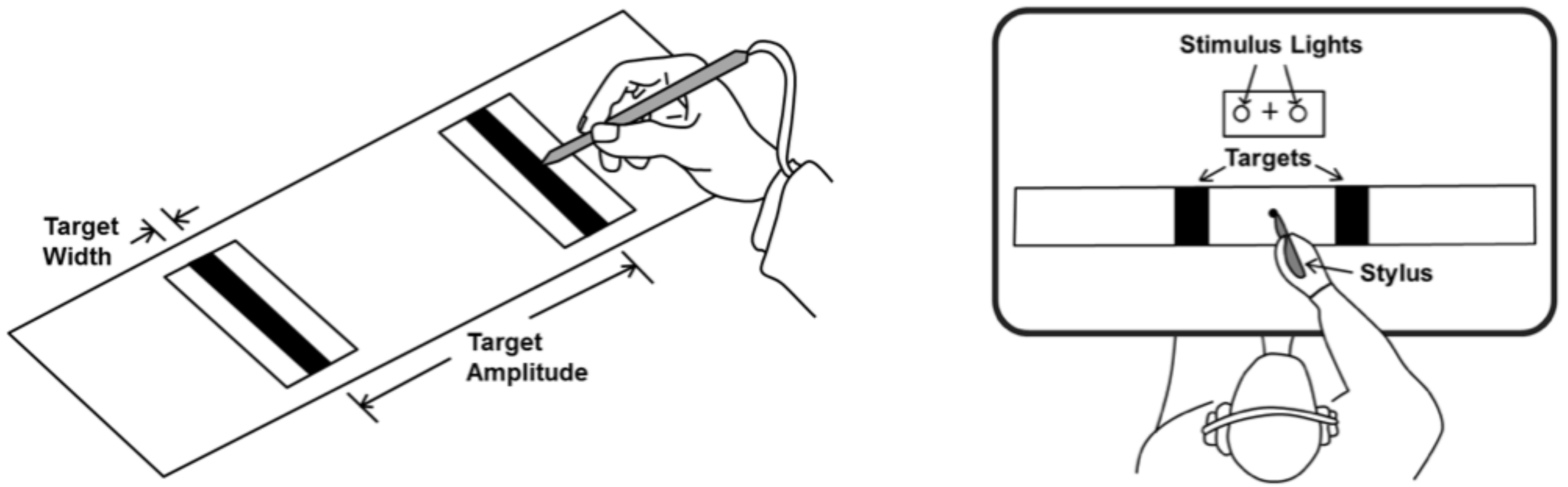
- Linear prediction equation
- **Fitts' law**
- Choice reaction time
- Keystroke-level model (KLM)

Fitts' Law

- One of the most widely used models in HCI
- Model for rapid aimed movements (e.g., moving a cursor toward a target and selecting the target)
- Three applications:
  - **Use a Fitts' law prediction equation to analyse and compare design alternatives**
  - Use Fitts' index of performance (now throughput) as a dependent variable in a comparative evaluation
  - Determine if a device or technique "conforms to Fitts' law"
- Origins: Two highly-cited papers in experimental psychology, one from 1954[1], the other for 1964[2]

1 Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, 47, 381-391.
2 Fitts, P. M., & Peterson, J. R. (1964). Information capacity of discrete motor responses. Journal of Experimental Psychology, 67, 103-112.

Fitts' Law – Task Paradigms



Serial task

Discrete task

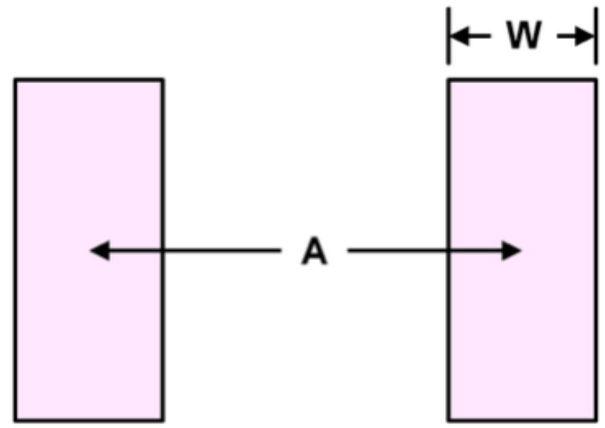
- These sketches were adapted from Fitts' 1954 and 1964 papers. It is easy to imagine comparable tasks implemented on computing technology.

Fitts' Index of Difficulty (ID)

- Fitts' index of difficulty (ID) is a measure of the difficulty of a target selection task:

$$ID = \log_2\left(\frac{A}{W} + 1\right)$$

Units: bits



- Normally the prediction equation is built using the *effective index of difficulty* (ID_e) – includes an "adjustment for accuracy"
- Fitts hypothesized that the relationship between movement time (*MT*) and *ID* is linear

Fitts' Law Models for Pointing Devices

- A research project compared four pointing devices, including two for remote pointing
- Twelve participants performed a series of serial target selection tasks using the four devices
- For our purpose, we'll look at the data and models for two of the devices:

Interlink RemotePoint

MS Mouse 2.0

MacKenzie, I. S., & Jusoh, S. (2001). An evaluation of two input devices for remote pointing. Proceedings - EHCI 2000, 235-249, Heidelberg, Germany: Springer-Verlag.

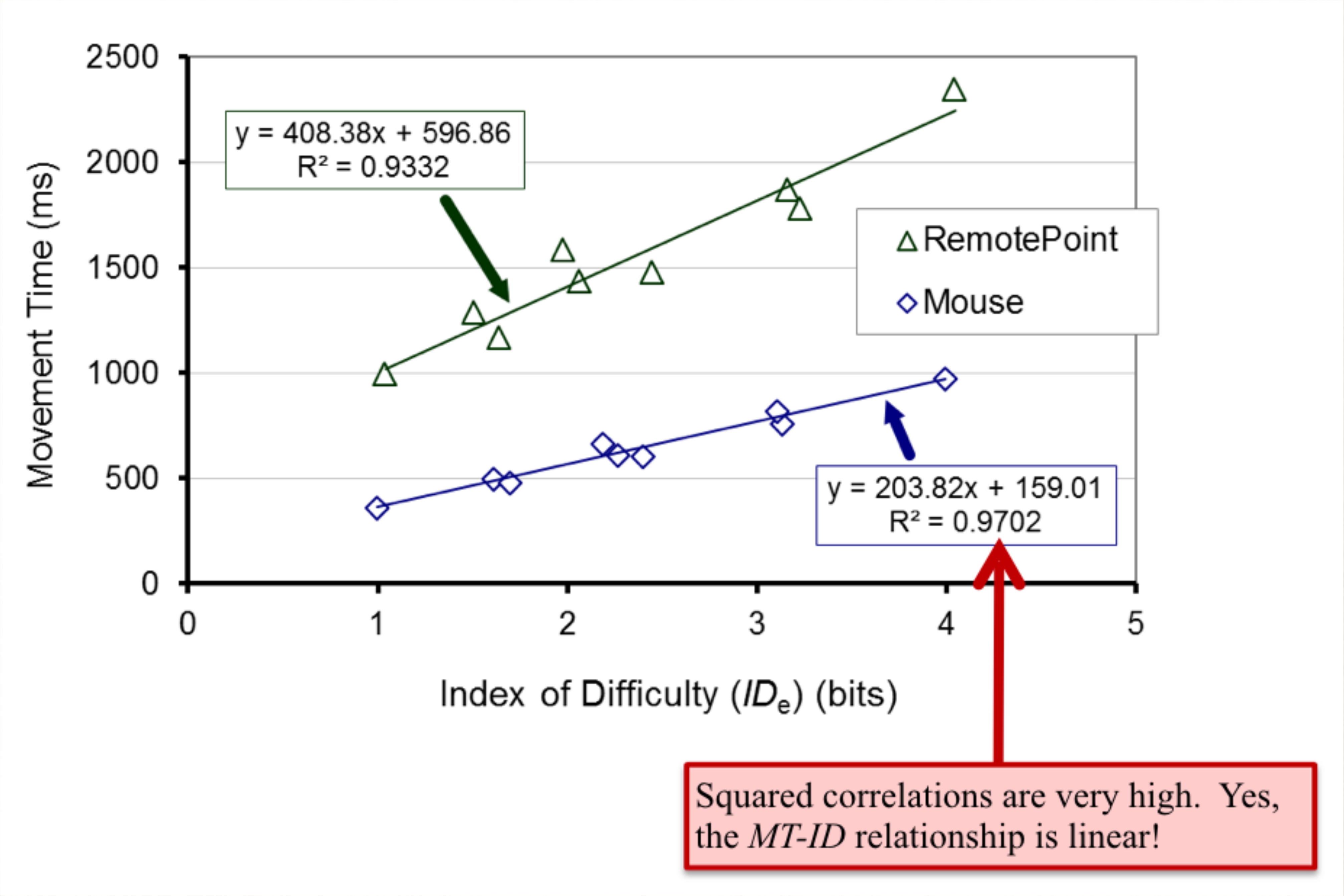
Experiment Conditions and Observations

Conditions			Mouse Observations				RemotePoint Observations			
			Mouse				RemotePoint			
A (pixels)	*W* (pixels)	*ID* (bits)	W_e (pixels)	ID_e (bits)	*MT* (ms)	*TP* (bits/s)	W_e (pixels)	ID_e (bits)	*MT* (ms)	*TP* (bits/s)
40	10	2.32	11.23	2.19	665	3.29	13.59	1.98	1587	1.25
40	20	1.58	19.46	1.61	501	3.21	21.66	1.51	1293	1.17
40	40	1.00	40.20	1.00	361	2.76	37.92	1.04	1001	1.04
80	10	3.17	10.28	3.13	762	4.11	10.08	3.16	1874	1.69
80	20	2.32	18.72	2.40	604	3.97	25.21	2.06	1442	1.43
80	40	1.58	35.67	1.70	481	3.53	37.75	1.64	1175	1.40
160	10	4.09	10.71	3.99	979	4.08	10.33	4.04	2353	1.72
160	20	3.17	21.04	3.11	823	3.77	19.09	3.23	1788	1.81
160	40	2.32	41.96	2.27	615	3.69	35.97	2.45	1480	1.65
		Mean	23.25	2.38	644	3.60	23.51	2.35	1555	1.46

x sample points
y sample points

x sample points
y sample points

Fitts' Law Prediction Equations



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Predictive Model Examples

- Linear prediction equation
- Fitts' law
- **Choice reaction time**
- Keystroke-level model (KLM)

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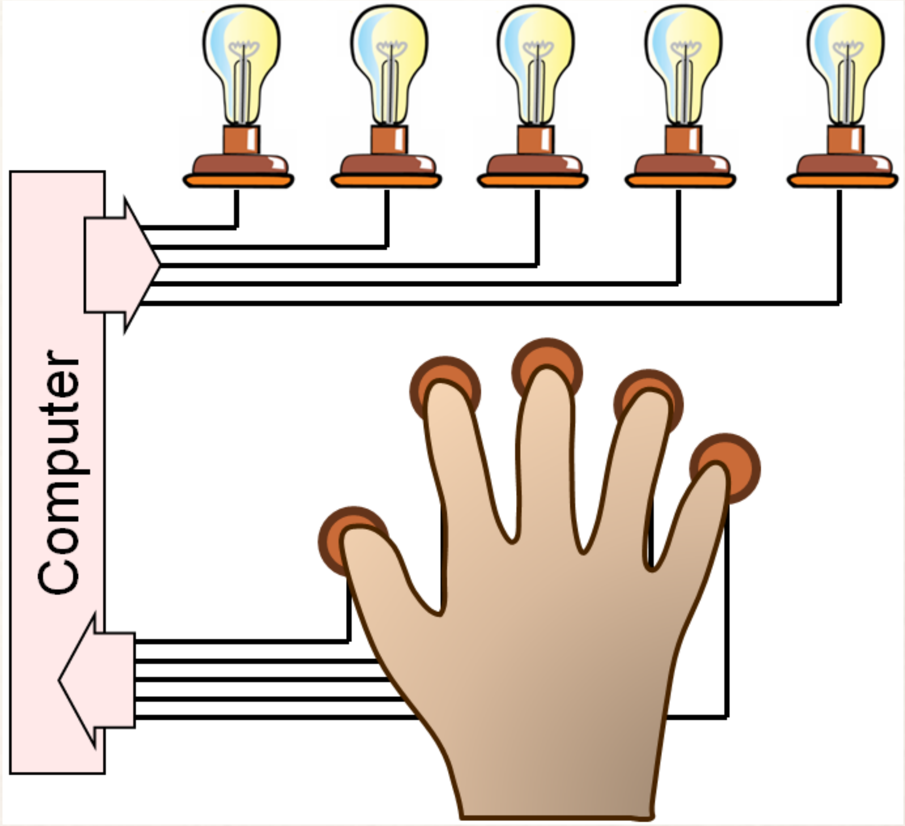
Choice Reaction Time

- Given *n* stimuli, associated one-for-one with n responses, the time to react to the onset of a stimulus is the choice *reaction time*
- Modeled by the Hick-Hyman law:
  - $RT = a + b \log_2(n + 1)$
- Coefficients:
  - $a \approx 200$ ms
  - $b \approx 150$ ms/bit
- An Information processing model (like Fitts' law)



Hick, W. E. (1952). On the rate of gain of information. Quarterly J Exp Psychol, 4, 11-36.
Hyman, R. (1953).Stimulus information as a determinant of reaction time. J Exp Psychol, 45, 188-196.

HCI Applications

- Not many, but…
  - A telephone operator selects among ten buttons when a light behind a button turns on[1]
  - Time to select items in a hierarchical menu (visual search eliminated by practicing participants to expert levels)[2]
  - Activation time for mode switching with non-dominant hand in a tablet interface[3]
- Difficult to apply because additional behaviours are often present, such as visual search or movement

[1] Card, S. K., Moran, T. P., & Newell, A. (1983). The psychology of human-computer interaction. Hillsdale, NJ: Erlbaum.
[2] Landauer, T. K., & Nachbar, D. W. (1985). Selection from alphabetic and numeric menu trees using a touch screen: Breadth, depth, and width. Proc CHI '85, 73-77, ACM.
[3] Ruiz, J., Bunt, A., & Lank, E. (2008). A model of non-preferred hand mode switching. Proceedings of Graphics Interface 2008, 49-56, Toronto: Canadian Information Processing Society.

Hick-Hyman Law and Information

- Like Fitts' law, the information content (*H*) of a choice reaction time task is given by the log term
- Examples (without the "+1")
  - With 8 stimuli, H = log2(8) = 3 bits
  - With 26 stimuli, H = log2(26) = 4.70 bits
- An interesting variation of the Hick-Hyman law occurs if the stimuli occur with different frequencies
- If the frequency of activation differs by stimulus, the information content of the task goes down because there is a small opportunity for the user to anticipate the stimulus

Predictive Model Examples

- Linear prediction equation
- Fitts' law
- Choice reaction time
- **Keystroke-level model (KLM)**

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Keystroke-Level Model (KLM)

- One of the earliest and most comprehensive models in HCI
- Developed specifically for predicting human performance with interactive computing systems
- Predicts expert error-free task completion times
- Elements of a KLM prediction
  - Task (or a series of tasks)
  - Method used
  - Command language of the system
  - Motor skill parameters of the user
  - Response time parameters of the system

Card, S. K., Moran, T. P., & Newell, A. (1980, July). The keystroke-level model for user performance time with interactive systems. Communications of the ACM, 23, 396-410.
Card, S. K., Moran, T. P., & Newell, A. (1983). The psychology of human-computer interaction. Hillsdale, NJ: Erlbaum.

Why Use the KLM?

- Consider a task such as "delete a file"
- Perhaps there are two ways to do the task:
  - Mouse + menu selection
  - Keyboard + command entry
- The KLM can predict the time for each method
- If used at the design stage, design alternatives may be considered and compared → design choices follow

A KLM Prediction

- A task is broken into a series of subtasks
- Total predicted time is the sum of the subtask times:
  - $t_{\text{EXCUTE}} = t_{\text{K}} + t_{\text{P}} + t_{\text{H}} + t_{\text{D}} + t_{\text{M}} + t_{\text{R}}$
- Operators:
  - K → keystroking P → pointing H → homing
  - D → drawing M → mental prep R → system response
- Some operators are omitted or repeated, depending on the task
  (e.g., if n keystroking operations are required, t_{K} becomes $n \times t_{\text{K}}$)

KLM Operators and Values

Operator	Description	Time (s)
K	PRESS A KEY OR BUTTON Pressing a modifier key (e.g., shift) counts as a separate operation, Time varies with typing skill: Best typist (135 wpm) Good typist (90 wpm) Average skilled typist (55 wpm) Average non-secretary typist (40 wpm) Typing random letters Typing complex codes Worst typist (unfamiliar with keyboard)	 0.08 0.12 0.20 0.28 0.50 0.75 1.20
P	POINT WITH A MOUSE Empirical value based on Fitts' law. Range from 0.8 to 1.5 seconds. Operator does *not* include the button click at the end of a pointing operation	 1.10
H	HOME HAND(S) ON KEYBOARD OR OTHER DEVICE	0.40
D(n_D.l_D)	DRAW n_D STRAIGHT-LINE SEGMENTS OF TOTAL LENGTH l_D. Drawing with the mouse constrained to a grid.	$.9\ n_D + .16\ l_D$
M	MENTALLY PREPARE	1.35
R(t)	RESPONSE BY SYSTEM Different commands require different response times. Counted only if the user must wait.	t

Original KLM Experiment

- The KLM was validated in an experiment with fourteen tasks performed using various methods and systems
  - Example: **Task 1 → Replace a 5-letter word with another word**
- Using one system, the task was broken down as follows:

Jump to next line	M K[LINEFEED]
Issue Substitute command	M K[S]
Type new word	K[word]
Terminate new word	M K[RETURN]
Type old word	K[word]
Terminate old word	M K[RETURN]
Terminate command	K[RETURN]

- 4 mental operations + 15 keystroking operations

KLM Prediction (Example)

$$t_{\text{EXECUTE}} = 4 \times t_{\text{M}} + 15 \times t_{\text{K}}$$

- M set to 1.35 seconds (two slides back)
- K set to 0.23 seconds, based on a 5-minute pre-test
- So…

$$t_{\text{EXECUTE}} = 4 \times \boldsymbol{1.35} + 15 \times \boldsymbol{0.23}$$
$$= 8.85 \text{ seconds}$$

- This is the prediction
- What about the observation?

Modern Applications

- Mouse interaction was just emerging when the KLM was introduced
- An obvious KLM update is to replace the pointing constant (t_P) with a Fitts' law prediction equation, as appropriate for the device (e.g., mouse vs. touchpad) and task (e.g., point-select vs. drag-select)
- For example, using the Fitts' law equation given earlier for the mouse…

$$t_P = 0.159 + 0.204 \times \log_2\left(\frac{A}{W} + 1\right)$$

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Pointing Operator – Update

- For example, a mouse point-select operation over 3.2 cm to click a 1.2 cm wide toolbar button should take about…

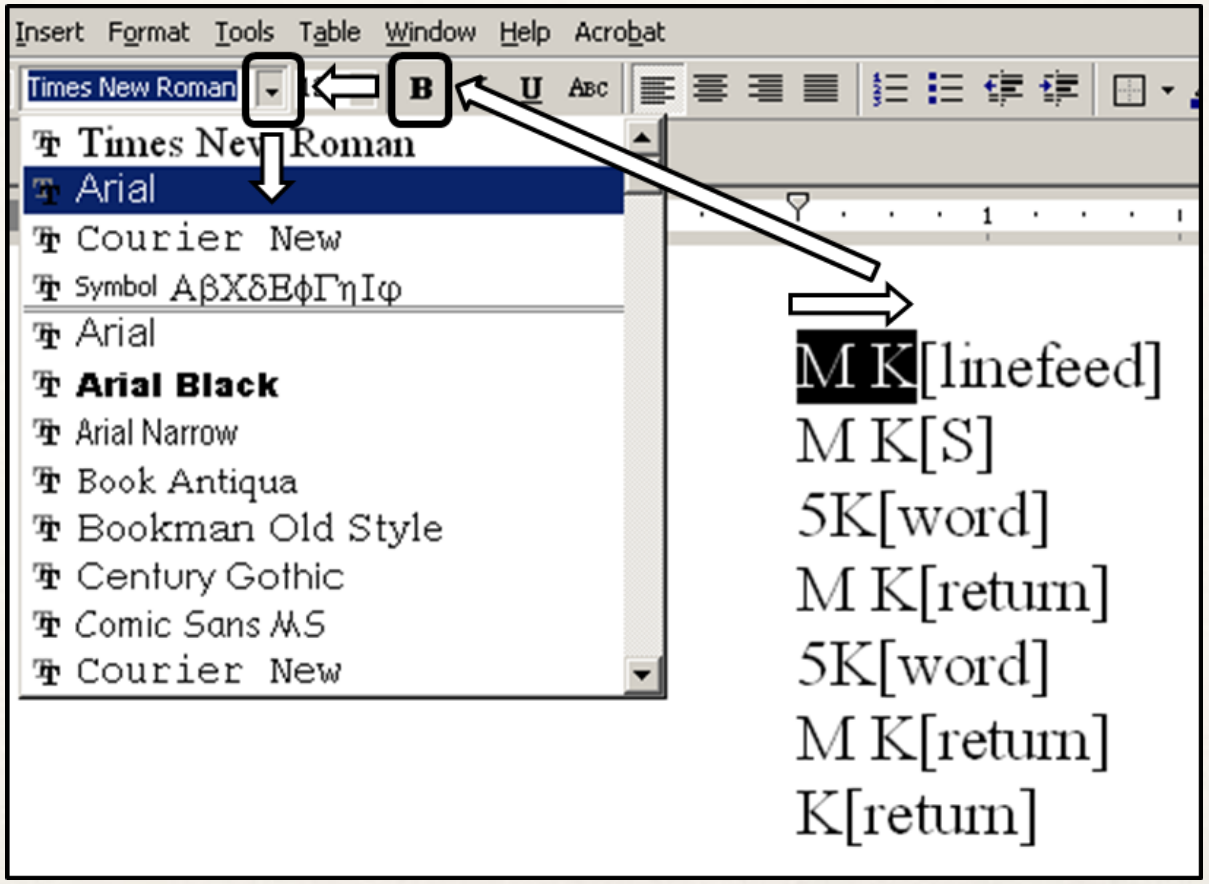
$$t_P = 0.159 + 0.204 \times \log_2\left(\frac{3.2}{1.2} + 1\right) = 0.45 \text{ seconds}$$

- If the same task involves moving the pointer 44.6 cm, the prediction becomes…

$$t_P = 0.159 + 0.204 \times \log_2\left(\frac{44.6}{1.2} + 1\right) = 1.22 \text{ seconds}$$

Pointing Operator – Example

- Develop KLM mouse and keyboard predictions for the GUI screen below
- Task: Change the font and style for "M K" to bold, Arial



Mouse Analysis

- Operations:

Mouse Subtasks	KLM Operators	t_P (s)
Drag across text to select “M K”	**M** **P**[2.5, 0.5]	0.686
Move pointer to Bold button and click	**M** **P**[13, 1]	0.936
Move pointer to Font drop-down button and click	**M** **P**[3.3, 1]	0.588
Move pointer down list to Arial and click	**M** **P**[2.2, 1]	0.501
	$\sum t_P =$	2.71

- Prediction:

$$t_{\text{EXECUTE}} = 4 \times t_{\text{M}} + \sum t_{\text{P}} = 4 \times 1.35 + 2.71 = 8.11 \text{ seconds}$$

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Keyboard Analysis

- Operations:

Keyboard Subtasks	KLM Operators
Select text	**M** **K**[shift] **3K**[→]
Convert to boldface	**M** **K**[ctrl] **K**[b]
Activate Format menu and enter Font sub-menu	**M** **K**[alt] **K**[o] **K**[f]
Type *a* ("Arial" appears at top of list)	**M** **K**[a]
Select "Arial"	**K**[↓] **K**[enter]

- Prediction:

$$t_{\text{EXECUTE}} = 4 \times t_{\text{M}} + 12 \times t_{\text{K}} = 4 \times 1.35 + 12 \times 0.75 = 14.40 \text{ seconds}$$

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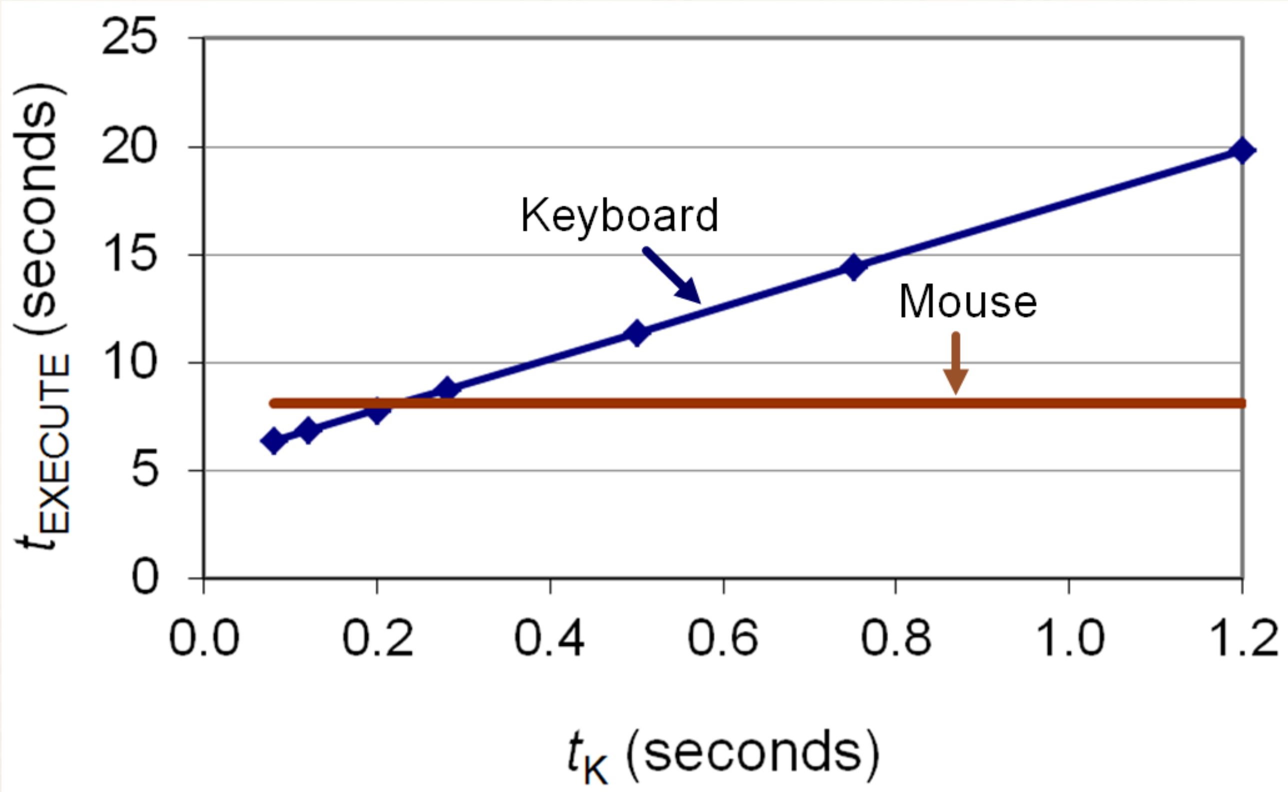
Sensitivity Analysis

- The keyboard prediction is sensitive to the parameter t_K, the keystroking time
- If t_K is allowed to vary, what is the effect on the predictions?



Implication: The mouse is faster than the keyboard, except for $t_K \leq 0.2$ seconds (which is unlikely, given the nature of the keyboard actions).

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Information Visualization

Data Explosion

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Data Explosion

- The information explosion is **the rapid increase in the amount of published information or data** and the effects of this abundance. As the amount of available data grows, the problem of **managing the information becomes more difficult**, which can **lead to information overload**.

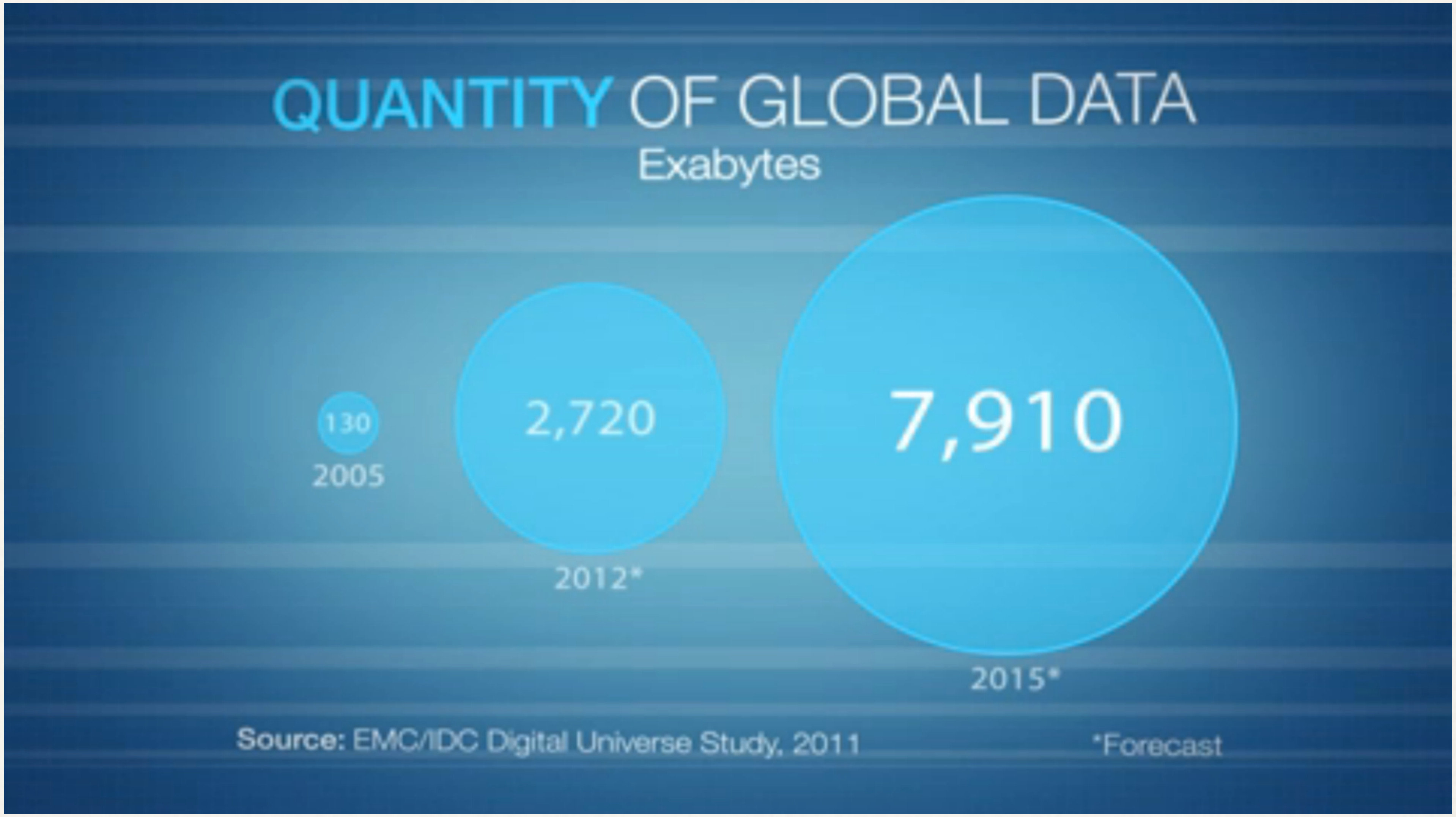
  - http://en.wikipedia.org/wiki/Information_explosion

Data Explosion

- A weekday edition of the New York Times contains more information than the average person was likely to come across in a lifetime in seventeenth-century England.

- Richard Saul Wurman, Information Anxiety

Data Explosion



The Economist _ http://www.economist.com/blogs/dailychart/2011/11/big-data-0

Original Data from http://www.emc.com/digital_universe

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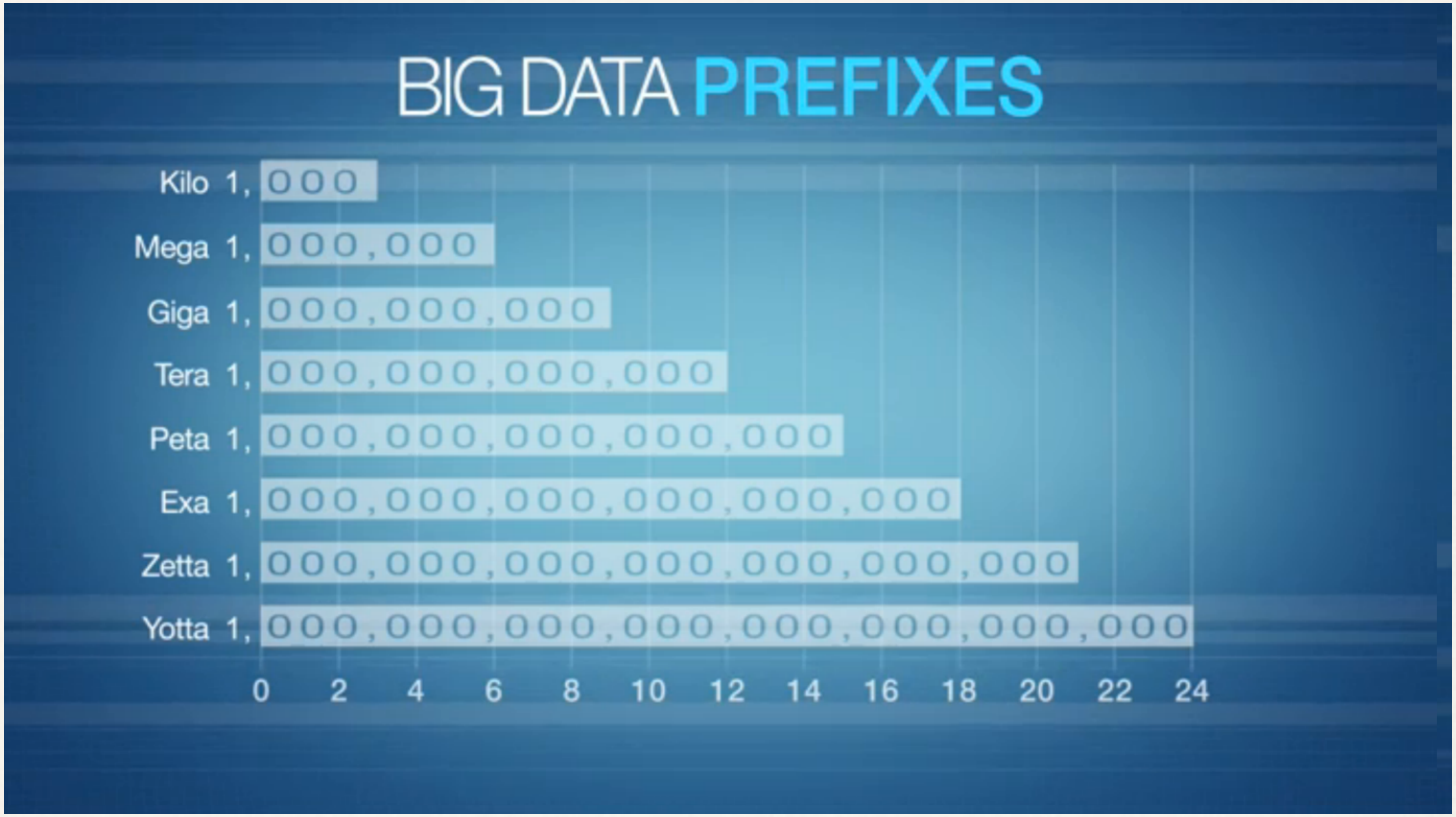
Data Explosion



***The Economist**_ http://www.economist.com/blogs/dailychart/2011/11/big-data-0*

Original Data from http://www.emc.com/digital_universe

Big Data Statistics

- Facebook stores, accesses, and analyzes 30+ Petabytes of user generated data.
  http://wikibon.org/blog/taming-big-data/
- More than 5 billion people are calling, texting, tweeting and browsing on mobile phones worldwide.
  http://www.sas.com/resources/whitepaper/wp_46345.pdf
- In 2008, Google was processing 20,000 terabytes of data (20 petabytes) a day.
  http://techcrunch.com/2008/01/09/google-processing-20000-terabytes-a-day-and-growing/

Big Data Statistics

- YouTube users upload 48 hours of new video every minute of the day.
- Brands and organizations on Facebook receive 34,722 Likes every minute of the day.
- 100 terabytes of data uploaded daily to Facebook.

  http://wikibon.org/blog/big-data-infographics/

- 30 Billion pieces of content shared on Facebook every month.

  http://www.mckinsey.com/Insights/MGI/Research/Technology_and_Innovation/ig_data_The_next_frontier_for_innovation

Data Overload

Data Overload

http://www.yvarbelotte.com/4-smart-ways-to-handle-information-overload/

Data Overload

- 이 많은 데이터를 어떻게 사용할 것인가?
  - 데이터에 어떤 의미를 부여할 것인지?
  - 데이터를 이용해 의사결정에 사용할 수 있는지?
  - 과도한 데이터에 압도당하지 않으려면?

Sensemaking & Issue

- Data 를 Information 으로 변환하여 유용하게 사용하자!
  - Q: Data와 Information의 차이?
  - Sensemaking: 데이터에 의미와 통찰력을 부여하는 과정
- Issue
  - “Human attention is the scarce resource”

    - Herbert Simon, 1969
  - 사람은 매우 빠른 정보 처리 속도를 가졌지만, 그렇다 하더라도 너무 많은 정보가 전달되면 정보를 처리할 수 없다 → information overload
- Solution?
  - People think visually.

Example of Sensemaking

slide courtesy: John Stasko, GATech

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

Q: 가장 많은/적은 칼륨(potassium)을 가진 시리얼은?
potassium과 fiber의 상관관계는?
가장 건강에 좋은 시리얼은?

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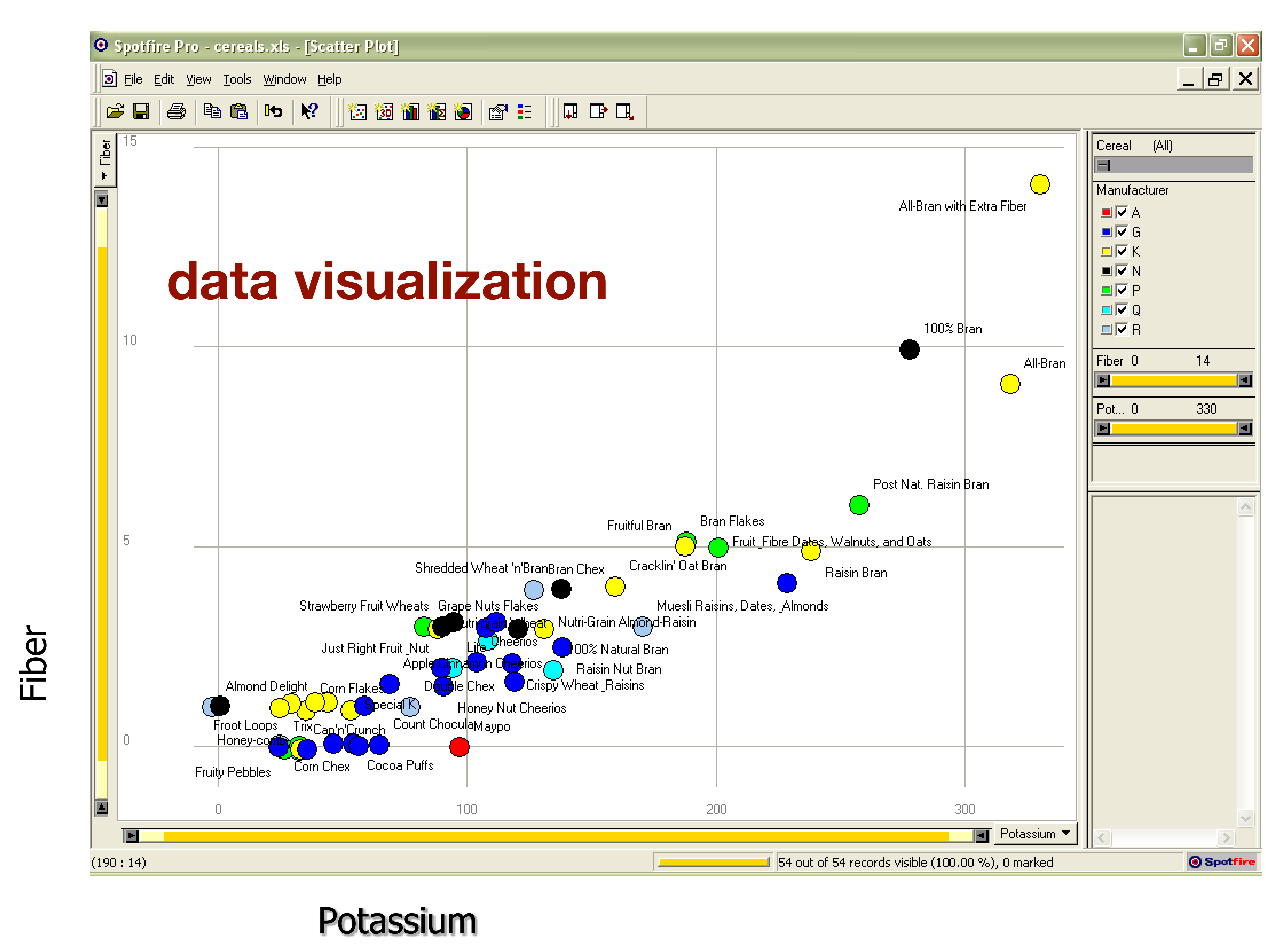
Example of Sensemaking

slide courtesy: John Stasko, GATech



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Think Visually..?

- 19세기 중반까지 유럽인들은 콜레라가 하수나 폐수에서 발생하는 독기(毒氣), 즉 나쁜 공기에 의해 발생한다고 믿었다. 1854년, 이를 의심하던 영국의 젊은 의사 존 스노우는 런던에서 발생한 콜레라 집단 발병이 눈에 보이지 않는 작은 벌레에 의한 것일 수 있다는 생각으로 이를 추적하기로 한다.
- 이듬해 런던의 소호에서 콜레라가 다시 집단 발생했을 때, 스노는 가가호호(家家戶戶)를 방문하면서 콜레라 환자를 조사했다. 그리고 환자가 발생한 지역과 환자 수를 지도에 일일이 기입했다.

서울대 자연과학대학 천종식 교수, 조선일보 (2006)

Think Visually..?

Think Visually..?

Think Visually..?

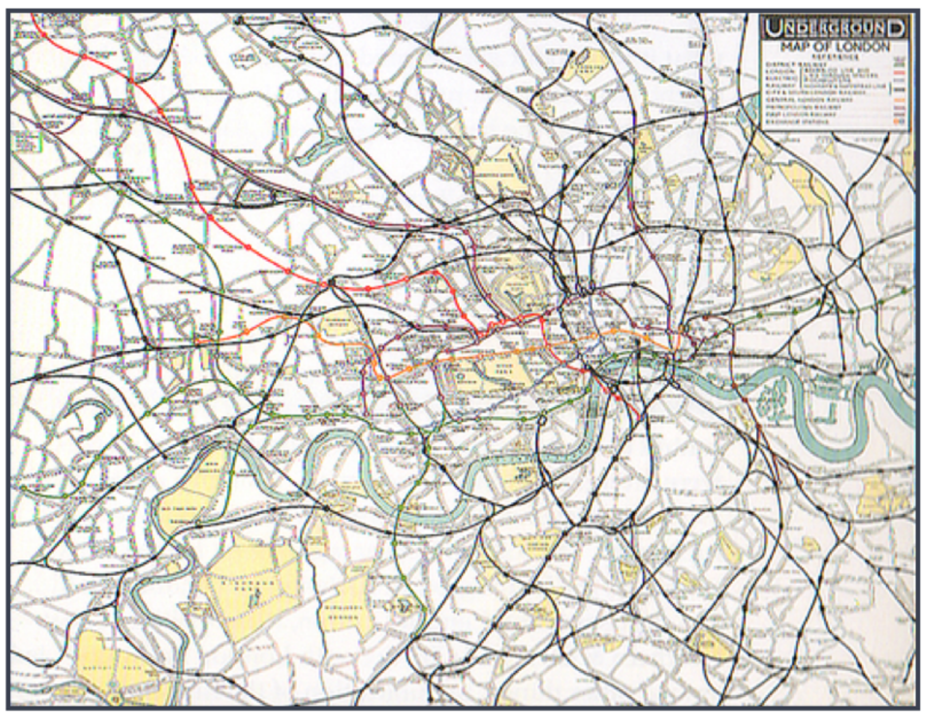
- 어느 정도 일이 진척되자 슬슬 수수께끼가 풀렸다. 가구당 콜레라 환자의 수는 브로드가(街)의 우물에 가까울수록 많다는 것을 발견한 것이다. 그리고 환자 대부분이 이 우물에서 물을 길어 식수로 이용했다는 사실도 확인했다. 콜레라를 일으킨다고 믿던 독기(毒氣)를 중화시키기 위해 거리에 석회를 열심히 뿌리던 런던 시당국은 그에게 속는 셈치고 우물을 폐쇄했다. 그러자 기적같이 콜레라 전염이 멈추게 된 것이다.

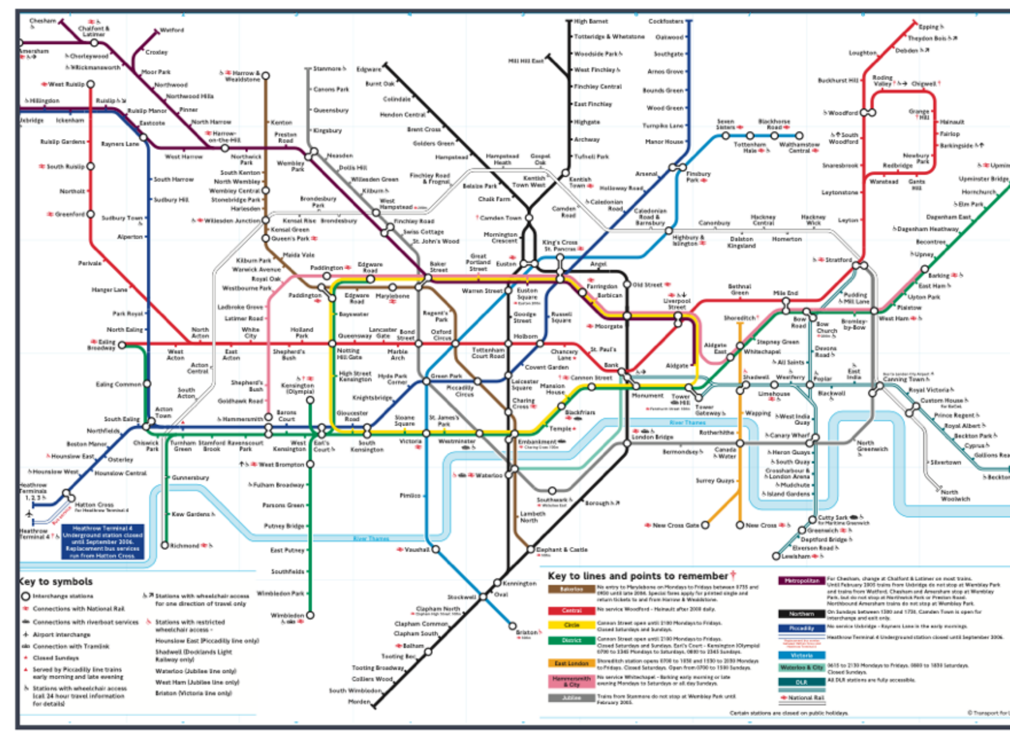
서울대 자연과학대학 천종식 교수, 조선일보 (2006)

데이터의 시각화는 보이지 않는 문제점을 발견하게 해준다.

Power of Visualization

London Underground Map 1920s





Recent London Underground Map

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Visualization

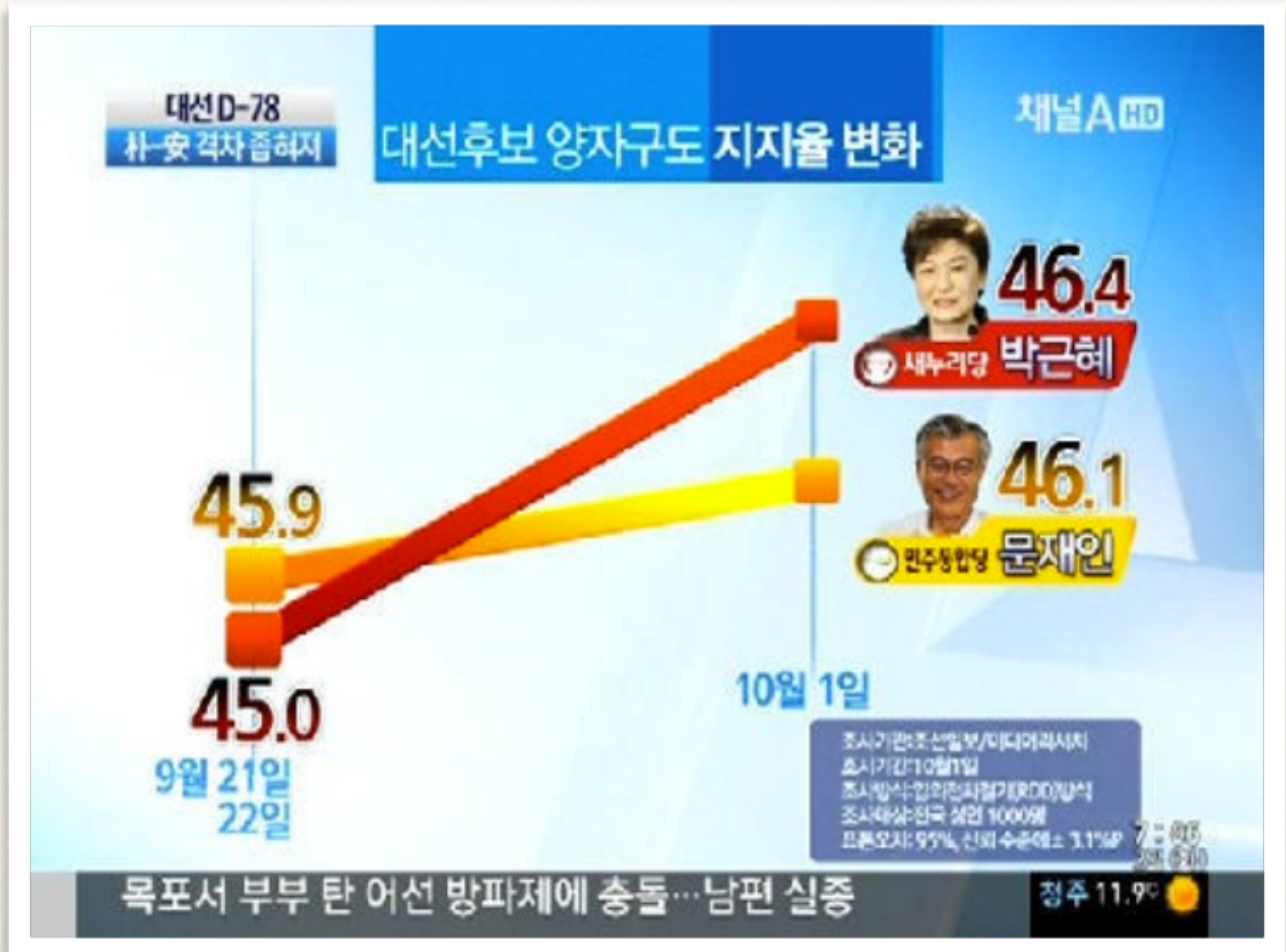
- "The use of computer-supported, interactive visual representations of data to amplify cognition."

  - Card, Mackinlay, Shneiderman (1998)

Visualization

- 비주얼라이제이션은 종종 그래픽이나 이미지를 만드는 과정으로 오해되곤 한다.
- 비주얼라이제이션은 단순히 이미지를 만드는 과정이 아니라 cognitive process 의 과정을 보여주는 것.
  - 어떠한 information 의 mental image 를 구축하는 것.
  - 이해(understanding)을 내면화(internalize)하는 것.
- “The purpose of visualization is insight, not pictures” *- Card, Mackinlay, Shneiderman (1998)*
  - Insight: discovery, decision making, explanation

Visualization is NOT...!



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Visualization

- Visualization은 생각하고 판단하는데에 도움을 준다.
  - Cognition → Perception
  - 패턴을 찾을 수 있어 정보를 이해하는데 도움이 된다.
- External cognition aid

- Card, Mackinlay, Shneiderman (1998)

Visualization

- The power of the unaided mind is highly overrated. Without external aids, memory, thought, and reasoning are all constrained. But human intelligence is highly flexible and adaptive, superb at inventing procedures and objects that overcome its own limits. The real powers come from devising **external aids** that enhance cognitive abilities. How have we increased memory, thought, and reasoning? By the invention of external aids: It is things that make us smart.

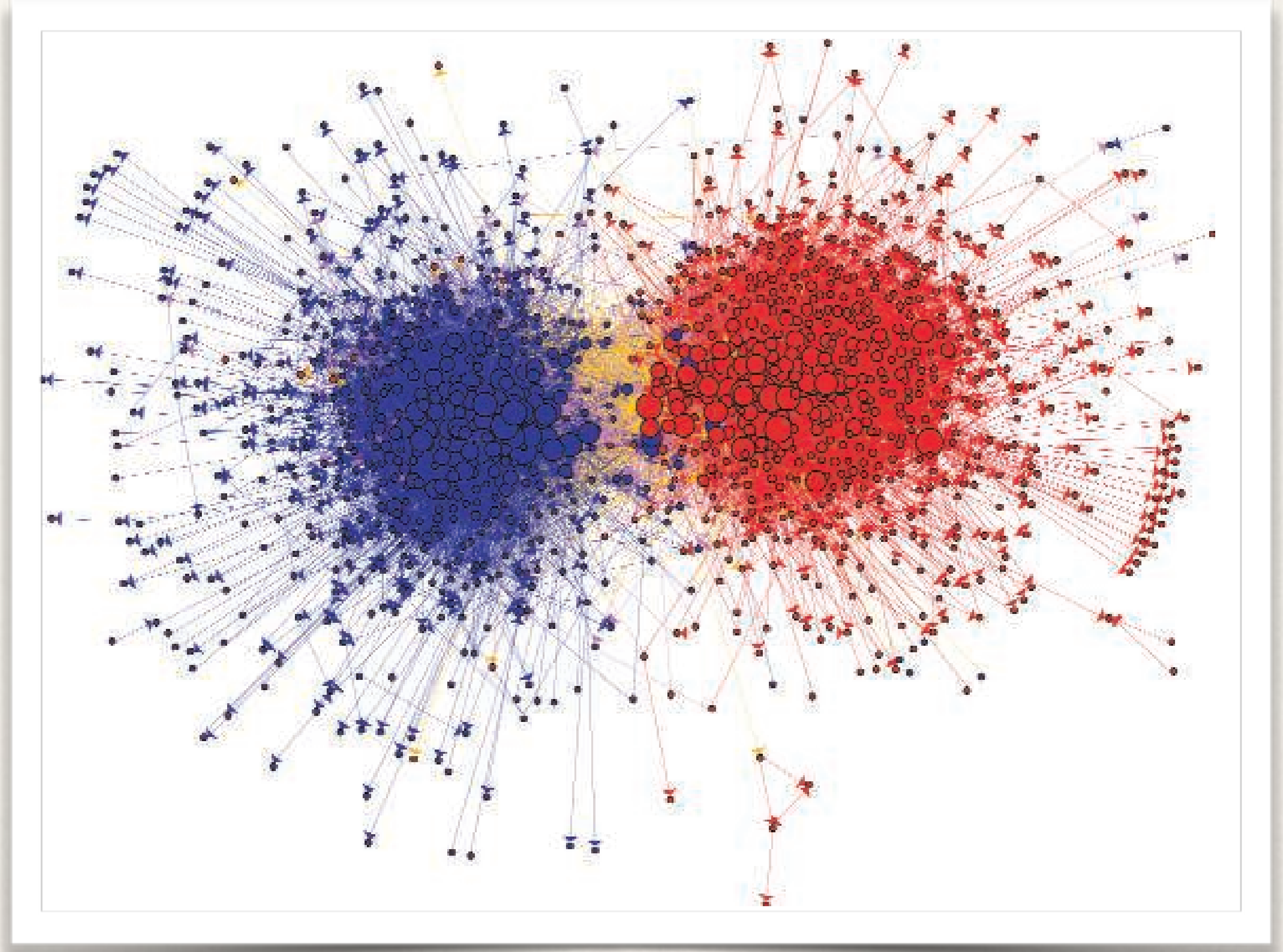
  - Donald Norman

Visualization의 목적

- Visualization은 일반적으로 다음과 같은 두 가지 목적으로 사용.
  - Analysis: 데이터를 보다 잘 이해하고, 그러한 이해를 바탕으로 판단을 내리고 행동을 하기 위한 것.
  - Presentation: 다른 사람들과 소통을 보다 효율적으로 하기 위한 것.

Analysis

- 주어진 데이터를 보다 잘 이해하고, 다른 데이터와 비교하고, 결정/판단을 하며 평가를 하기 위한 것.
- 궁극적으로는 문제해결을 하기 위함.



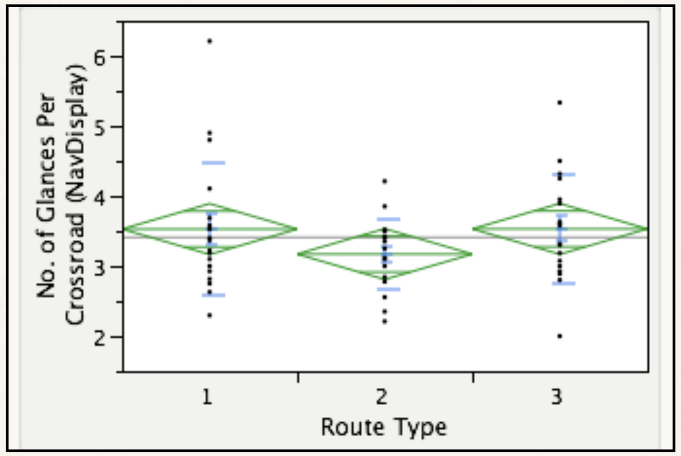
Lazer et al. (2009)
Computational Social Science

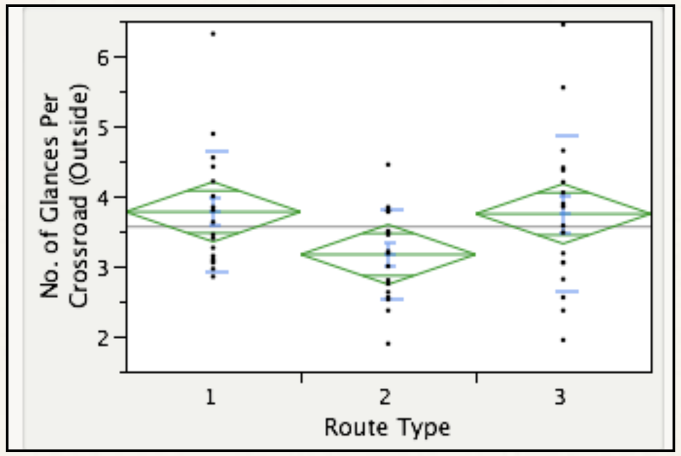
Analysis

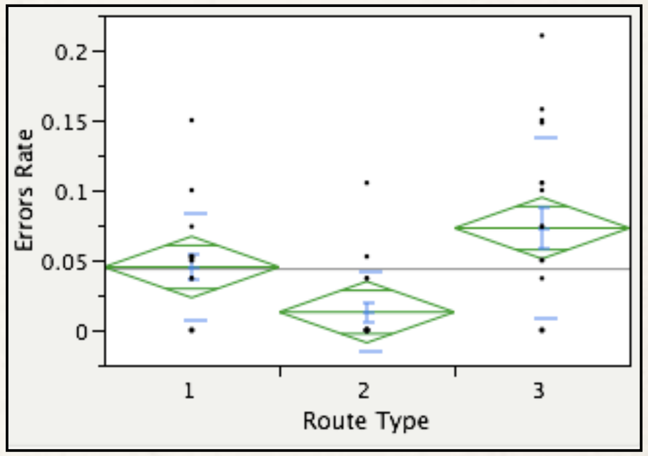
- 언제 필요한가?
  - statistics, DB, data ming, machine learning 등 여러 분야에서 사용.
  - visualization technique 은 특히 **exploratory data analysis** 에 도움이 됨.
    - 연구문제가 무엇인지 확실하지 않을 때
    - 데이터를 통해 무엇을 살펴봐야 하는지 명확하지 않을 때
  - EDA is the process of using statistical tools (such as graphs, measures of center, and measures of variation) to investigate data sets in order to understand their important characteristics.

    http://www.aw-bc.com/info/Triola/tes09_02_07.pdf

EDA Examples







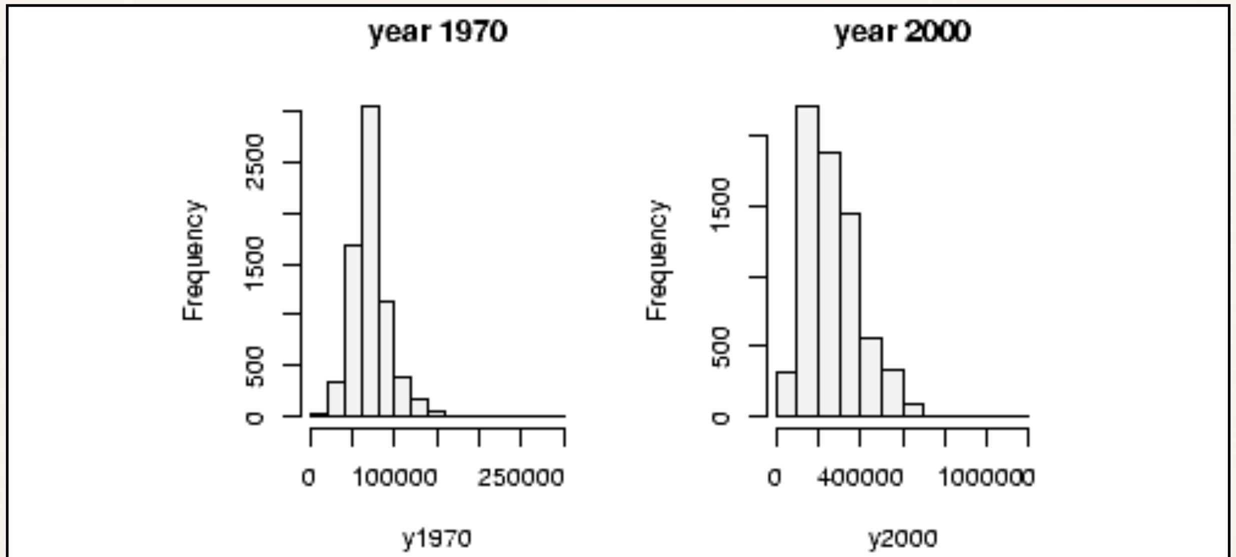
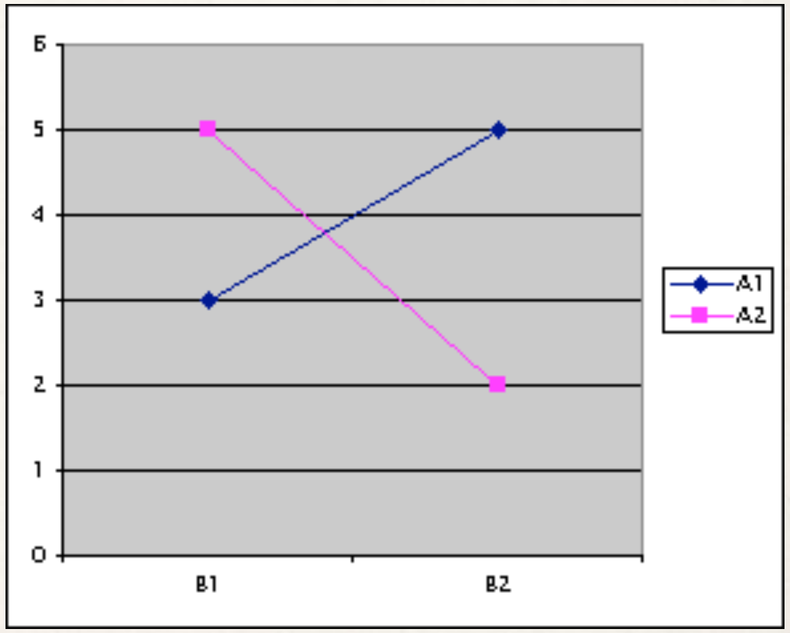


Figure 35: Histograms of Maplewood homes in 1970 and 2000



EDA Examples

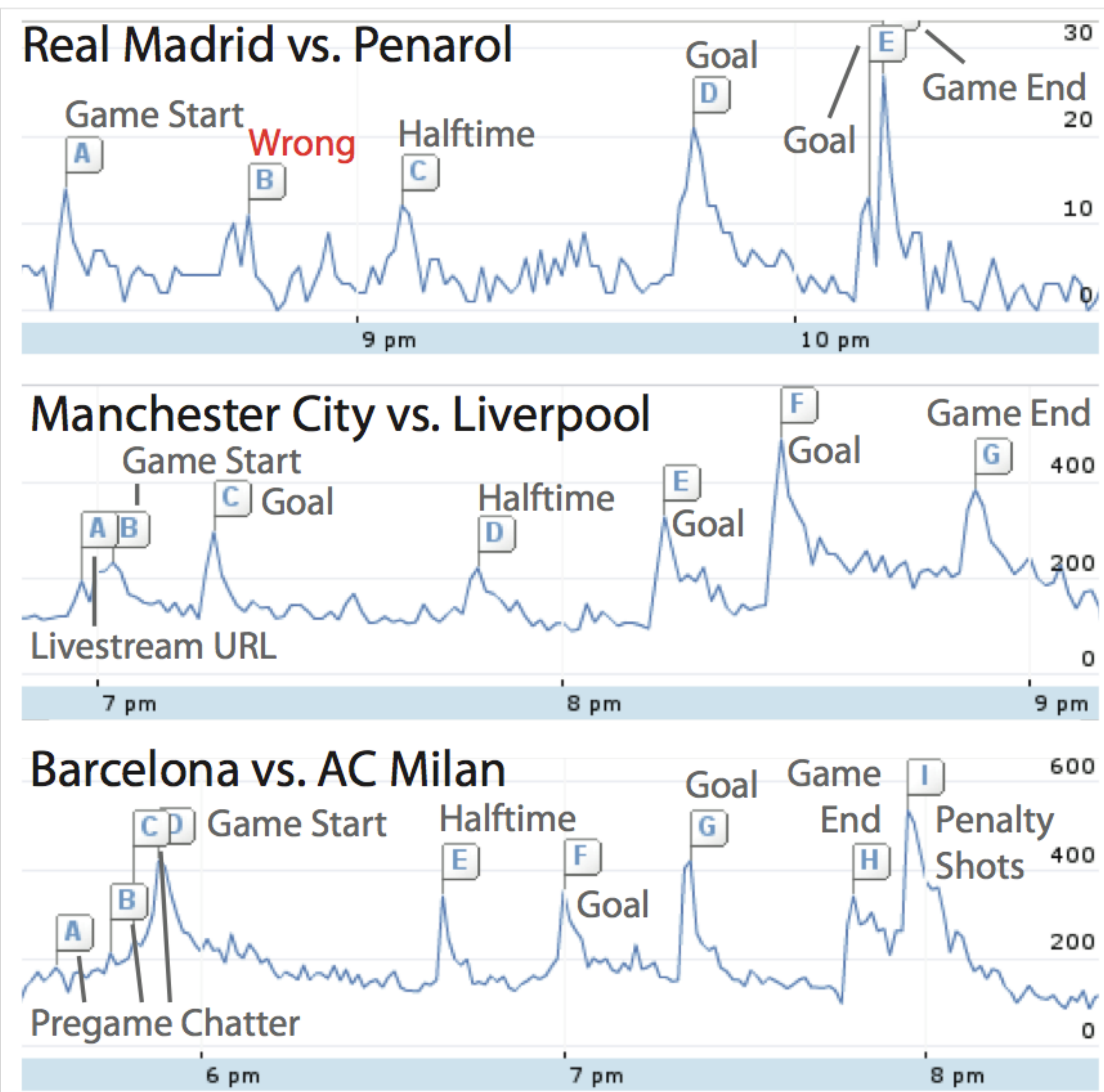


Figure 3. The TwitInfo timeline displaying three soccer games. The peak detection algorithm finds only 1 false positive, labeled red. The algorithm did not find Yellow Card events, but there was no spike in Twitter usage to suggest it. The algorithm occasionally flagged pregame chatter like retweeting a livestream URL.

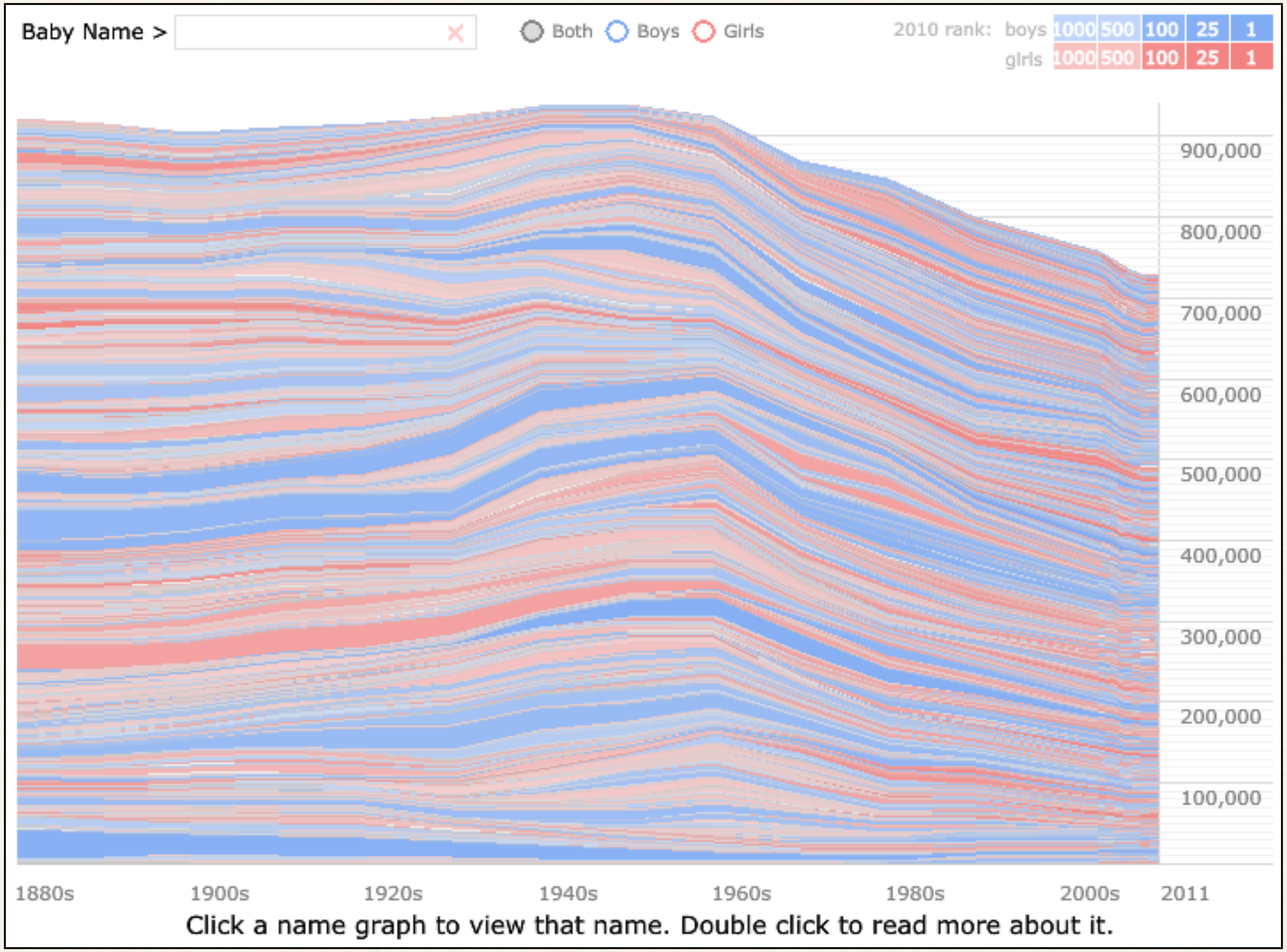
A. Marcus et al. (2011)
"TwitInfo: Aggregating and Visualizing Microblogs for Event Exploration"

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"

Interactive EDA

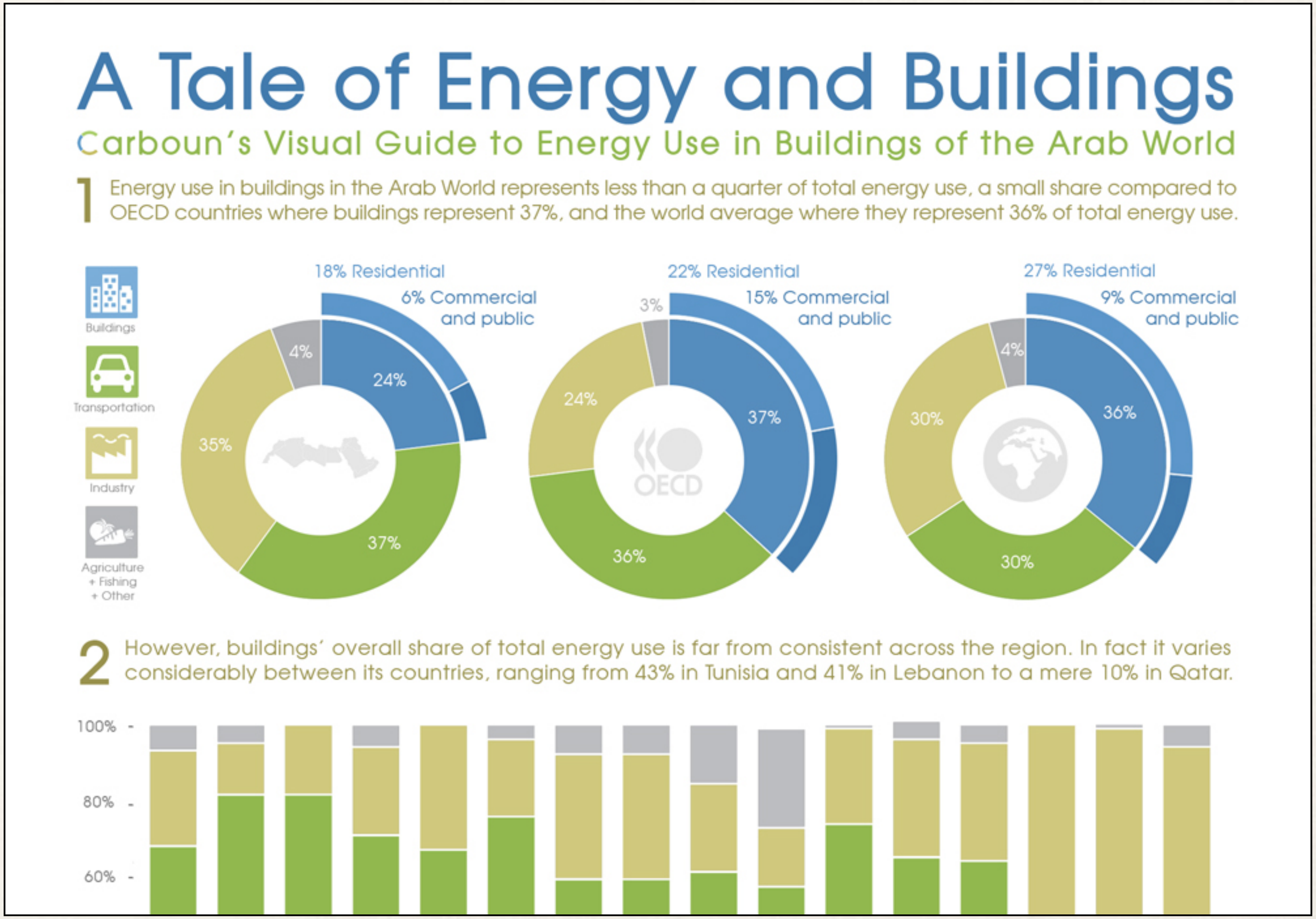


Baby Name Voyager: *http://www.babynamewizard.com/voyager*

Presentation

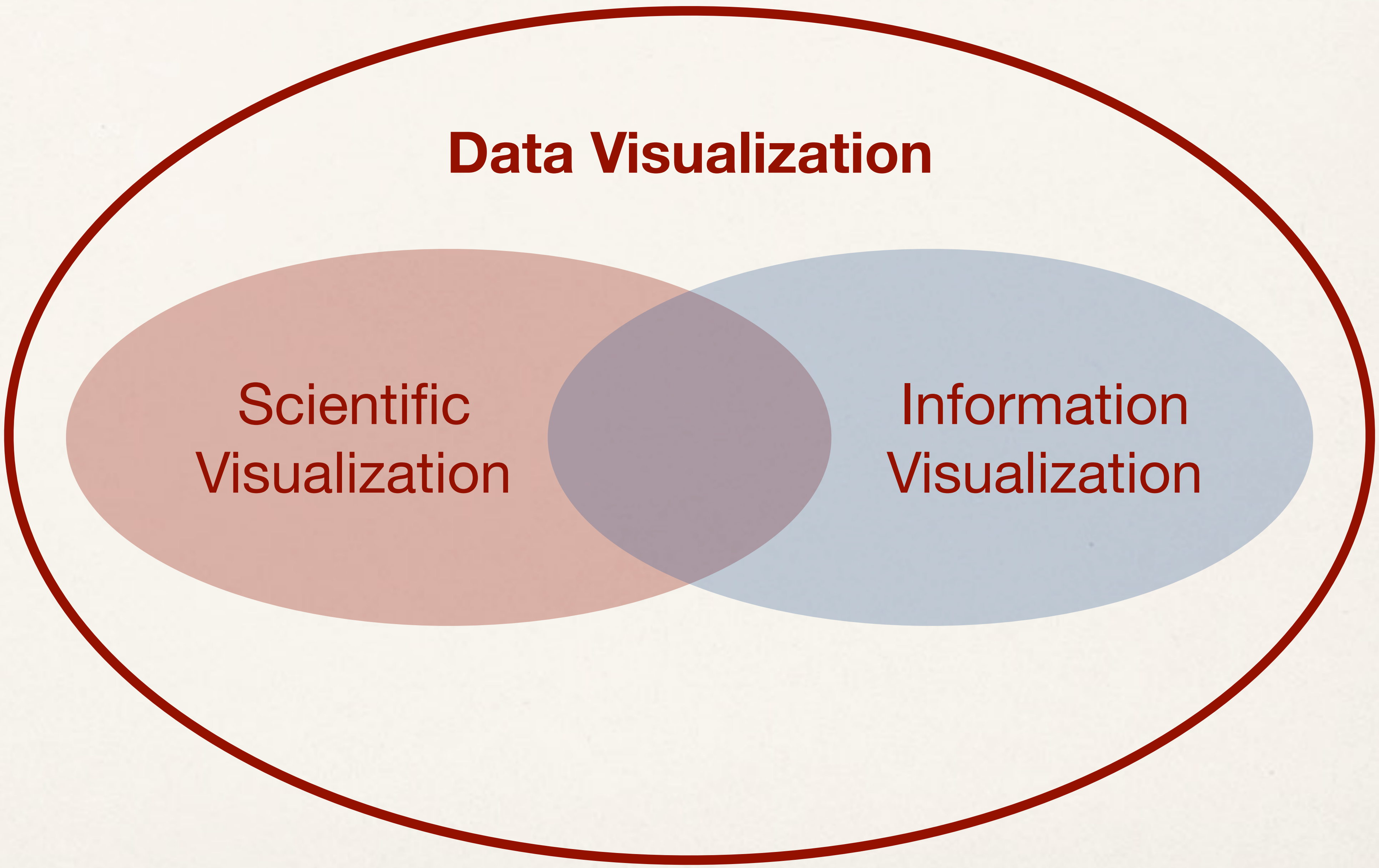
- Visualization을 이용하여 생각을 보다 손쉽게 다른 사람에게 전달하거나 설명하거나 설득할 수 있다.
- 시각적인 자료들은 증거의 역할을 하거나 아이디어를 강력하게 서포트 할 수 있는 자료가 된다.

Presentation Example

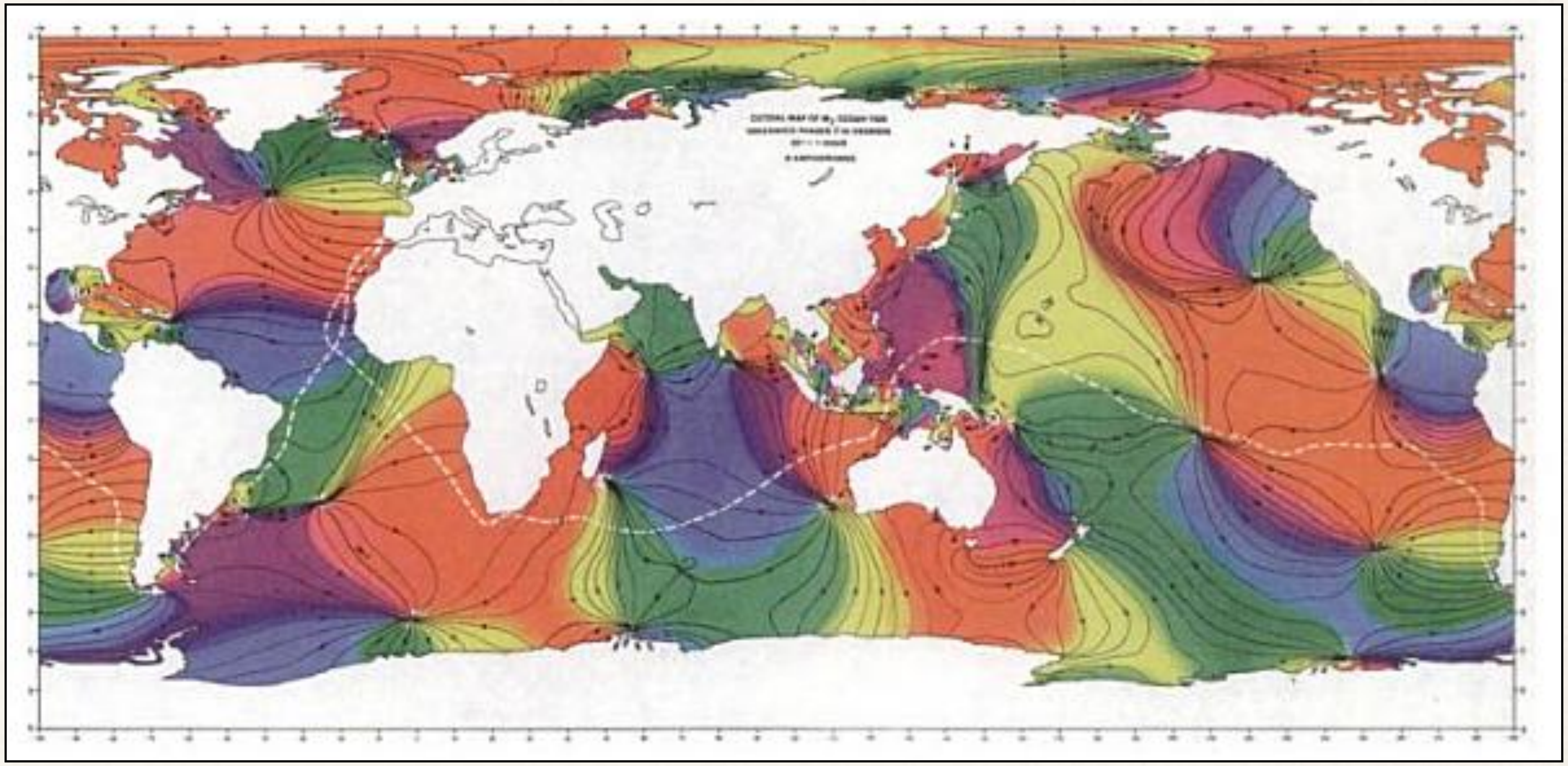


http://visual.ly/visual-guide-energy-use-buildings-middle-east

Visualization in Academic Areas



Scientific Visualization



Tide phases (Winfree, 1987)

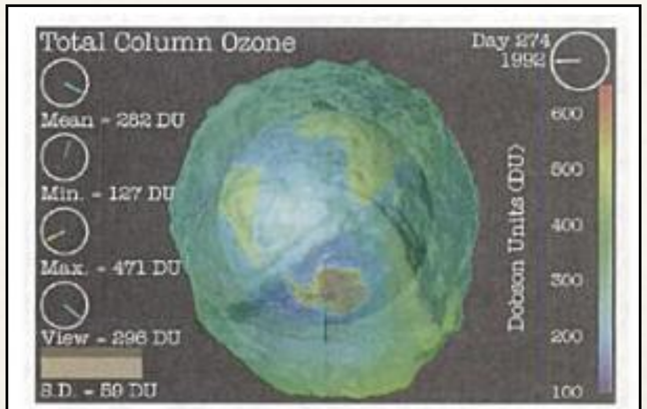


FIGURE **1.10**

Ozone layer surrounding earth. L. Treinish, IBM. Used with permission.

Ozone layer (L. Treinish, IBM)

Information Visualization

- Scientific visualizations tend to be based on physical data -- the human body, the earth, molecules, or other.
- Information
  - items, entities, things which do not have a direct physical correspondence
    → abstractness, non physical are the key
    - *Card, Mackinlay, Shneiderman (1998)*

Visualization

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

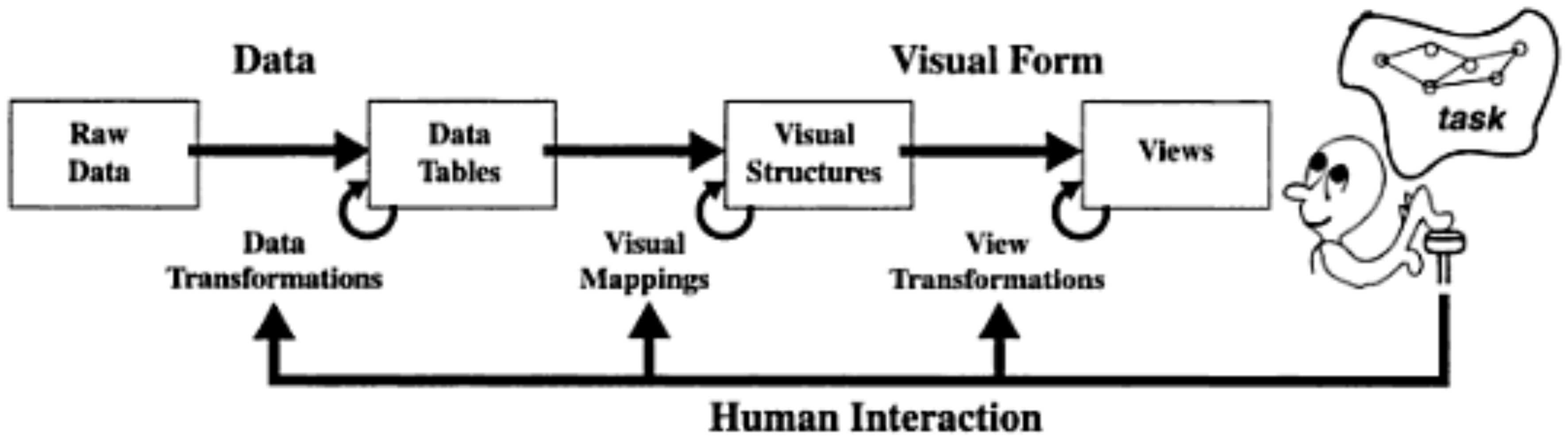
  - Card, Mackinlay, Shneiderman (1998)

Information Visualization

- “The use of computer-supported, interactive visual representations of **abstract, non physically based data** to amplify cognition.”

  - Card, Mackinlay, Shneiderman (1998)

InfoVis Process Model



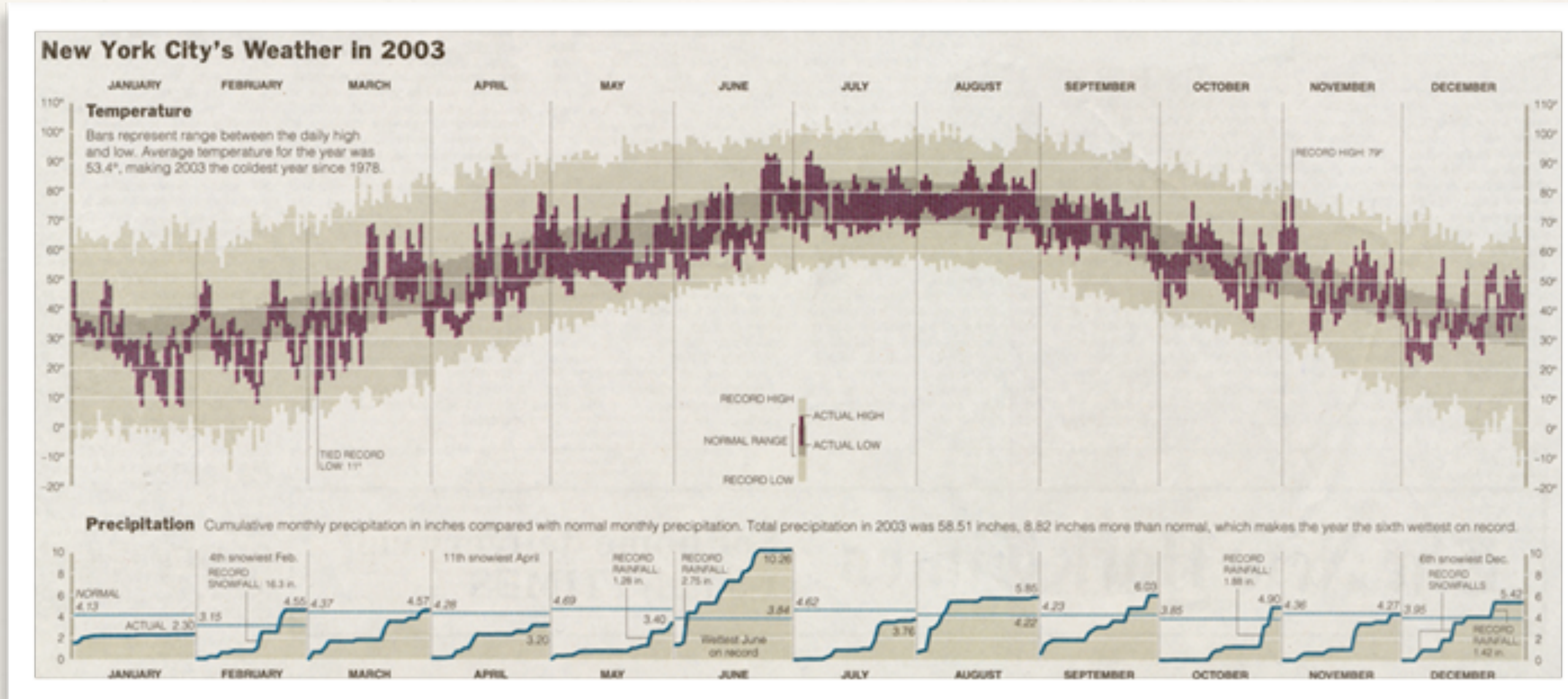
Raw Data: idiosyncratic formats
Data Tables: relations (cases by variables) + metadata
Visual Structures: spatial substrates + marks + graphical properties
Views: graphical parameters (position, scaling, clipping, ...)

FIGURE **1.23**

Reference model for visualization. Visualization can be described as the mapping of data to visual form that supports human interaction in a workspace for visual sense making.

- Card, Mackinlay, Shneiderman (1998)

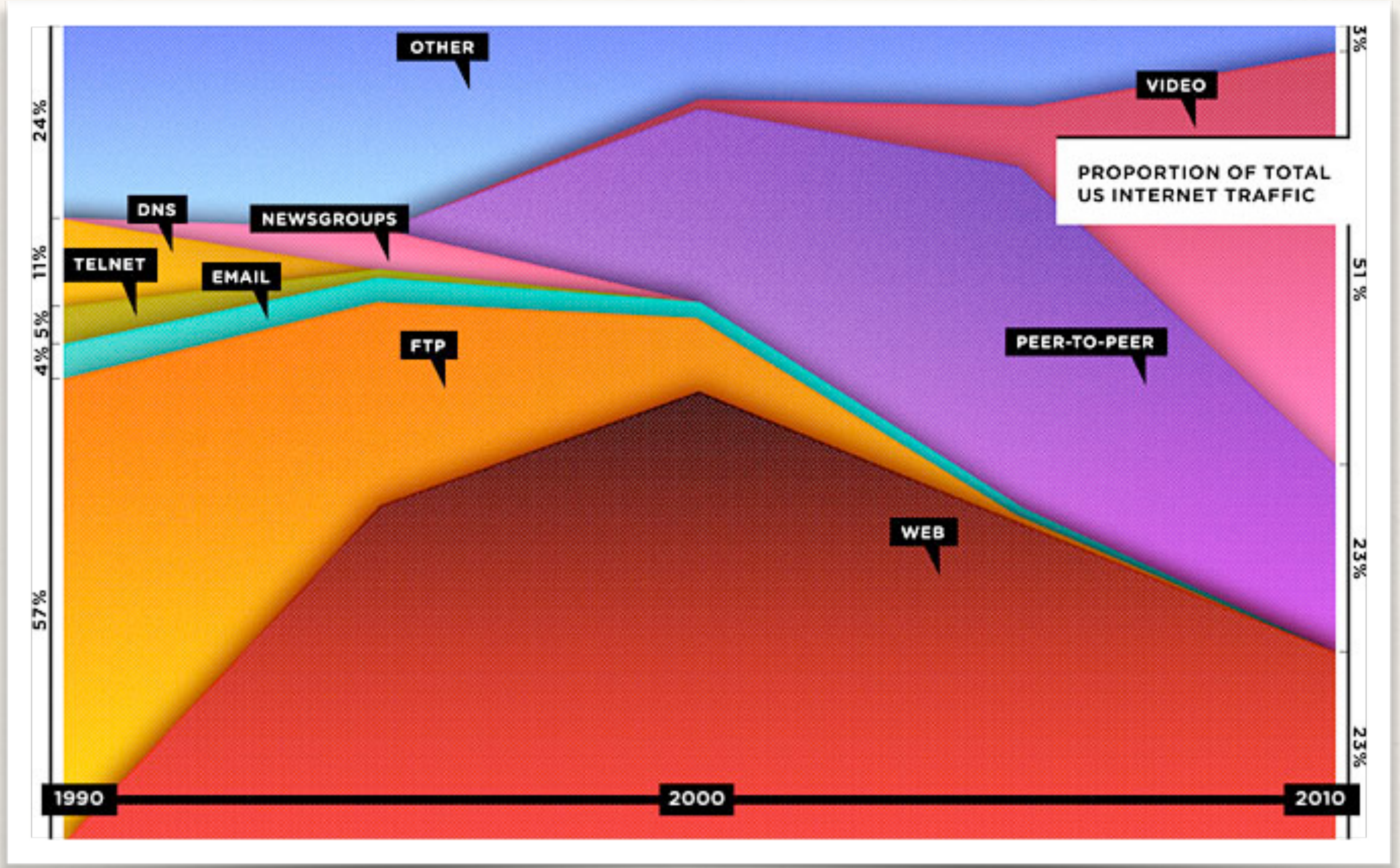
Information Visualization Examples



"The annual review of the weather by The New York Times appears below. It shows daily high and low temperatures for 2003, for a normal year, and for record days, along with cumulative monthly precipitation."

http://www.edwardtufte.com/bboard/q-and-a-fetch-msg?msg_id=00014g

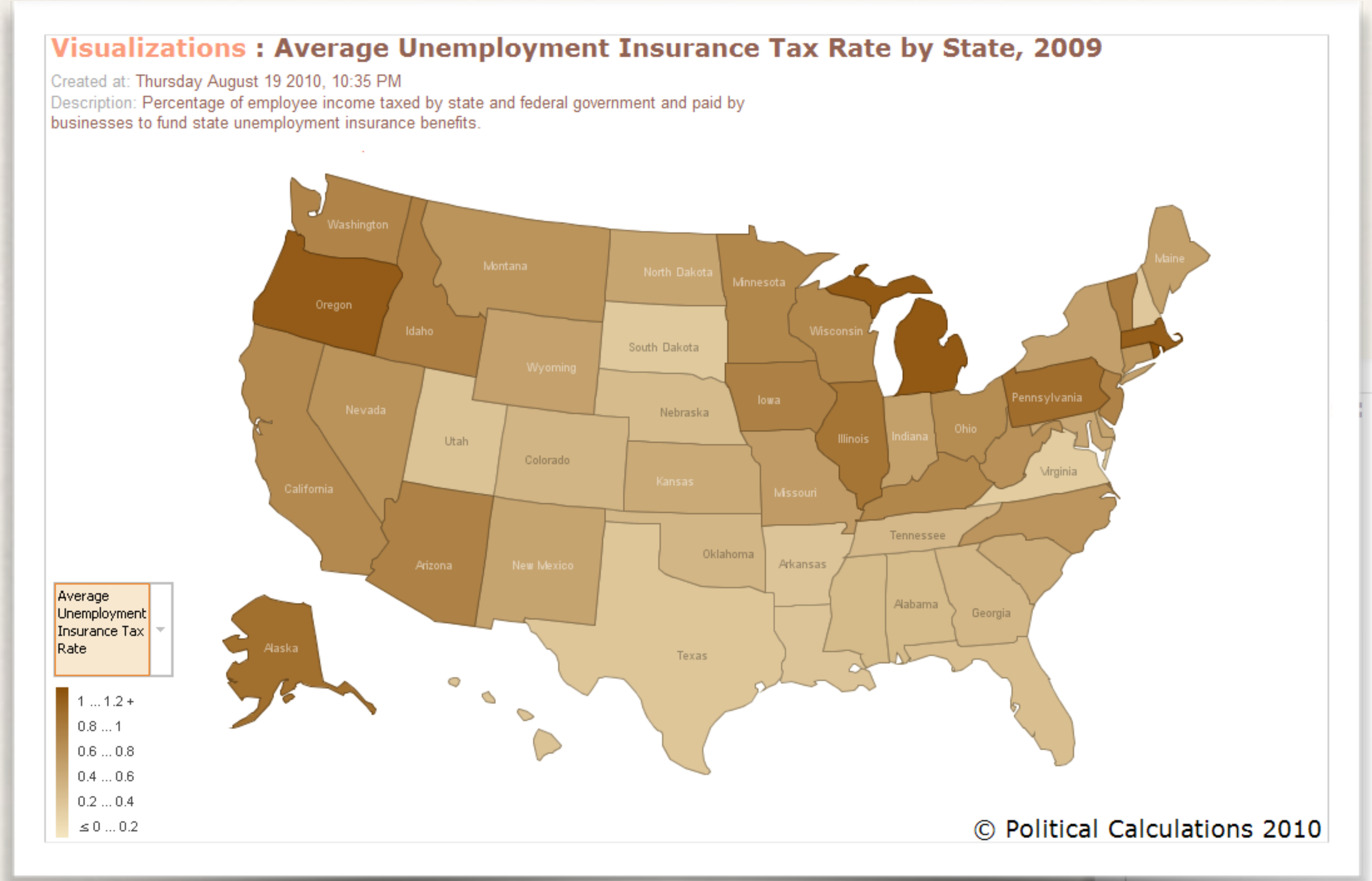
Information Visualization Examples

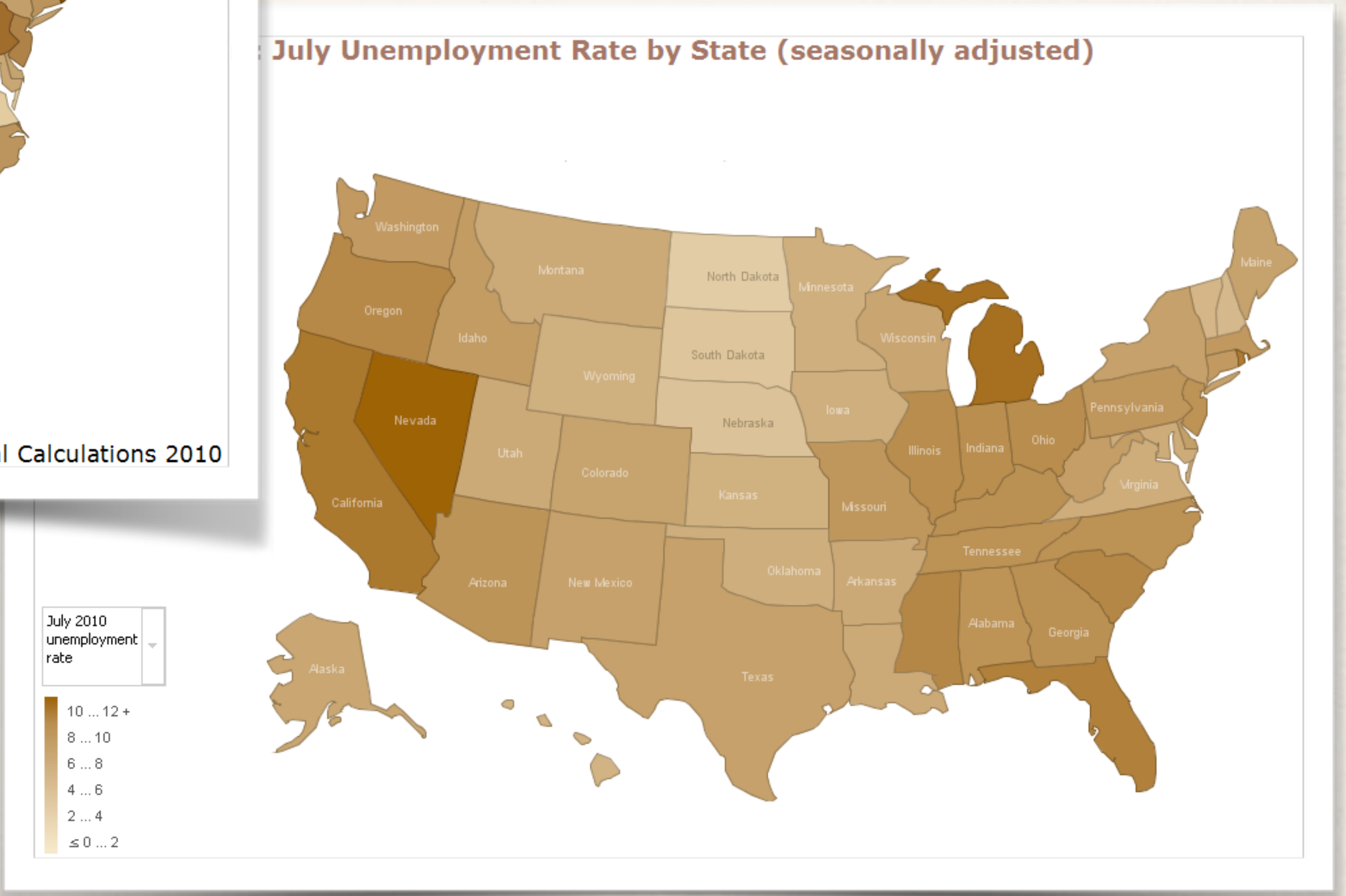


The Web Is Dead. Long Live the Internet

http://www.wired.com/magazine/2010/08/ff_webrip/all/1

Information Visualization Examples





Information Visualization Examples

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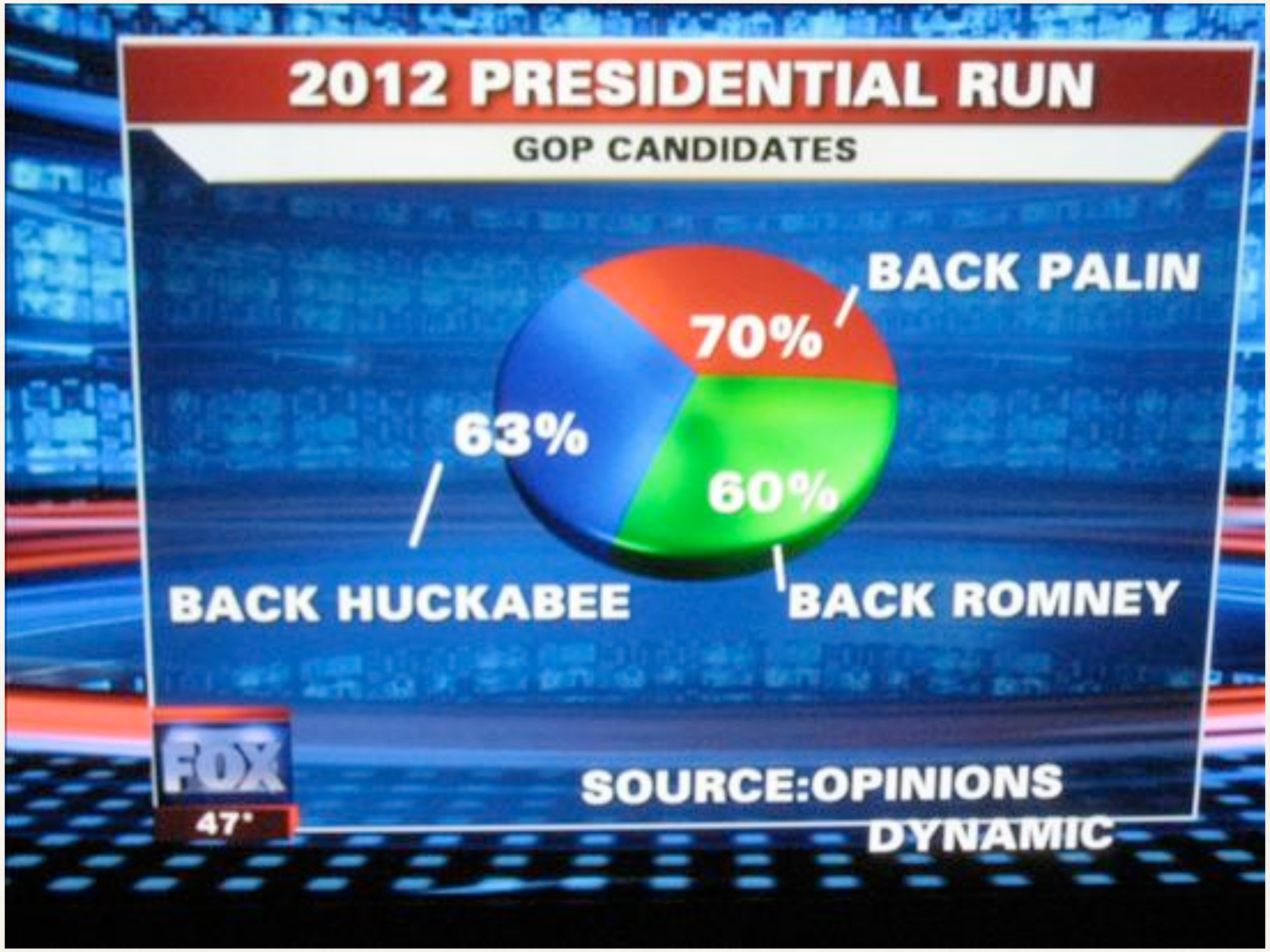
Information Visualization Examples



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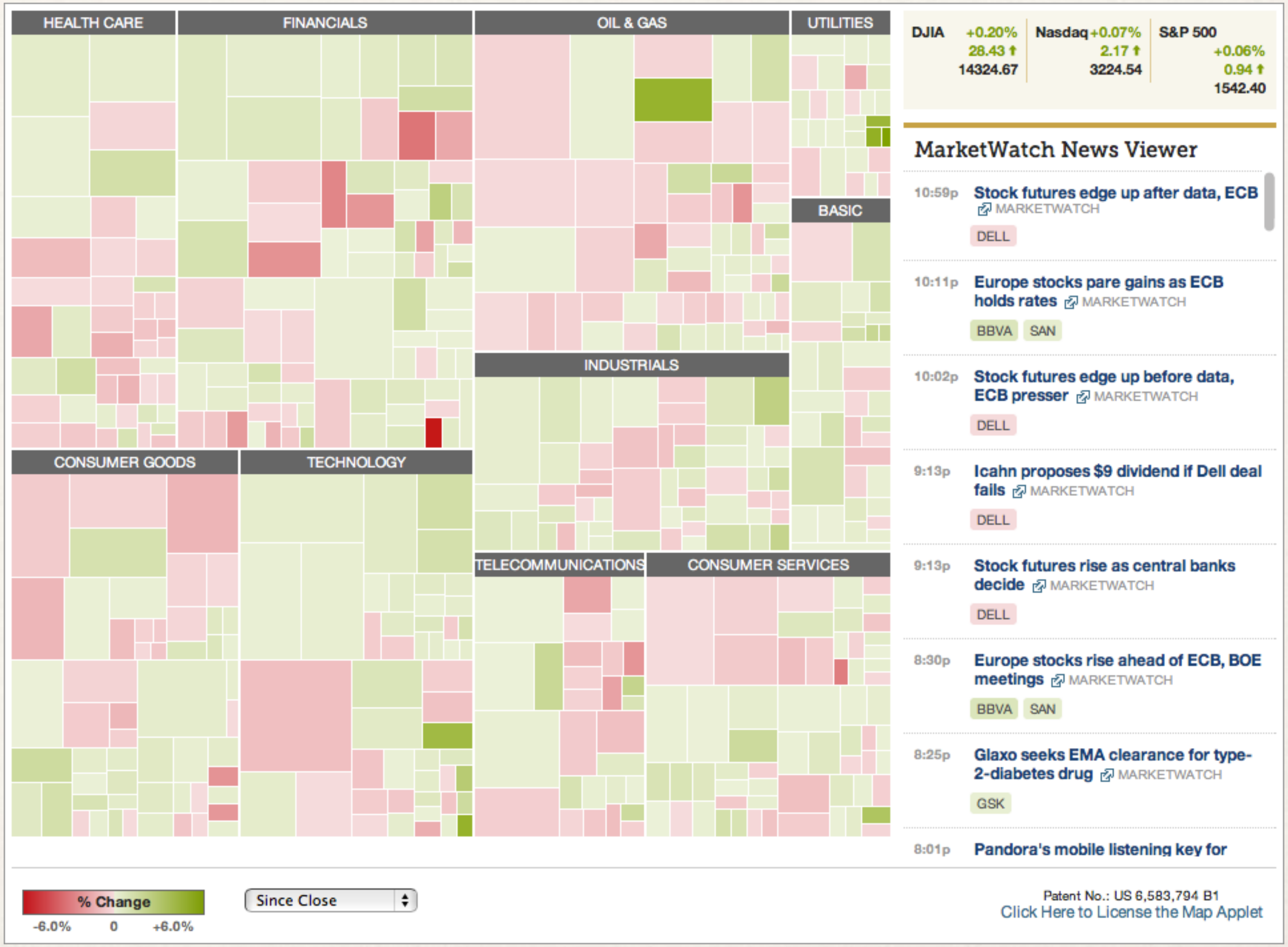
All 193% of Republicans Support Palin, Romney and Huckabee

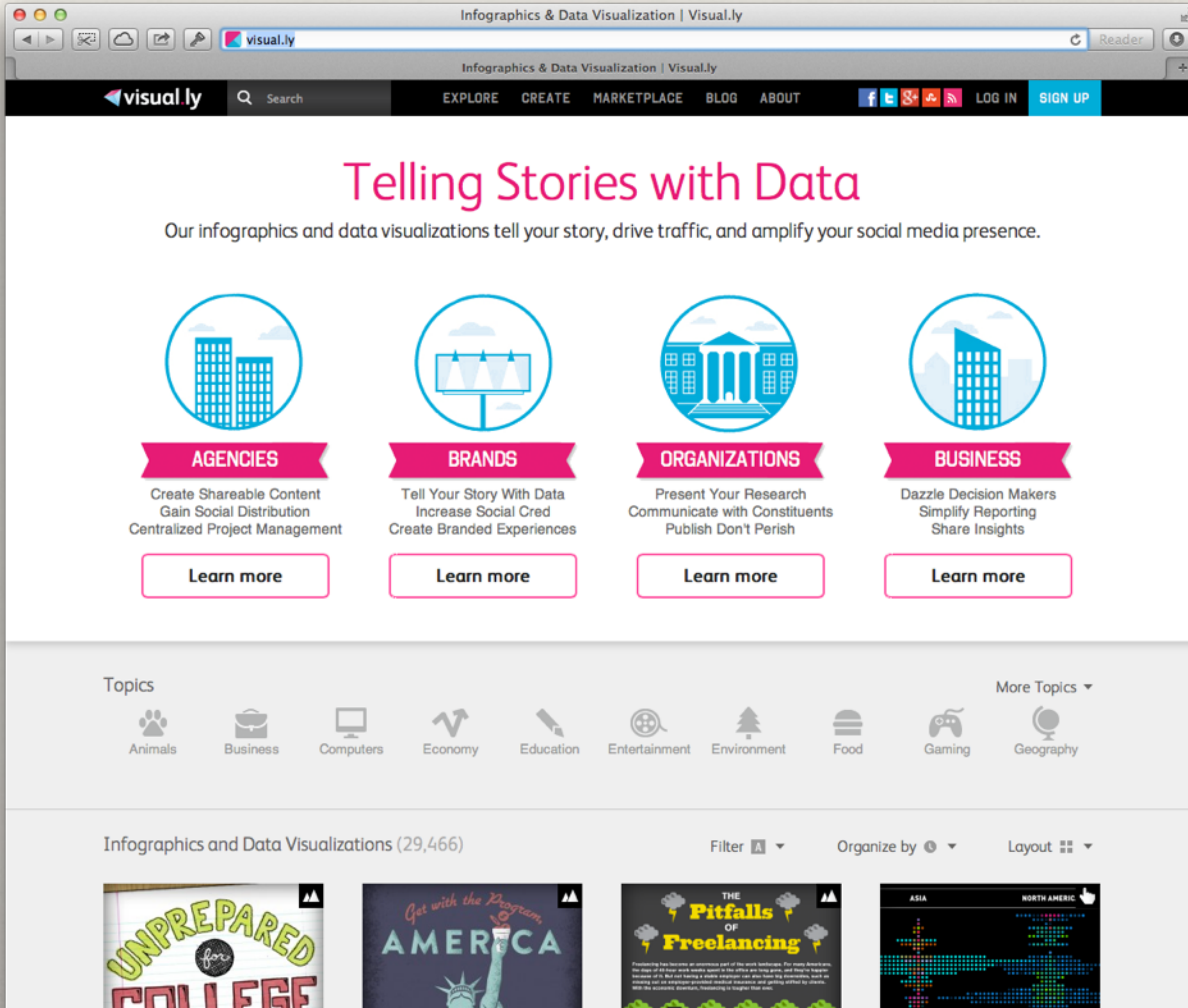
http://wonkette.com/412361/all-193-of-republicans-support-palin-romney-and-huckabee

Information Visualization Examples



http://www.smartmoney.com/map-of-the-market/

visual.ly



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Next Week: Reading Assignments

- T2: Human-Computer Interaction
  - T2: Chapter 8 - Writing and Publishing a Research Paper

Questions…?

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