

INTERACTION IN VISUALIZATION

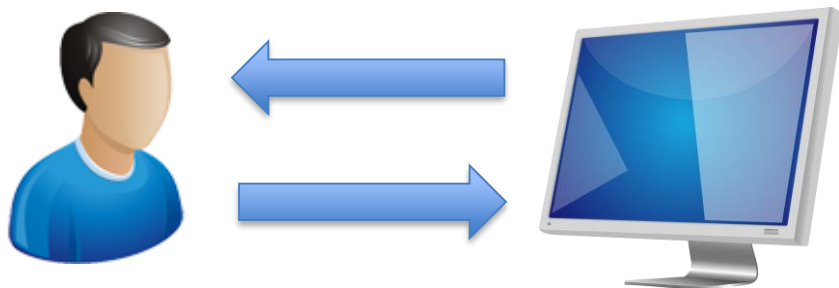
Petra Isenberg

RECAP

- Interaction is fundamental to the definition of visual exploration
- You have already seen examples
 - for graphs
 - for multi-dimensional data

RECAP

- Visual exploration is more than just looking



- So far we focused mostly on output
 - but we have already used limited input earlier in the course
- Today: input for steering visual output

WHY INTERACT?

DEFINITION OF INTERACTION

STATIC CONTENT

- many infographics

DYNAMIC CONTENT

- Animated content
Changes independently from the user
- Interactive content
Changes as a result of user actions

PERCEPTION

LATERAL
MOTION



PRESSURE



STATIC
CONTACT



UNSUPPORTED
HOLDING



ENCLOSURE



CONTOUR
FOLLOWING

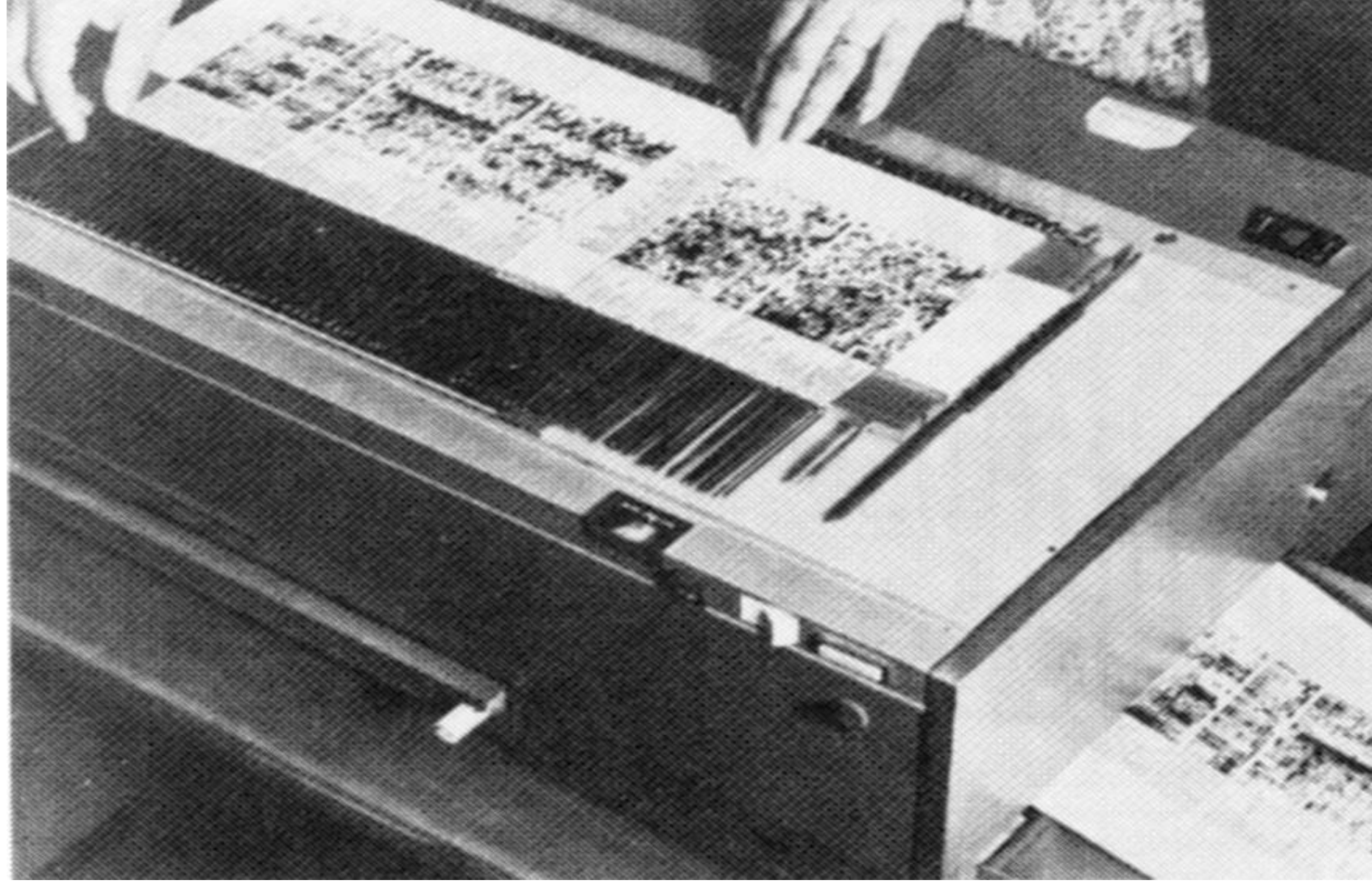


FUNCTION
TEST



PART MOTION
TEST





THERE IS TOO MUCH
DATA TO SHOW

THERE ARE MANY WAYS
TO SHOW IT

LET THE USER DYNAMICALLY CONTROL WHAT TO SHOW AND HOW

NOT TOO LONG

1970s

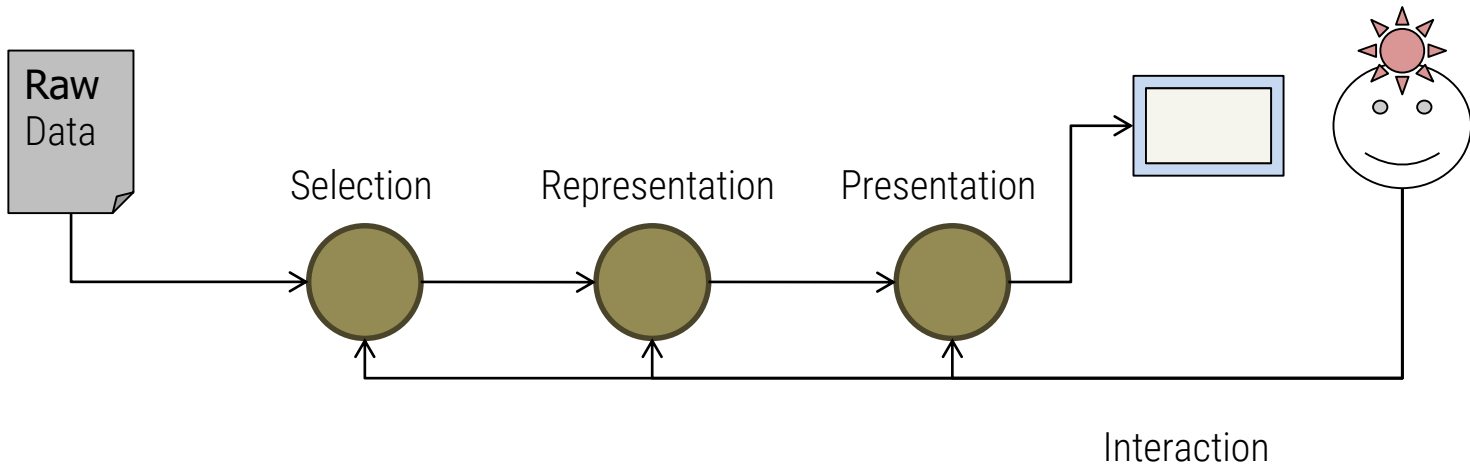


TAXONOMIES OF INTERACTION

- What?
 - What is the user doing?
- Why?
 - Why is the user doing it?
- How?
 - How is the user doing it?

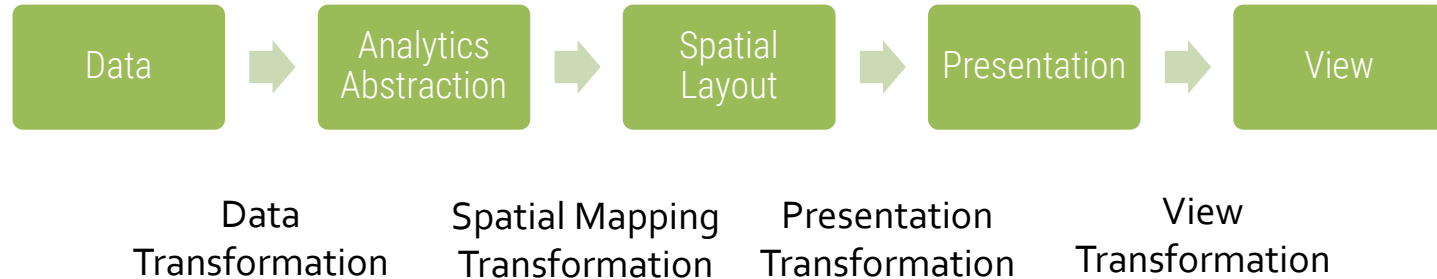
THE VISUALIZATION PIPELINE

THE VISUALIZATION

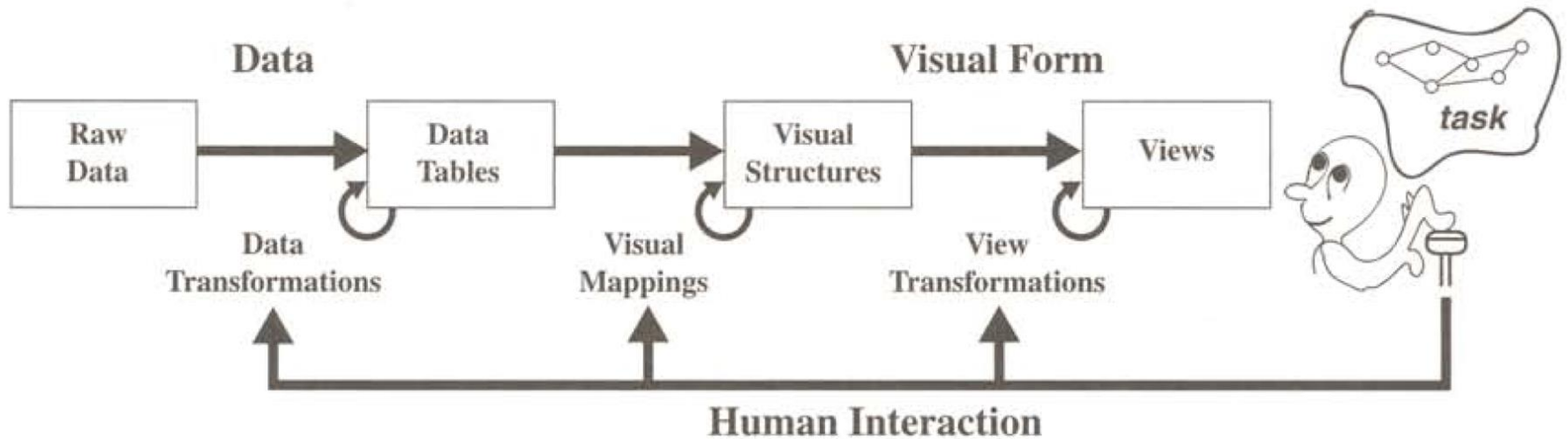


The Visualization Pipeline

THE VISUALIZATION PIPELINE



THE VISUALIZATION PIPELINE



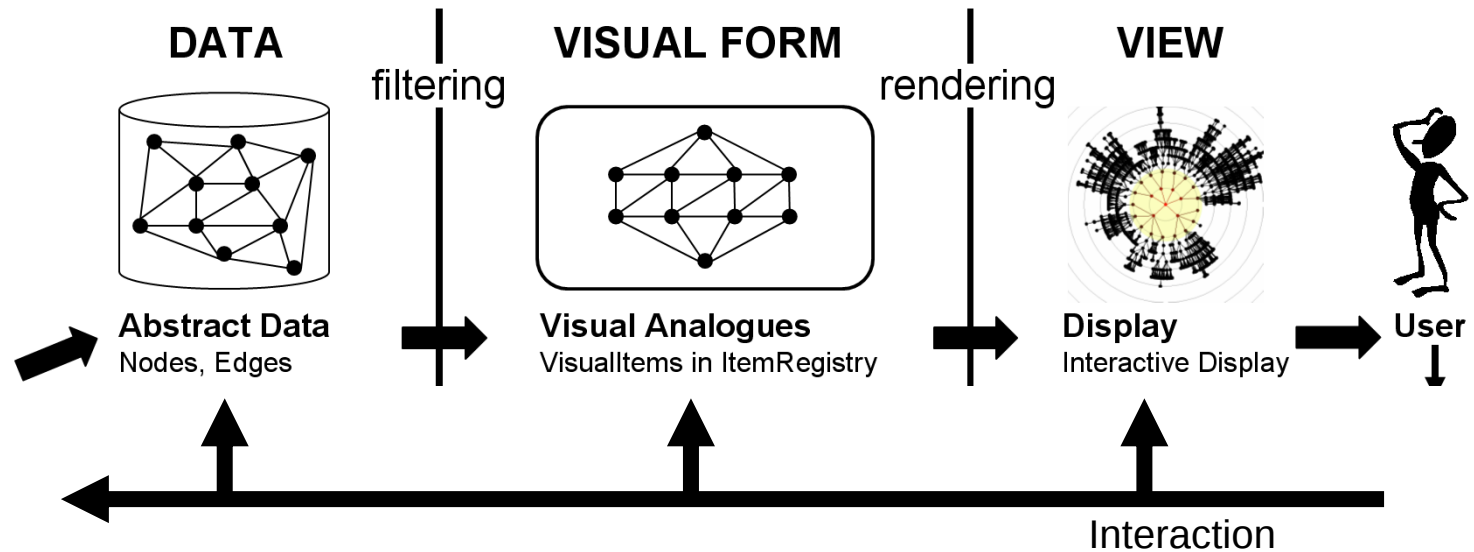
Raw Data: idiosyncratic formats

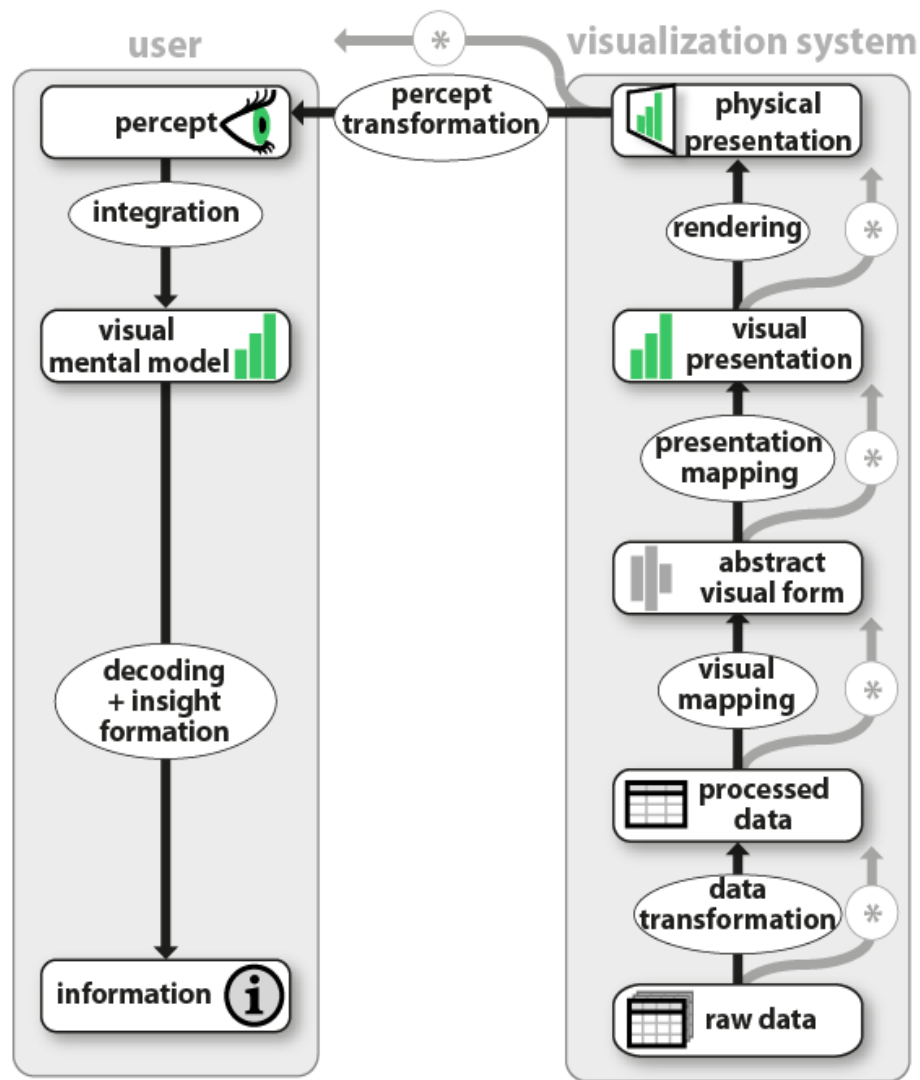
Data Tables: relations (cases by variables) + metadata

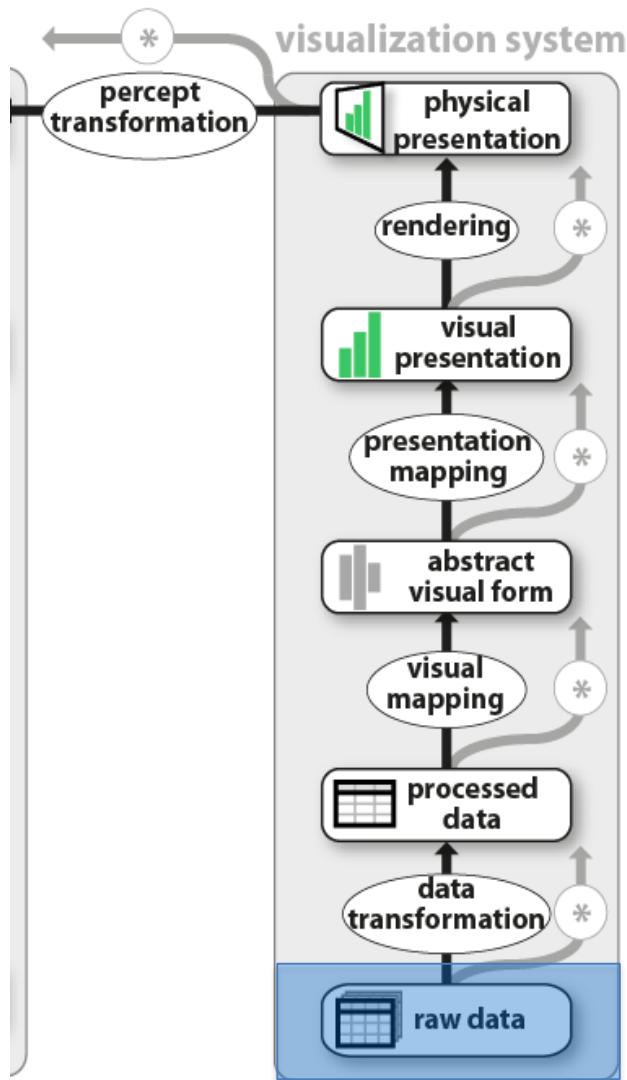
Visual Structures: spatial substrates + marks + graphical properties

Views: graphical parameters (position, scaling, clipping, ...)

THE VISUALIZATION PIPELINE



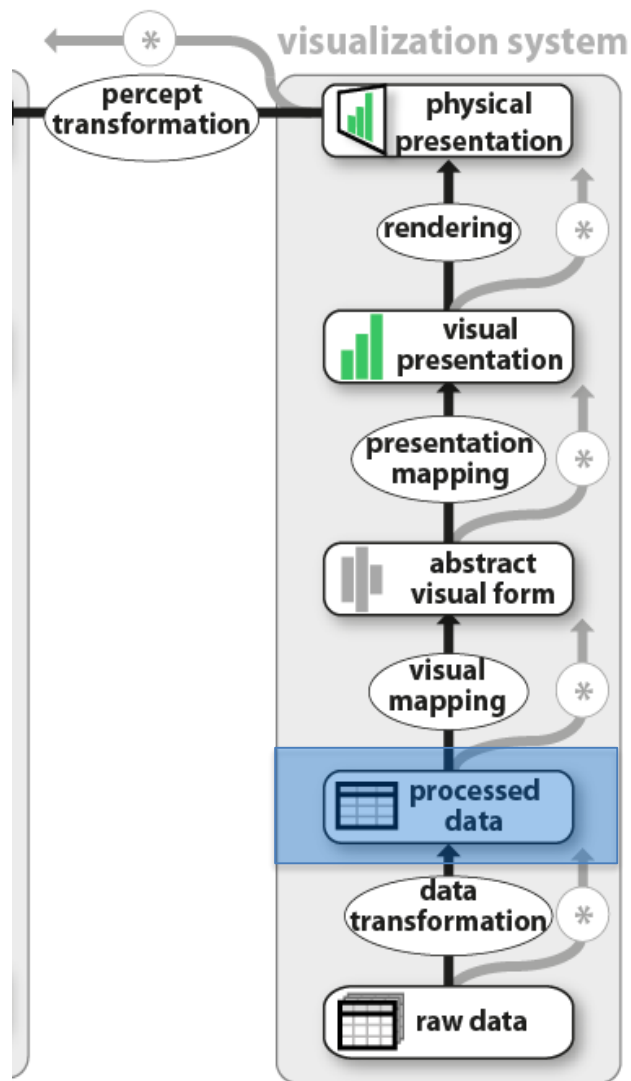




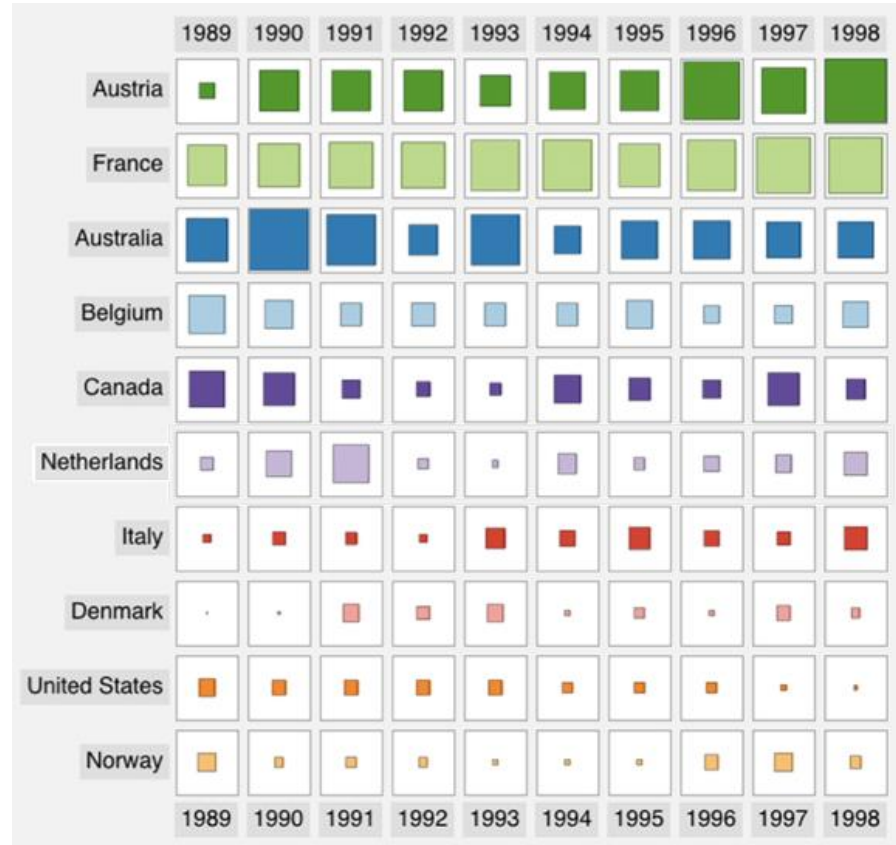
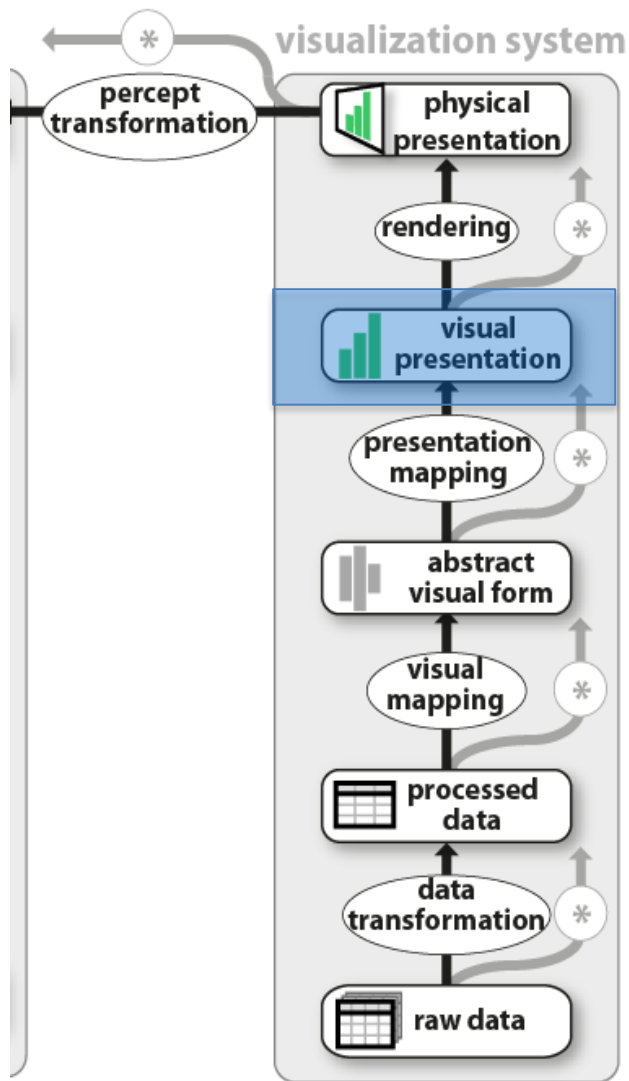
GAPMINDER for a fact-based world view

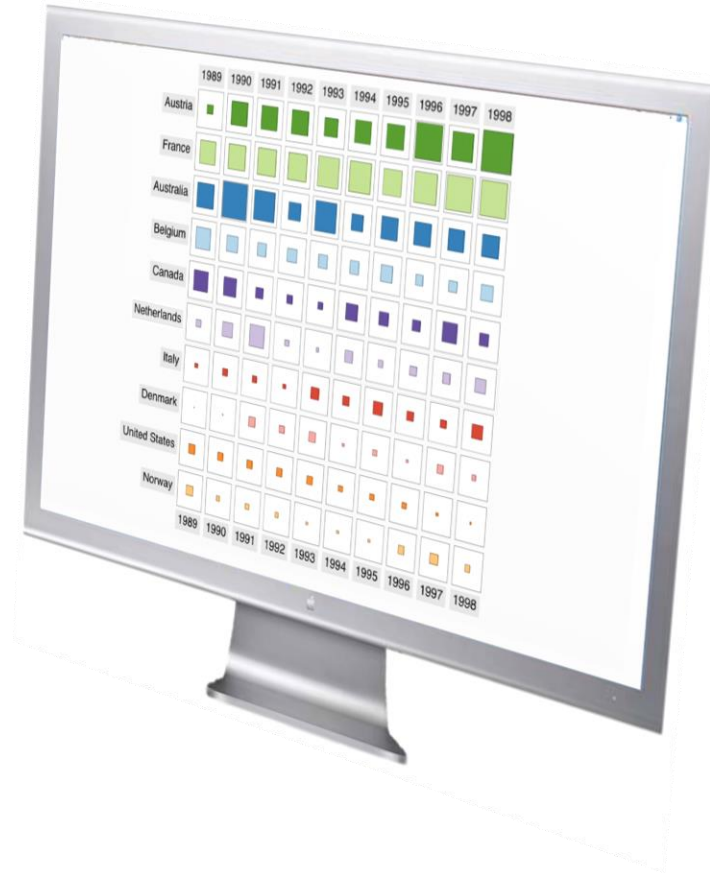
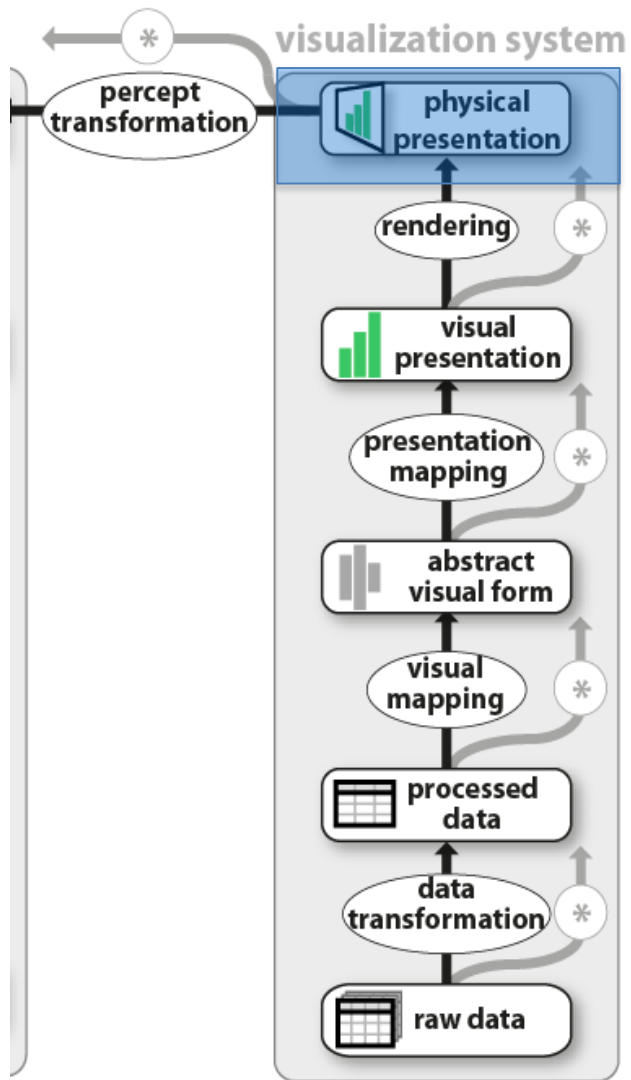
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	
1	Education aid (% of total aid)	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2	Australia	4.7	33	20	24	28	30	11	12	11	20	24	25	21	49	50	45	41	38	34	47	39	23	39	21	29	29	28	28	27	23	14	11	10	9.7	8.1	12	12						
3	Austria	25	42	13	2.5	16	4.9	19	17	45	18	7.6	0.7	15	32	44	30	32	16	12	32	31	32	24	29	31	45	35	49	38	29	43	60	41	39	39	41							
4	Belgium	85	84	11	11	16	19	27	22	20	20	6.8	4.5	16	37	37	34	28	24	30	22	18	19	18	17	22	14	15	20	21	20	22	20	19	21	25								
5	Canada	84	38	18	20	8.4	5.1	8.4	3.3	4.4	7.3	8.7	8.4	7.1	16	10	19	12	20	26	14	11	11	11	11	14	26	19	19	20	26	16	19	11										
6	Denmark	100	100	14	19	5.6	15	3.8	14	8.2	9.5	14	0.5	5.8	10	3.7	3.3	3.7	4.6	1.5	1.9	14	11	13	4.2	7.9	4.3	11	7.8	1.6	11	4.9	13	5.5	9.2	9.6	2.1	5.6						
7	Finland	36	14	14	20	15	1.5	6.8	3.7	3	4.8	5	4.5	3.3	7.9	8.2	3.7	6.8	3.6	5.3	10	5.3	11	6.6	14	10	12	14	15	24	10	6.4	7.6											
8	France	63	64	47	33	38	38	40	39	42	45	30	33	38	35	34	28	30	28	32	34	36	36	39	40	33	39	43	44	37	37	41	42	41	40	38	37							
9	Germany	55	55	22	19	24	19	19	20	17	19	17	20	21	24	26	22	19	20	22	21	23	21	25	25	21	20	25	22	25	21	25	26	24	6.9	24	24							
10	Greece																																											
11	Ireland																																											
12	Italy	20	96																																									
13	Japan	13	12	2.9	1.1	2.2	2.6	2.9	3.2	2.9	3.1	3.6	3.7	7.1	6	6.8	11	7.7	6.1	6.6	8.8	8.8	8.5	6	10	10	6.5	6.9	7.9	13	7.6	9.5	13	13	15	6.8	11	8.1						
14	Luxembourg																																											
15	Netherlands	42	33	12	15	11	12	12	13	11	16	17	16	17	19	13	7.4	10	11	20	29	8.7	5.1	15	8.1	12	14	18	20	18	17	18	18	19	21	29	22							
16	New Zealand	20	21	5.1	8.8	28	23	17	19	19	17	19	15	13		47	68	15	48	31	30	22	22	31	30	29																		
17	Norway	55	49	32	9.7	5.7	7	13	5.9	5.5	2.8	2.6	2.5	8.7	7.5	11	8.8	12	3.1	14	7.8	8.2	7.3	4	4.3	4.5	11	15	9.3	15	10	9.7	14	14	15	14	13	13						
18	Portugal																																											
19	Spain																																											
20	Sweden	33	23	15	14	21	18	17	21	17	6.8	16	17	17	12	11	16	13	15	6.5	8.7	14	7.6	9.7	11	13	12	14	10	11	9	6.2	11	8.9	11	8.9	8.5	6.4						
21	Switzerland	47	48	12	15	8.7	11	15	19	15	13	12	12	11	17	5	13	13	17	16	12	13	15	10	10	7.5																		
22	United Kingdom	61	57	16	16	0.9	0.7	20	13	8.8	21	27	19	16	13	26	17	17	19	20	16	16	16	21	20	20	16	16	17	16	12	16	8.7	15	15	11	13	18						
23	United States	69	64	10	7.8	6.2																																						
24																																												

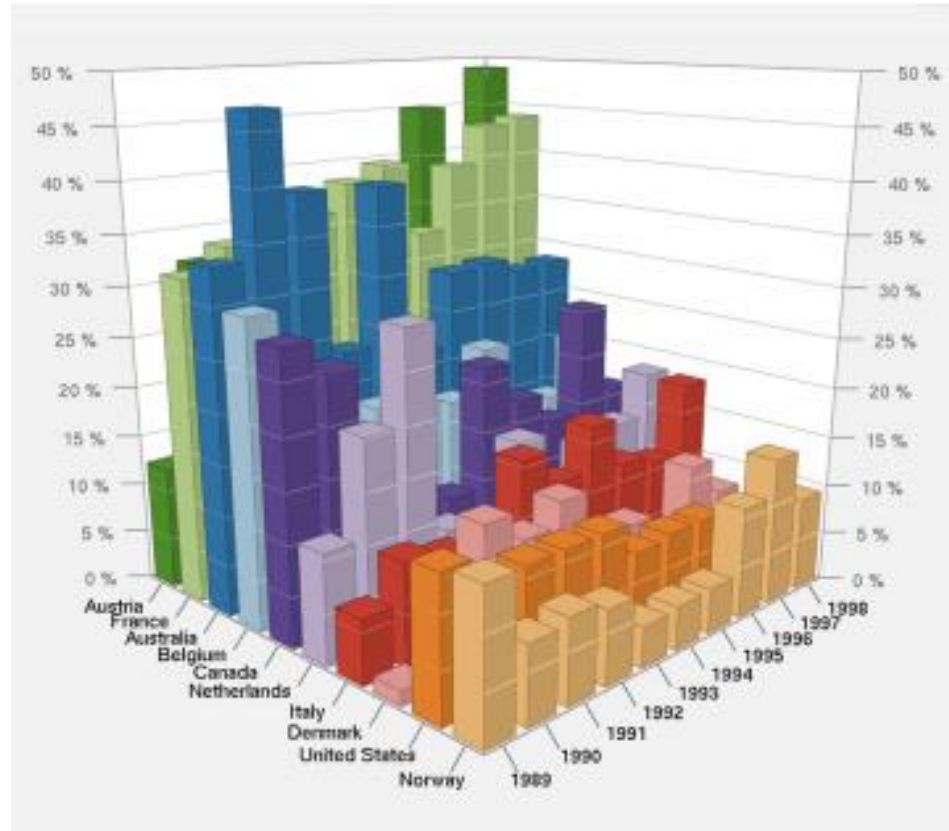
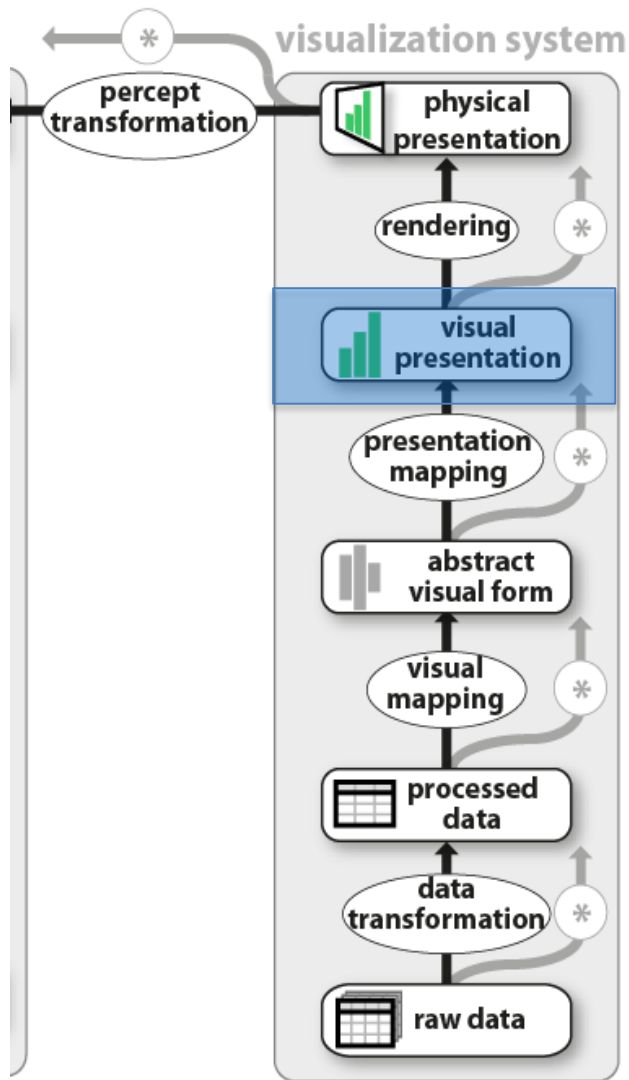
	A	B	C	D	E	F	G	H	I	J	K
1	Education aid (% of total aid)	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
2	Australia					4.75	33.2	19.7	23.7	26.3	30.
3	Austria					24.7	42.3	13.5	2.52	15.9	4.8
4	Belgium					84.5	83.7	11	11.4	15.9	18.
5	Canada					33.7	38.6	18	25.3	8.41	5.1.
6	Denmark					100	100	13.7	19	5.6	15.
7	Finland							29.6	13.5	14.1	20.
8	France					62.9	63.7	46.8	33.4	38.2	38.
9	Germany					54.6	54.8	21.7	18.8	23.6	18.
10	Greece										
11	Ireland										
12	Italy					20.1	95.8			39.5	
13	Japan					12.6	12.3	2.92	1.08	2.15	2.5
14	Luxembourg										
15	Netherlands						42	32.6	12.4	15	1
16	New Zealand							19.5	20.9	5.15	8.8
17	Norway					54.7	48.8	32.4	9.71	5.74	7.0
18	Portugal										
19	Spain										
20	Sweden					32.6	23.4	15	13.7	20.7	18.
21	Switzerland					47	46	12	15	8.7	11.
22	United Kingdom					49.8	32.4	15.9	16.2	0.91	0.
23	United States					69.3	64	9.97		7.76	6.1
24											

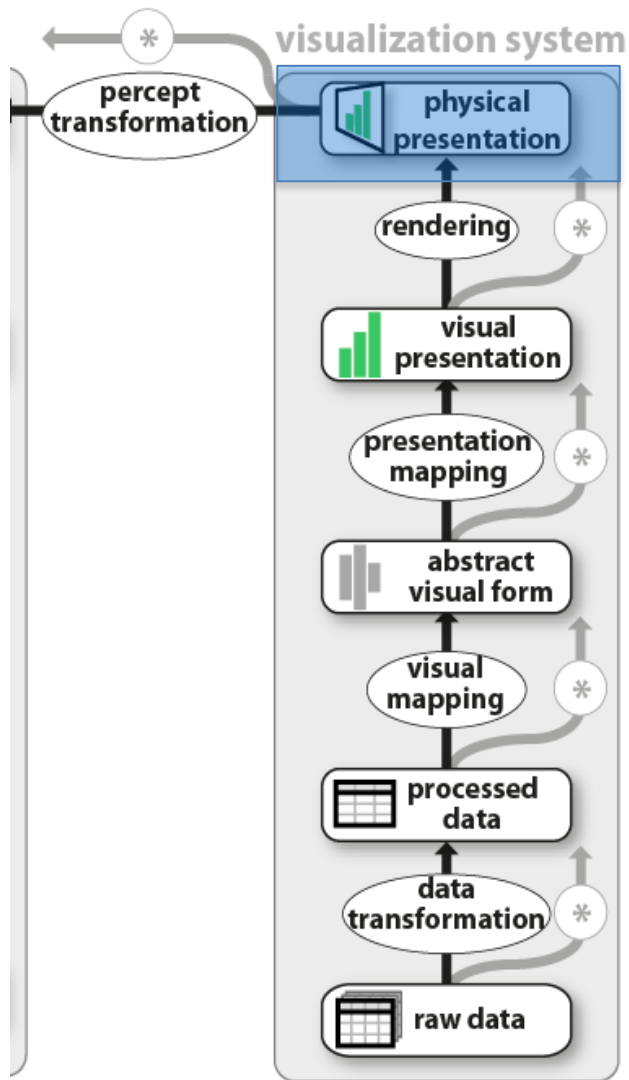


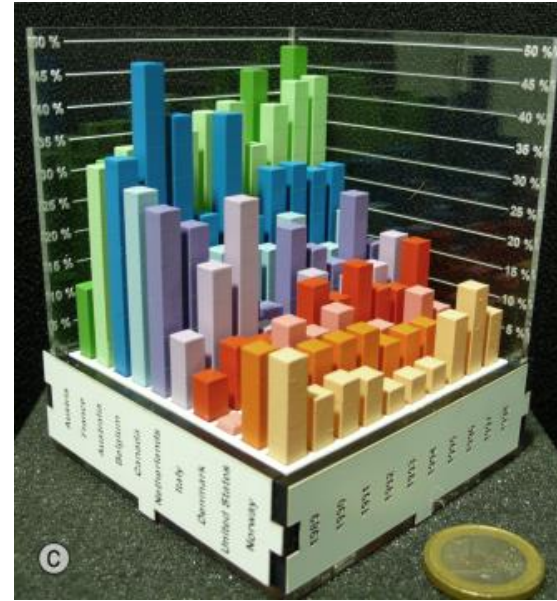
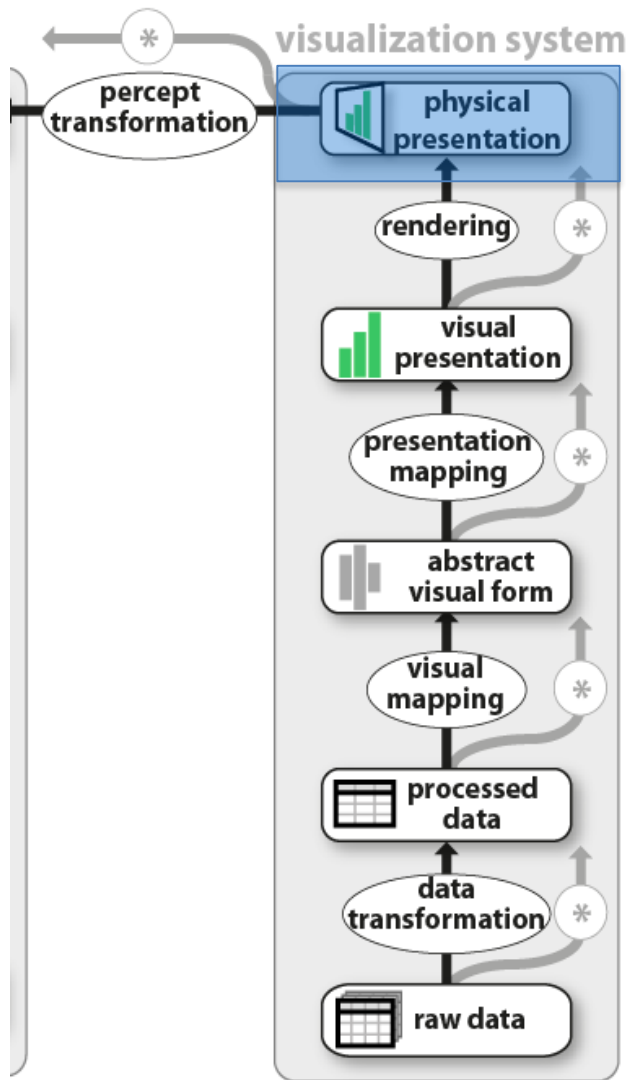
	A	B	C	D	E	F	G	H	I	J	K
1		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
2	Austria	12.23	31.86	31.07	31.57	24.02	28.61	30.52	44.99	35.41	48.95
3	France	31.87	34.18	35.95	36.06	38.78	40.18	32.68	39.26	43.15	43.9
4	Australia	33.57	46.93	39.24	23.18	38.94	21.38	29.1	29.43	27.97	28.32
5	Belgium	29.93	22.13	17.64	18.52	17.72	17.13	21.77	13.63	14.69	20.38
6	Canada	28.11	25.09	14.35	11.19	9.291	21.67	17.33	13.98	25.19	15.66
7	Netherlands	10.78	20.12	29.08	8.702	5.085	15.12	9.117	12.48	13.75	18.17
8	Italy	6.278	9.992	9.04	6.076	15.66	12.26	16.75	11.75	10.75	17.98
9	Denmark	1.485	1.933	13.52	10.71	13.01	4.193	7.937	4.303	11.42	7.581
10	United States	13.69	11.25	11.22	11.22	11.22	7.992	8.465	8.409	4.702	3.038
11	Norway	14.25	7.561	8.219	7.255	3.967	4.307	4.476	10.99	14.62	9.296

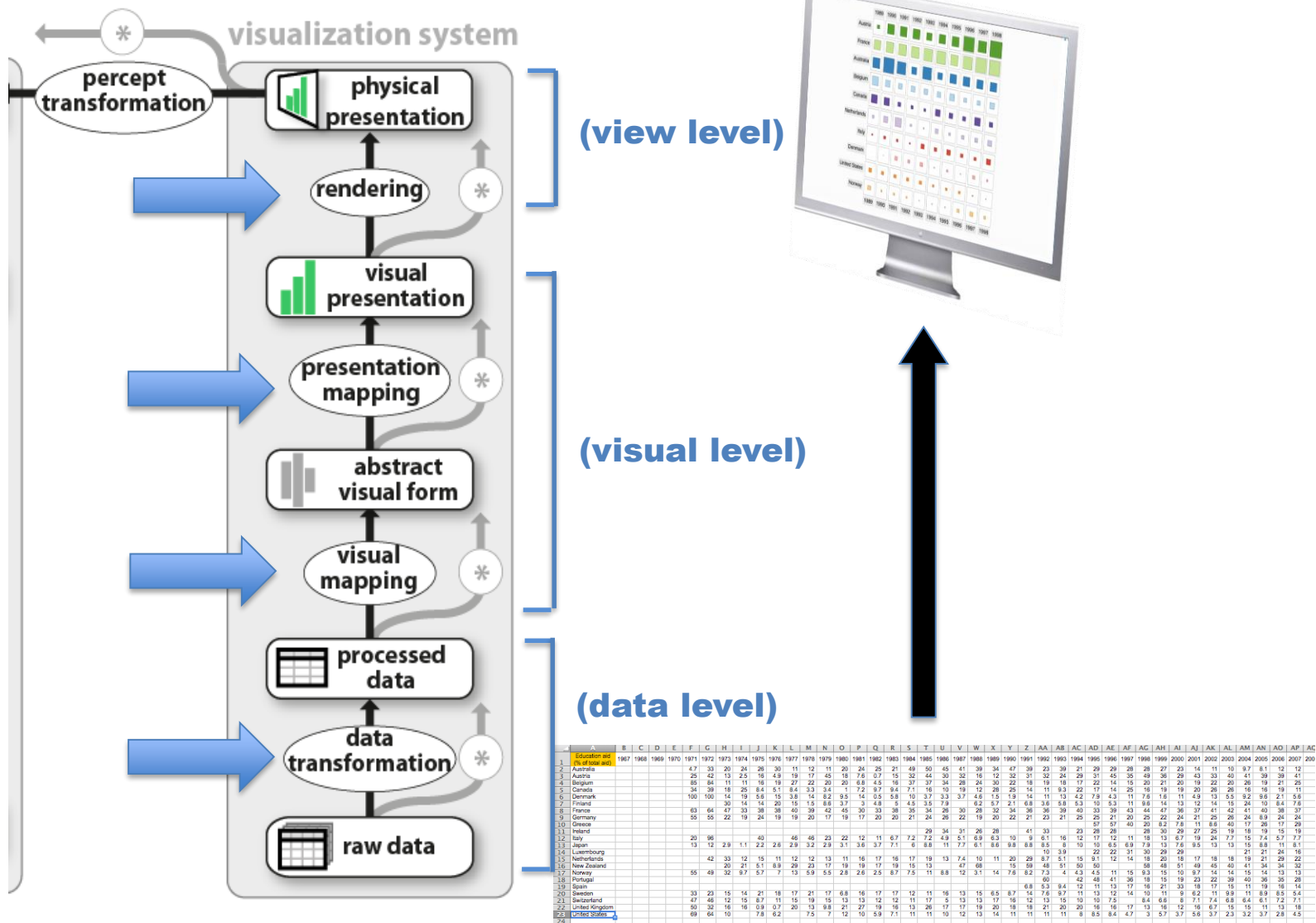












TAXONOMIES OF INTERACTION

- What?
 - What is the user doing?
- Why?
 - Why is the user doing it?
- How?
 - How is the user doing it?

Tasks

INTERACTION AS TASKS

ANALYTIC TASKS

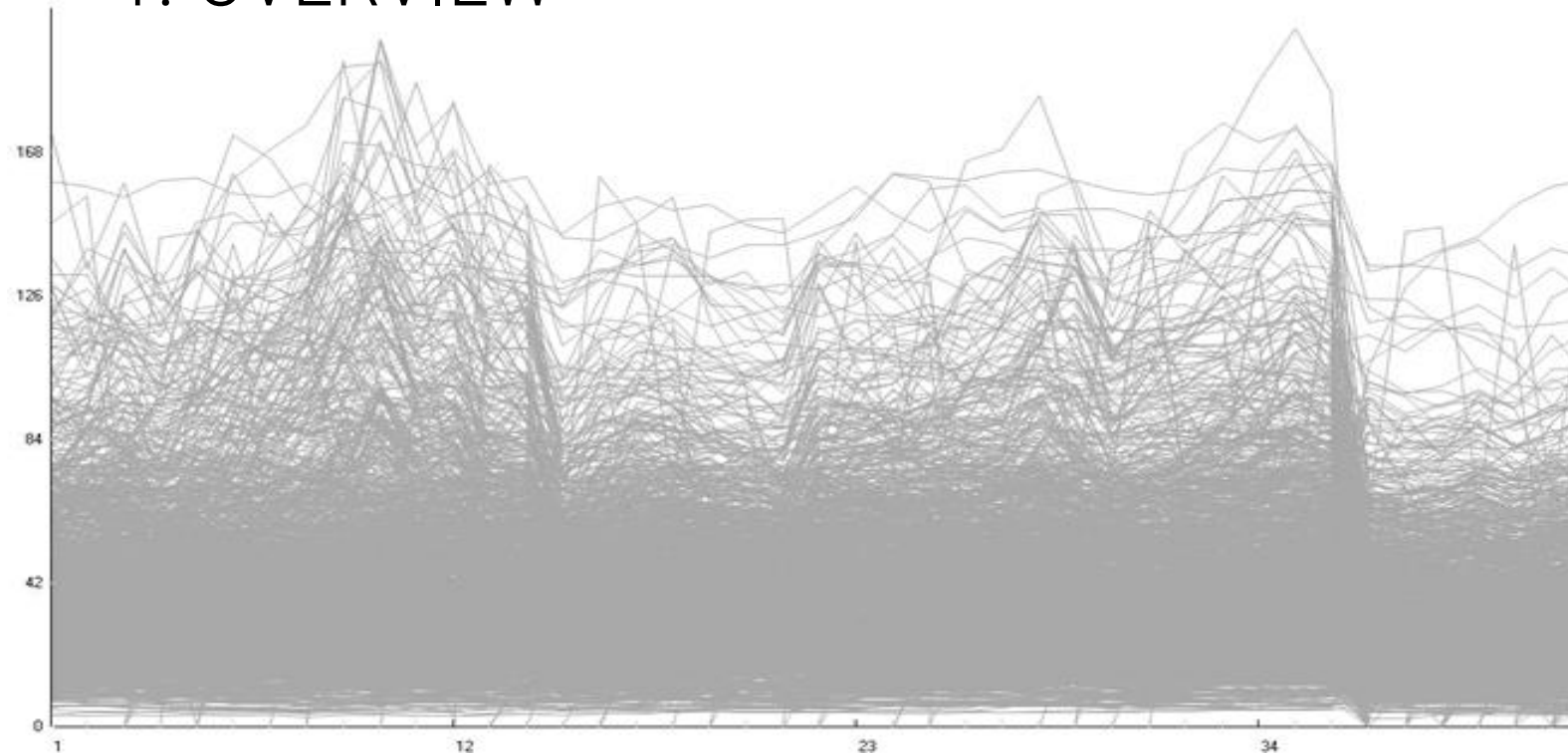
BEN SHNEIDERMAN 1996



1. **OVERVIEW:** GAIN AN OVERVIEW OF THE ENTIRE COLLECTION
2. **ZOOM:** ZOOM IN ON ITEMS OF INTEREST
3. **FILTER:** FILTER OUT UNINTERESTING ITEMS
4. **DETAILS-ON-DEMAND:** SELECT AN ITEM OR GROUP AND GET DETAILS WHEN NEEDED
5. **RELATE:** VIEW RELATIONSHIPS AMONG ITEMS
6. **HISTORY:** KEEP PAST ACTIONS FOR UNDO, REPLAY, AND PROGRESSIVE REFINEMENT
7. **EXTRACT:** ALLOW EXTRACTION OF SUB-COLLECTIONS AND QUERY PARAMETERS.

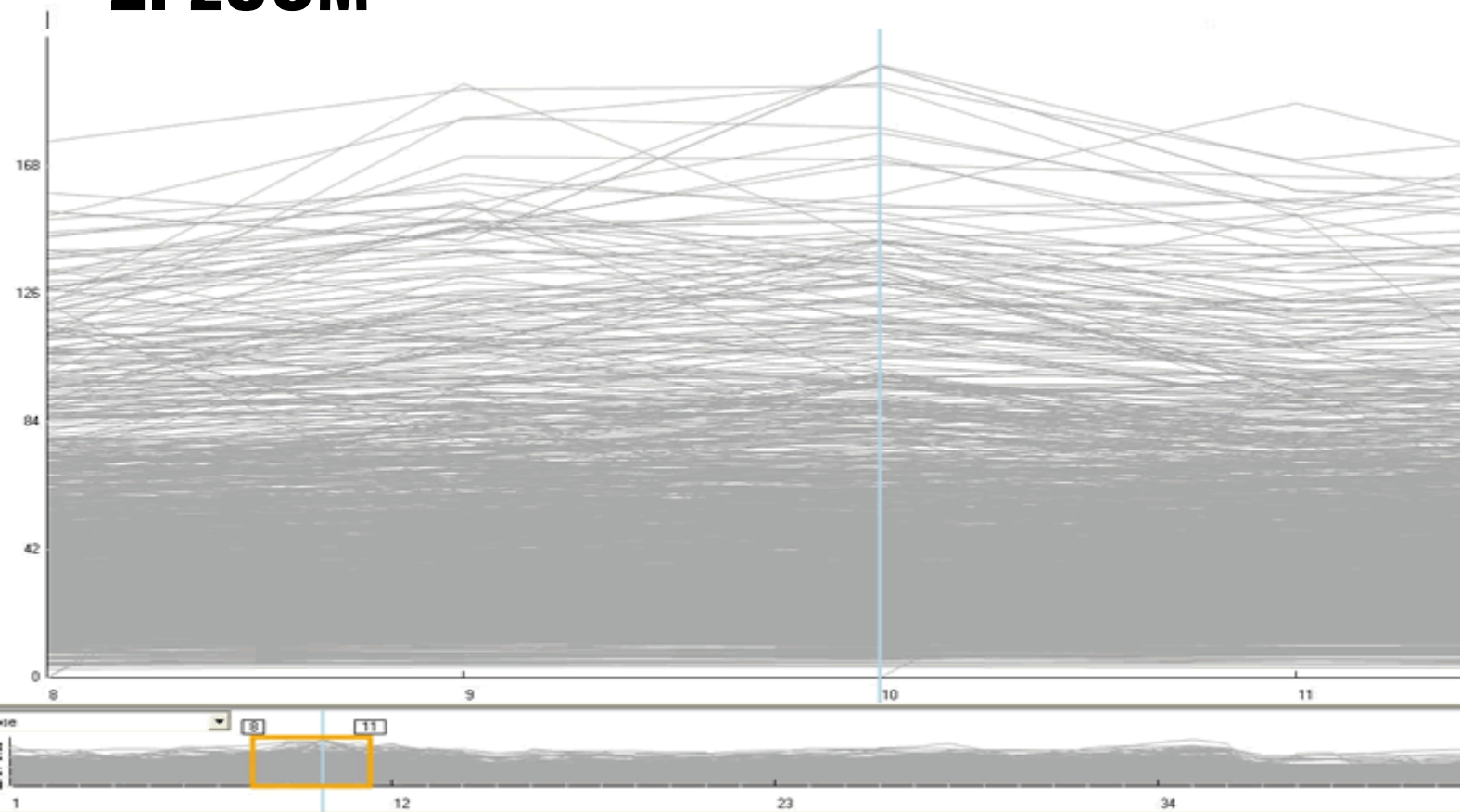
ANALYTICAL

1. OVERVIEW



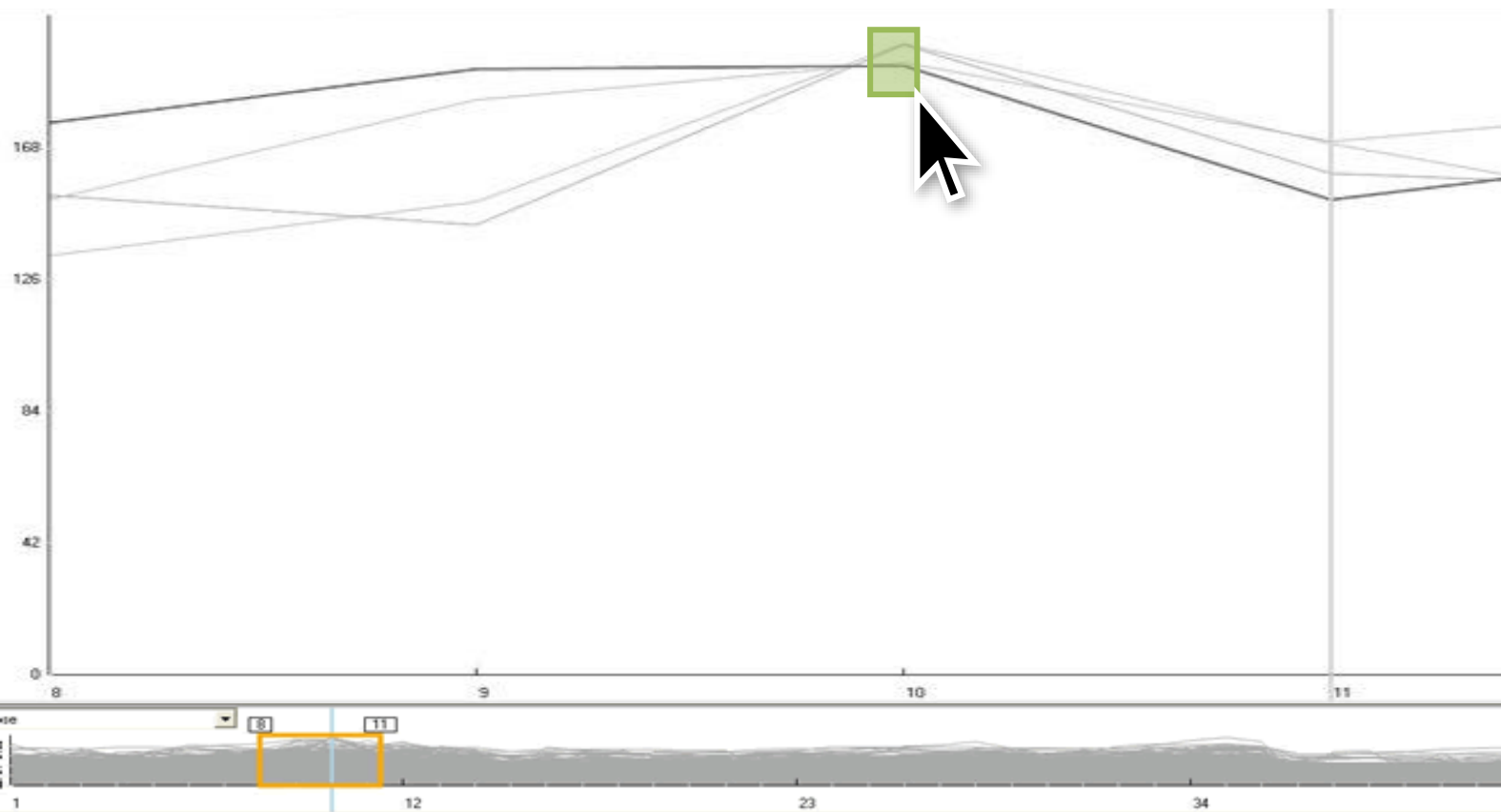
ANALYTICAL

2. ZOOM



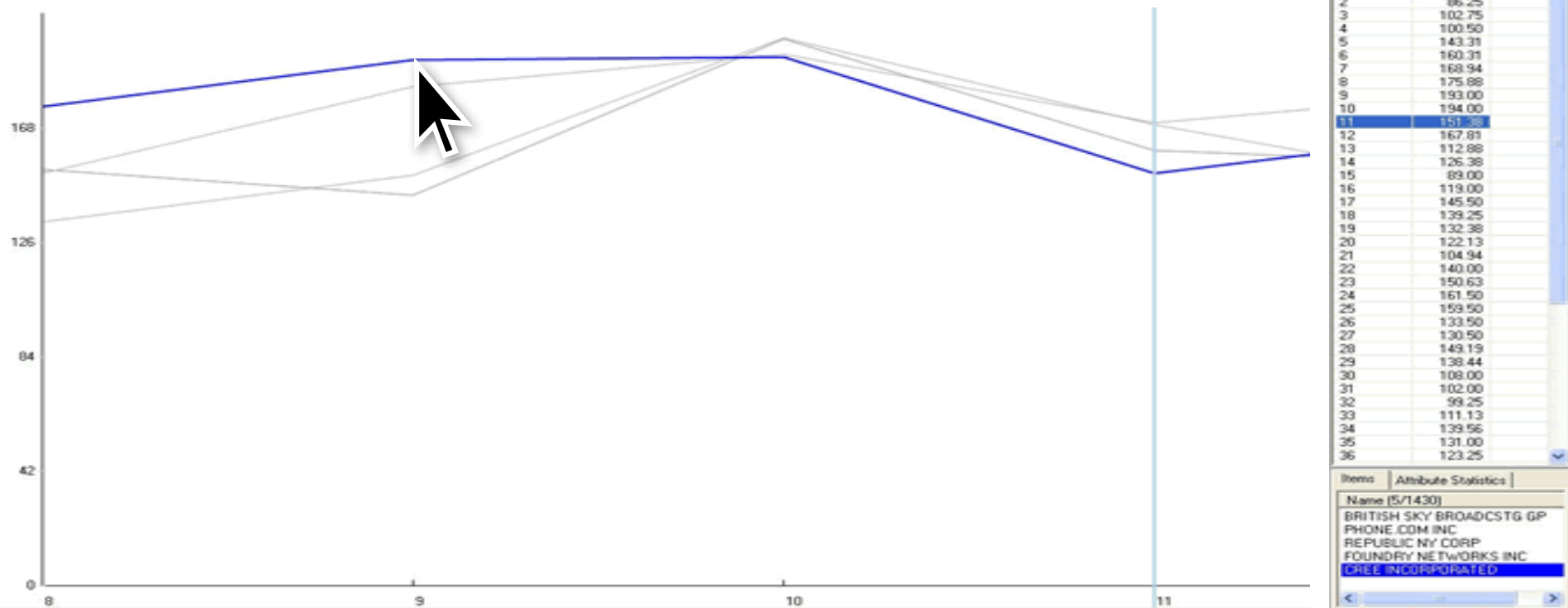
ANALYTICAL

3. FILTER



ANALYTICAL

4. DETAILS ON DEMAND



VISUAL INFORMATION SEEKING MANTRA

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

OVERVIEW FIRST, ZOOM AND FILTER, THEN DETAILS ON DEMAND

INTERACTION AS INTENTS

SEVEN CATEGORIES OF INTERACTION BY INTENT

YI ET AL. 2007

SELECT

EXPLORE

FILTER

RECONFIGURE

ENCODE

ABSTRACT/ELABORATE

CONNECT

SELECT

MARK SOMETHING AS
INTERESTING

EXPLORE

FILTER

RECONFIGURE

ENCODE

ABSTRACT/ELABORATE

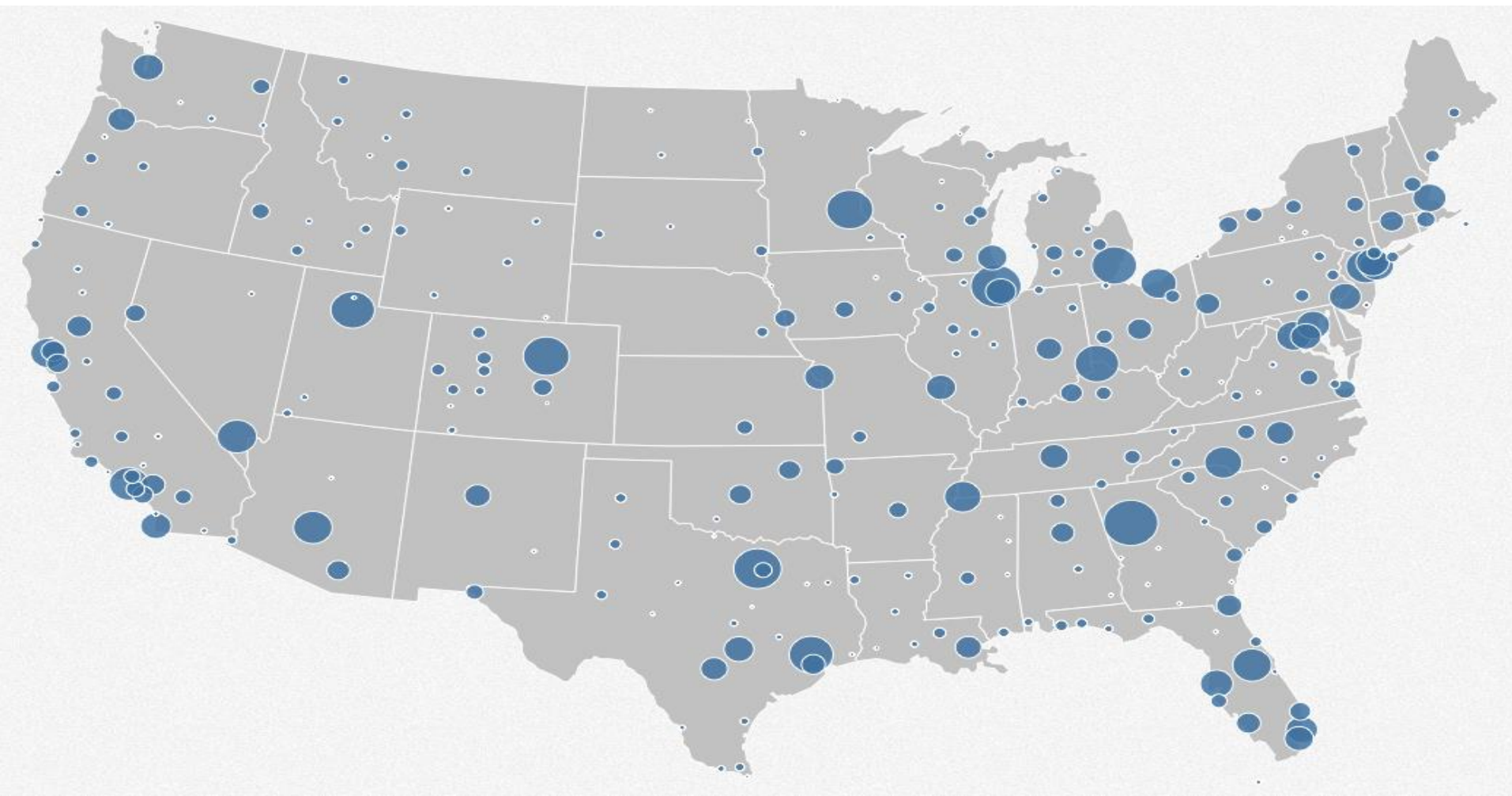
CONNECT

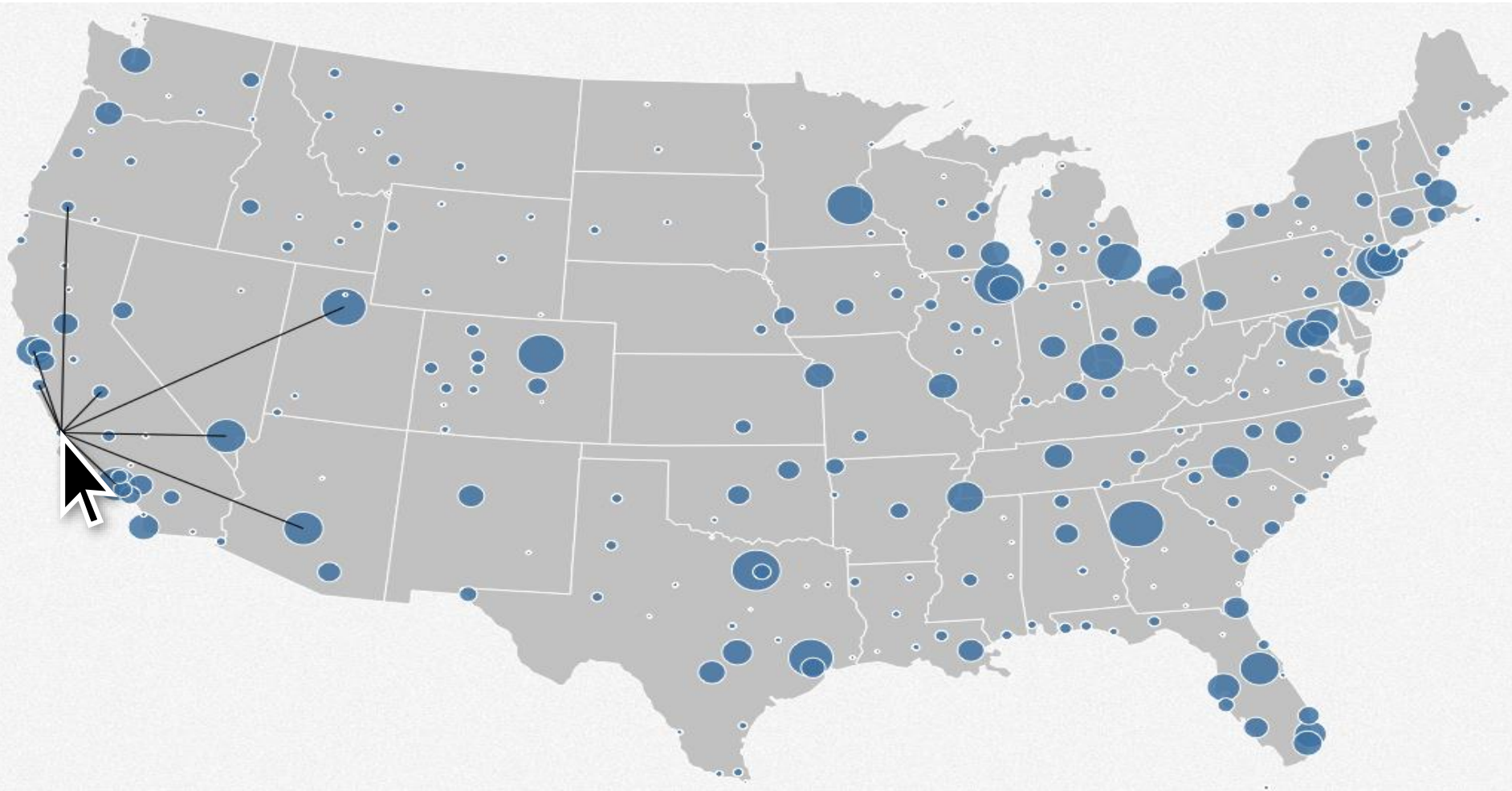
BASIC

Point Selection

Mouse Hover / Click

Touch / Tap





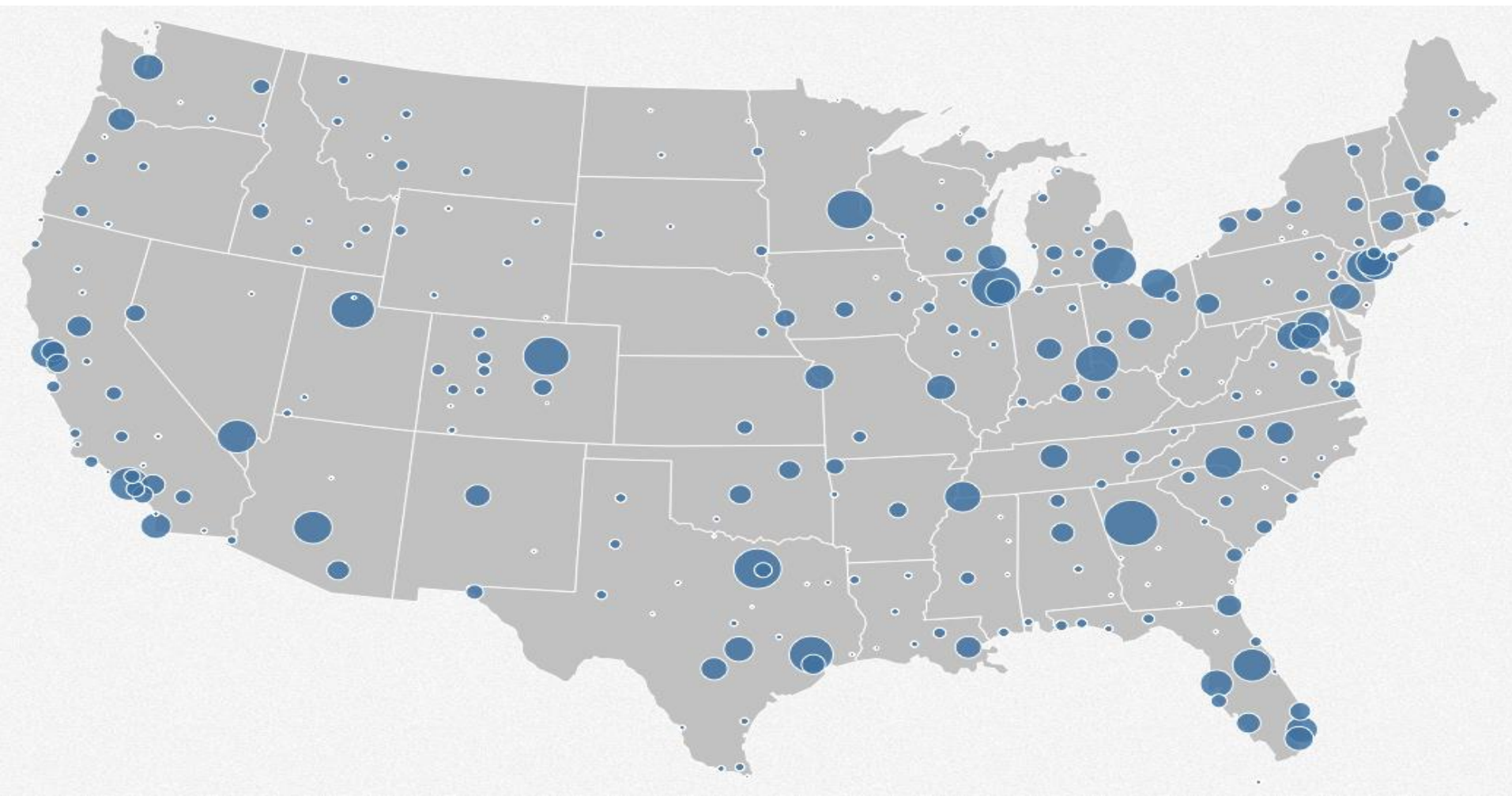
BASIC

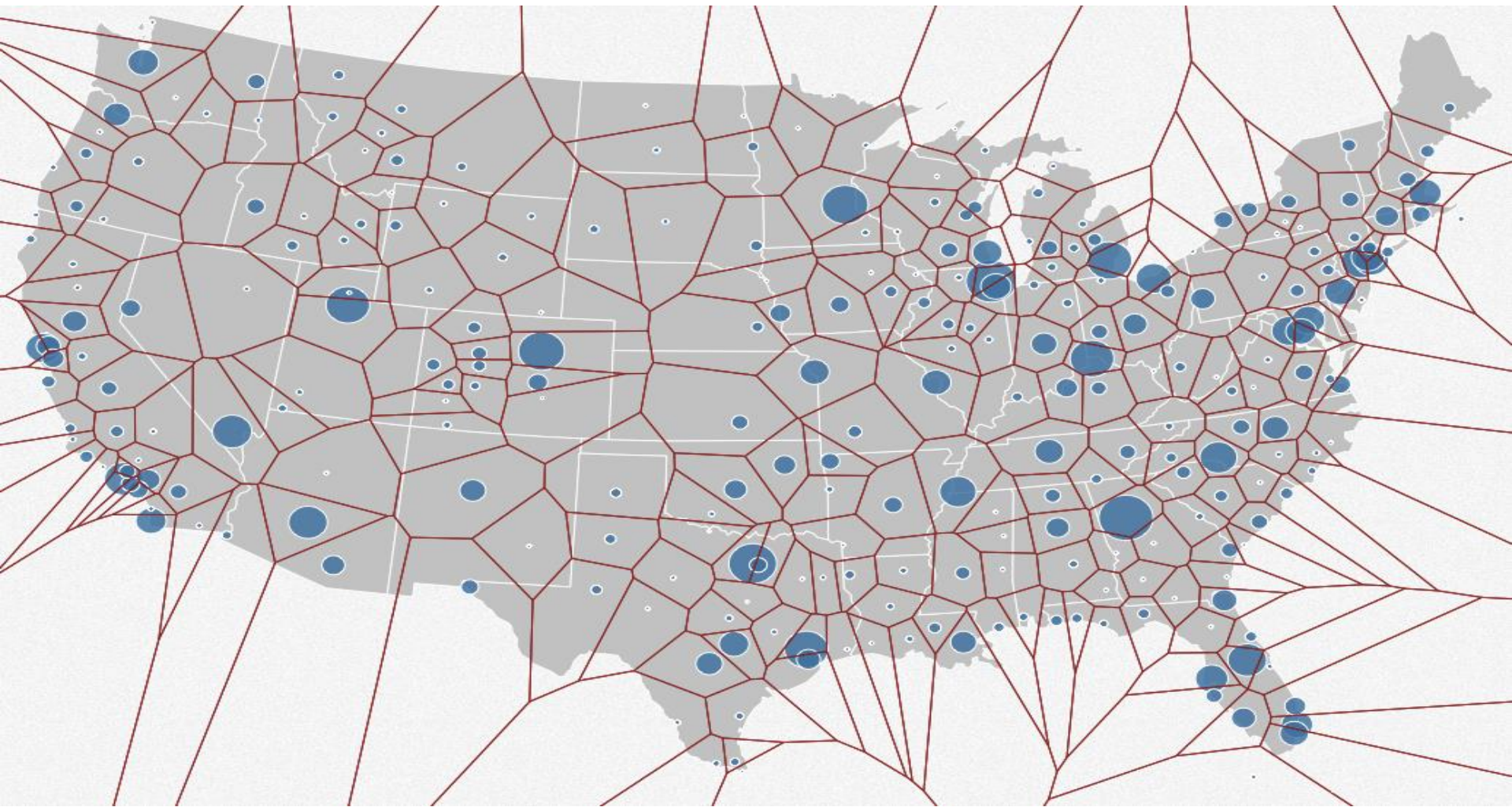
Point Selection

Mouse Hover / Click

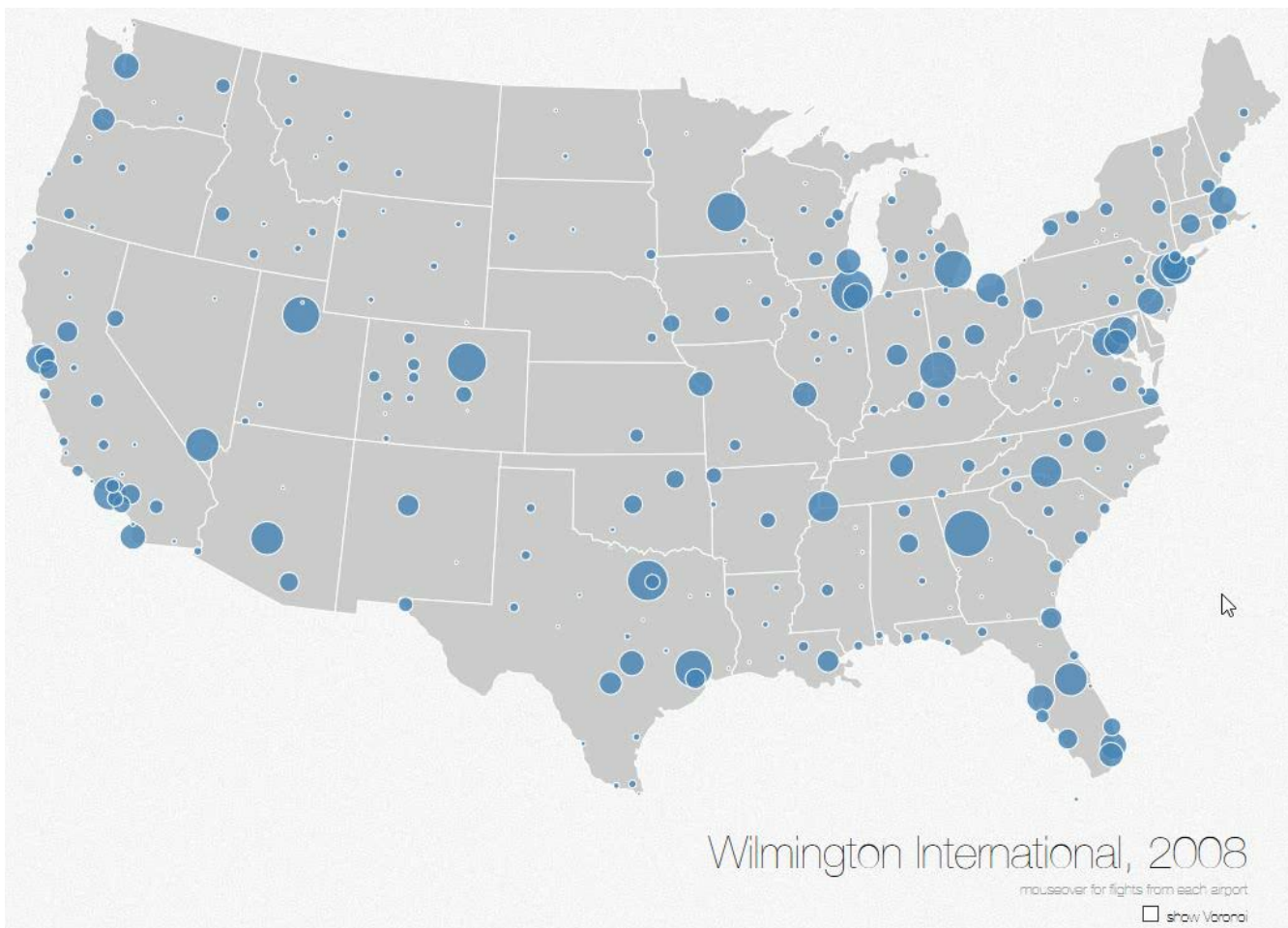
Touch / Tap

Select Nearby Element (e.g., Bubble Cursor)





<http://mbostock.github.io/d3/talk/20111018/#28>



BASIC

Point Selection

Mouse Hover / Click

Touch / Tap

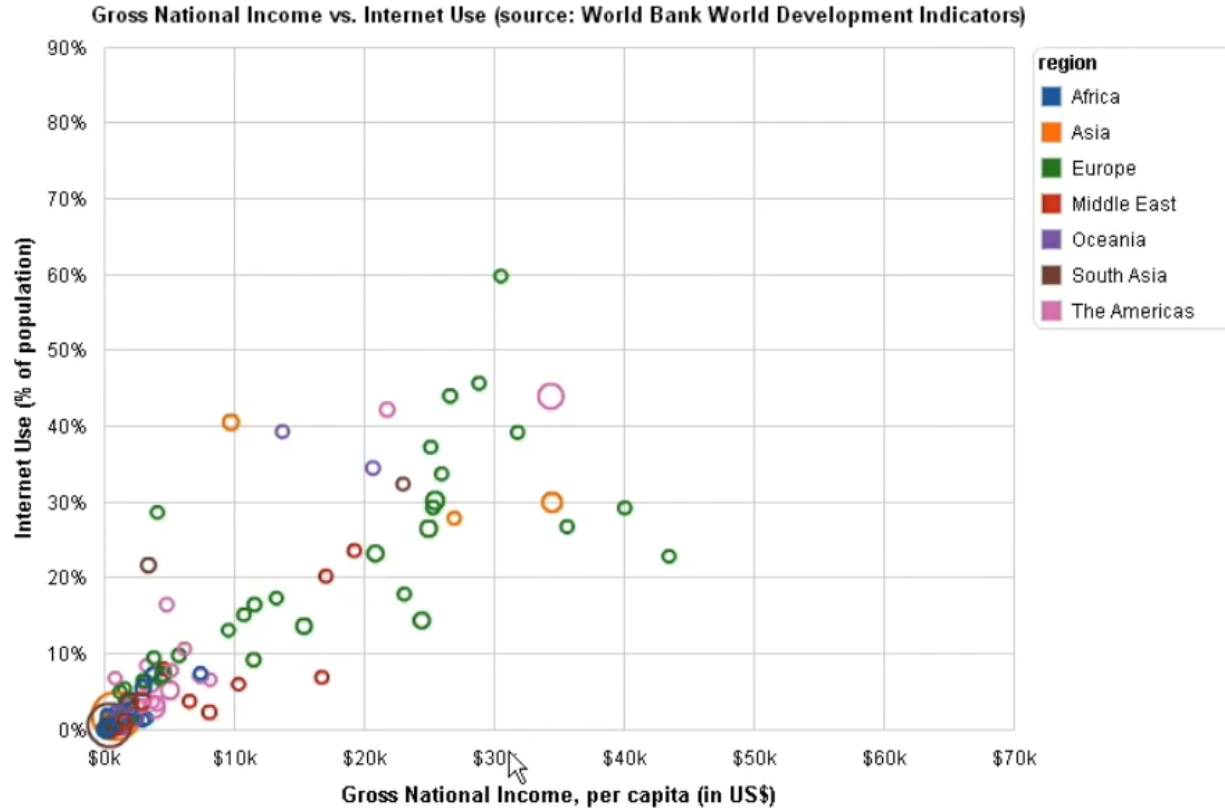
Select Nearby Element (e.g., Bubble Cursor)

Region Selection

Rubber-band or Lasso

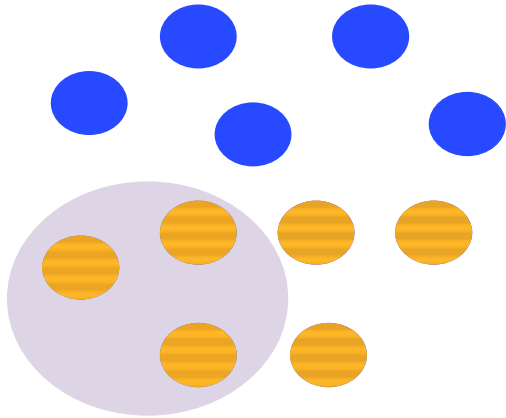
Area Cursors (“Brushes”)

RANGE

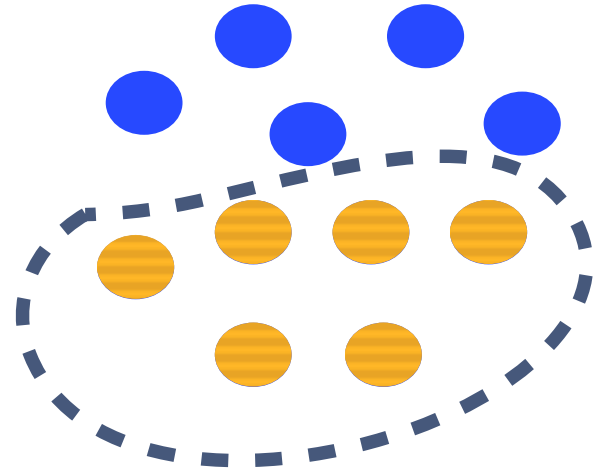


GENERALIZED SELECTION HEER ET AL. 2008

BRUSHES



LASSOS



WILLS' SELECTION TAXONOMY:

WILLS' SELECTION TAXONOMY

SELECTION MEMORY

MEMORY

25 < AGE < 35

COUNTRY = CANADA

**EDU LEVEL =
POSTSECONDARY**

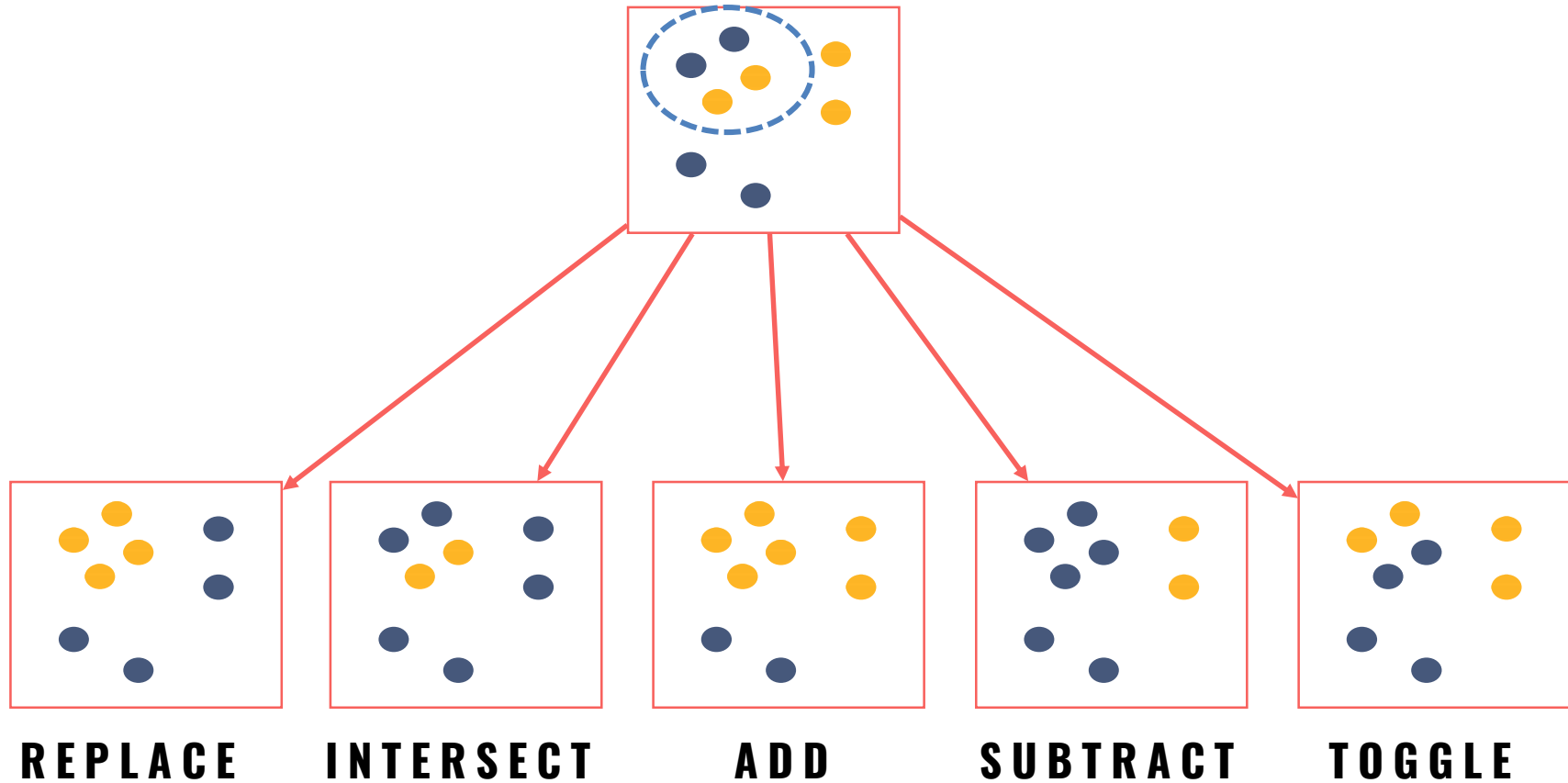
MEMORYLESS

25 < AGE < 35

COUNTRY = CANADA

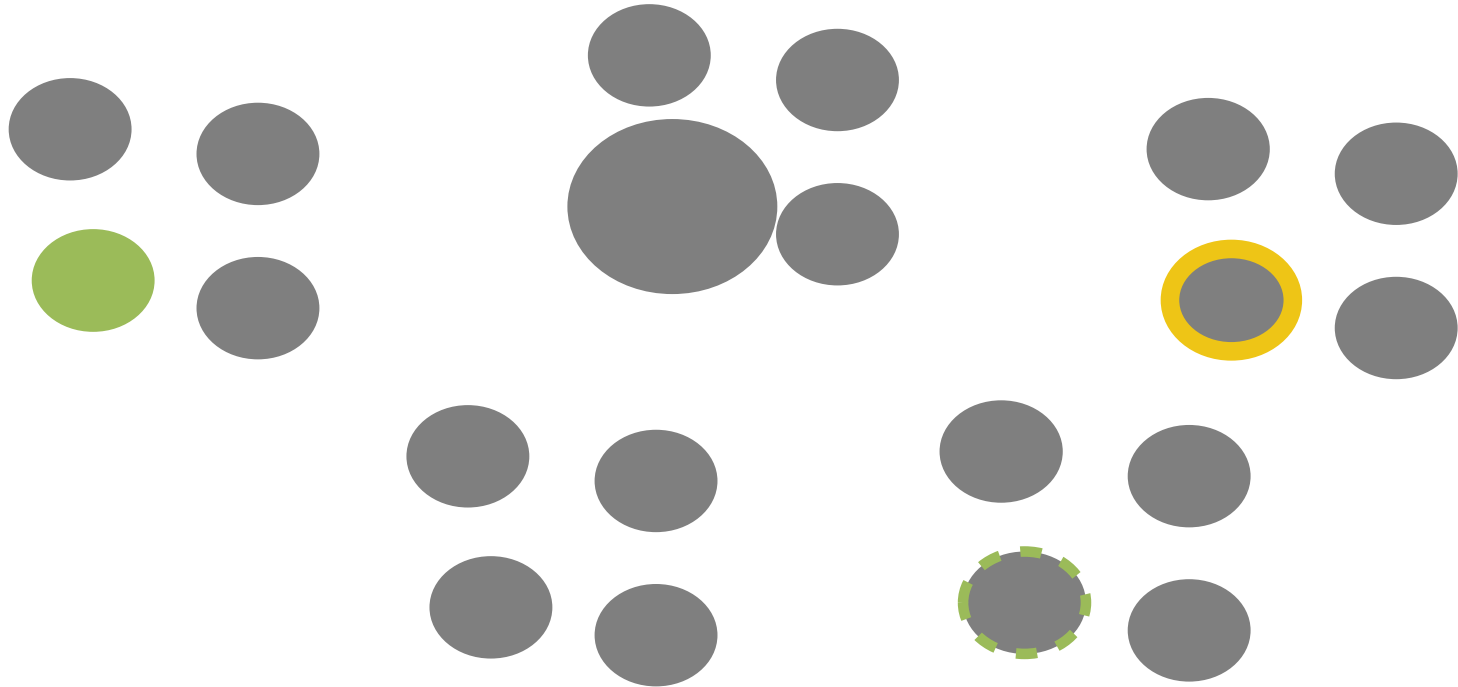
**EDU LEVEL =
POSTSECONDARY**

SELECTION OPERATIONS



HIGHLIGHTING

SELECTION + CHANGE IN APPEARANCE



SELECT

EXPLORE

FILTER

RECONFIGURE

ENCODE

ABSTRACT/ELABORATE

CONNECT

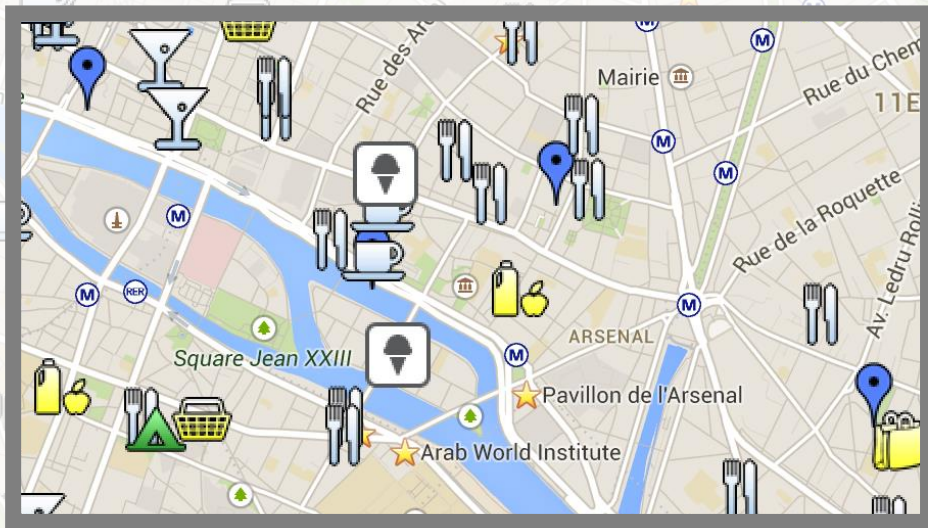
SHOW ME SOMETHING
ELSE

PROBLEM

Where am I?



NAVIGATION



PANNING



ZOOMING



NAVIGATION

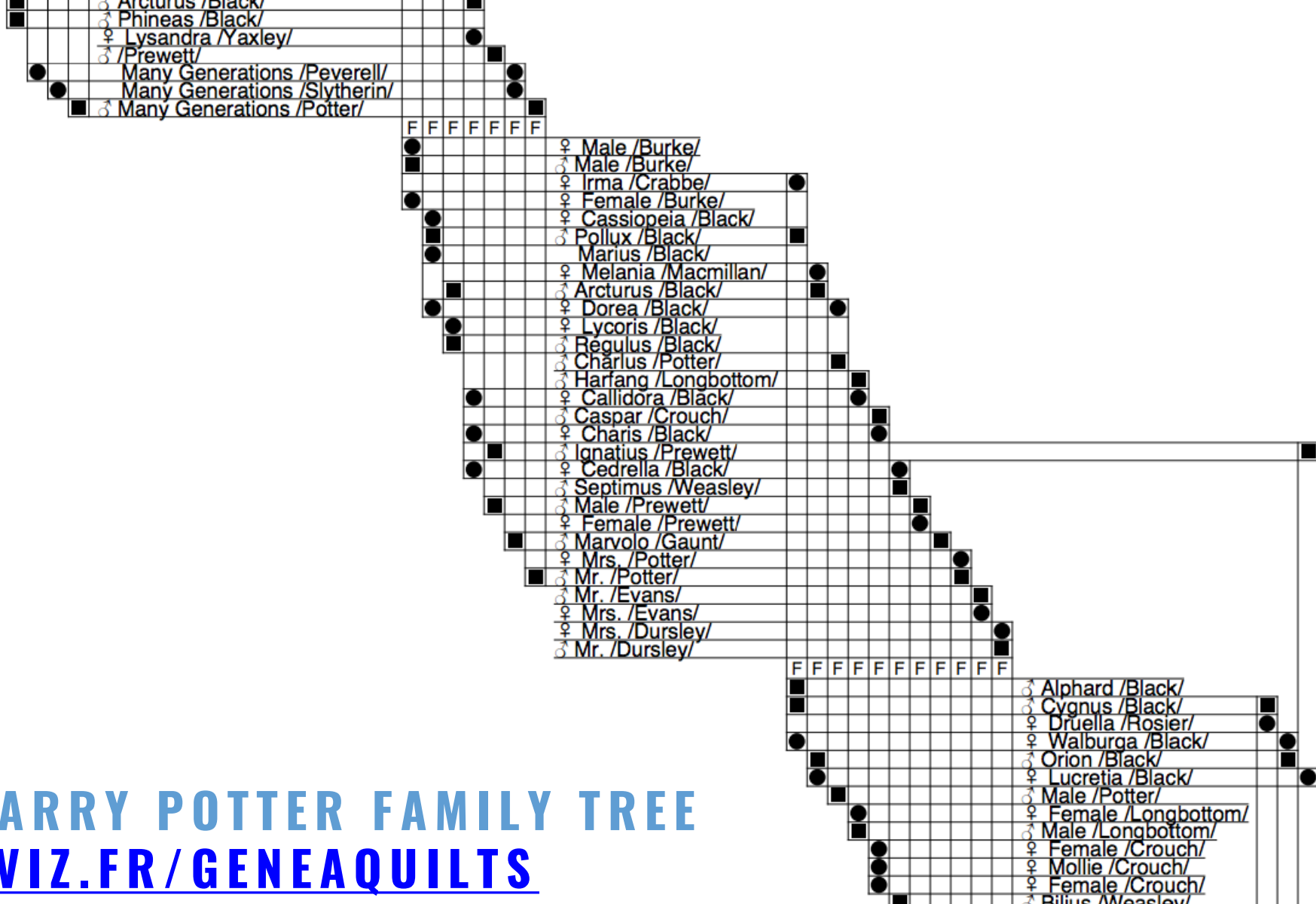


PANNING



ZOOMING





HARRY POTTER FAMILY TREE
AVIZ.FR/GENEAQUILTS

SELECT

EXPLORE

FILTER

SHOW ME SOMETHING
CONDITIONALLY

RECONFIGURE

ENCODE

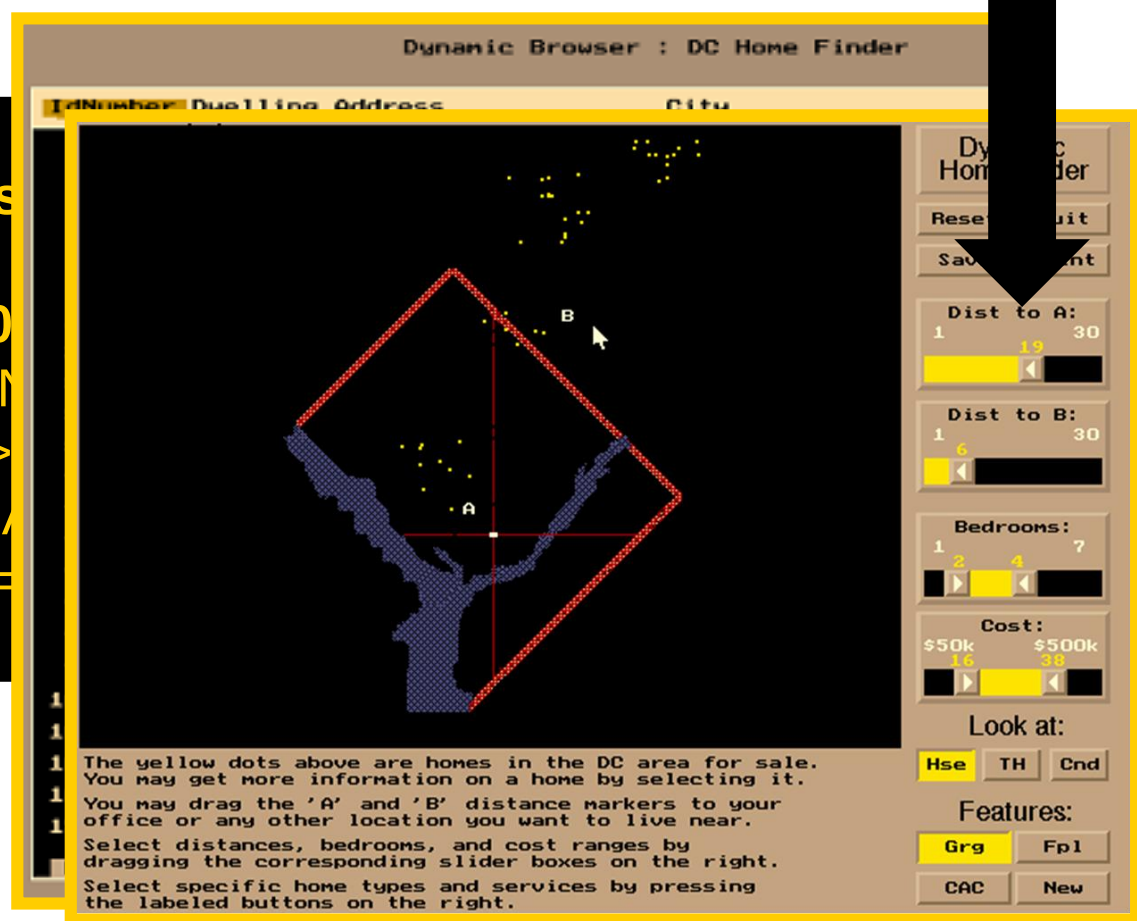
ABSTRACT/ELABORATE

CONNECT

FILTERING

```
> SELECT house-address  
FROM realty-db  
WHERE price >= 200,000  
price <= 400,000 AND  
bathrooms > 1  
garage == 2  
bedrooms >= 3
```

REPLACING A QUERY WITH
“DYNAMIC QUERY WIDGETS”



HOMEFINDER WILLIAMSON AND SCHNEIDERMAN 1992

**Dynamic Queries Demos:
Revised Homefinder
and Text Version
plus Health Statistics Atlas**

Ben Shneiderman

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DIRECT MANIPULATION

1. Visual representation of objects and actions
2. Rapid, incremental and reversible actions
3. Selection by pointing (not typing)
4. Immediate and continuous display of results

**Dynamic Queries Demos:
Revised HomeFinder
and Text Version
plus Health Statistics Atlas**

Ben Shneiderman

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CRIMESPOTTING



Report data last published by Oakland Police: 314 days ago

Home

Map

Crime Reports

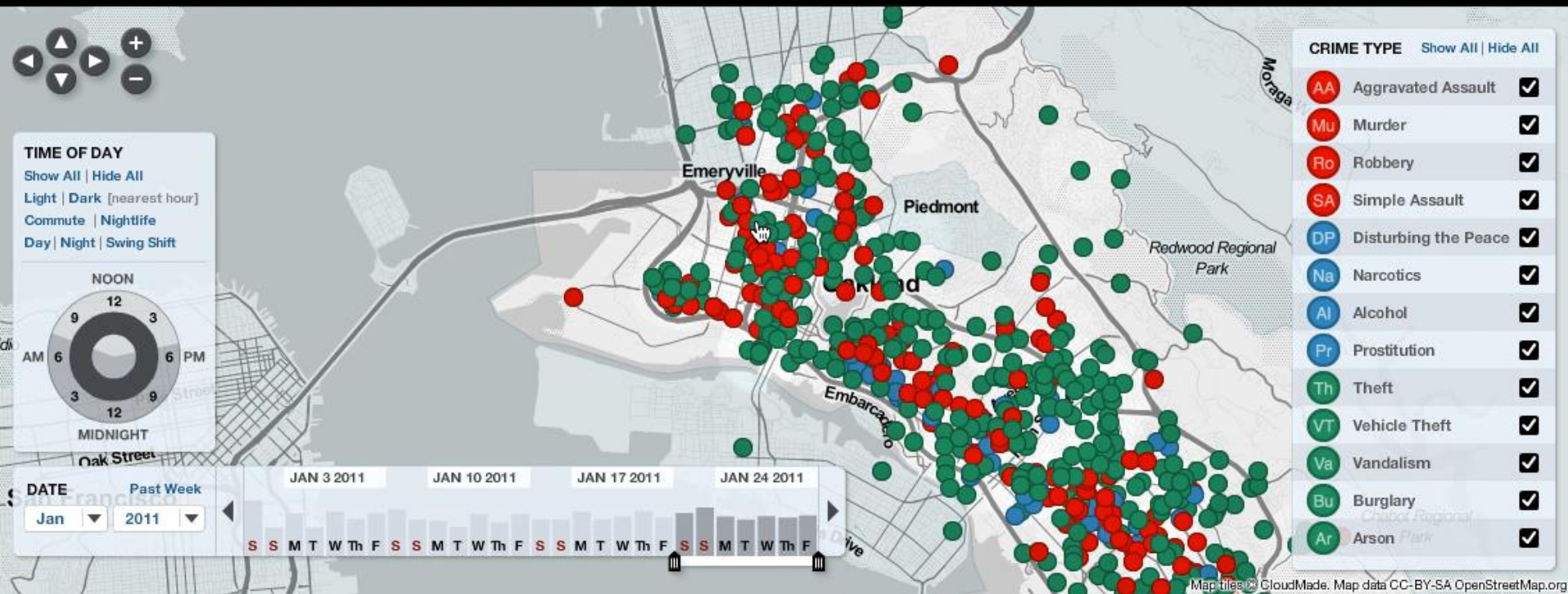
Police Beats

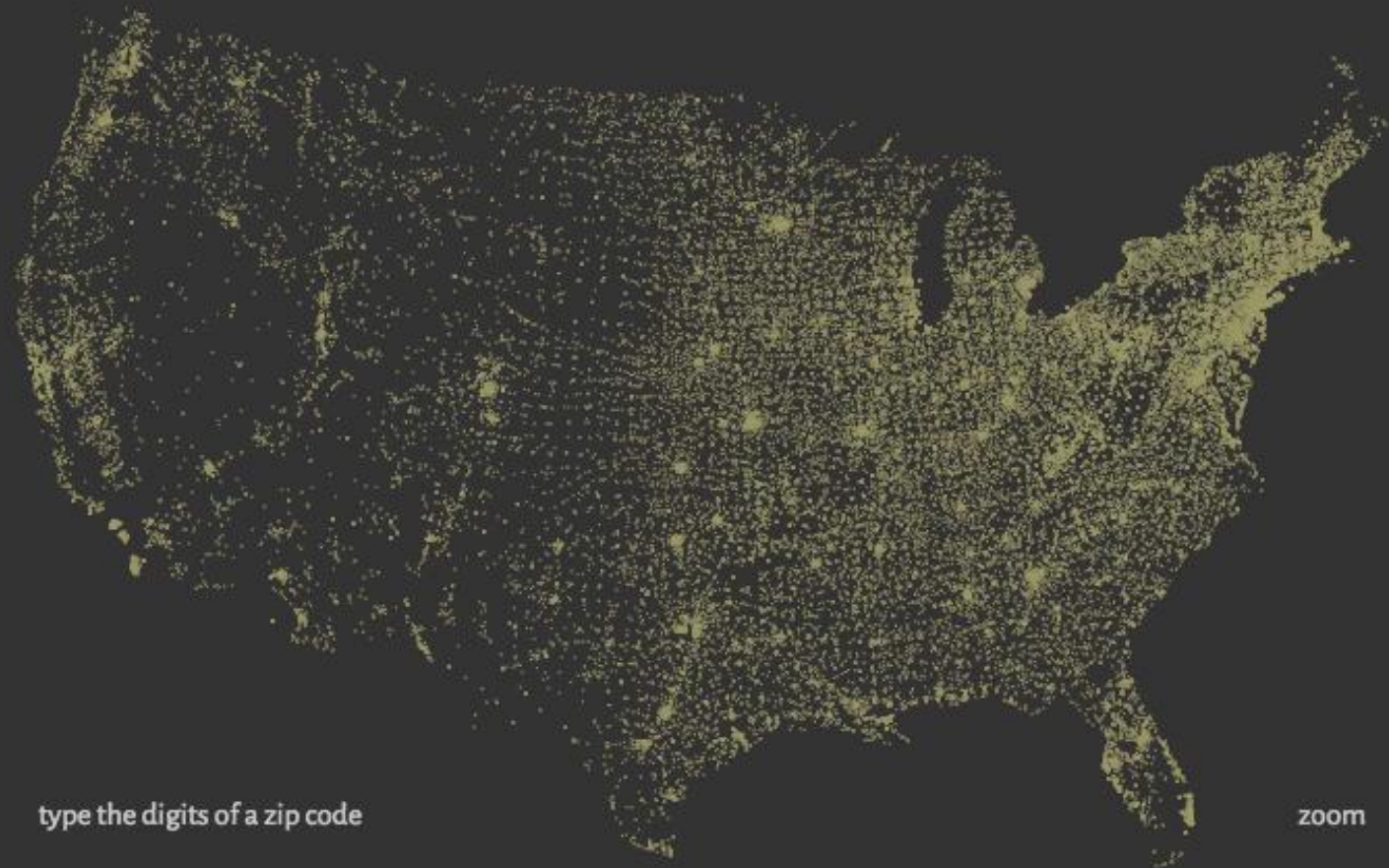
Alerts

API

About

Feedback





Hit the letter **z**, or click the word **zoom** to enable or disable zooming.

Baby Name >

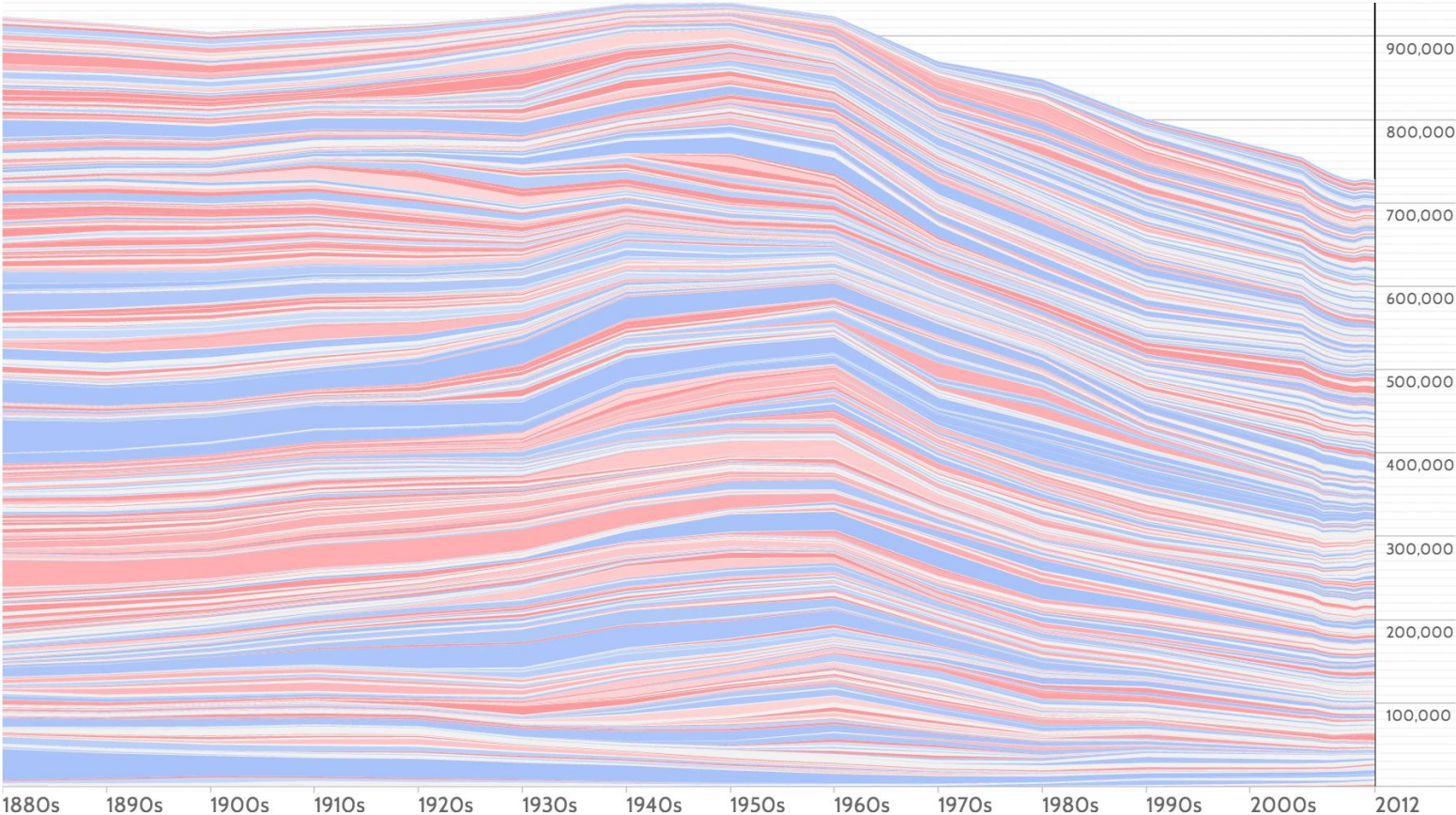
☒ Both ☐ Boys ☐ Girls

Current rank: boys

1000	500	100	25	1
------	-----	-----	----	---

girls

1000	500	100	25	1
------	-----	-----	----	---



BABY NAME VOYAGER MARTIN WATTENBERG 2005

SELECT

EXPLORE

FILTER

SHOW ME A DIFFERENT
ARRANGEMENT

RECONFIGURE

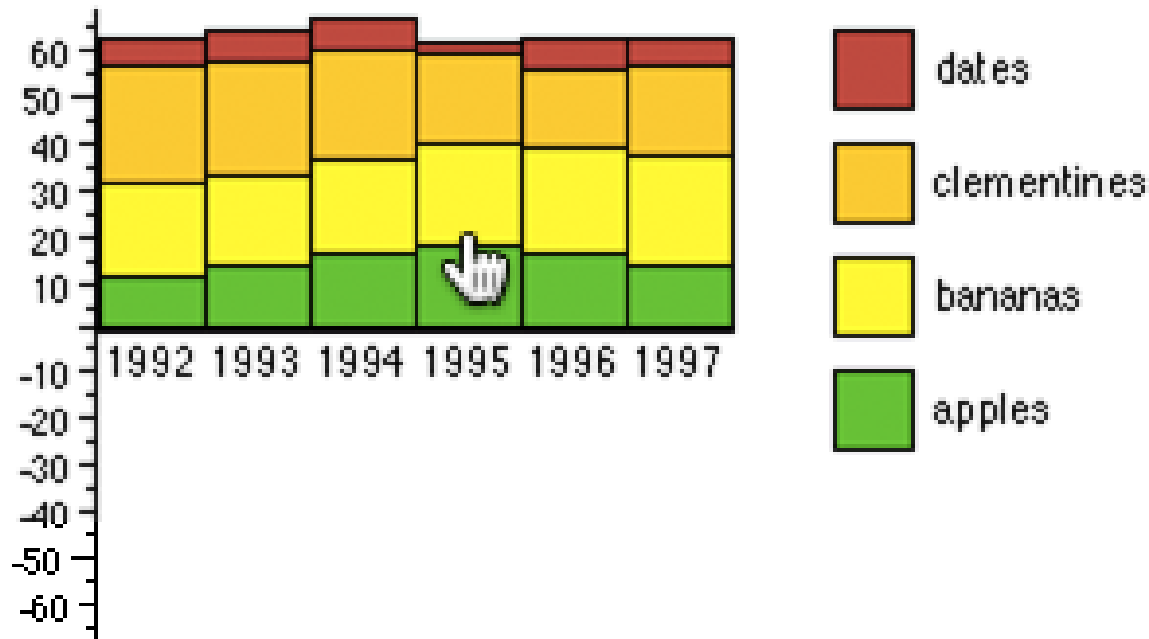
ENCODE

ABSTRACT/ELABORATE

CONNECT

RE-ARRANGING DATA

Fruit Sales 1992-1997



INTERACTIVE STACKED HISTOGRAMS [DIX & ELLIS, 1998]

Graph Viewer

Roll-up by:

All

Visualization:

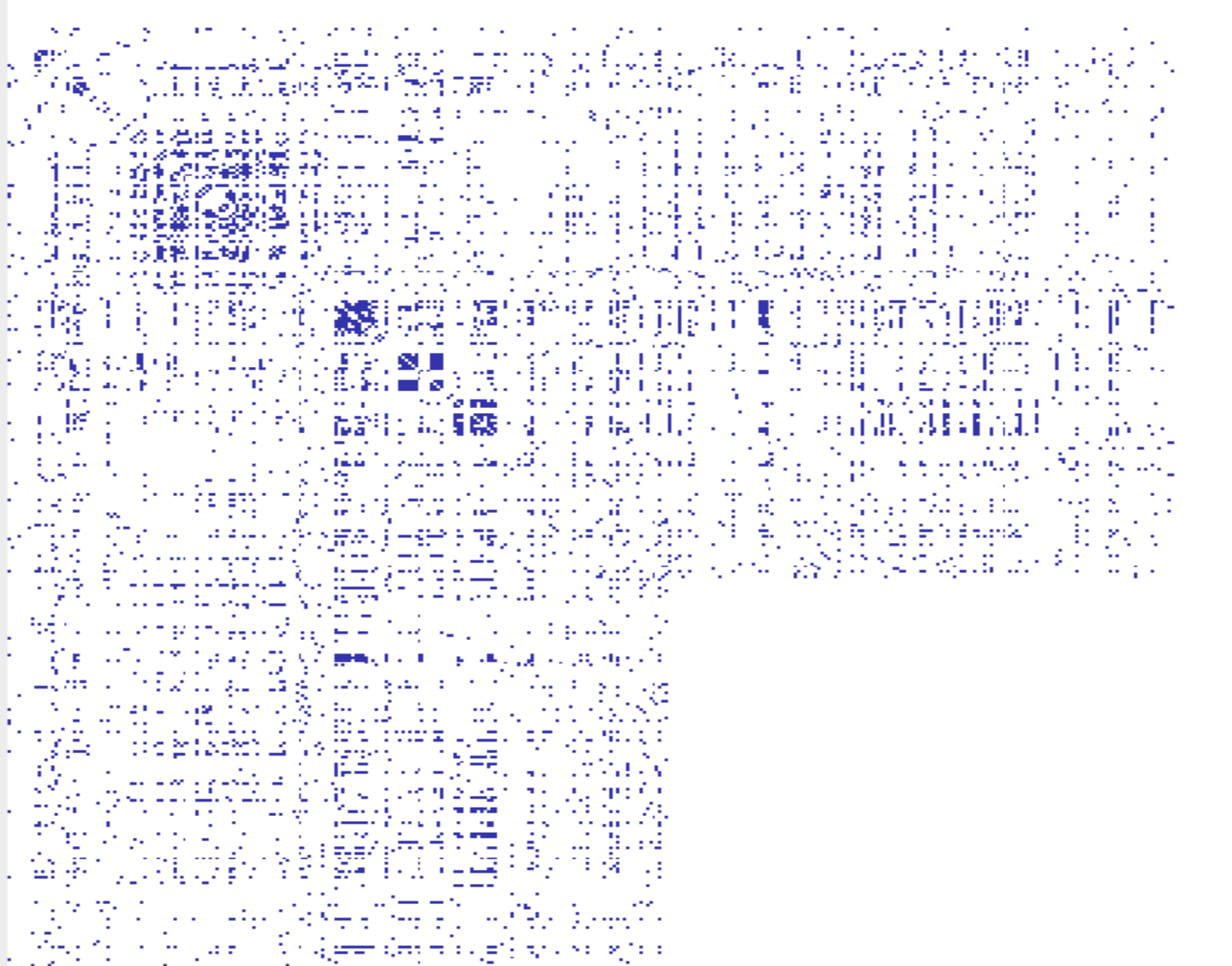
Matrix

Sort by:

None

Edge centrality

0 1



Graph Viewer

Roll-up by:

All

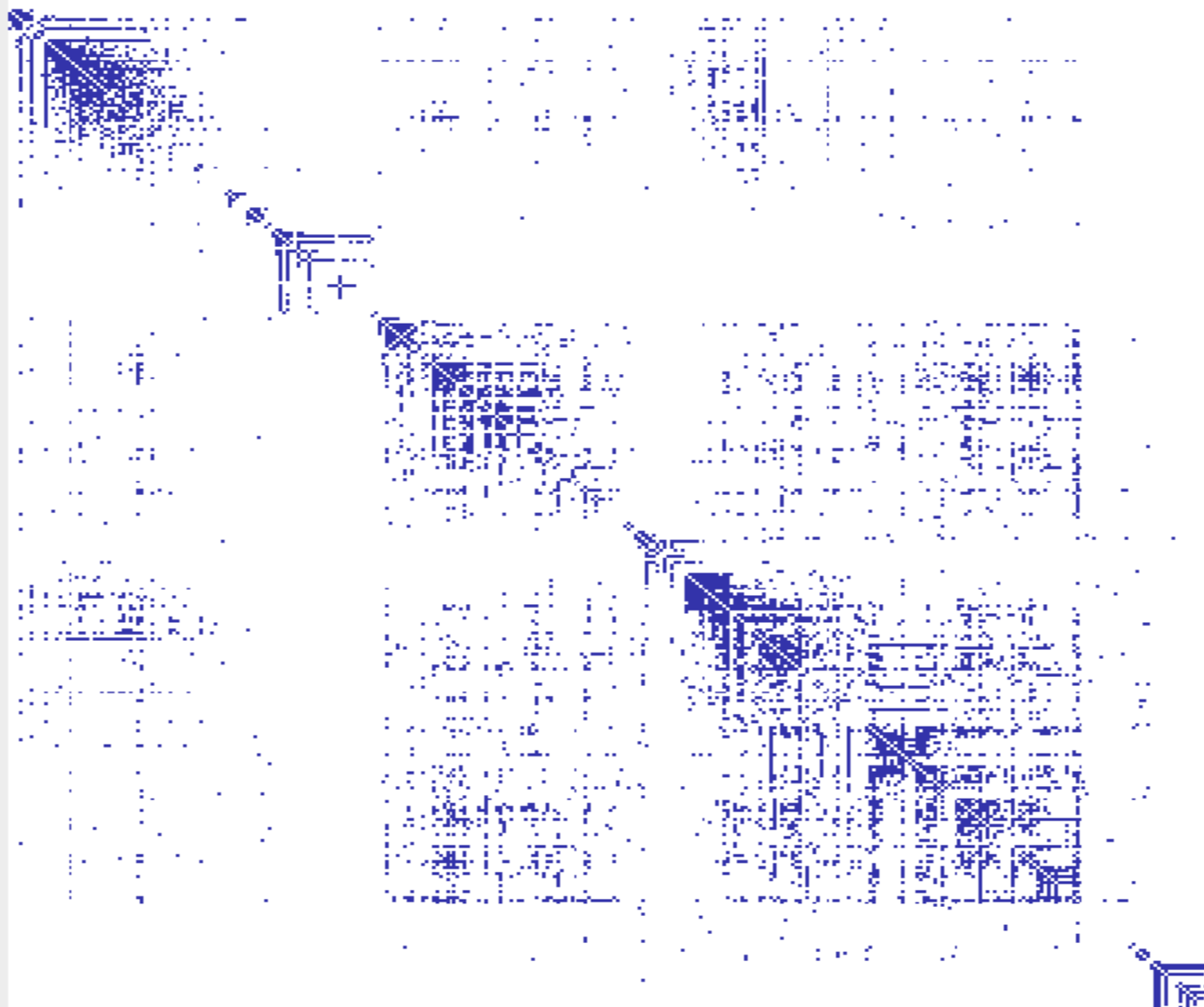
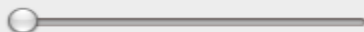
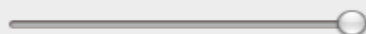
Visualization:

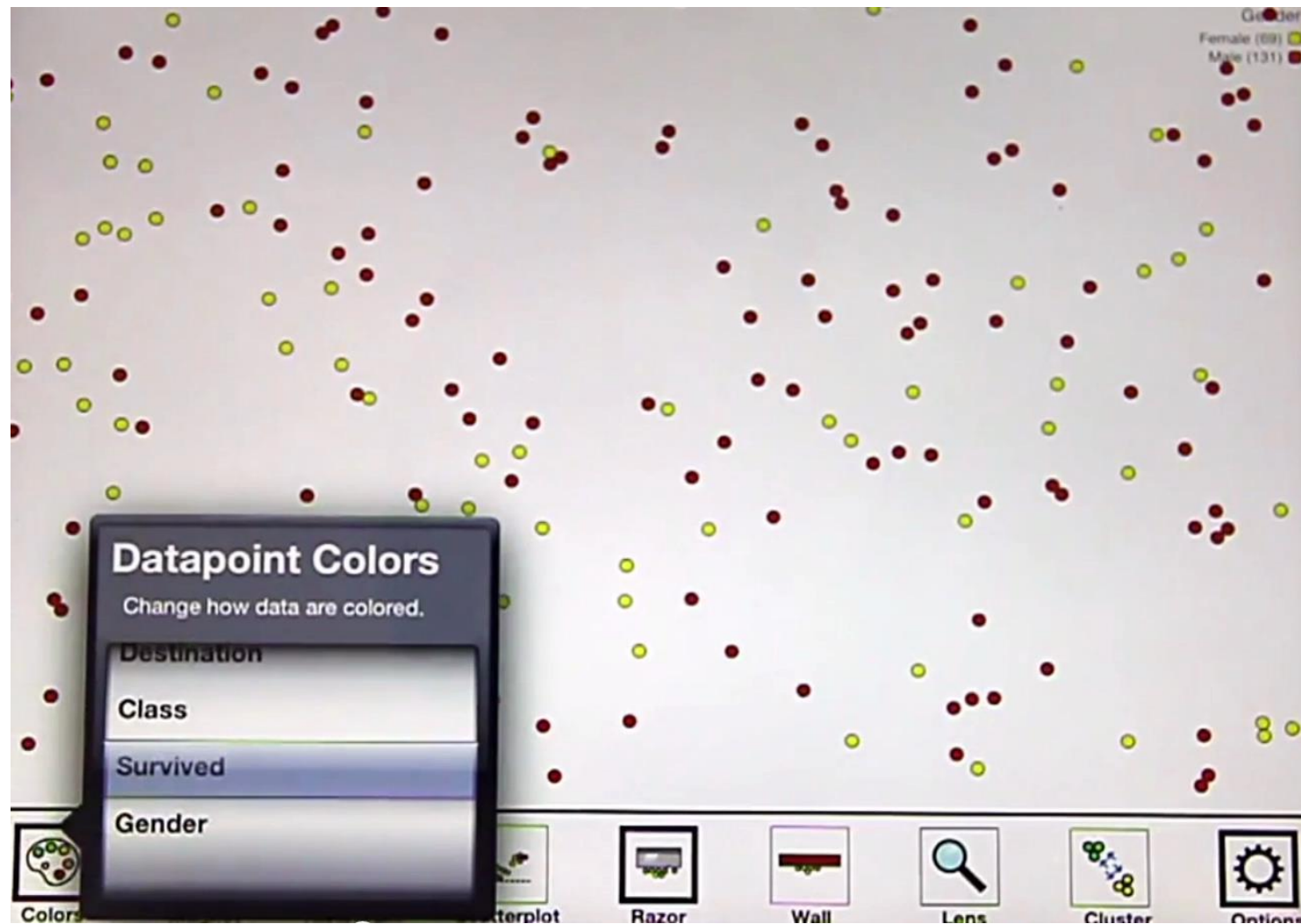
Matrix

Sort by:

Linkage

Edge centrality filters:





KINETICA [RZESZORTARKSI & KITTUR 2013]

SELECT
EXPLORE
FILTER
RECONFIGURE
ENCODE
ABSTRACT/ELABORATE
CONNECT

SHOW ME A DIFFERENT
REPRESENTATION

SELECT

EXPLORE

FILTER

RECONFIGURE

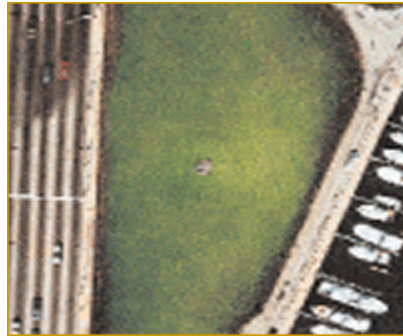
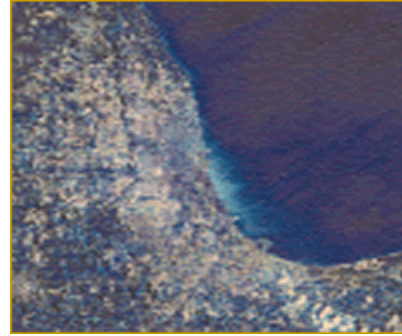
ENCODE

SHOW ME MORE
OR LESS DETAIL

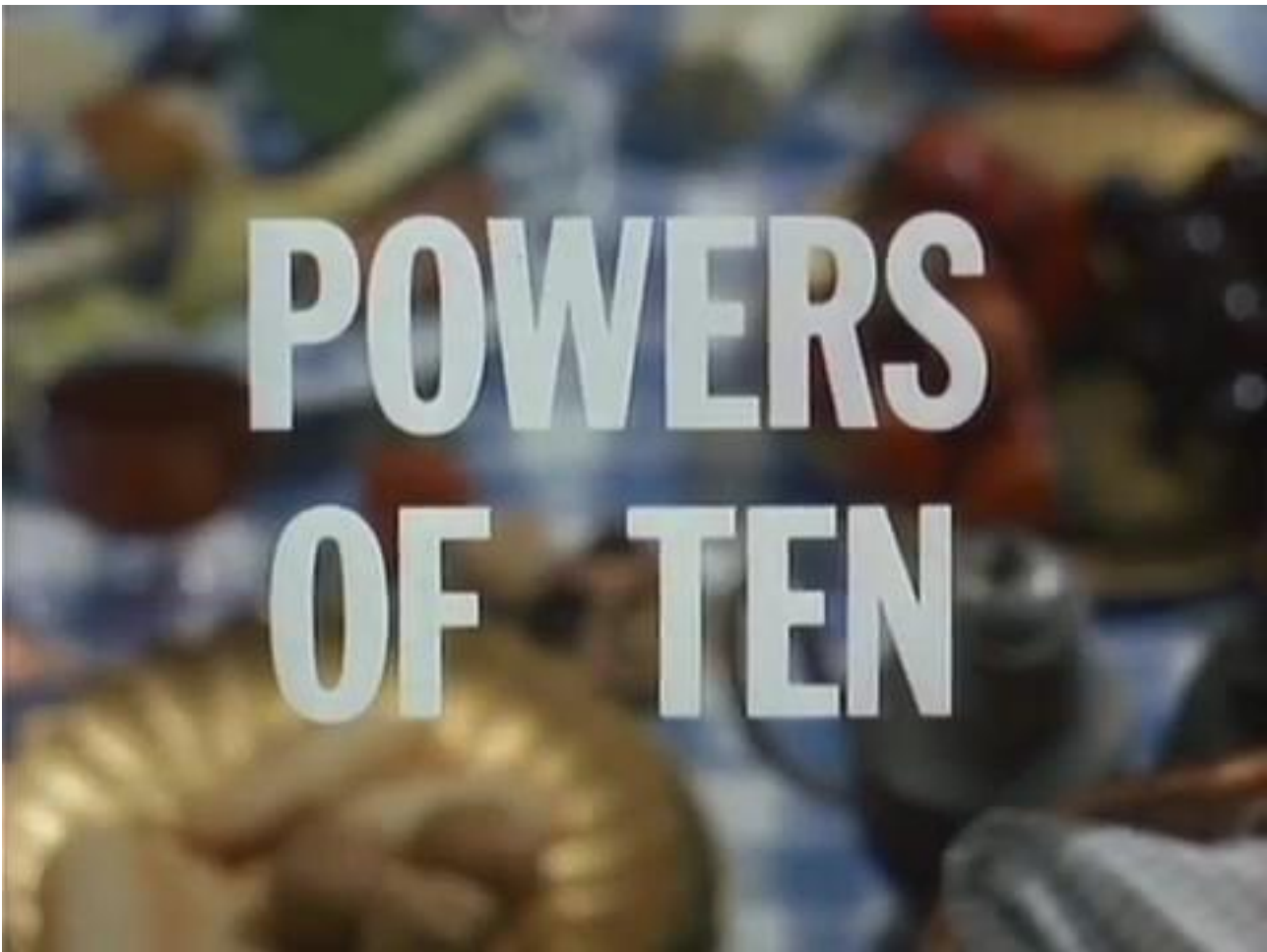
ABSTRACT/ELABORATE

CONNECT

CHANGING LEVELS OF ABSTRACTION

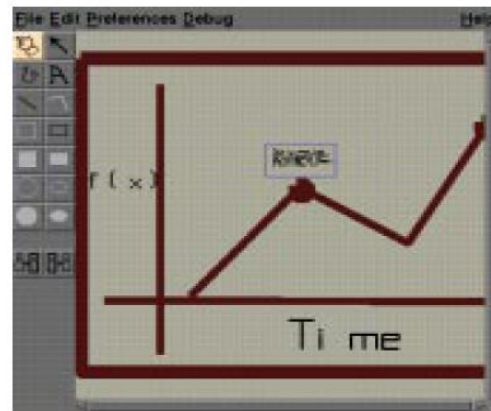
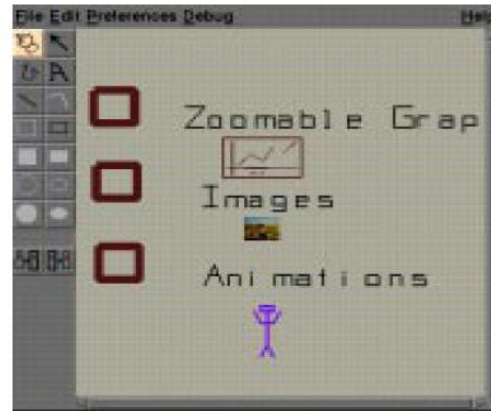
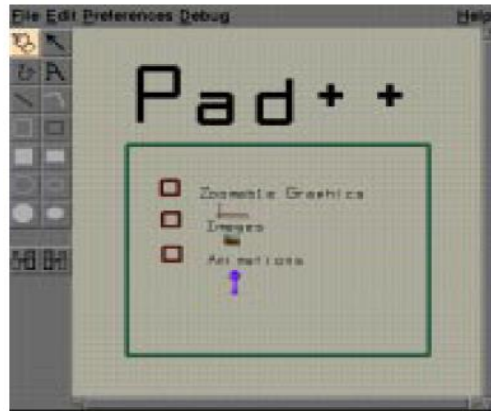
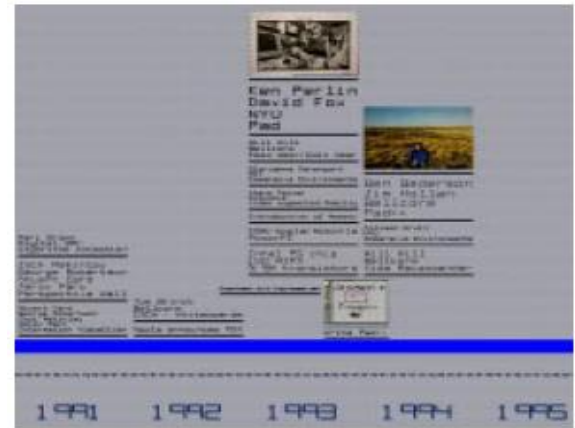
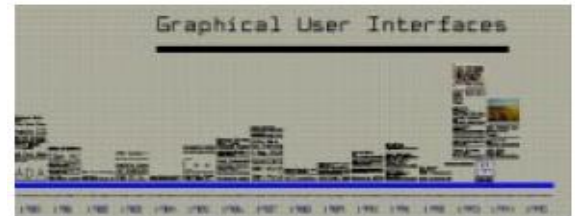
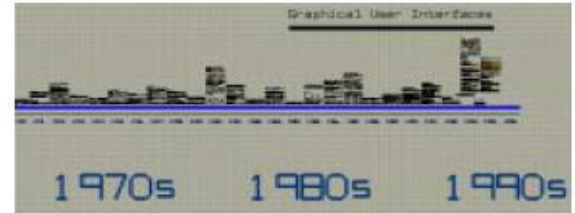


POWERS OF TEN RAY & CHARLES EAMES 1977



POWERS OF TEN

SEMANTIC ZOOMING



PAD++ BEDERSON AND HOLLAN 1994

LiveRAC

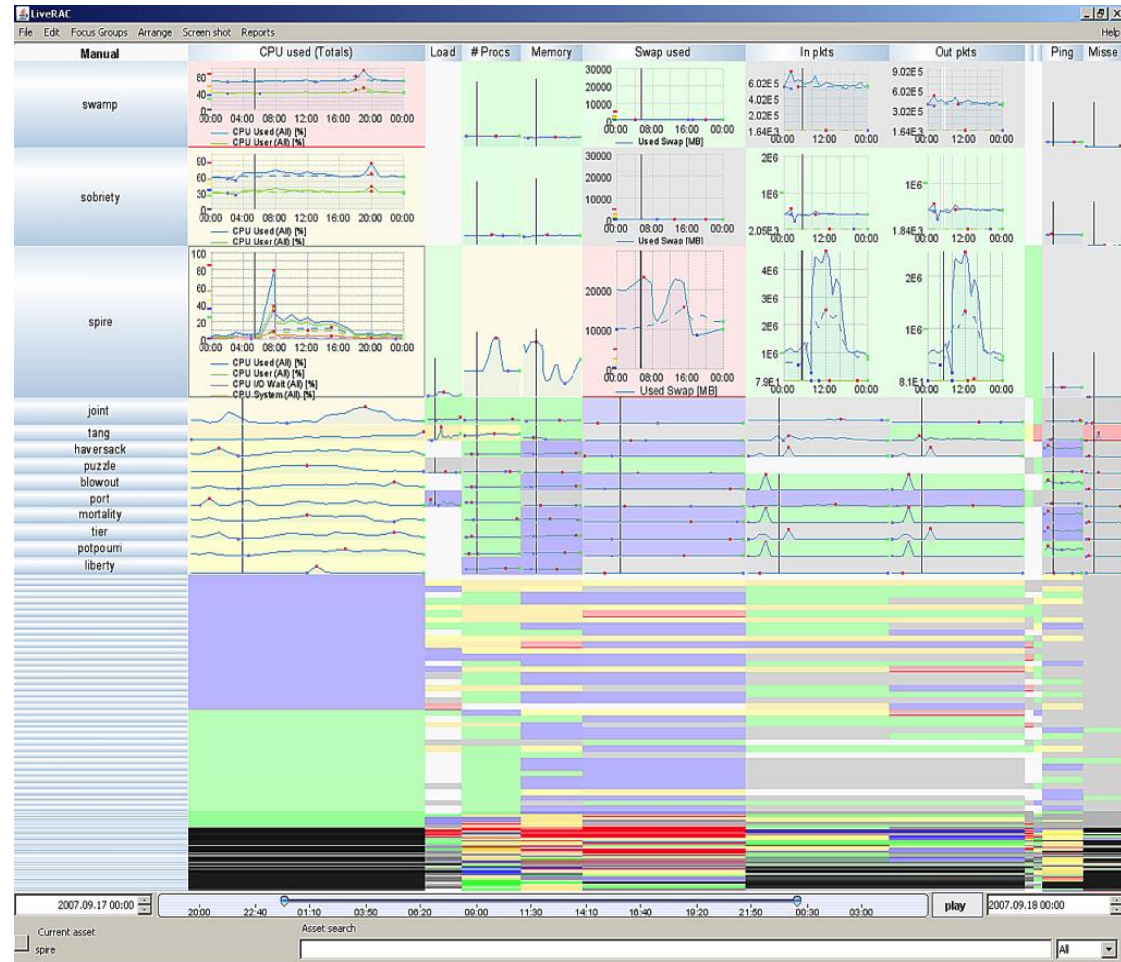
ENCODINGS CHANGE

—COLORED BOX

—SPARKLINE

—SIMPLE LINE CHART

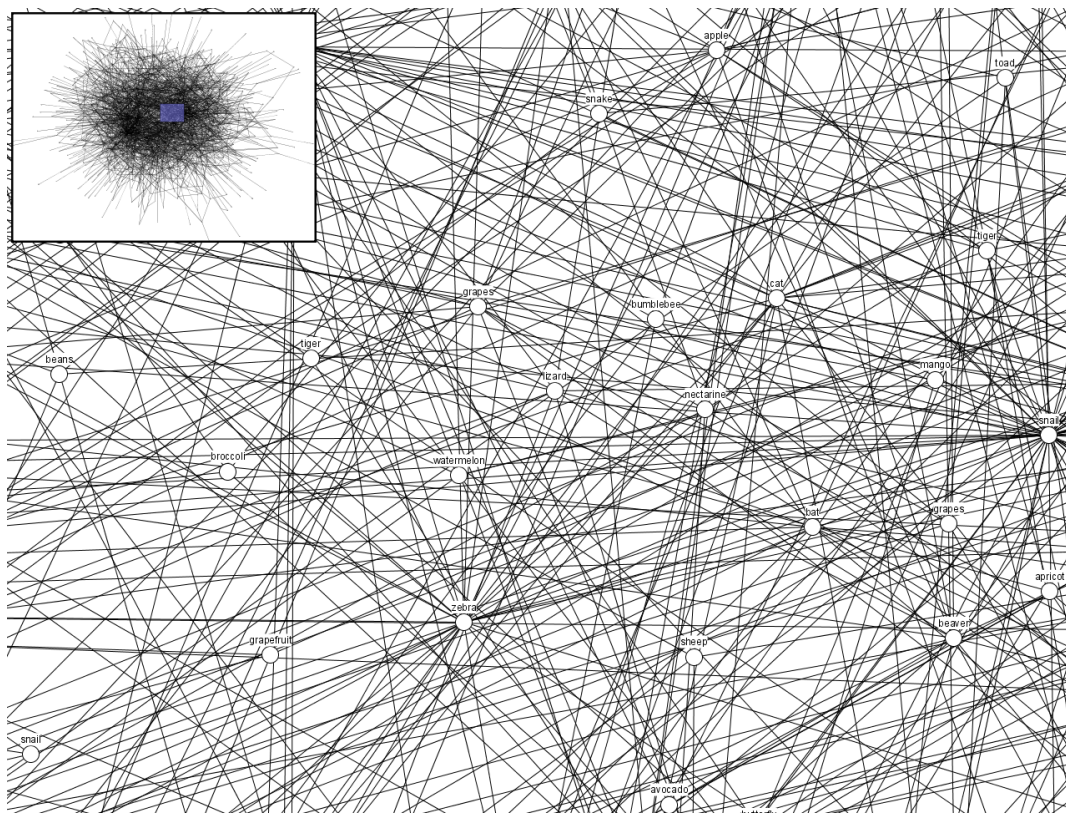
—FULL CHART: AXES AND
TICKMARKS



MCLACHLAN ET AL. 2008

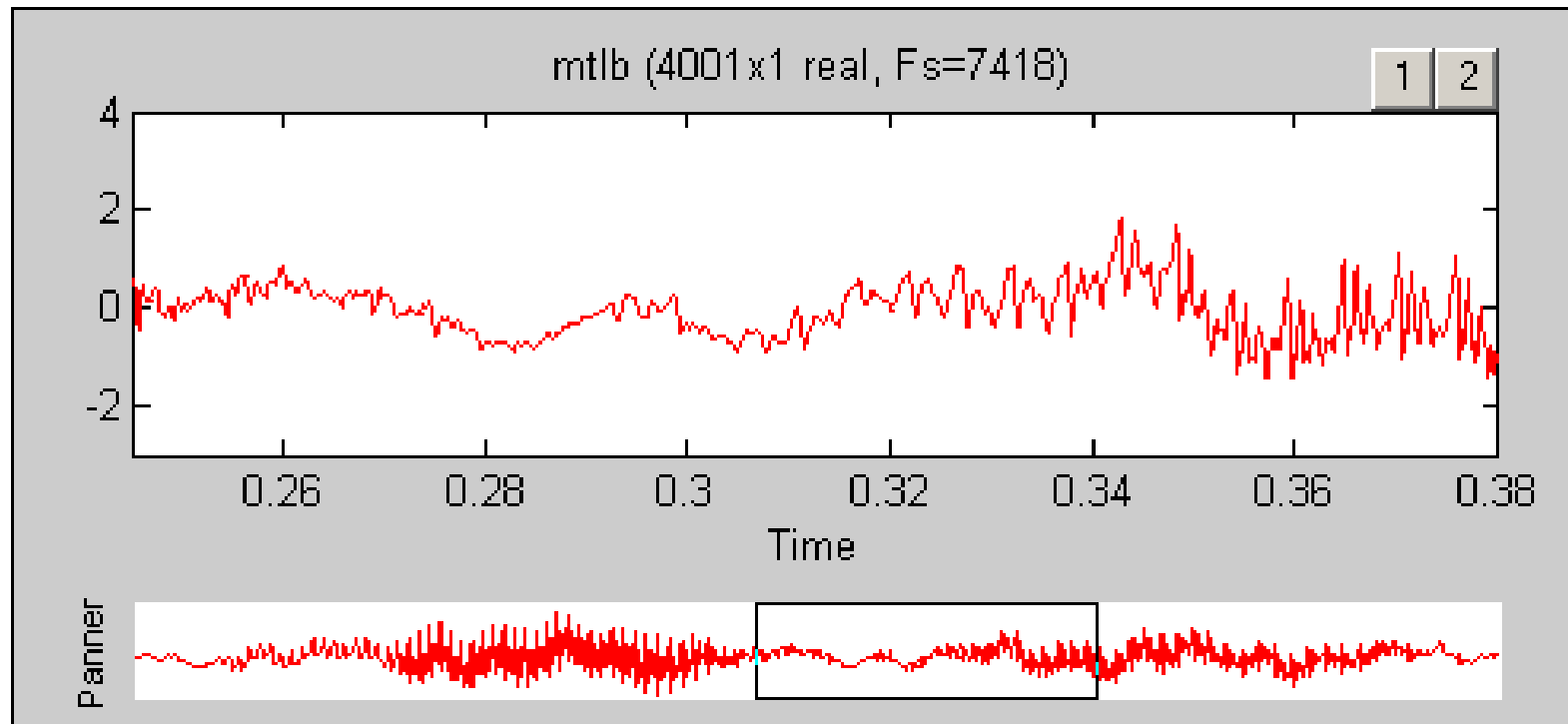
OVERVIEW + DETAIL

Panning a large graph



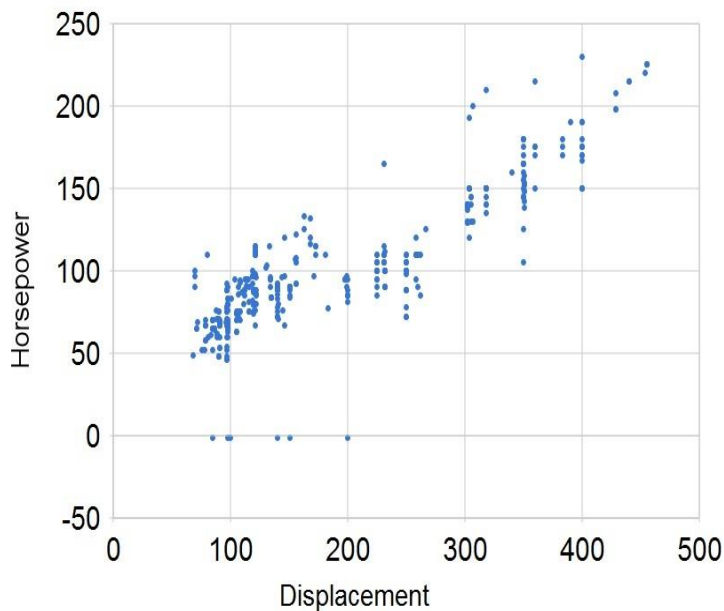
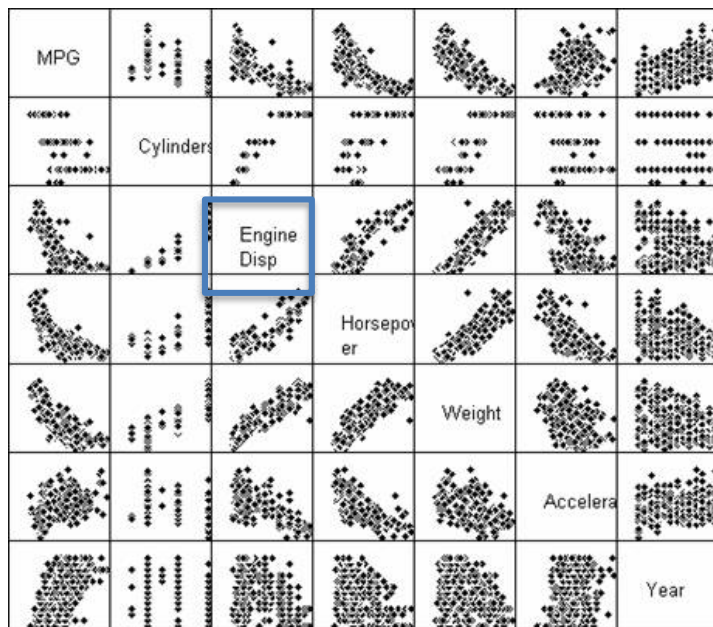
OVERVIEW + DETAIL

Panning a line chart



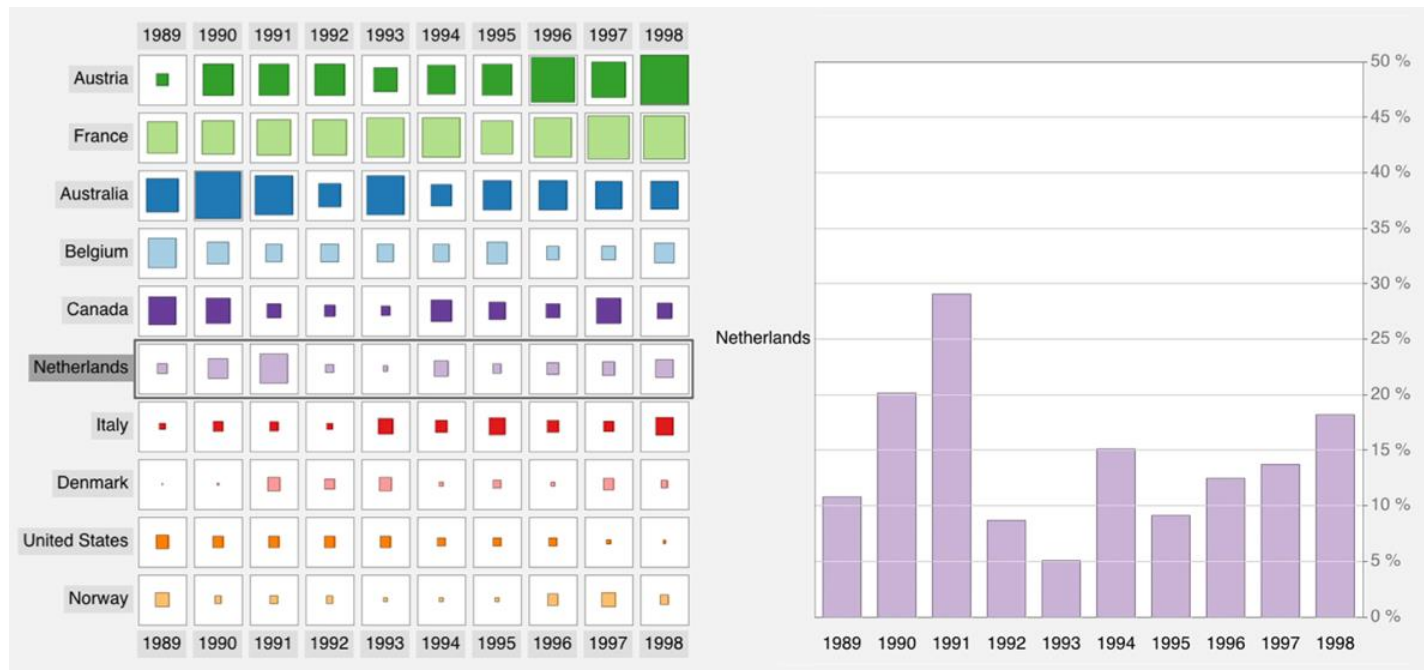
OVERVIEW + DETAIL

Browsing Multiple Views



OVERVIEW + DETAIL

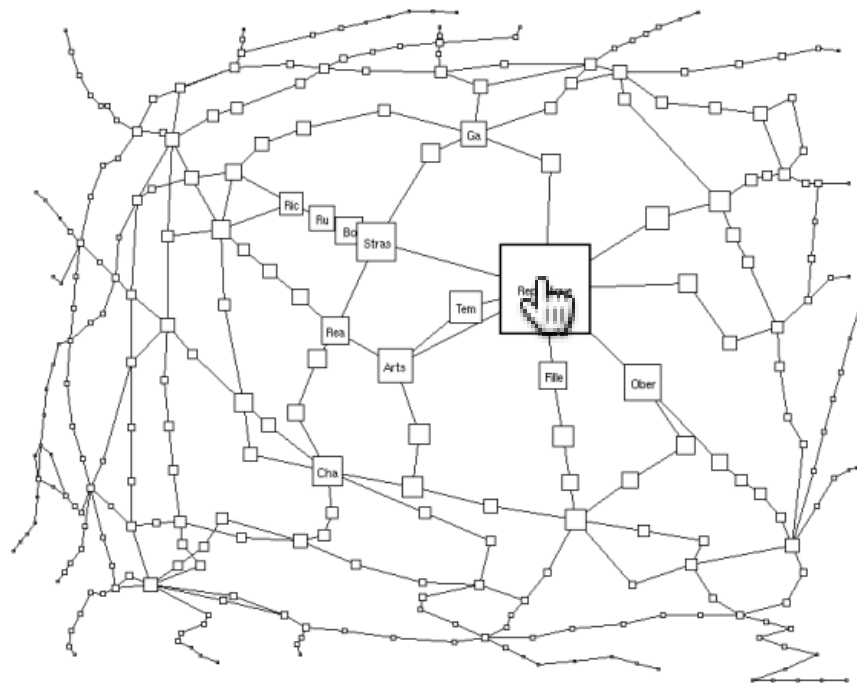
Browsing Multiple Views



FOCUS + CONTEXT

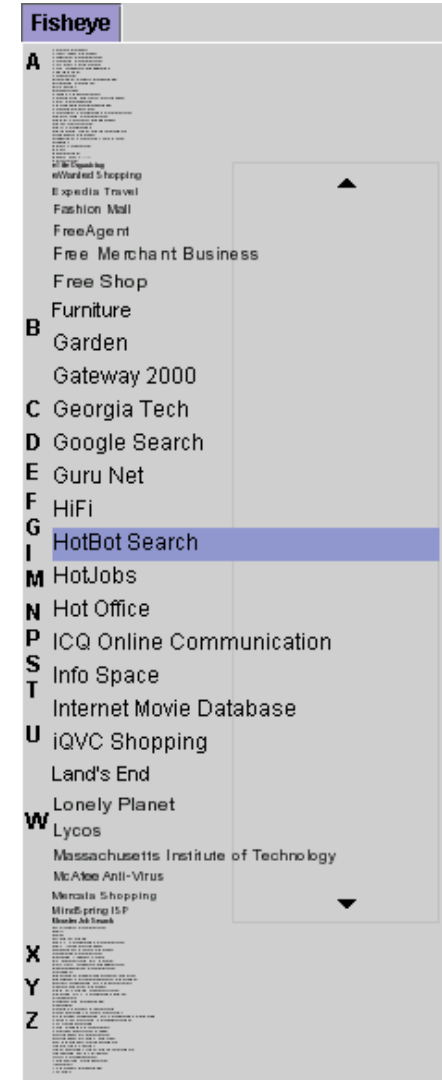
Space Distortion

1) Fisheye Views of Graphs



FOCUS + CONTEXT

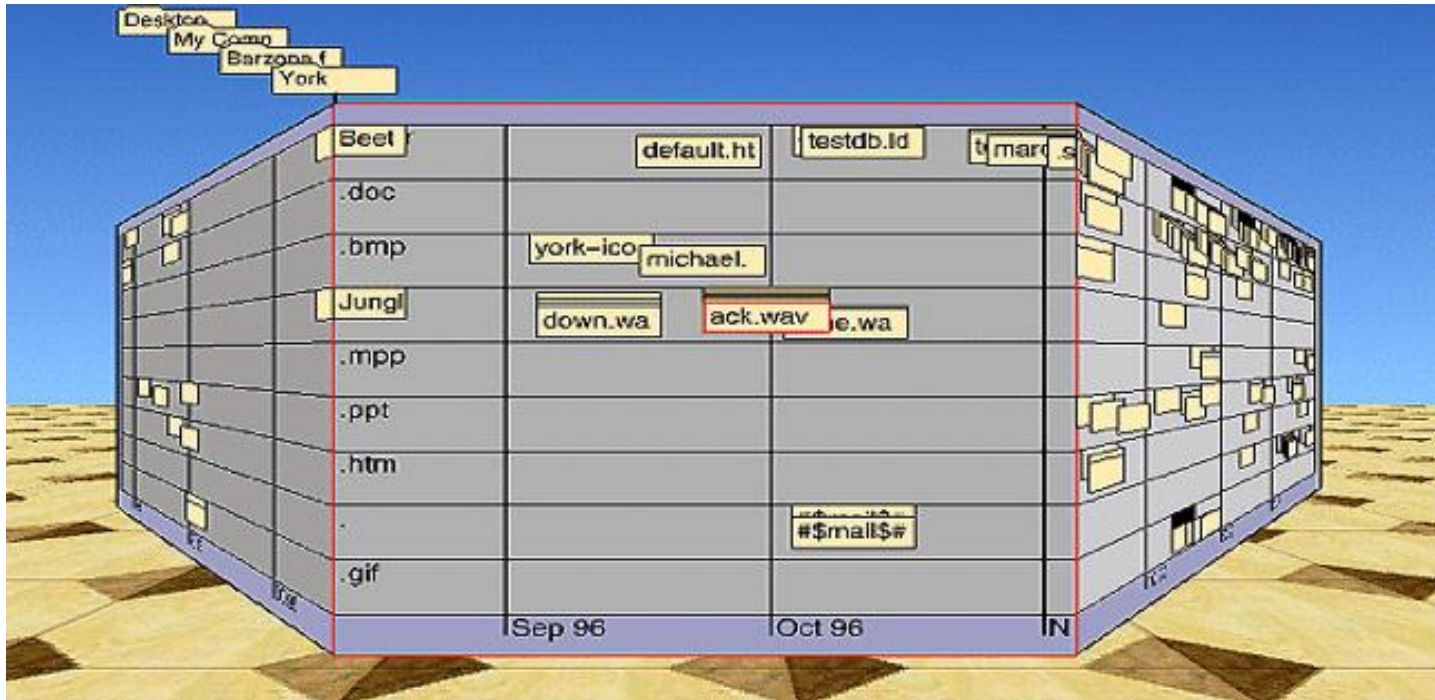
Space Distortion
2) Fisheye Menus



FOCUS + CONTEXT

Space Distortion

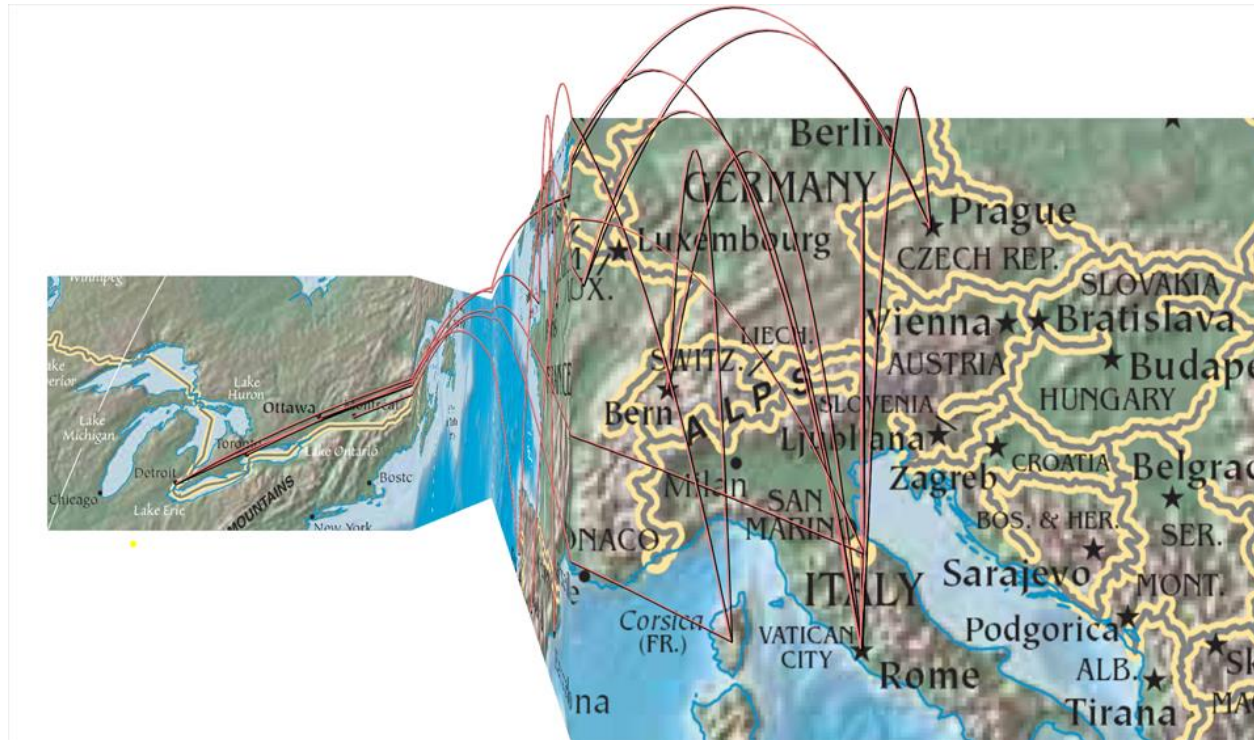
3) Perspective Wall



FOCUS + CONTEXT

Space Distortion

4) Melange



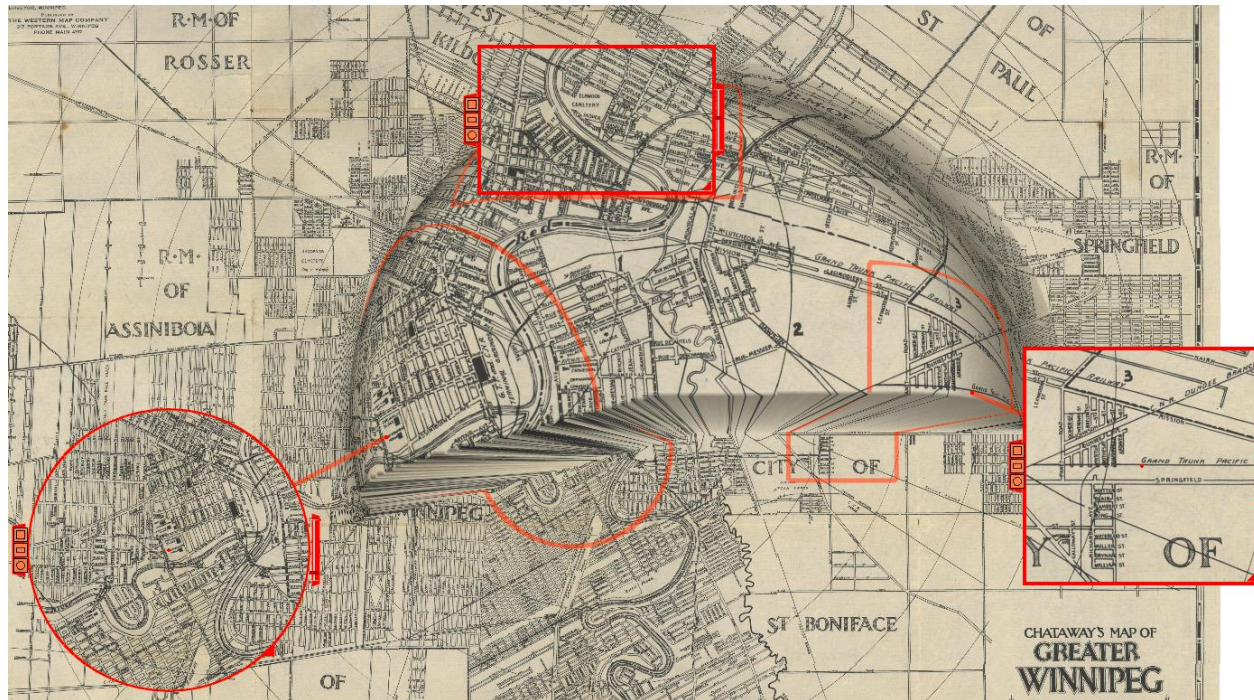
Mélange

Space-Folding for Multi-Focus Interaction

Niklas Elmqvist¹, Nathalie Henry^{1,2,3}, Yann Riche^{1,2,4} and Jean-Daniel Fekete¹
¹INRIA ²LRI, Univ. Paris-Sud ³University of Sydney ⁴University of Queensland
{elm, nhenry, riche, fekete}@lri.fr

FOCUS + CONTEXT

The Undistort Lens





FOCUS + CONTEXT

Table Lens

The screenshot shows the Inxight Table Lens application window titled "Inxight Table Lens - [foremost.txt]". The menu bar includes File, Edit, View, Tools, Options, Window, and Help. The toolbar contains icons for file operations and navigation. The main display area shows a table with columns: Year, Quarter, Product, Channel, Region, Saleperson, Units, Revenue, and Profits. The table is divided into two sections: a "Context" view on the left showing a dense, colorful grid of data points, and a "Focus" view on the right showing a detailed view of the selected data rows. The focus view highlights rows 126, 444, 445, 446, and 447. The data in the focus view is as follows:

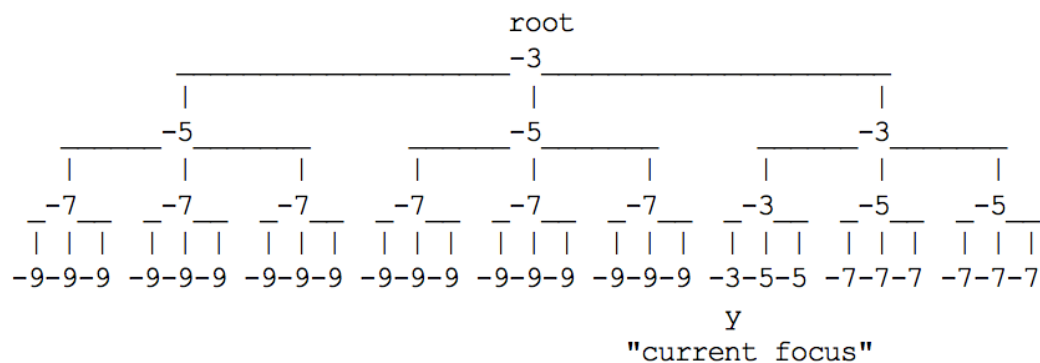
	Year	Quarter	Product	Channel	Region	Saleperson	Units	Revenue	Profits
126	1993	2	ForeCode Pro	Direct Sales	Southwest	Kevin Polen	1029	439898	171561
444	1993	4	ForeCode Pro	VAR	West	Tom Tuttle	302	122310	51371
445	1993	4	ForeCode Pro	VAR	West	Ann Thomas	302	122310	51371
446	1993	3	ForeMost S...	Direct Sales	Midwest	Sal Vitatone	301	2.8595e+006	929338
447	1993	3	ForeMost S...	VAR	South	Gary Copper	301	2.709e+006	948150

FOCUS + CONTEXT

Generalized Fisheye Views

(c) The Fisheye DOI:

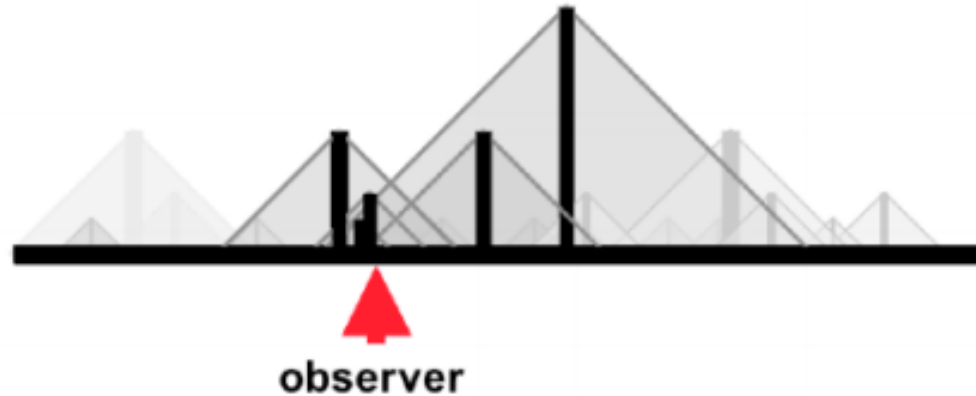
$$\begin{aligned} \text{DOI}_{\text{fisheye}(\text{tree})}(x|y) &= \text{API}(x) - D(x,y) \\ &= -(d_{\text{tree}}(x,y) + d_{\text{tree}}(x,\text{root})) \end{aligned}$$



FOCUS +

Generalized Fisheye Views

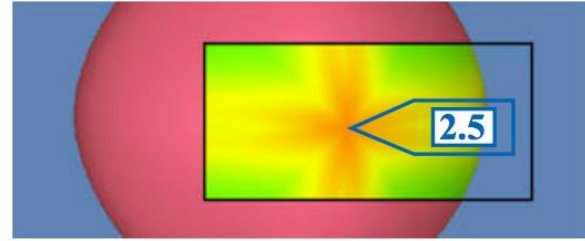
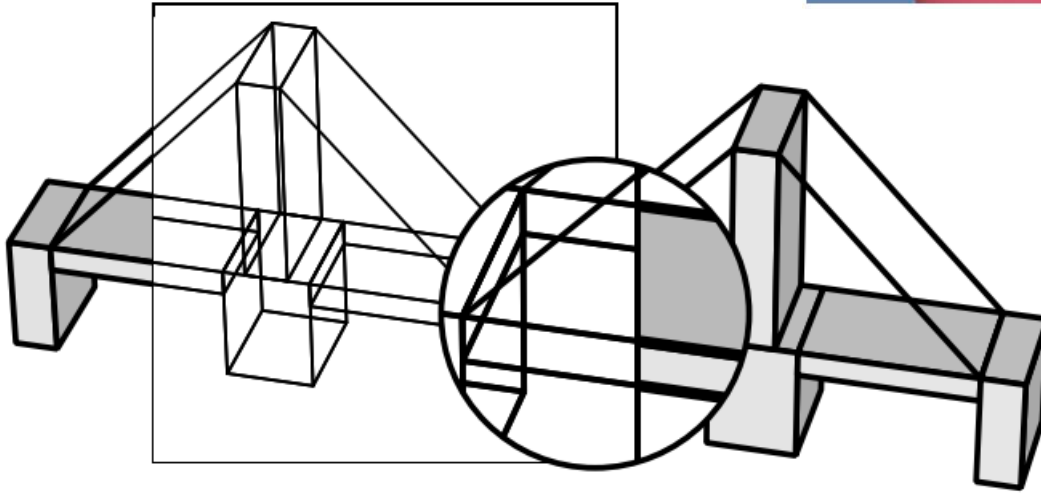
**Pattern of Influence
on the Observer:
Fisheye Subset of
entities**



Furnas, 2010

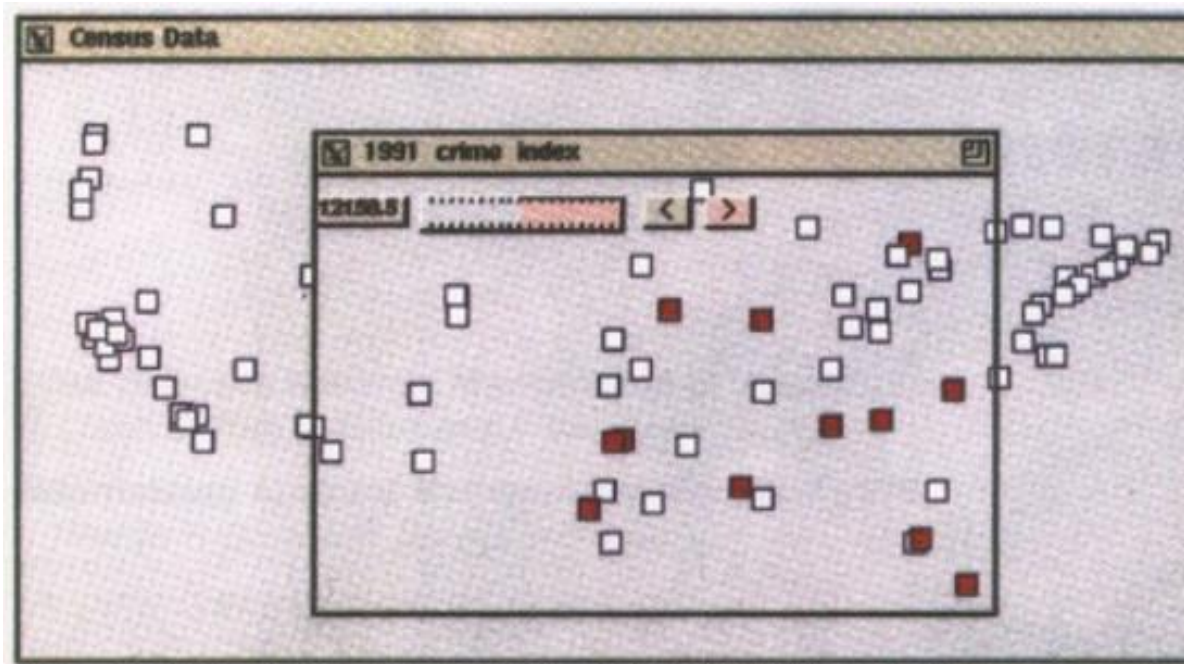
A Fisheye Follow-Up: Further Reflections on Focus + Context

MAGIC LENSES



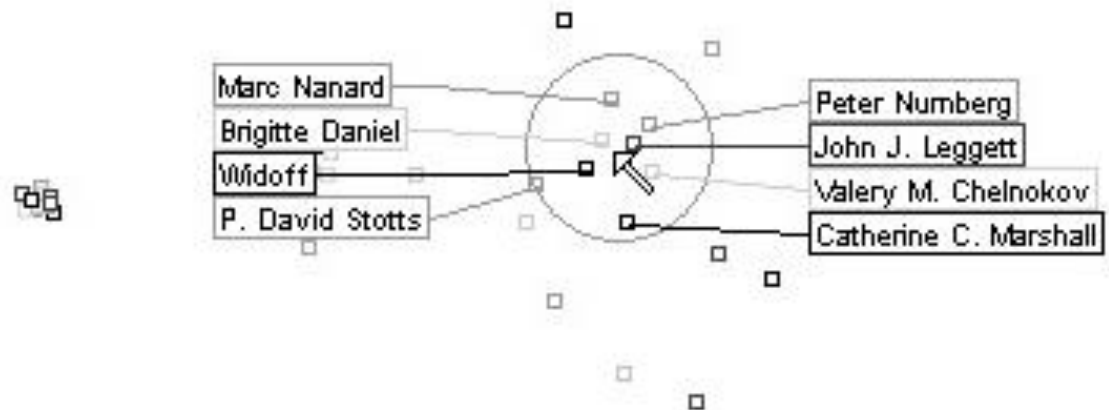
MAGIC LENSES

Movable filters for dynamic queries



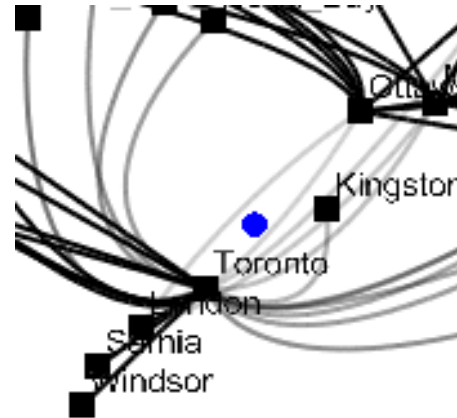
MAGIC LENSES

Exentric Labeling



MAGIC LENSES

Edge lenses



SELECT
EXPLORE
FILTER
RECONFIGURE
ENCODE
ABSTRACT/ELABORATE
CONNECT

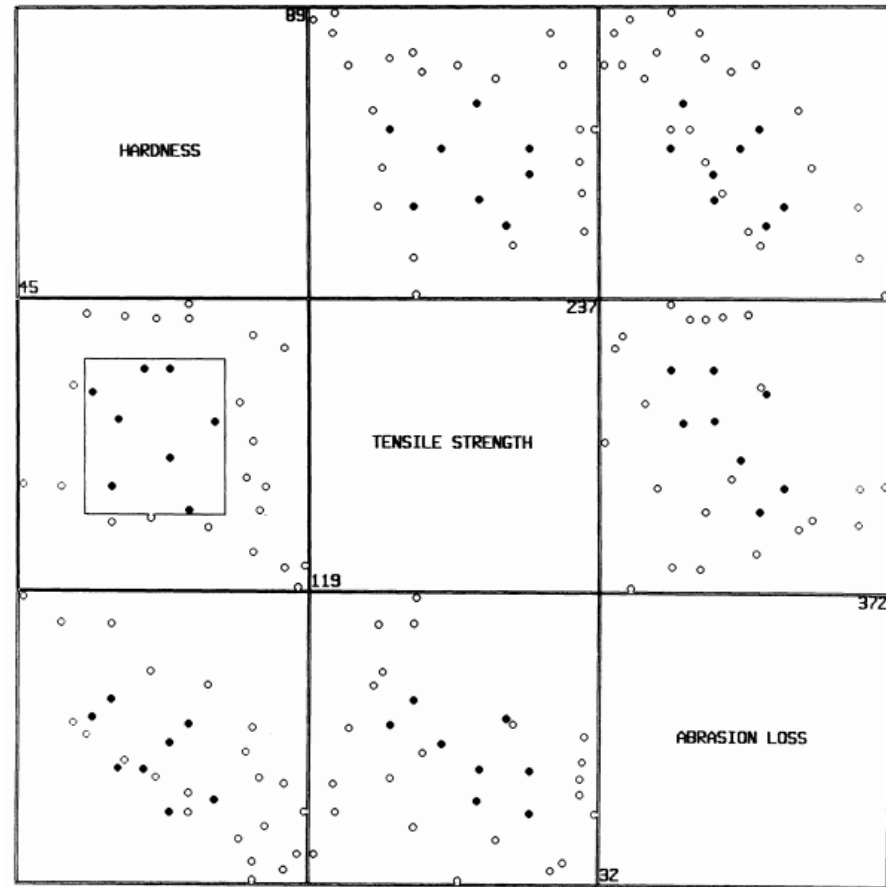
**SHOW ME RELATED
ITEMS**

BRUSHING AND LINKING

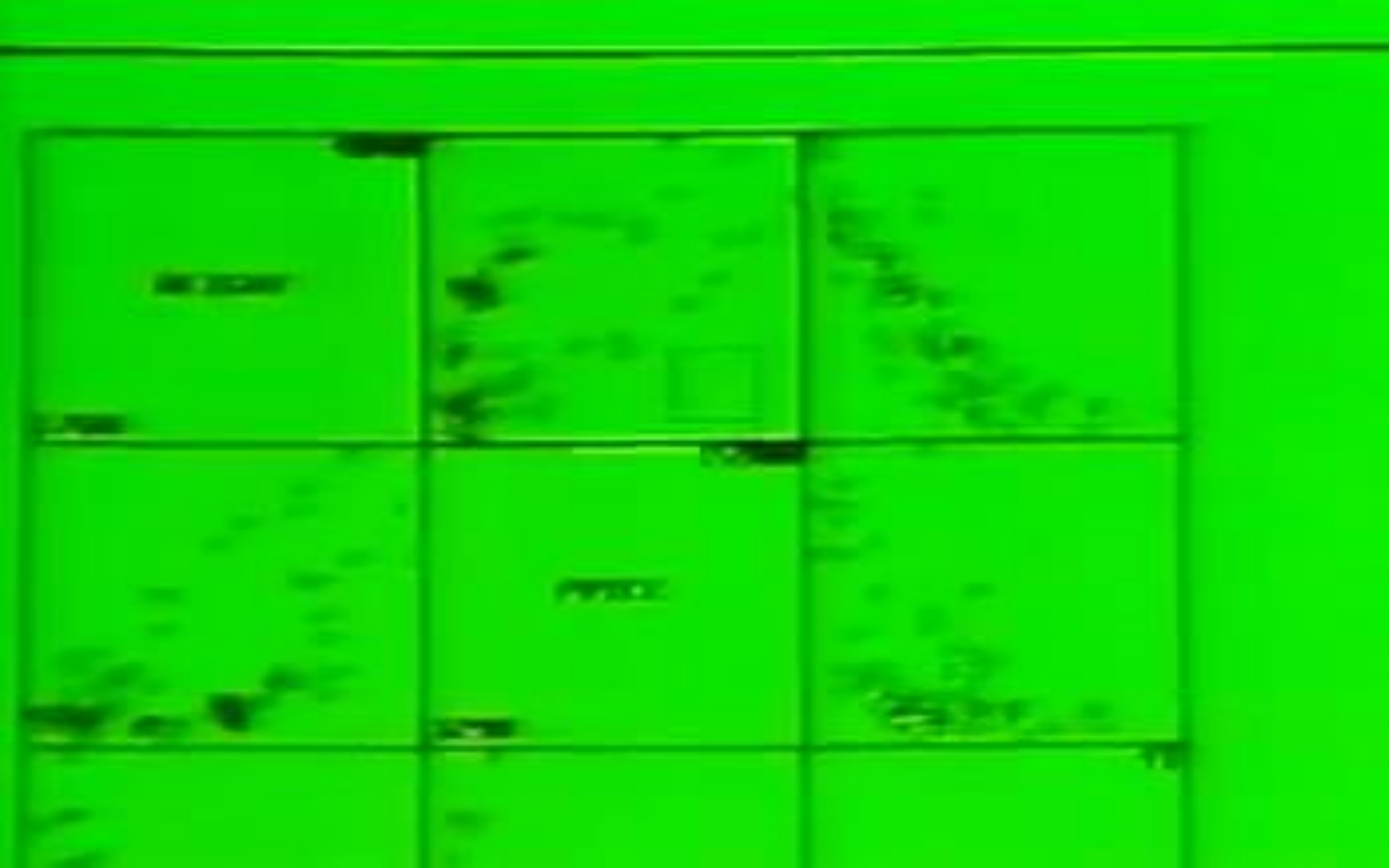
SELECT (“BRUSH”) A SUBSET OF DATA
SEE SELECTED DATA IN OTHER VIEWS

THE COMPONENTS MUST BE *LINKED*
BY *TUPLE*(MATCHING DATA POINTS), OR
BY *QUERY*(MATCHING RANGE OR VALUES)

BRUSHING AND LINKING

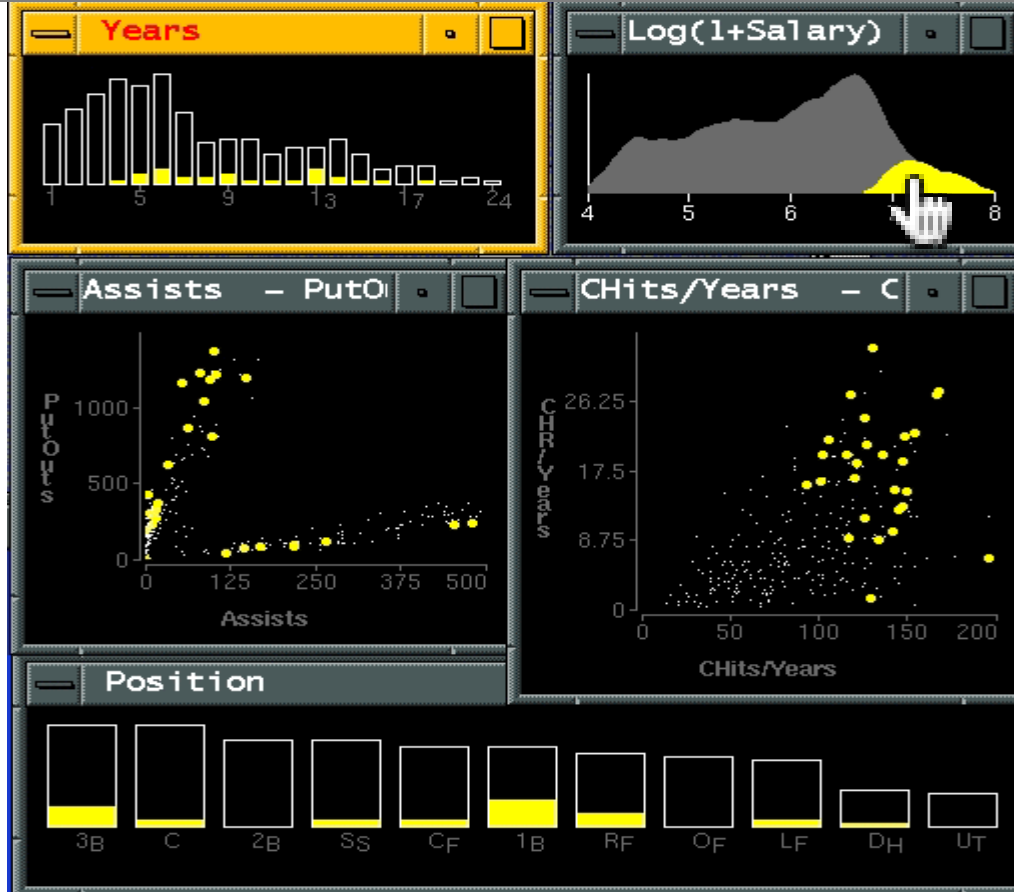


BRUSHING SCATTERPLOTS BECKER & CLEVELAND 1982



BRUSHING & LINKING

HOW LONG
IN MAJORS



SALARIES

ASSISTS VS
PUTOUTS
(FIELDING
ABILITY)

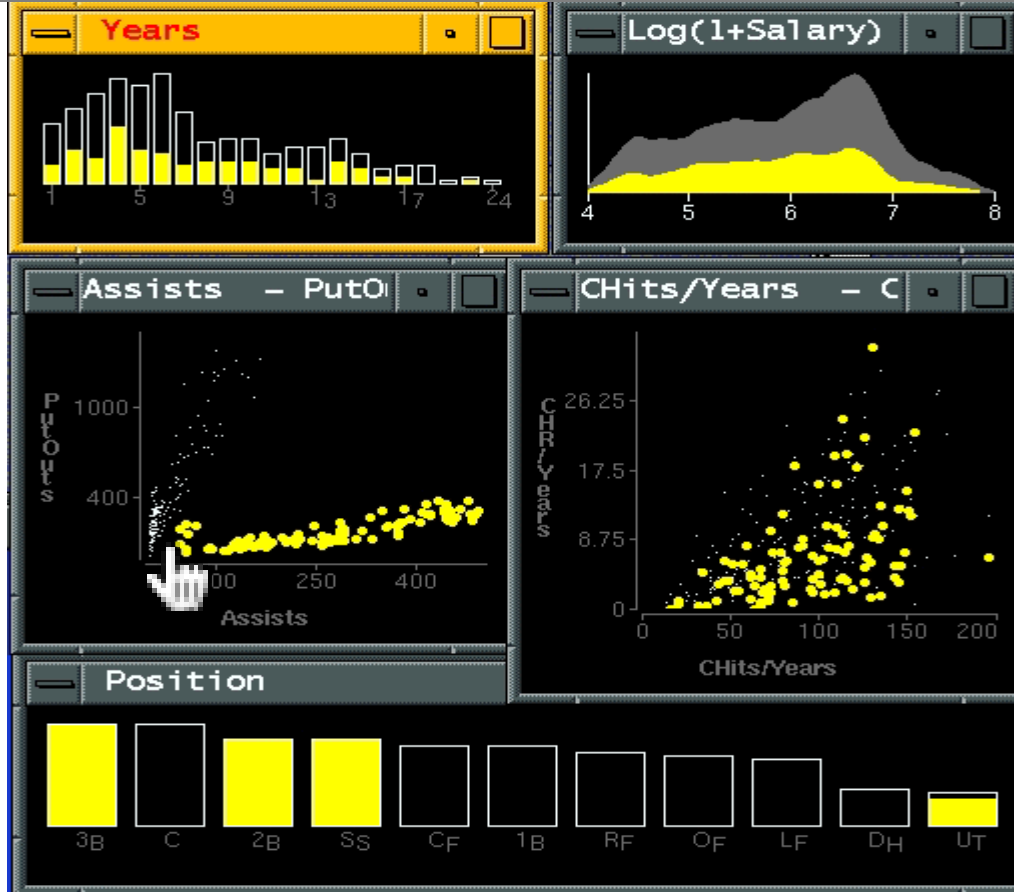
HOME RUNS
VS HITS
(BATTING
ABILITY)

DISTRIBUTION
OF POSITIONS
PLAYED

BASEBALL STATISTICS [FROM WILLS 95]

BRUSHING & LINKING

HOW LONG
IN MAJORS



SALARIES

ASSISTS VS
PUTOUTS
(FIELDING
ABILITY)

HOME RUNS
VS HITS
(BATTING
ABILITY)

DISTRIBUTION
OF POSITIONS
PLAYED

BASEBALL STATISTICS [FROM WILLS 95]

Generalized Selection via Interactive Query Relaxation

Jeffrey Heer | Maneesh Agrawala | Wesley Willett
University of California, Berkeley

SEVEN CATEGORIES OF INTERACTION BY INTENT

YI ET AL. 2007

SELECT

EXPLORE

FILTER

RECONFIGURE

ENCODE

ABSTRACT/ELABORATE

CONNECT

TAXONOMIES OF

- What?
 - What is the user doing?
- Why?
 - Why is the user doing it?
- How?
 - How is the user doing it?

HOW?

INTERACTION TECHNIQUE

“An interaction technique is the fusion of **input and output**, consisting of all **software and hardware** elements, that provides a way for the user to accomplish a task”

(Tucker, 2004)

TYPES OF INTERACTION TECHNIQUES

Input: mouse, touch, keyboard, speech,...

Shneiderman: **Command-line interfaces vs. Direct manipulation interfaces**

HOW?

INTERACTION TECHNIQUE

“An interaction technique is the fusion of **input and output**, consisting of all **software and hardware** elements, that provides a way for the user to accomplish a task”

(Tucker, 2004)

TYPES OF INTERACTION TECHNIQUES

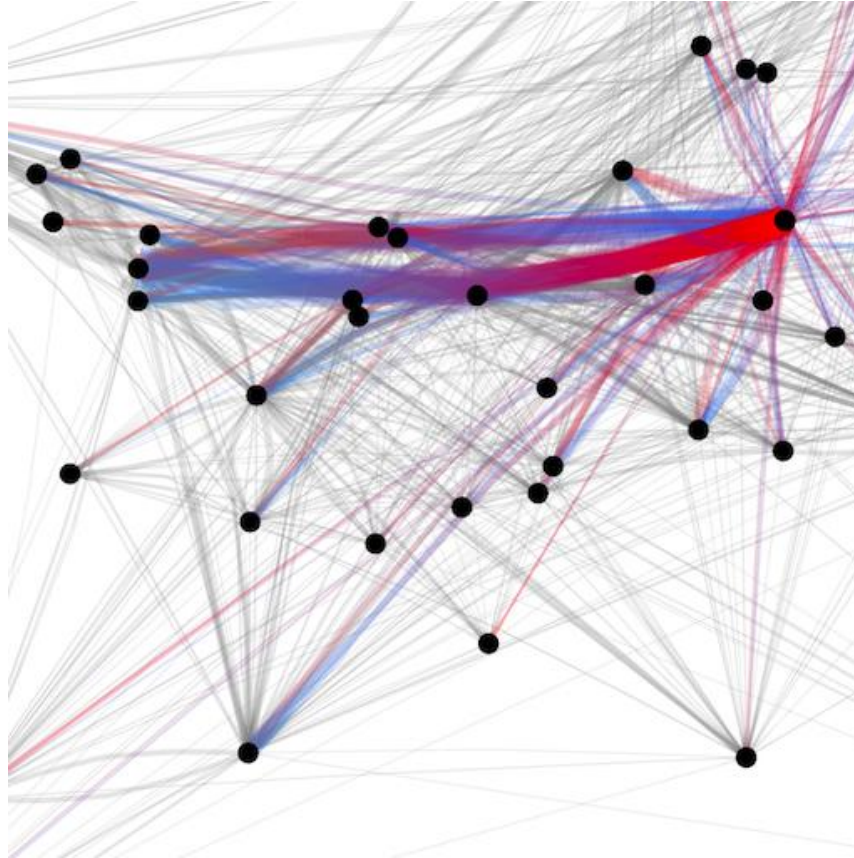
Input: mouse, touch, keyboard, speech,...

Shneiderman: **Command-line interfaces vs. Direct manipulation interfaces**

Beaudouin-Lafon: **Instruments** with different degrees of **directness**

PITFALLS

#1 - Interaction has a cost



PITFALLS

#2 - Controls take screen real-estate

Layout	Excetric	Fisheyes	Rulers
Detail	Filters	Visual	
XAxisColumn	Release date		
YAxisColumn	Max resolution		
dataBounds	java.awt.geom.Rectangle2D\$Dou		
fisheye	infovis.visualization.magicLens.De		
format			
interactor	infovis.visualization.inter.DefaultVt		
itemRenderer	infovis.visualization.render.Default		
margin	0		
name	Table Scatter Plot		
orientation	5		
parent	infovis_panel.VisualizationPanel.0		
permutation			

Layout	Excetric	Fisheyes	Rulers
Detail	Filters	Visual	
0/1038	No selection		
Dimensions			
Effective pixels			
Low resolution			
Macro focus range			
Max resolution			
Name			
Normal focus range			
Price			
Release date			
Storage included			
Weight (inc. batteries)			
Zoom tele (T)			
Zoom wide (W)			

Layout	Excetric	Fisheyes	Rulers
Detail	Filters	Visual	
☐ Enable Excetric Labels			
Radius			
Max Labels			
☐ Opaque Labels			

Layout	Excetric	Fisheyes	Rulers
Detail	Filters	Visual	
☐ Enable Fisheyes			
Metrics			
☐ L1 ☒ L2 ☐ Linf			
Lens Shape			
Linear			
Maximum Scale			
Lens Radius			
Shape Tolerance			

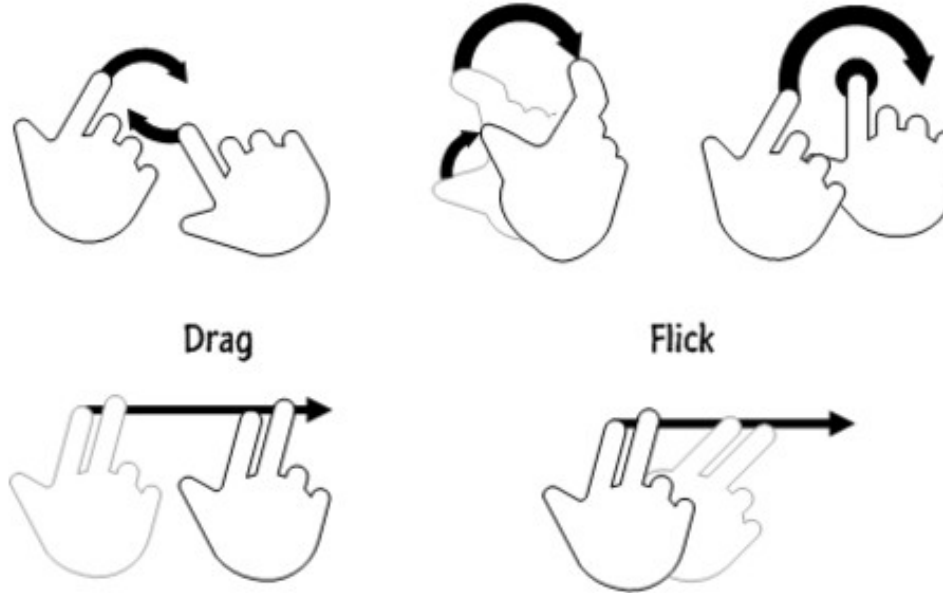
Layout	Excetric	Fisheyes	Rulers
Detail	Filters	Visual	
☒ Visible			
Alpha			
(None)			
Default %			

Layout	Excetric	Fisheyes	Rulers
Detail	Filters	Visual	
Hide			
Filtered Selected Unselected			
Show All			
Dimensions			
Effective pixels			
Low resolution			
Macro focus range			
Max resolution			
Name			
Normal focus range			
Price			
Release date			
Storage included			
Weight (inc. batteries)			
Zoom tele (T)			
Zoom wide (W)			

Layout	Excetric	Fisheyes	Rulers
Detail	Filters	Visual	
Alpha			
(None)			
Default %			
Area			
(None)			
Default %			
Orientation			
☒ North			
☐ West ☐ Center ☐ East			
☐ South			
Bordercolor			
(None)			
Default Color			
Smooth			
☐			
Color			
(None)			
Default Color			
Smooth			
☐			
Label			
Name (String)			
☒ Label all items ☒ Clip ☐ Outline			
Font			
Orientation			
☐ Horizontal ☒ Automatic ☐ Vertical			
0 10 20 30 40 50 60 70 80 90 100			
Size			

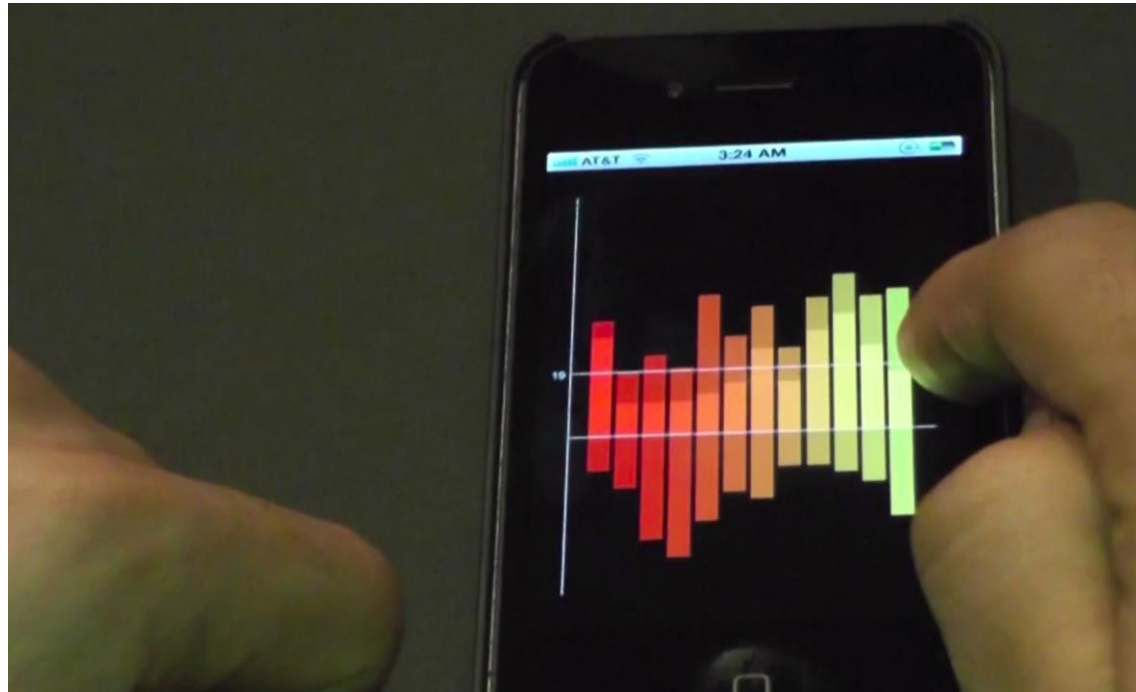
PITFALLS

#3 - Few techniques are self-explanatory



GOING BEYOND THE DESKTOP

TOUCH DEVICES



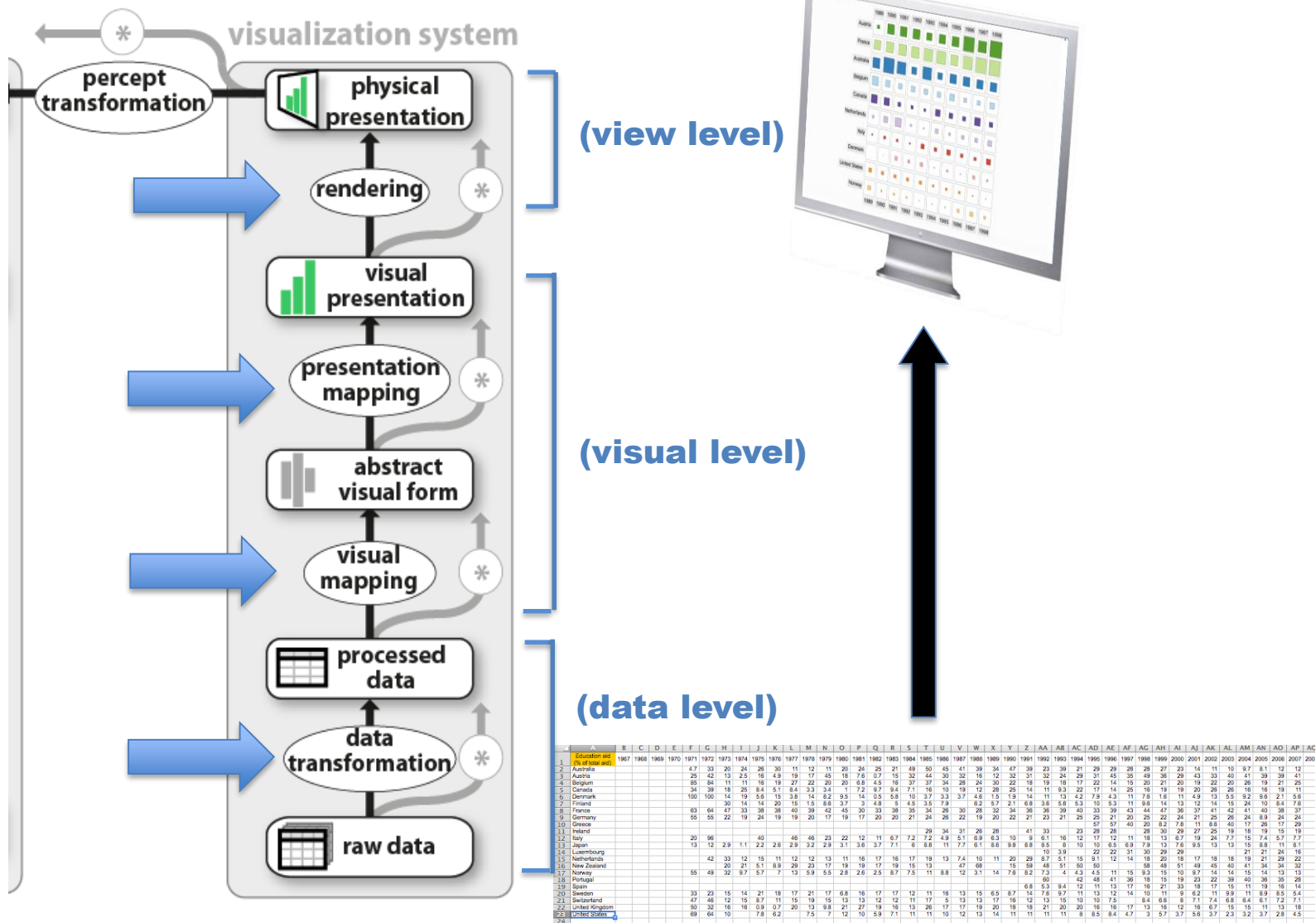
TABLETOP

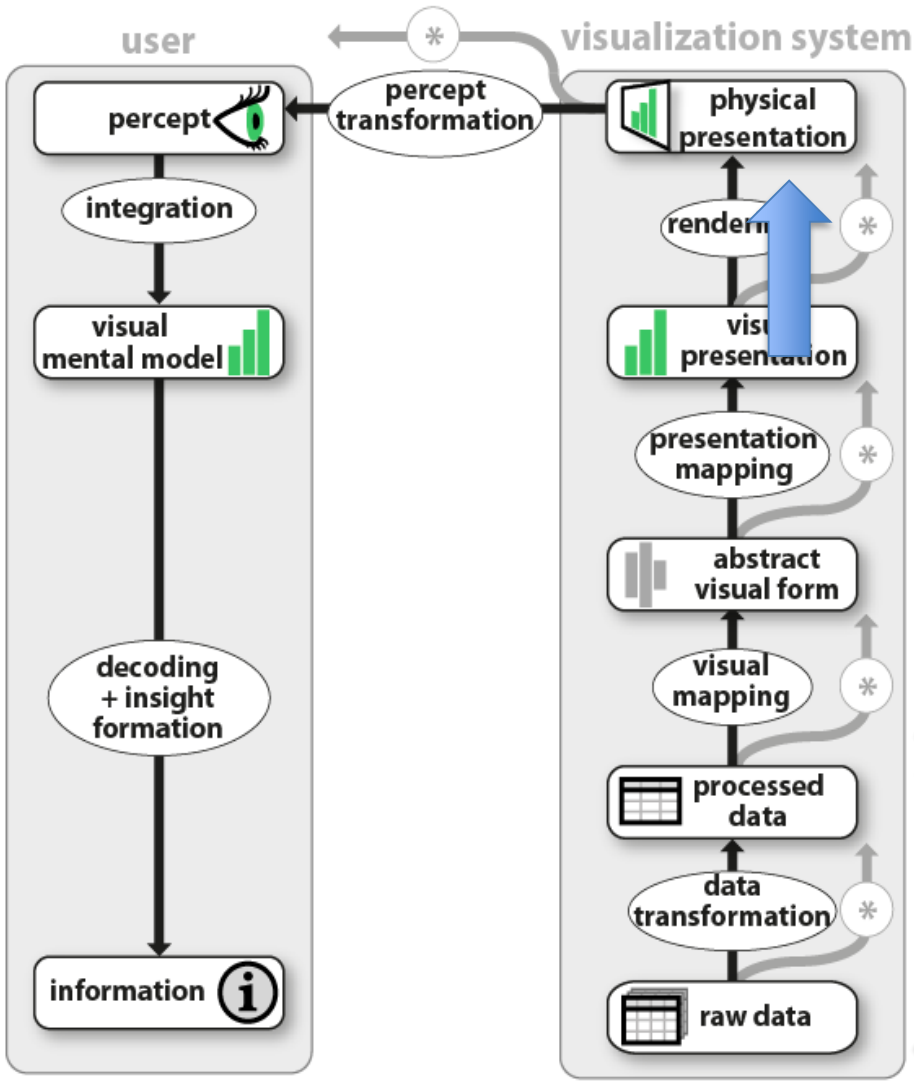


WALL-SIZED DISPLAYS









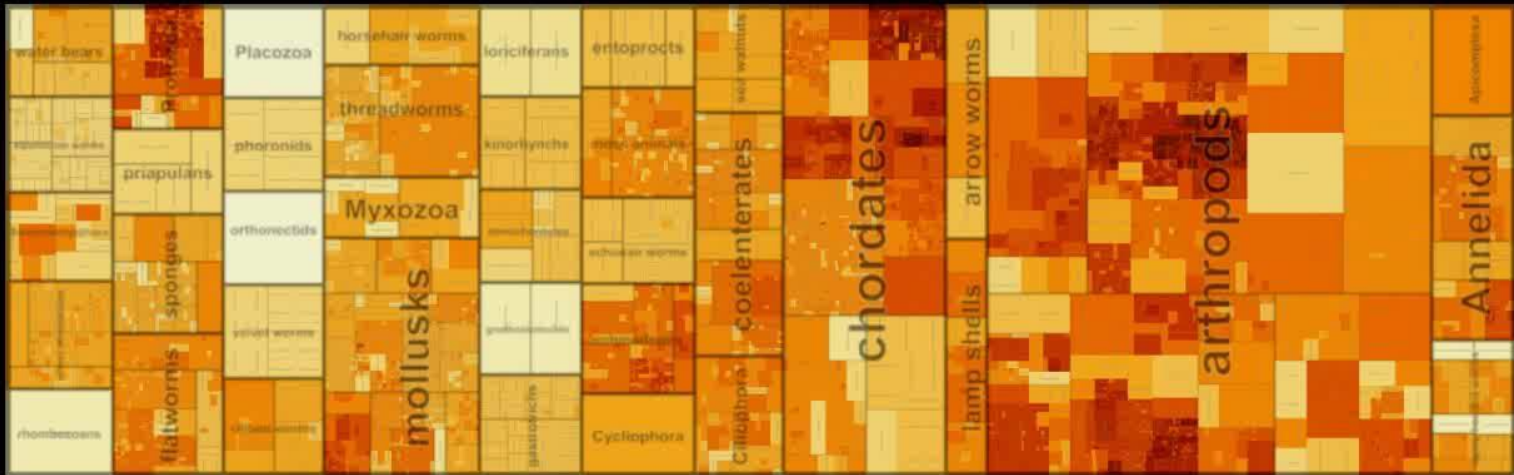
(view level)

(visual level)

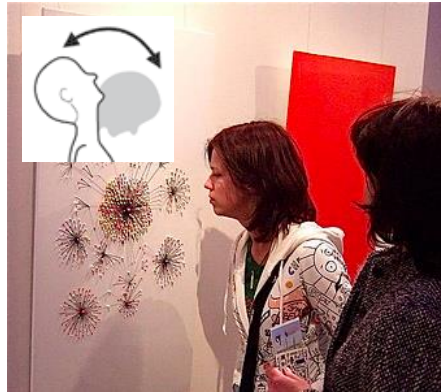
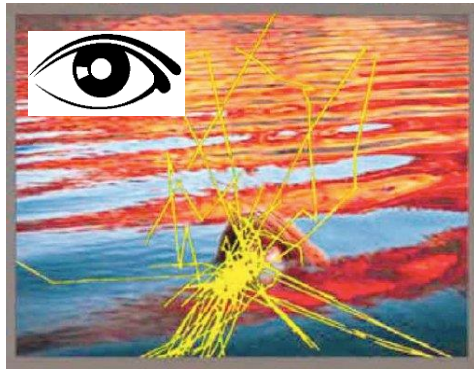
(data level)



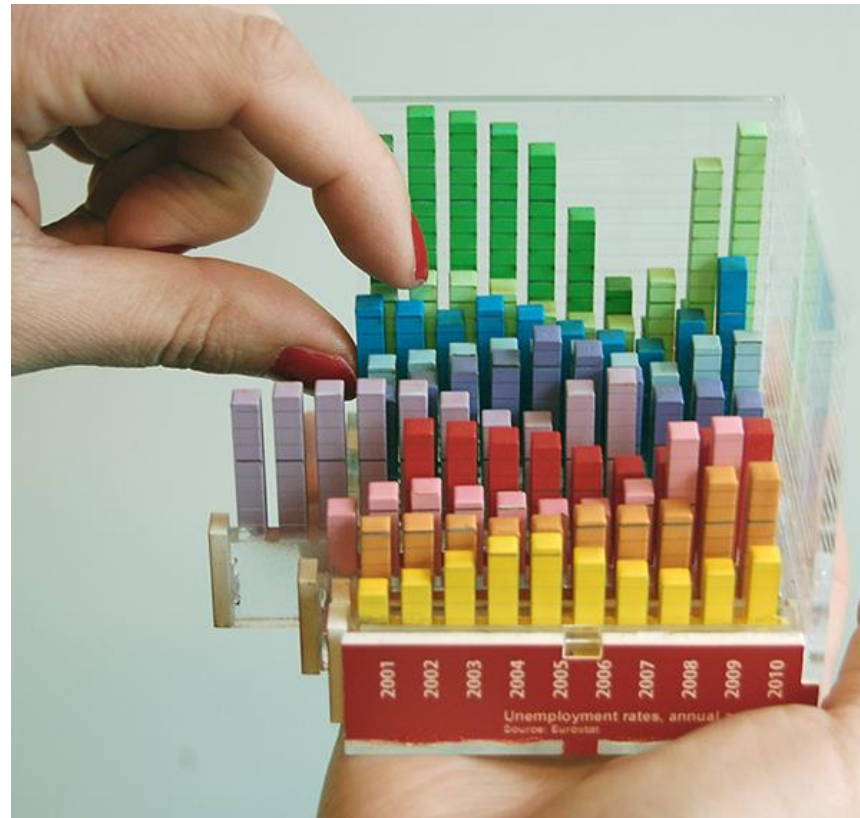
		B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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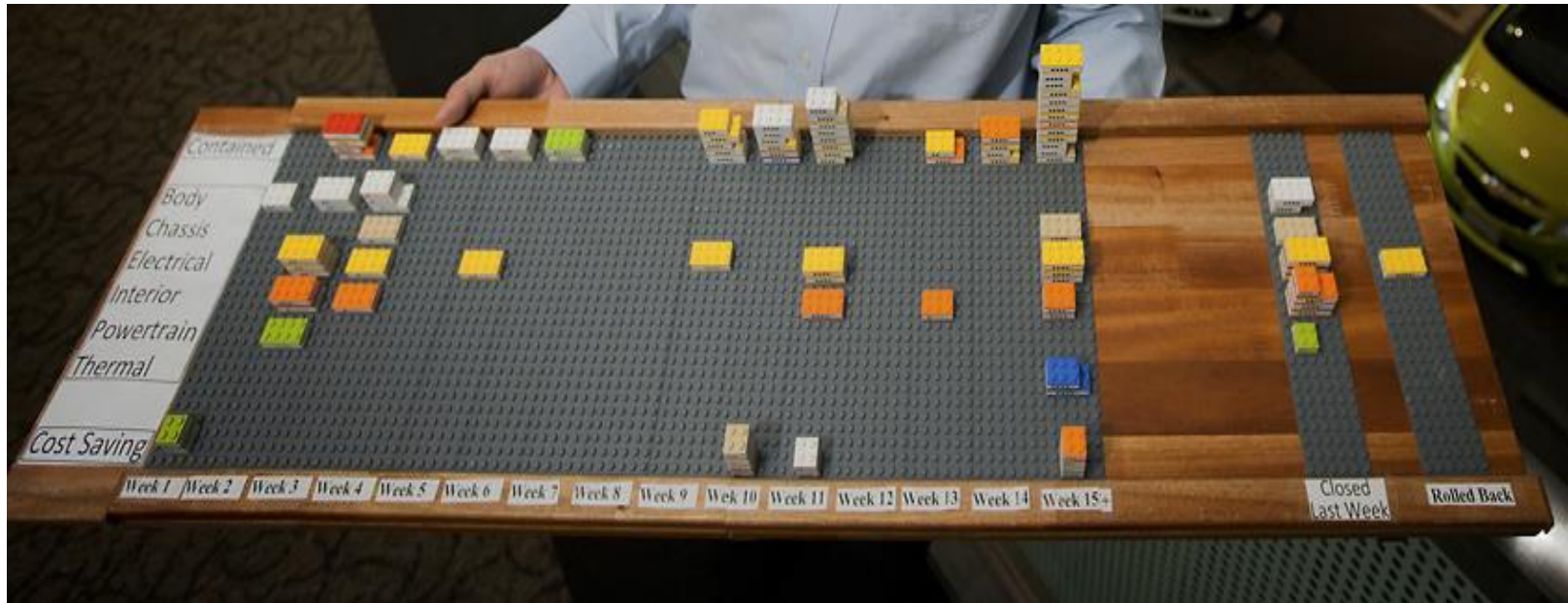
INTERACTION WITH THE PHYSICAL WORLD



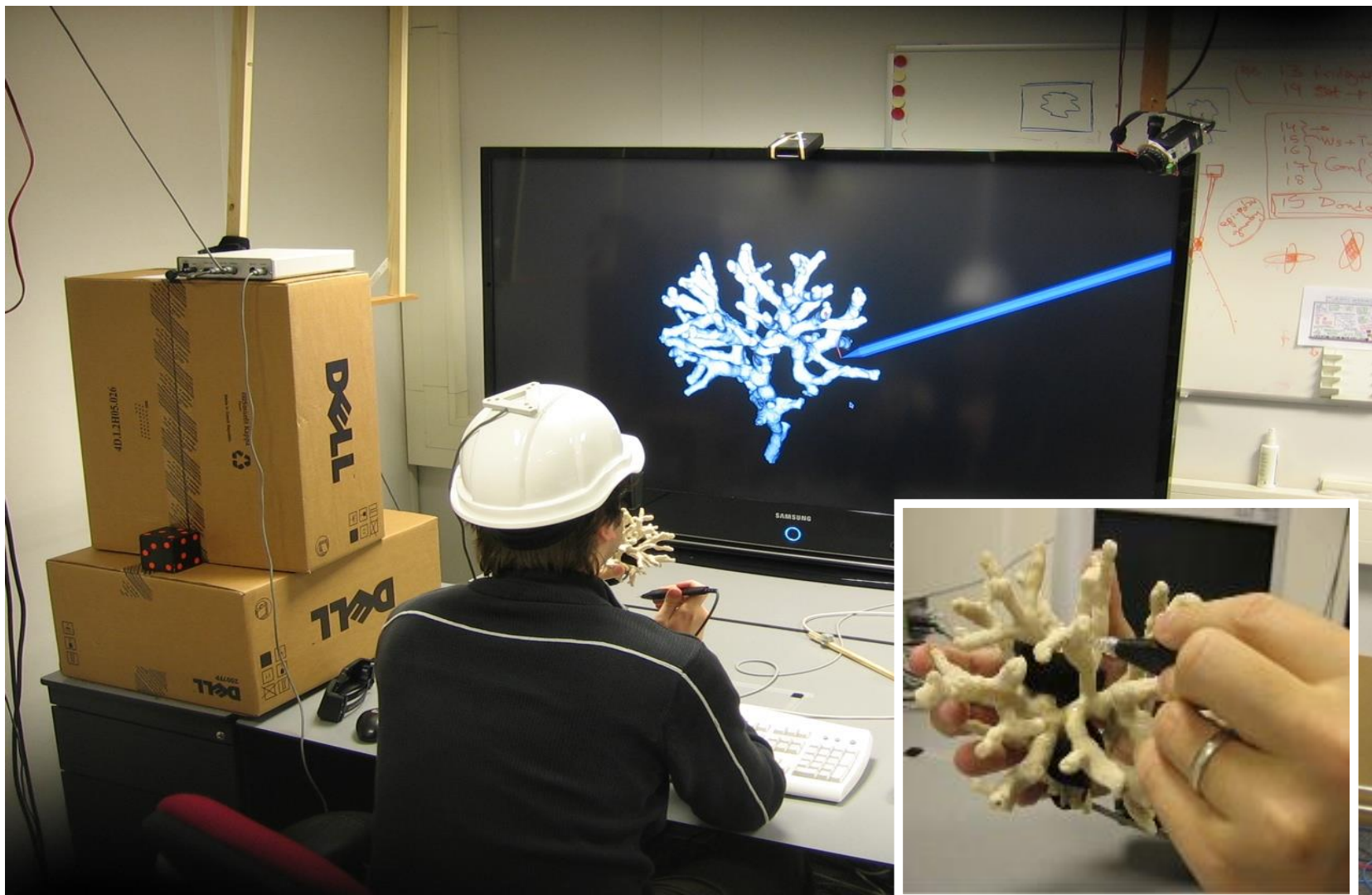
PHYSICAL VISUALIZATIONS



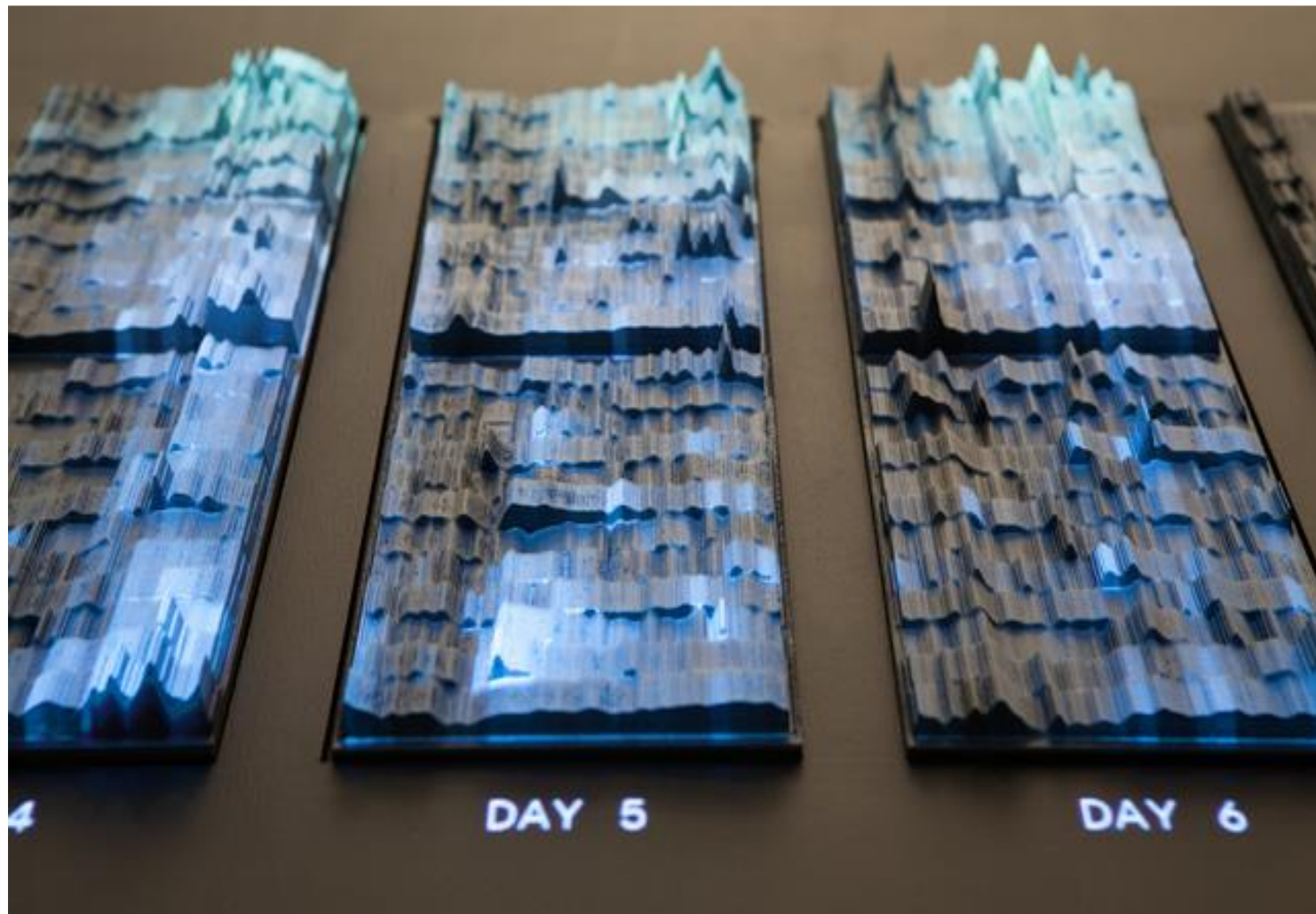
tinyurl.com/physvis



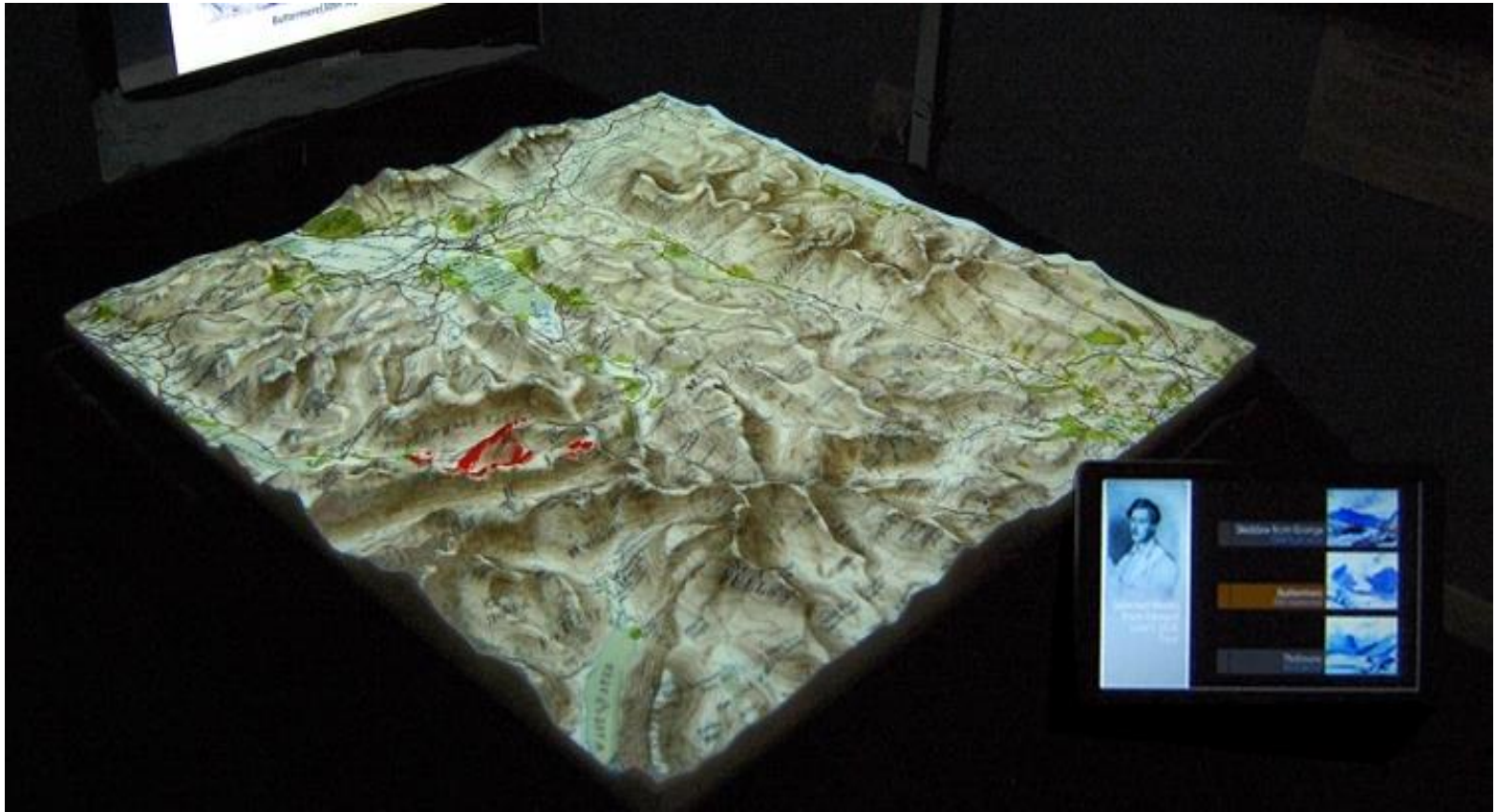
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[Kruszynski & van Liere, Tangible Props for Scientific Visualization, Virtual Reality 13 (4) 2009]



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