

INTERACTION IN VISUALIZATION

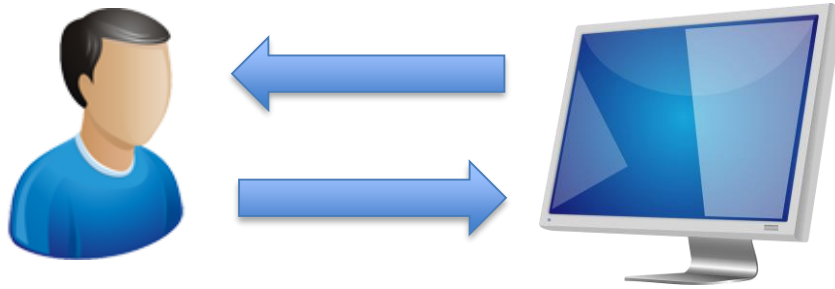
Petra Isenberg

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



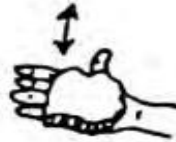
PRESSURE



STATIC
CONTACT



UNSUPPORTED
HOLDING



ENCLOSURE



CONTOUR
FOLLOWING

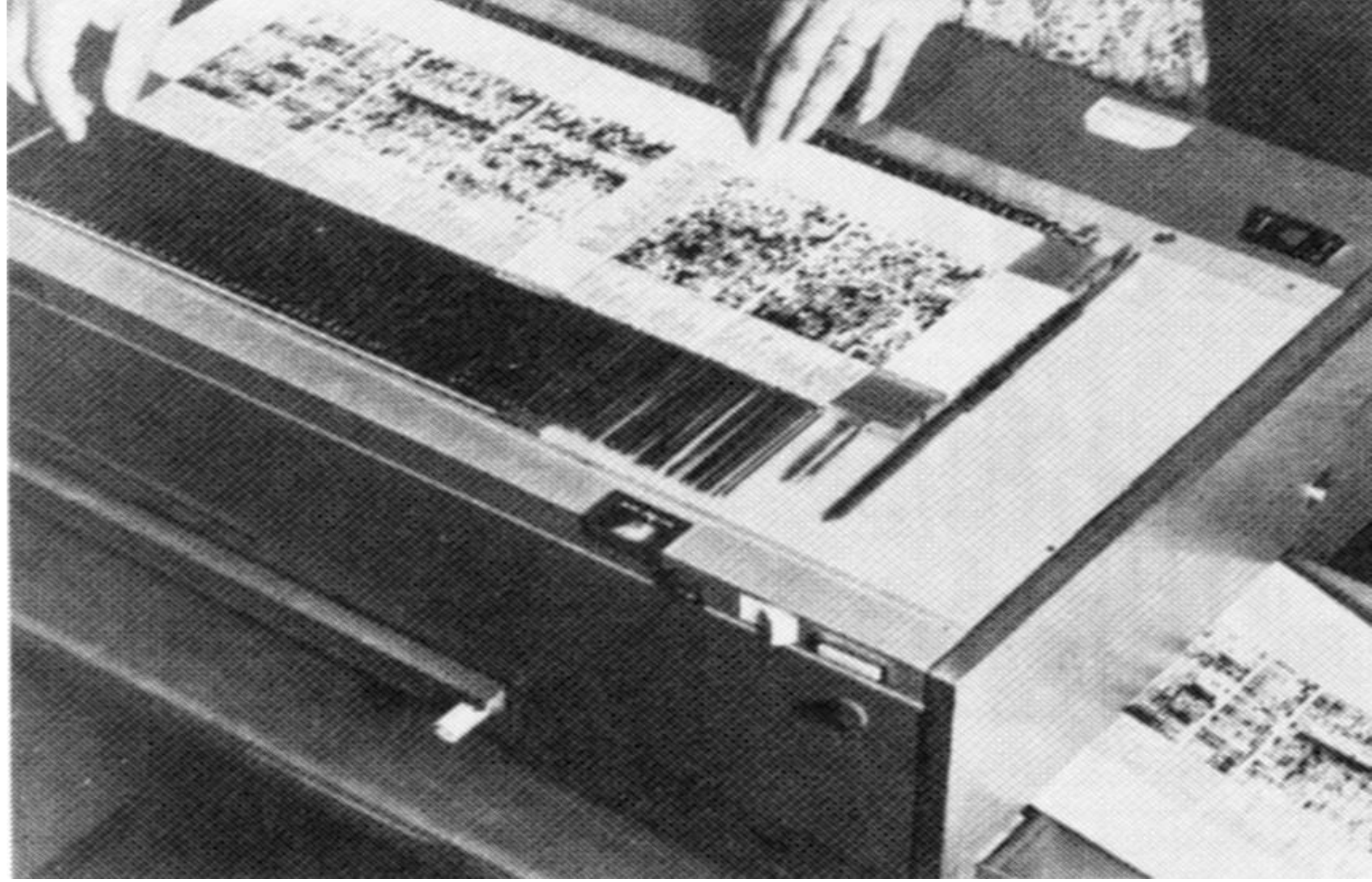


FUNCTION
TEST



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



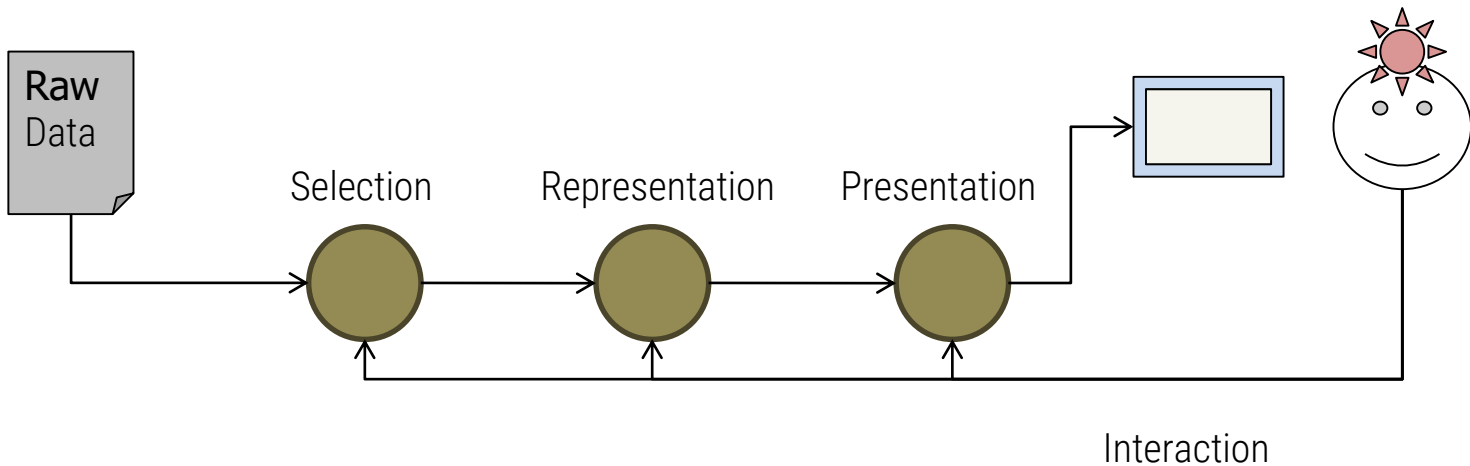
1970s

TAXONOMIES OF INTERACTION

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

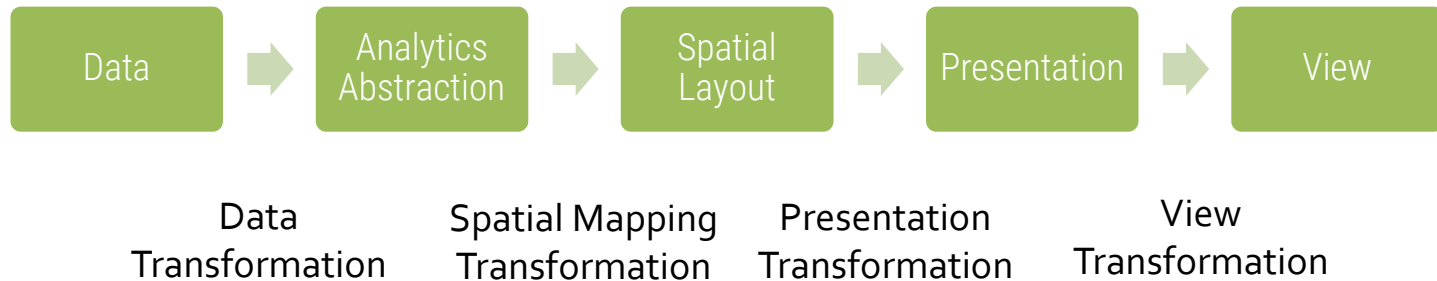
THE VISUALIZATION PIPELINE

THE VISUALIZATION

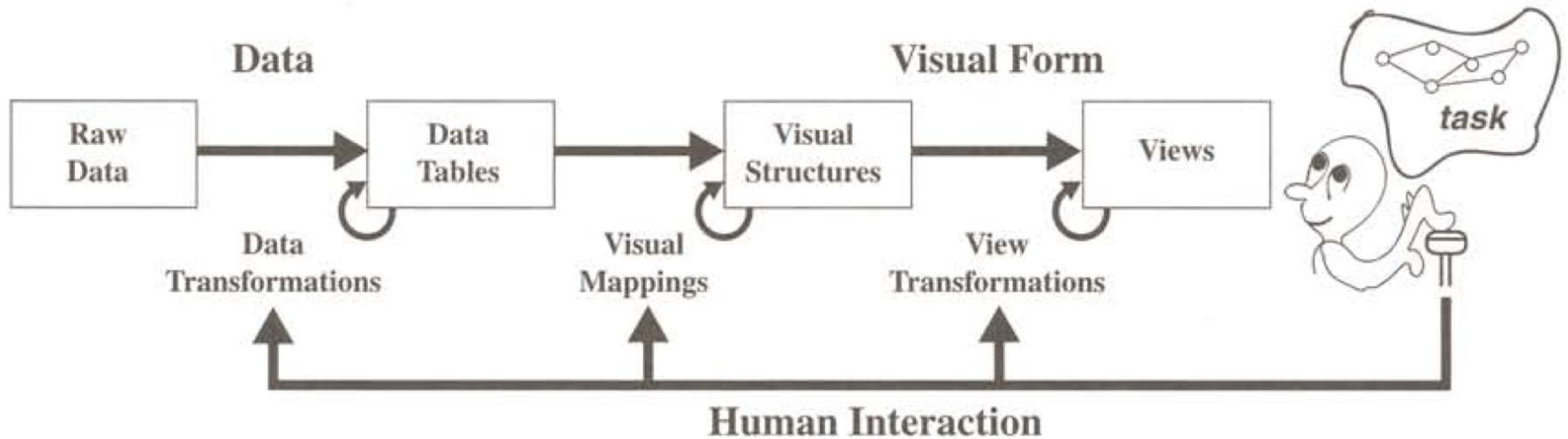


The Visualization Pipeline

THE VISUALIZATION PIPELINE



THE VISUALIZATION PIPELINE



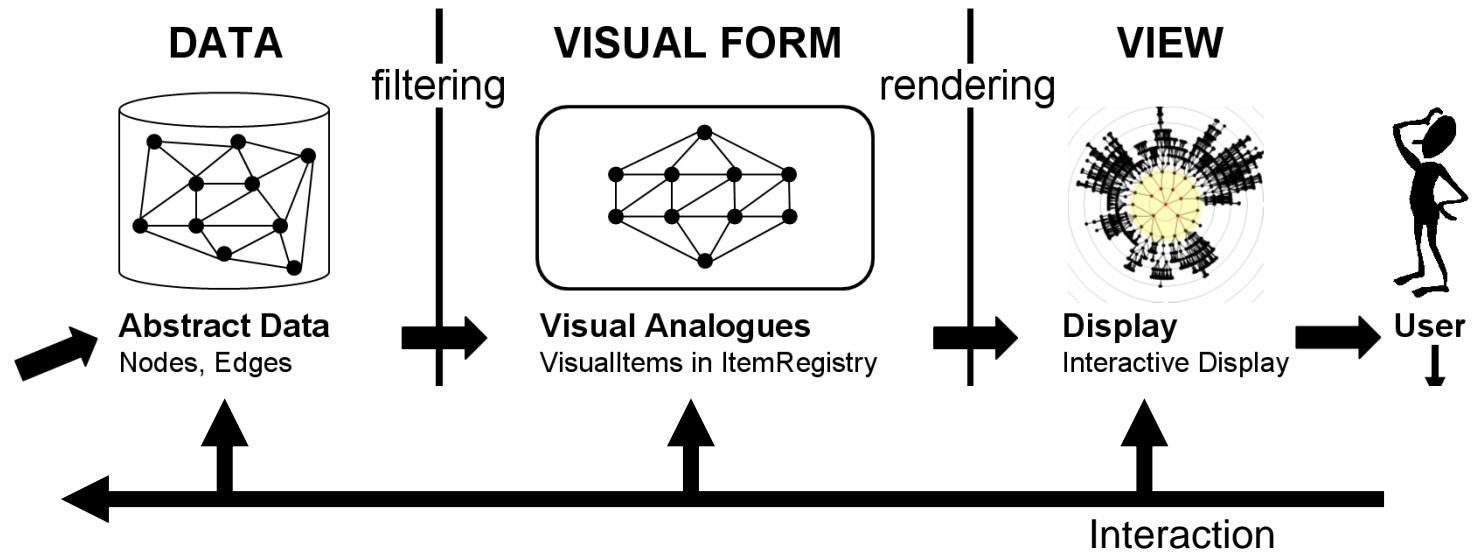
Raw Data: idiosyncratic formats

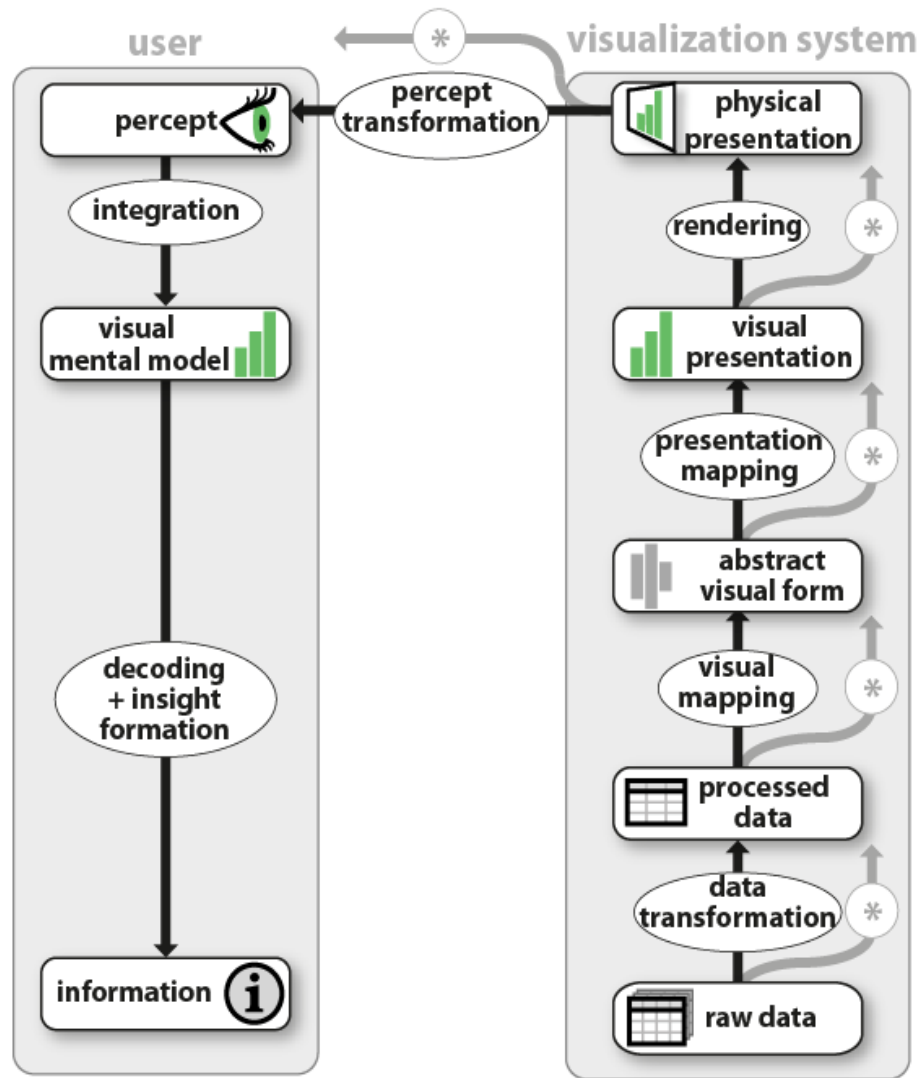
Data Tables: relations (cases by variables) + metadata

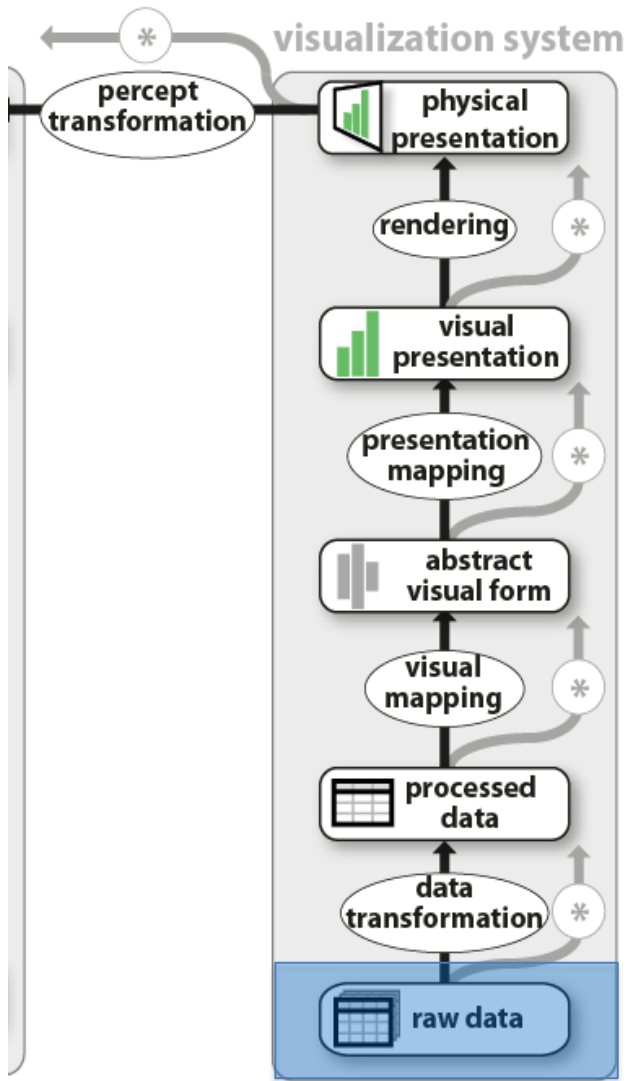
Visual Structures: spatial substrates + marks + graphical properties

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

THE VISUALIZATION PIPELINE



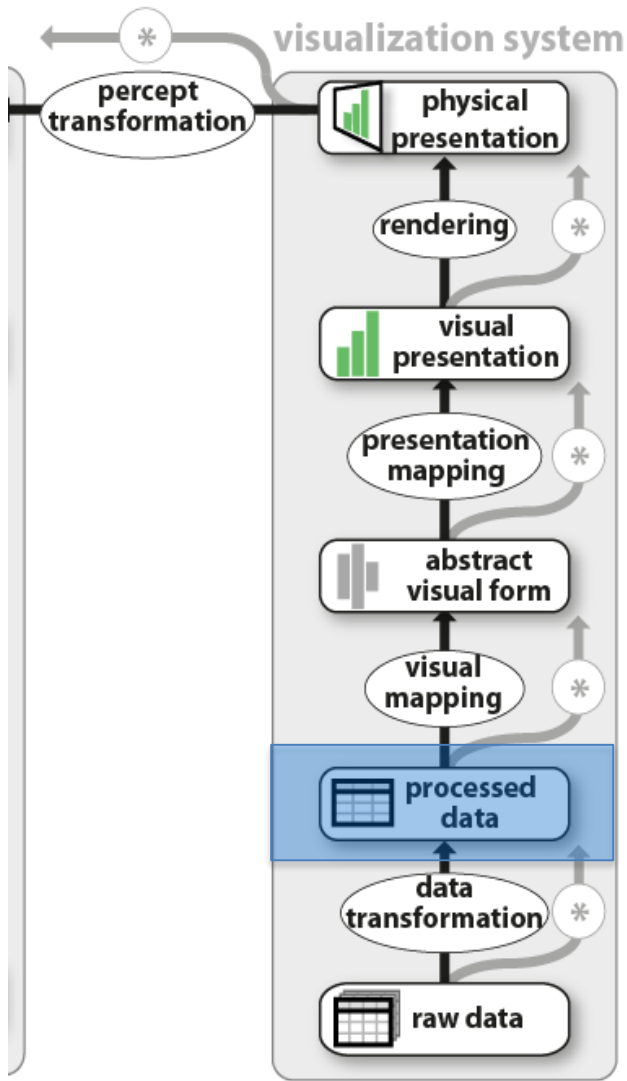




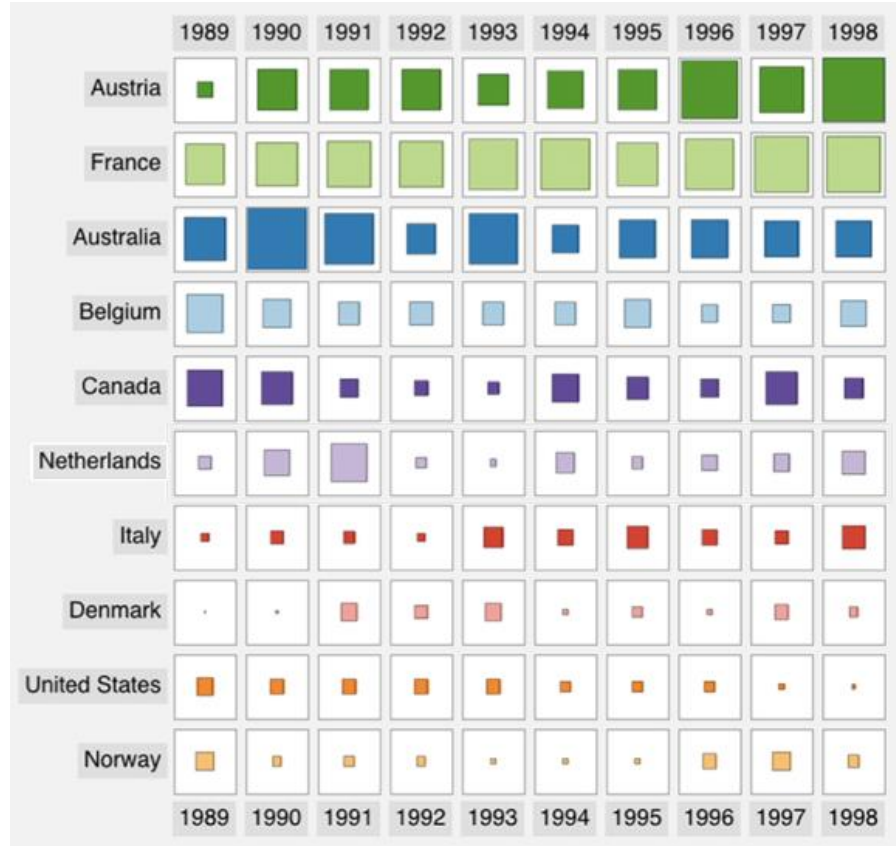
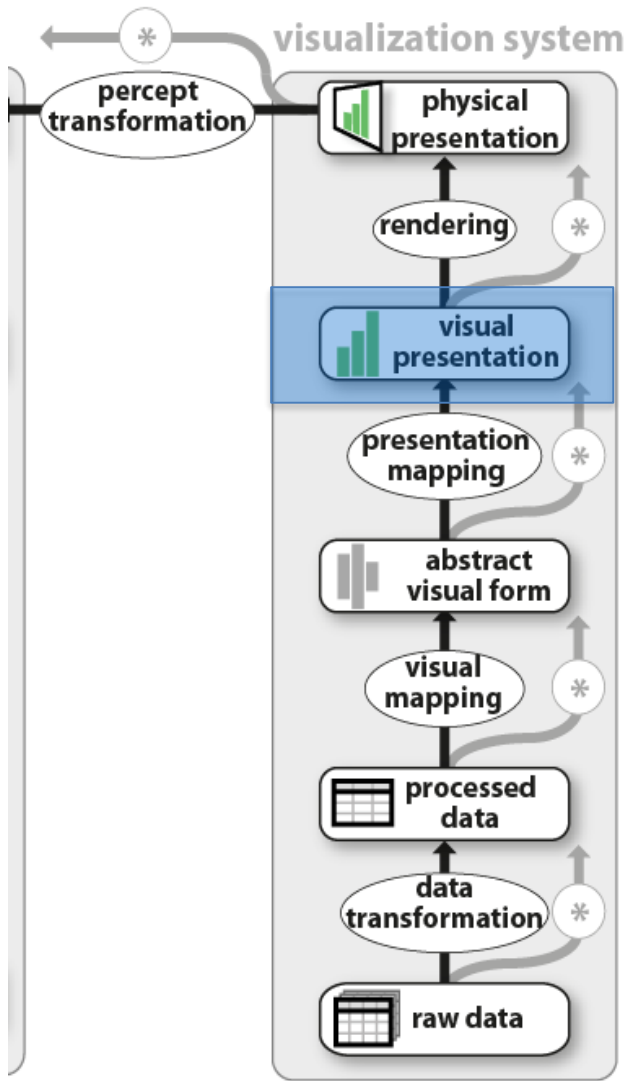
GAPMINDER for a fact-based world view

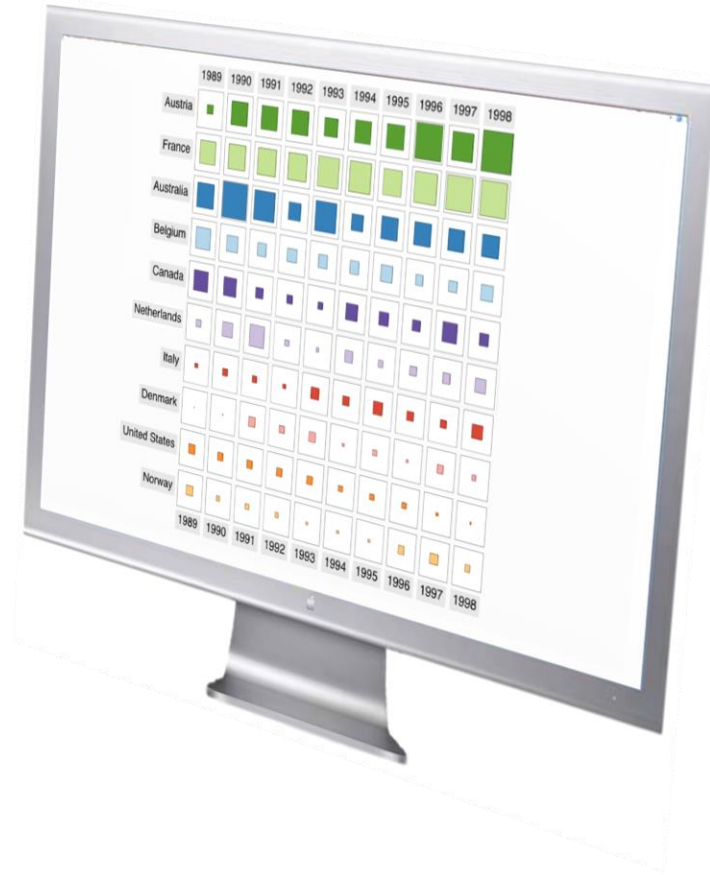
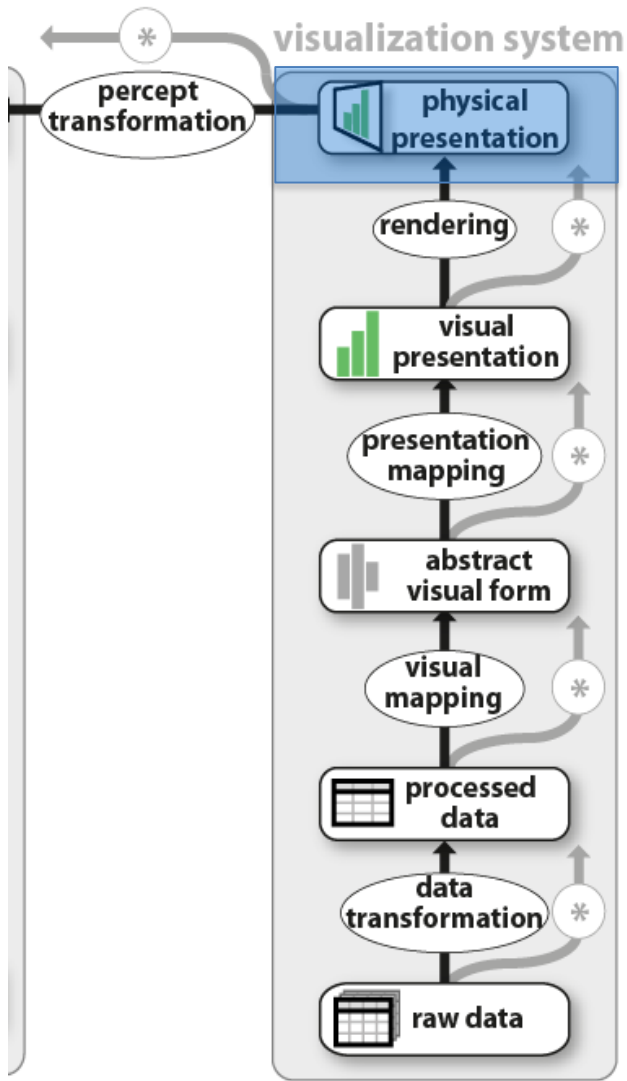
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1	Education aid (% of total aid)	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008								
2	Australia	4.7	3.3	20	24	28	30	11	12	11	20	24	25	21	49	50	45	41	39	34	47	39	23	29	21	29	29	28	28	27	23	14	11	10	9.7	8.1	12	12													
3	Austria	25	42	13	25	16	4.9	19	17	45	18	7.6	0.7	15	32	44	30	32	16	12	33	32	24	29	31	45	25	48	38	29	43	33	40	41	39	39	41														
4	Belgium	85	84	11	11	16	19	27	22	20	20	8.8	4.5	16	37	37	34	28	24	30	22	18	19	18	17	22	14	15	20	21	20	19	22	20	20	19	21	25													
5	Canada	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													
6	Denmark	30	14	20	15	1.5	6.8	3.7	3	4.8	5	4.5	3.3	7.9	0.2	5.7	2.1	6.8	3.6	5.8	5.3	10	5.3	11	6.6	14	12	12	14	16	26	10	6.4	7.6																	
7	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	47	36	37	41	42	41	40	38	37													
8	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	25	21	20	25	22	26	21	25	26	24	6.9	24	24													
9	Greece																																																		
10	Ireland																																																		
11	Italy	20	96				40		46	46	23	22	12	11	6.7	7.2	7.2	4.9	5.1	6.8	8.5	10	8	6.1	16	23	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28					
12	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	6.6	11	7.7	6.1	6.6	9.8	6.8	8.5	6	10	10	6.5	6.9	7.9	13	7.6	9.5	13	15	8.8	11	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1					
13	Luxembourg																																																		
14	Netherlands																																																		
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17	Portugal																																																		
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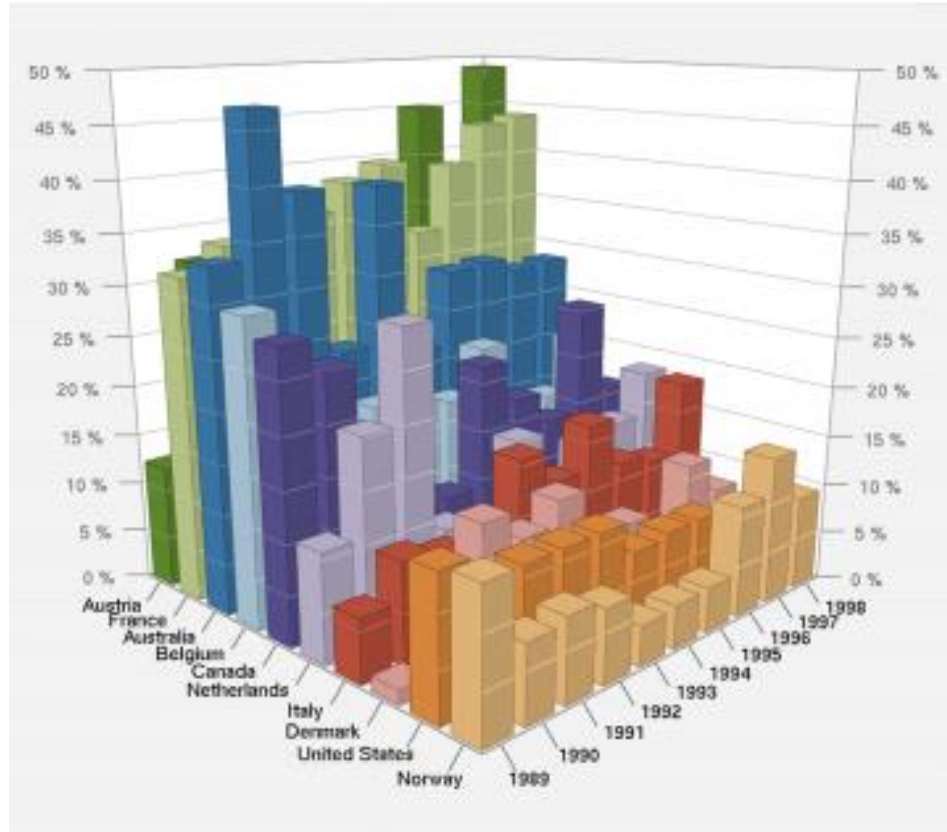
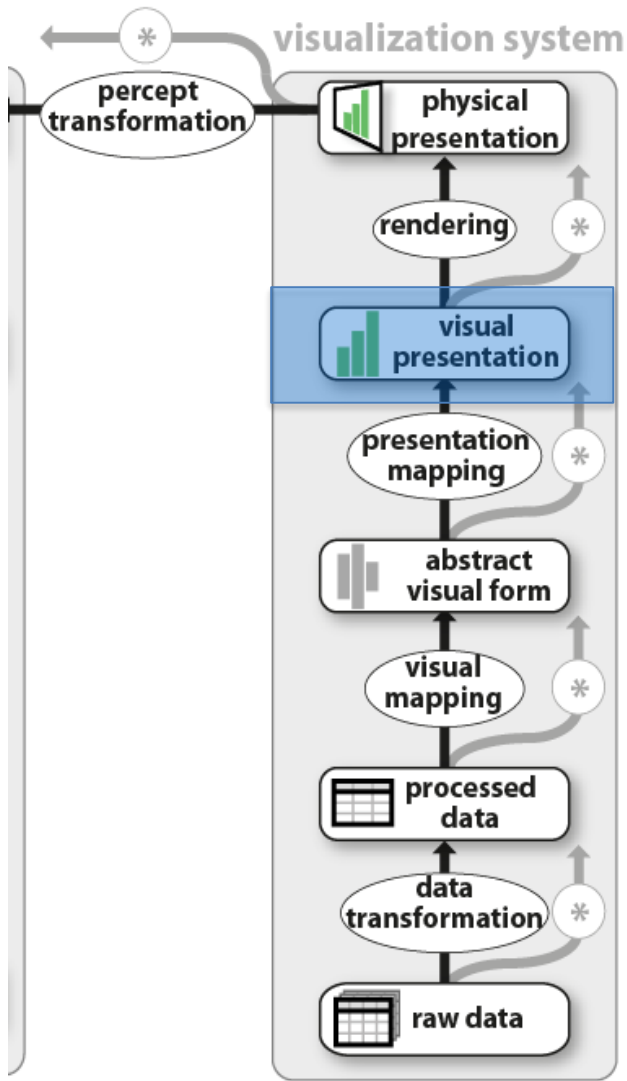
	A	B	C	D	E	F	G	H	I	J	K
1	Education aid (% of total aid)	1967	1968	1969	1970	1971	1972	1973	1974	1975	197
2	Australia					4.75	33.2	19.7	23.7	26.3	30.
3	Austria					24.7	42.3	13.5	2.52	15.9	4.8
4	Belgium					84.5	83.7	11	11.4	15.9	18.
5	Canada					33.7	38.6	18	25.3	8.41	5.1.
6	Denmark					100	100	13.7	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											

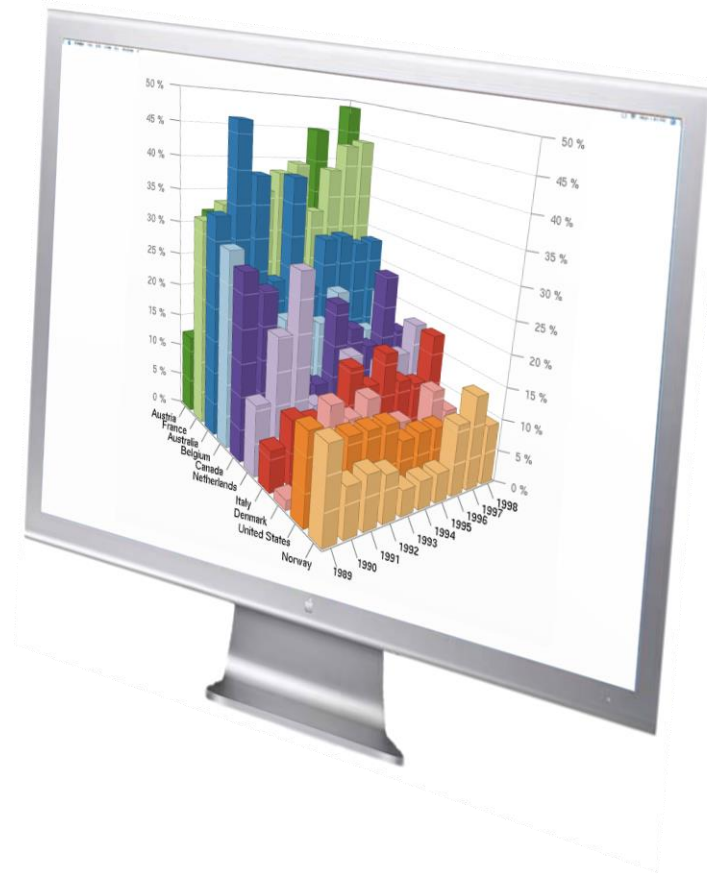
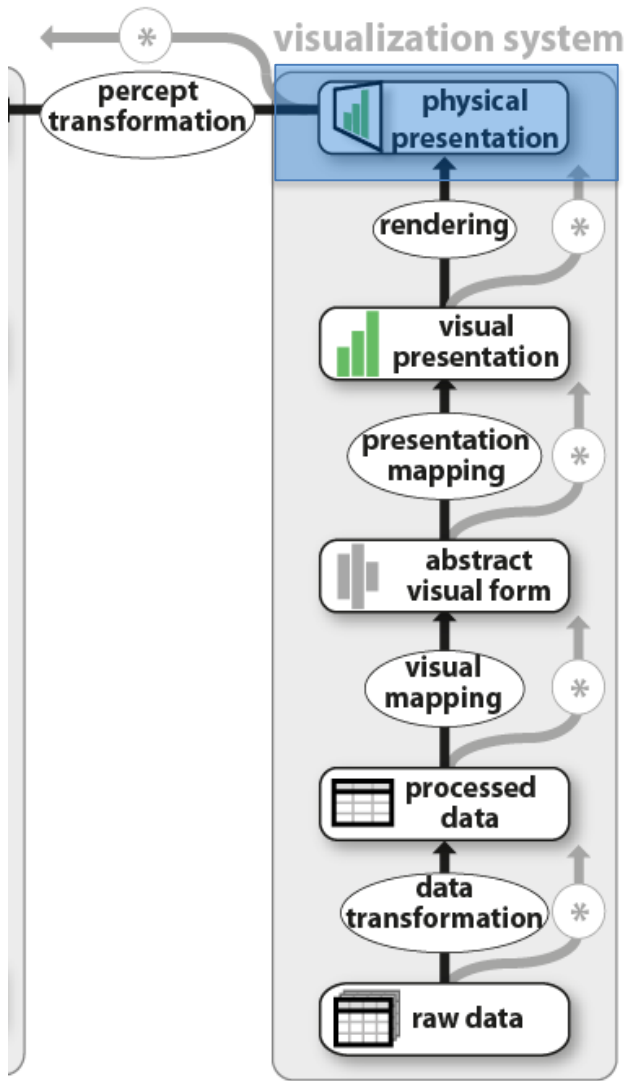


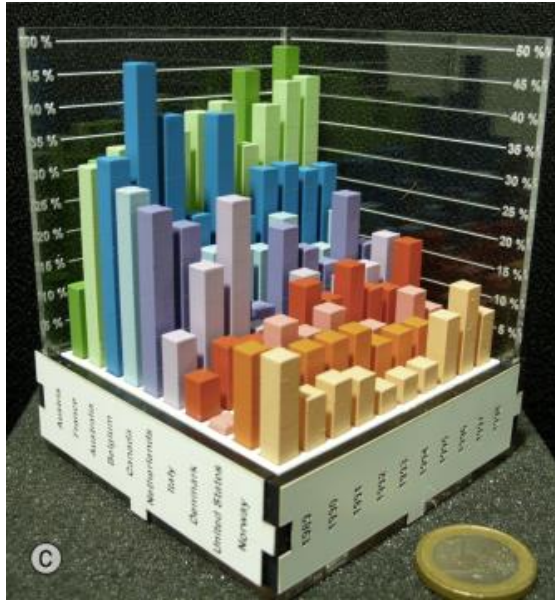
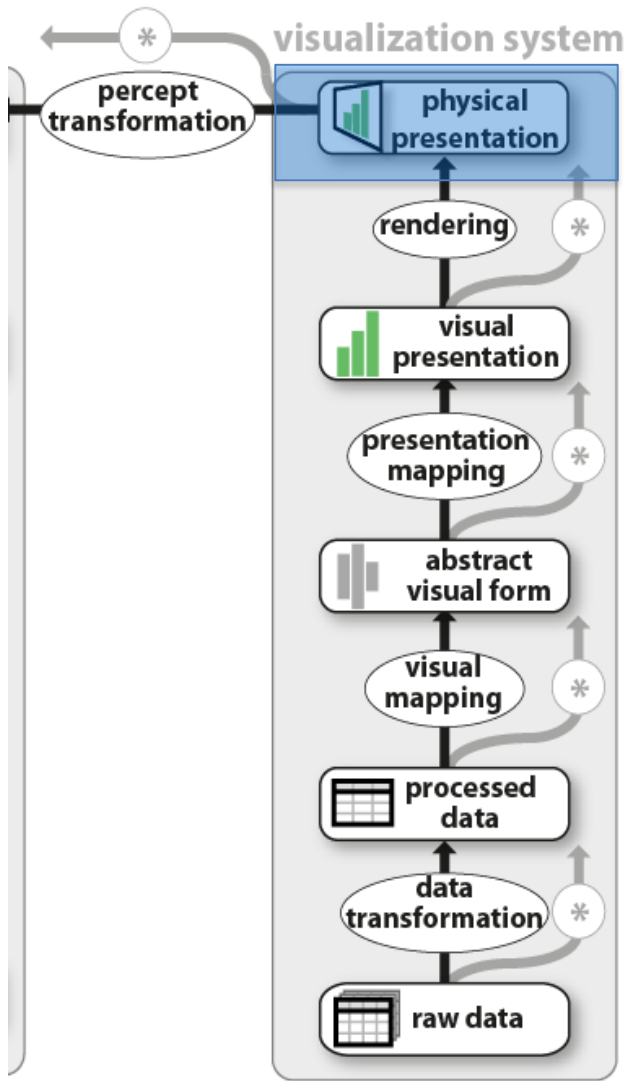
	A	B	C	D	E	F	G	H	I	J	K
1		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
2	Austria	12.23	31.86	31.07	31.57	24.02	28.61	30.52	44.99	35.41	48.95
3	France	31.87	34.18	35.95	36.06	38.78	40.18	32.68	39.26	43.15	43.9
4	Australia	33.57	46.93	39.24	23.18	38.94	21.38	29.1	29.43	27.97	28.32
5	Belgium	29.93	22.13	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

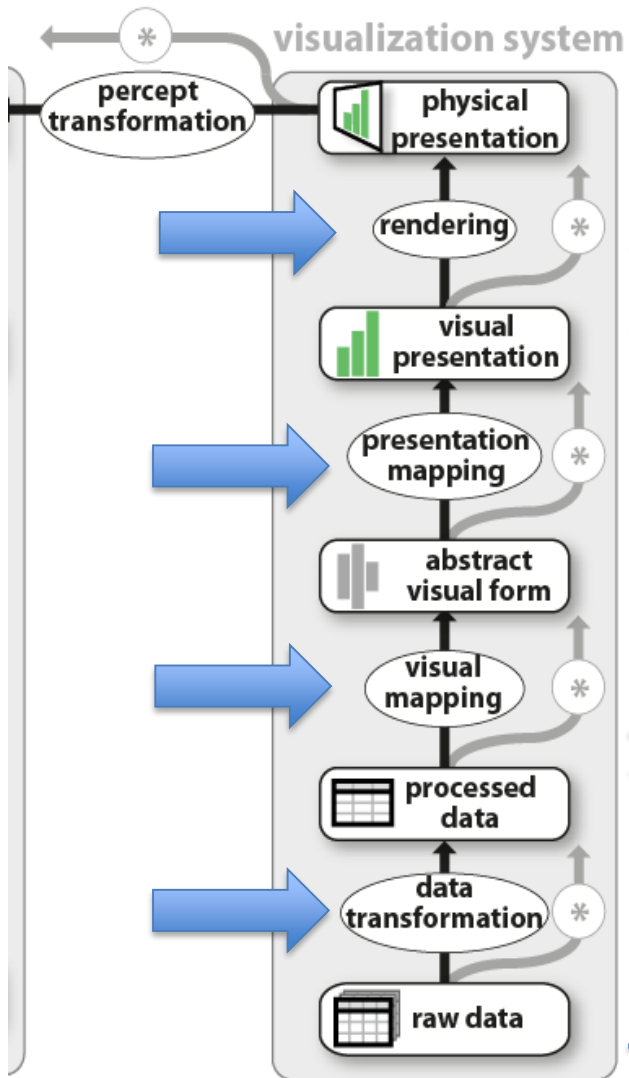












(view level)

(visual level)

(data level)



	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	AC								
1	Education and health expenditure	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								
2	Australia	4.7	3.3	2.0	2.4	2.8	3.0	1.1	1.2	1.1	2.0	2.4	2.5	2.1	4.8	5.0	4.5	4.1	3.9	3.4	4.7	3.8	2.3	3.9	2.1	2.9	2.9	2.8	2.8	2.7	2.3	1.4	1.1	1.0	0.7	0.1	1.2	1.2													
3	Austria	29	42	13	2.5	16	4.5	19	17	4.5	18	7.6	0.7	1.5	32	44	30	32	1.6	12	32	31	32	24	29	31	45	35	48	36	29	43	33	40	41	39	29	41													
4	Belgium	85	84	11	11	16	19	27	22	20	20	6.8	4.5	1.6	37	27	34	28	24	20	22	18	19	18	17	22	14	15	20	21	20	19	22	20	26	19	21	25													
5	Canada	34	39	18	25	18.4	5.1	8.4	3.3	3.4	1.1	7.2	9.7	9.4	7.1	1.6	10	19	12	26	25	1.5	11	9.3	2.9	1.7	14	25	1.6	1.9	19	20	26	16	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	7.9	1.6	11	4.9	13	5.5	8.2	9.6	2.1	5.6													
7	Finland	34	39	14	1.2	2.5	1.6	1.5	0.8	3.7	3	4.8	5	4.5	3.5	7.9	6.2	3.7	3.1	6.8	3.6	6.8	5.3	10	5.3	11	8.6	14	13	12	14	15	34	10	8.4	7.6															
8	France	63	64	47	33	38	38	40	39	42	45	30	33	35	34	26	30	28	32	34	38	36	39	40	33	39	43	44	47	36	37	41	42	41	40	38	37														
9	Germany	55	55	22	19	24	19	19	20	17	19	17	20	20	21	24	26	22	19	20	22	21	25	21	25	25	21	20	25	22	24	21	25	26	24	19	25	24													
10	Greece																																																		
11	Ireland																																																		
12	Italy	13	12	2.9	1.1	2.2	2.6	2.9	3.2	2.9	3.1	3.6	2.7	7.1	6	8.8	11	7.7	6.1	8.6	9.8	8.8	8.5	8	10	10	6.5	6.9	7.8	13	7.6	9.5	13	15	6.7	5.7	7.7														
13	Japan																																																		
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24																																																			

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

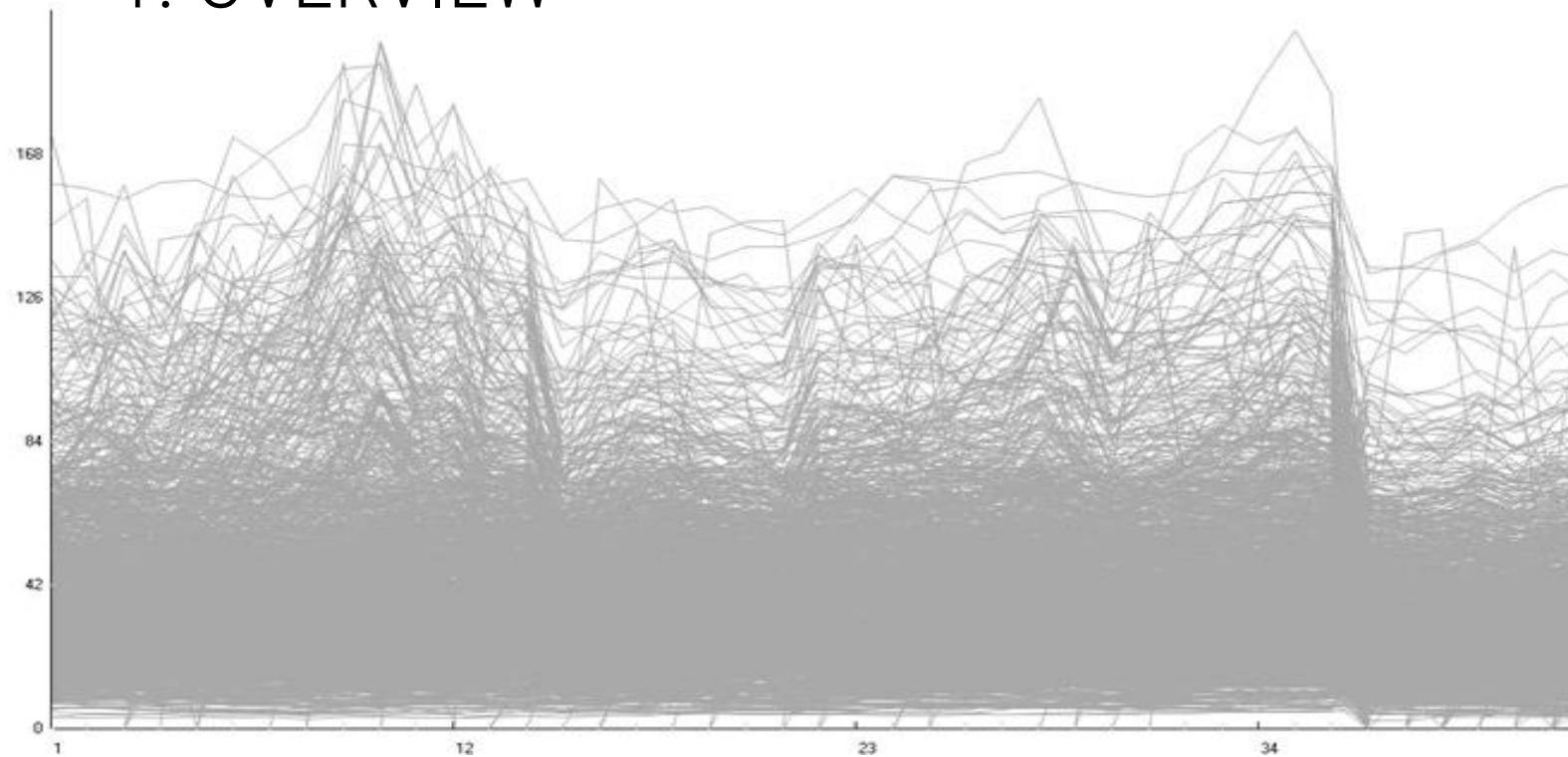
BEN SHNEIDERMAN 1996



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.

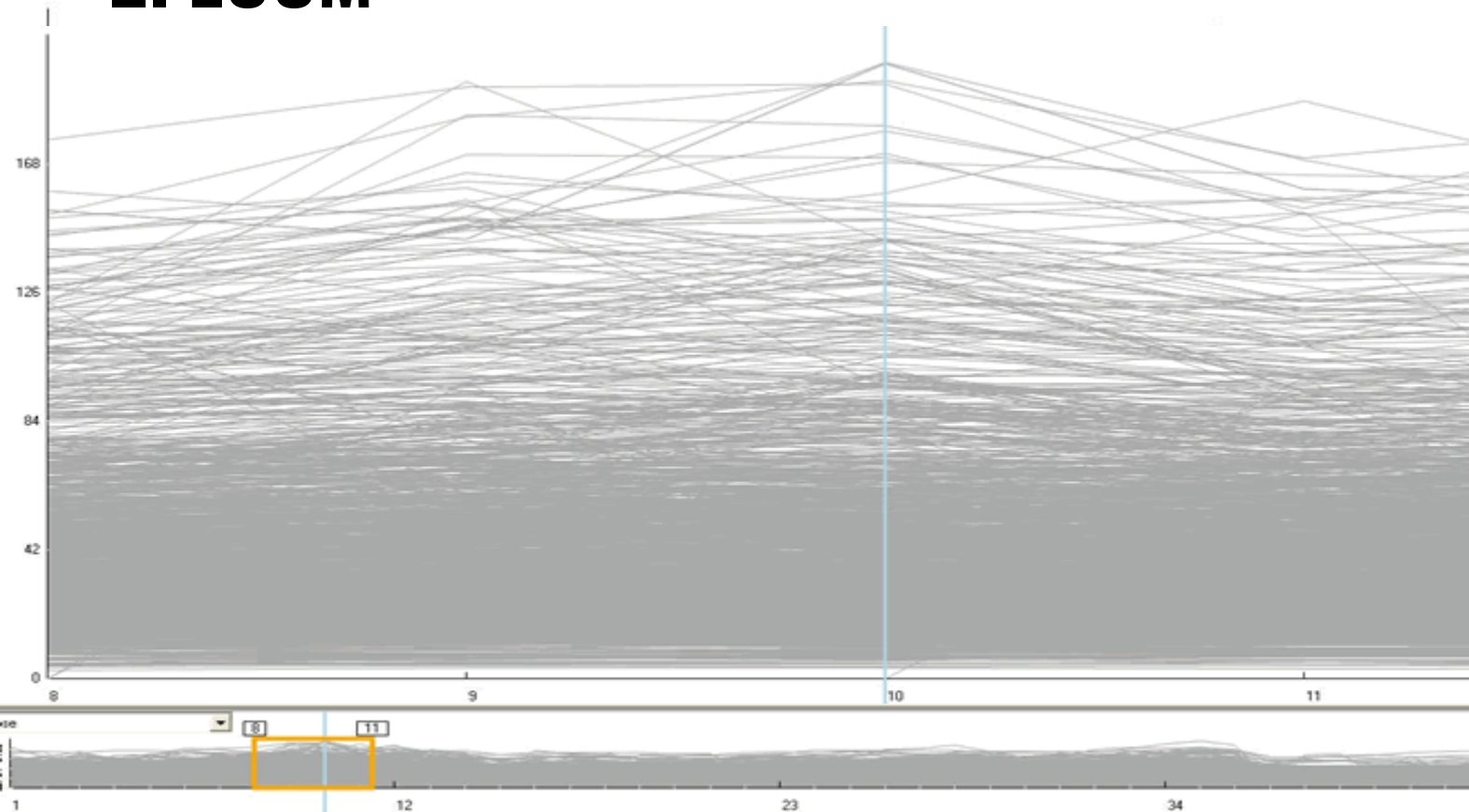
ANALYTICAL

1. OVERVIEW



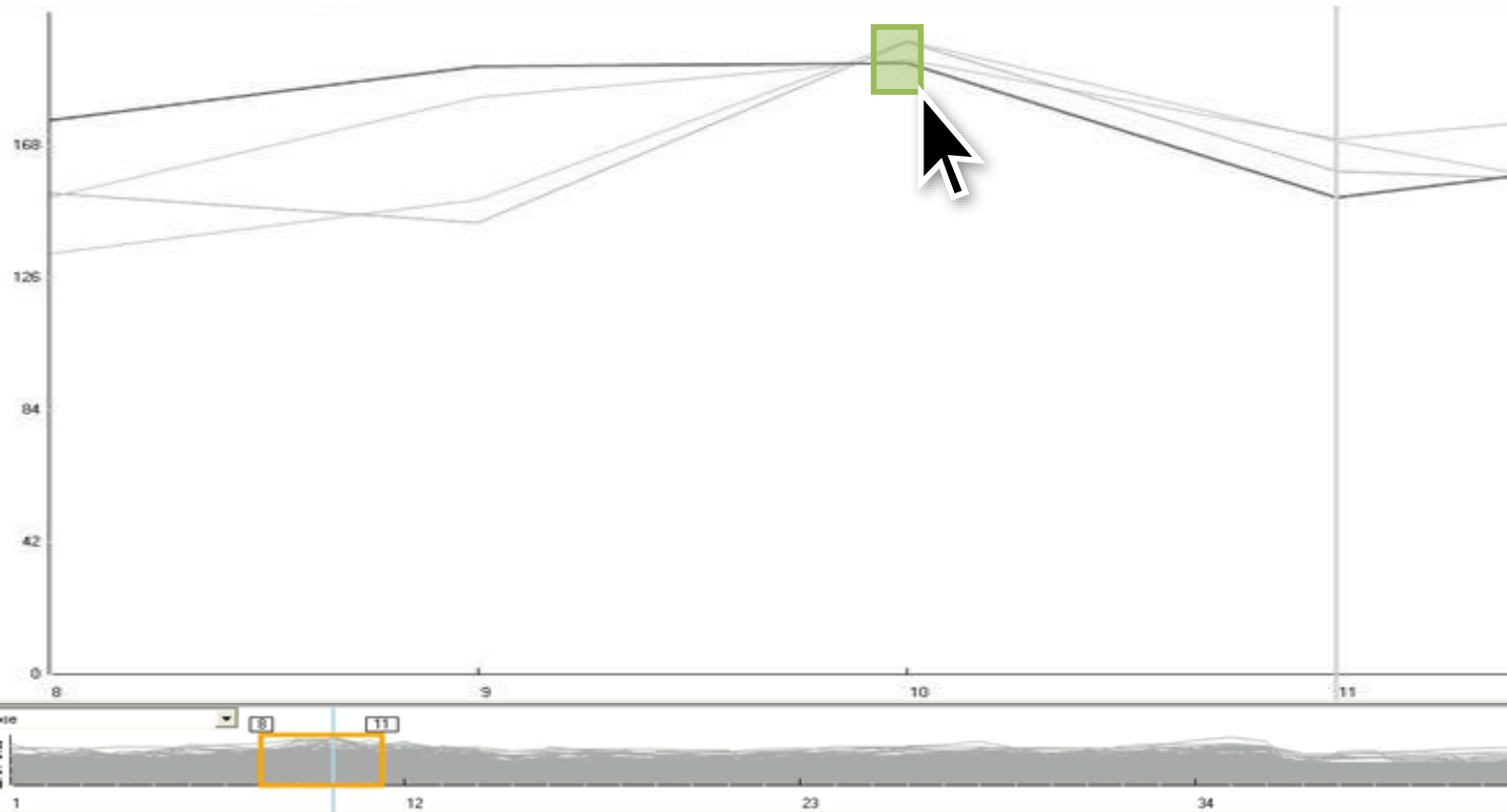
ANALYTICAL

2. ZOOM



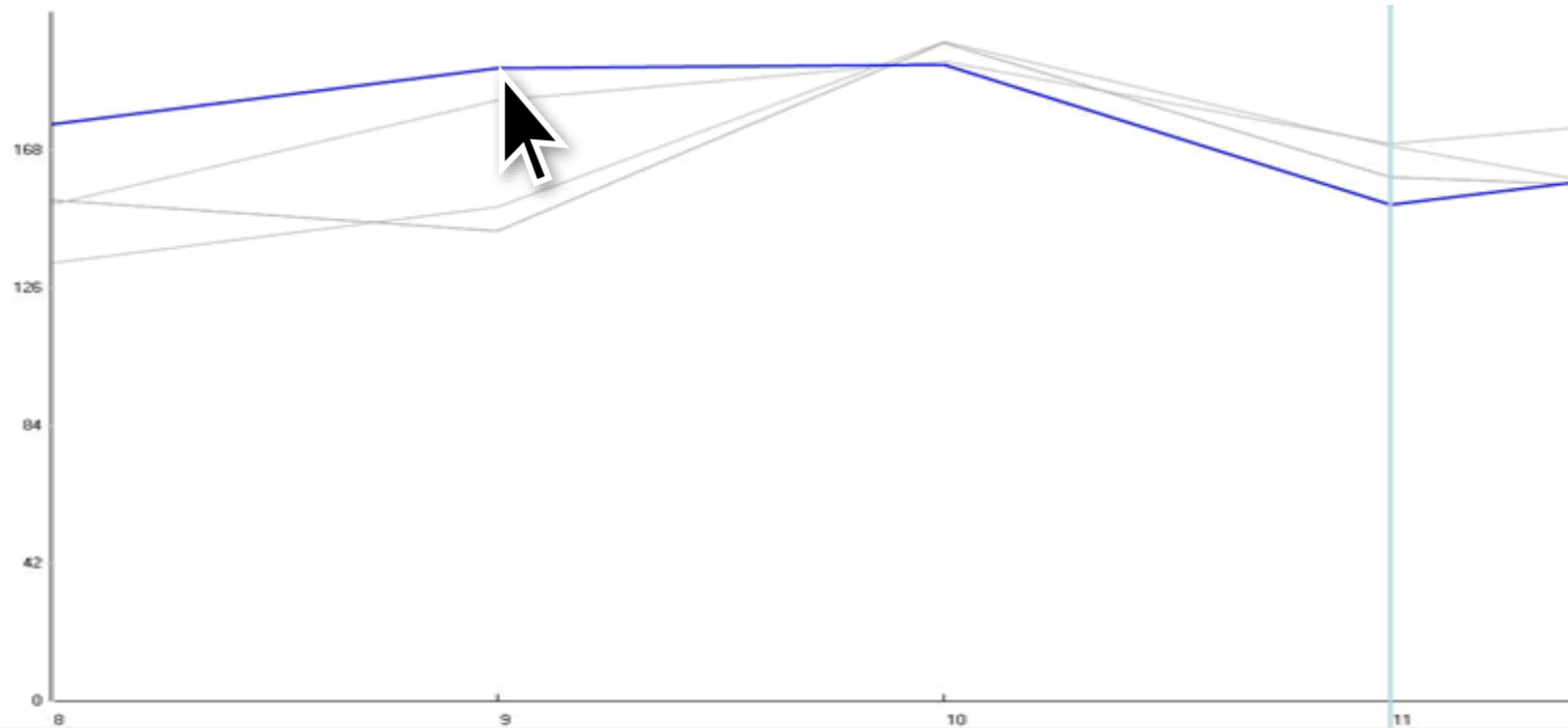
ANALYTICAL

3. FILTER



ANALYTICAL

4. DETAILS ON DEMAND



Name [...]	Close
1	74.06
2	86.25
3	102.75
4	100.50
5	143.31
6	160.31
7	168.94
8	175.88
9	193.00
10	194.00
11	151.00
12	167.81
13	112.88
14	126.38
15	89.00
16	119.00
17	145.50
18	139.25
19	132.38
20	122.13
21	104.94
22	140.00
23	150.63
24	161.50
25	159.50
26	133.50
27	130.50
28	149.19
29	138.44
30	108.00
31	102.00
32	99.25
33	111.13
34	139.56
35	131.00
36	123.25

Items | Attribute Statistics |

Name (5/1430)

BRITISH SKY BROADCASTING GP
PHONE.COM INC
REPUBLIC NY CORP
FOUNDRY NETWORKS INC
CREE INCORPORATED

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

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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

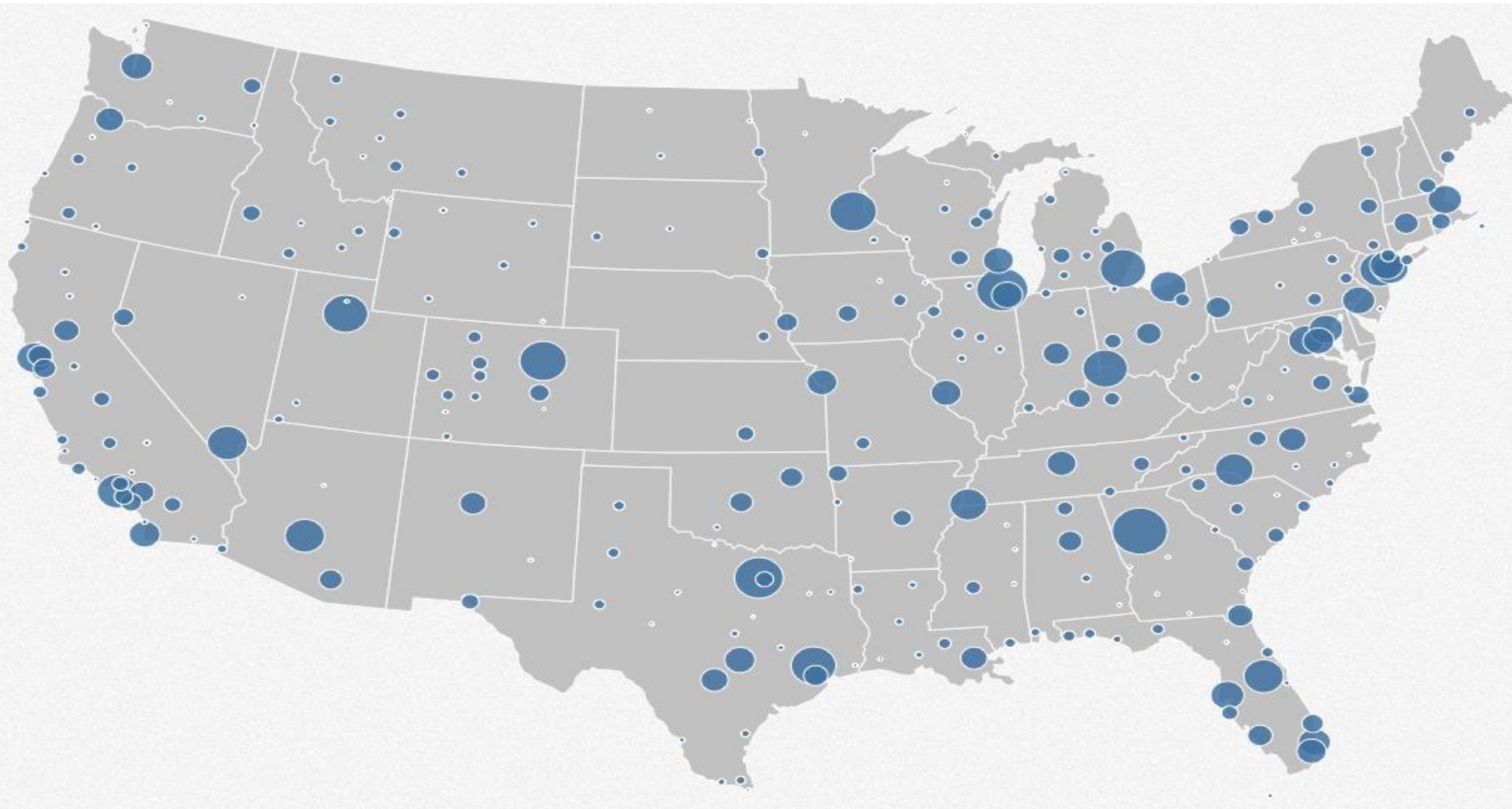
CONNECT

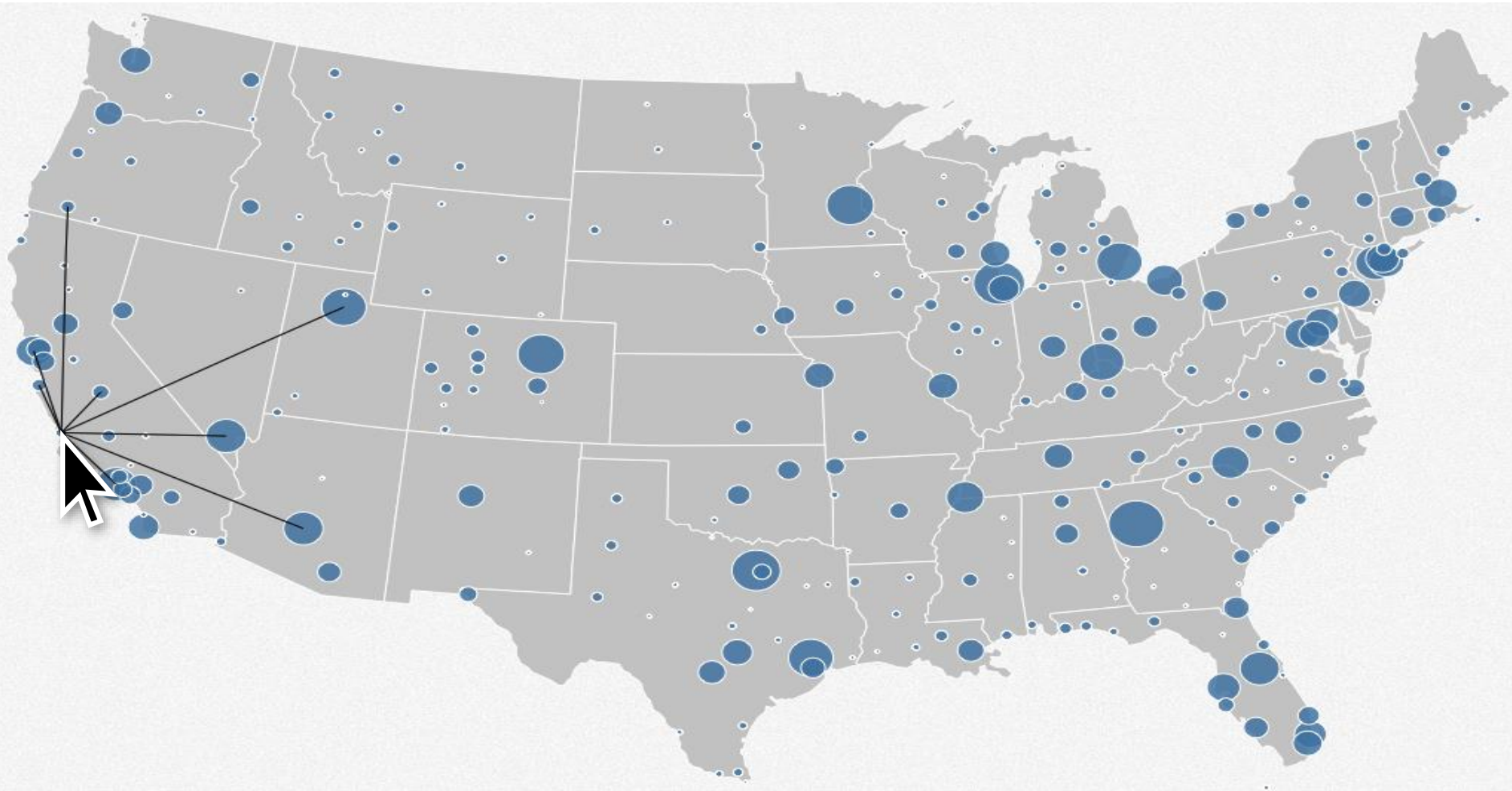
BASIC

Point Selection

Mouse Hover / Click

Touch / Tap





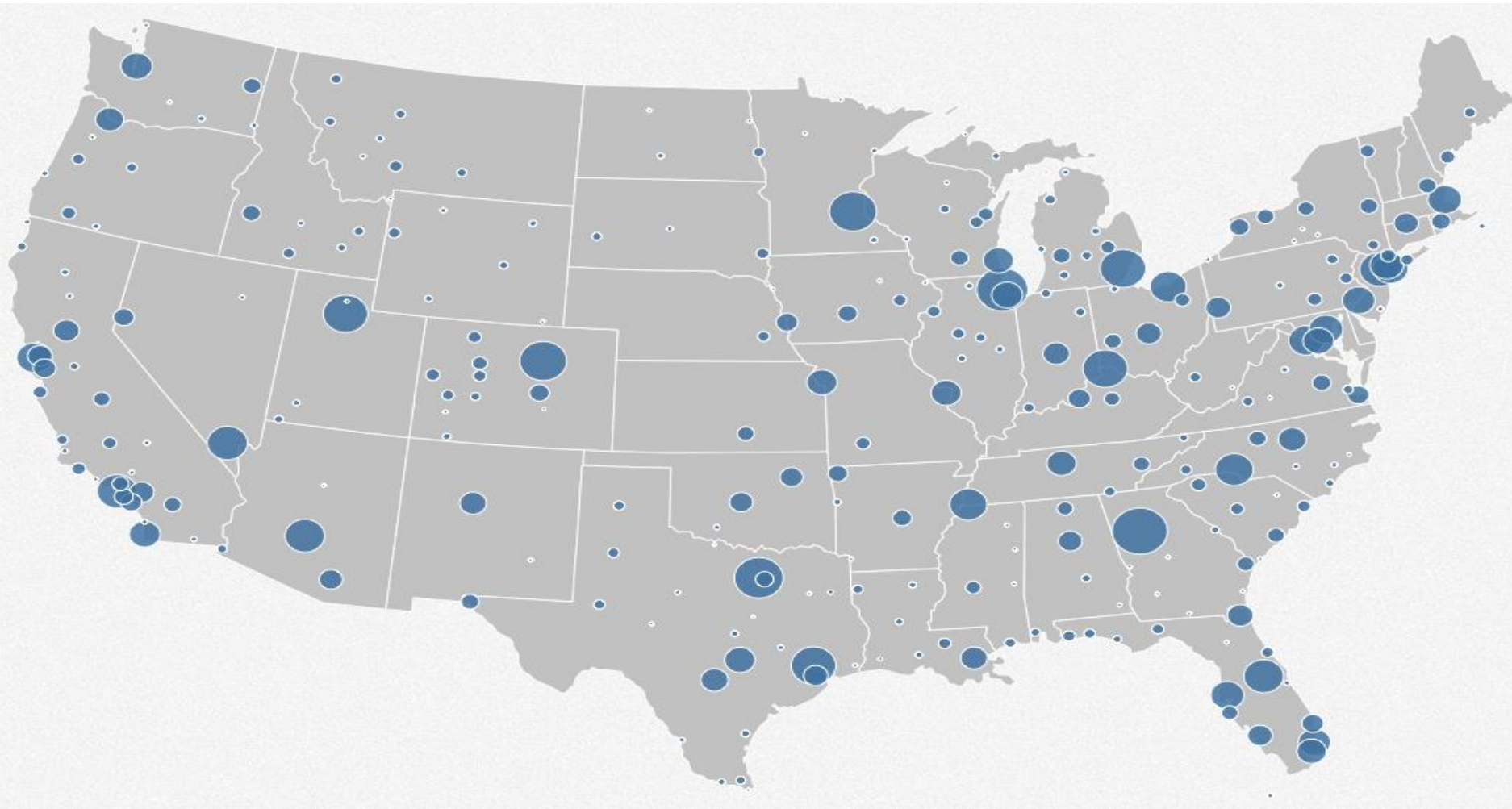
BASIC

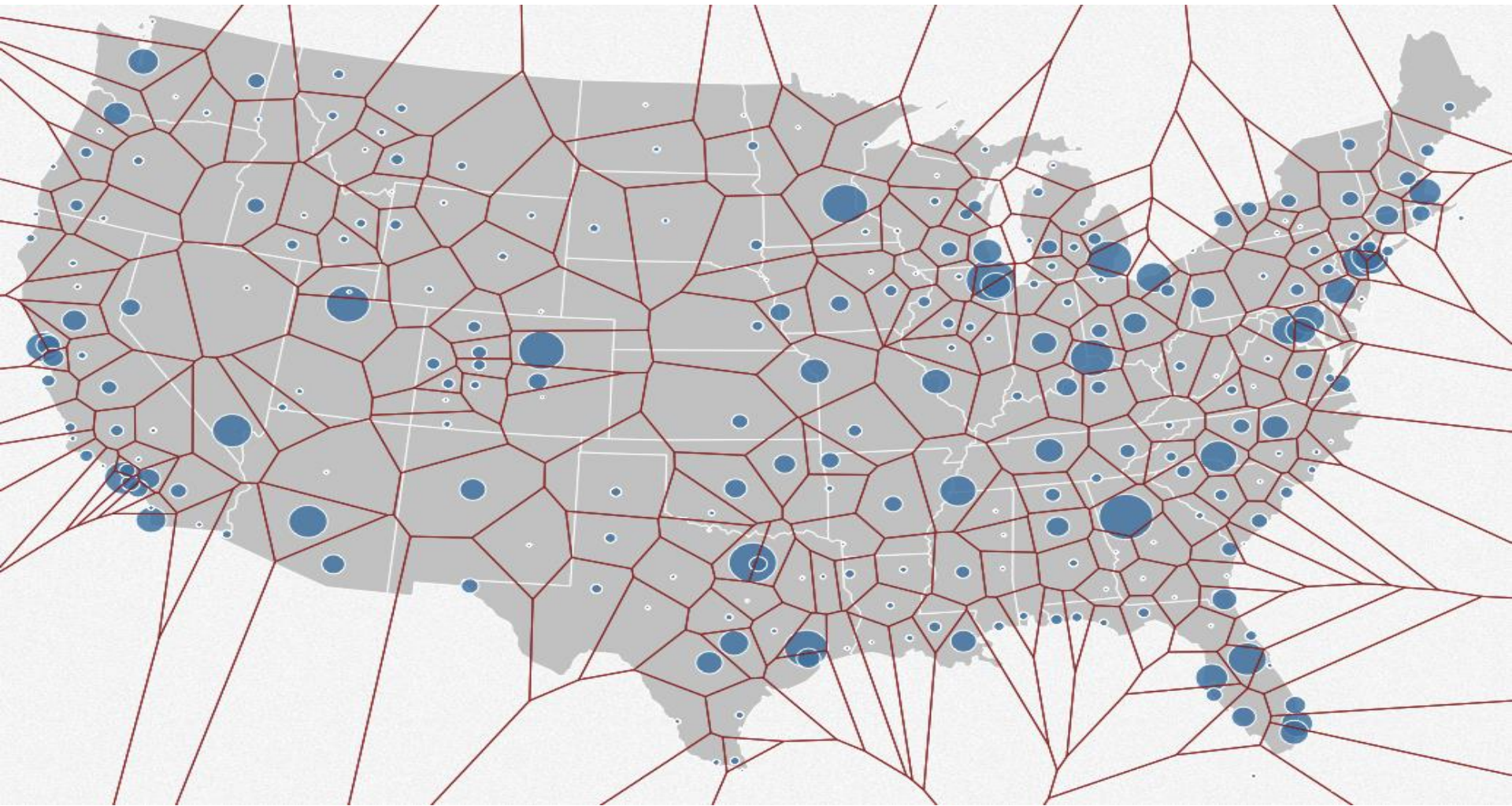
Point Selection

Mouse Hover / Click

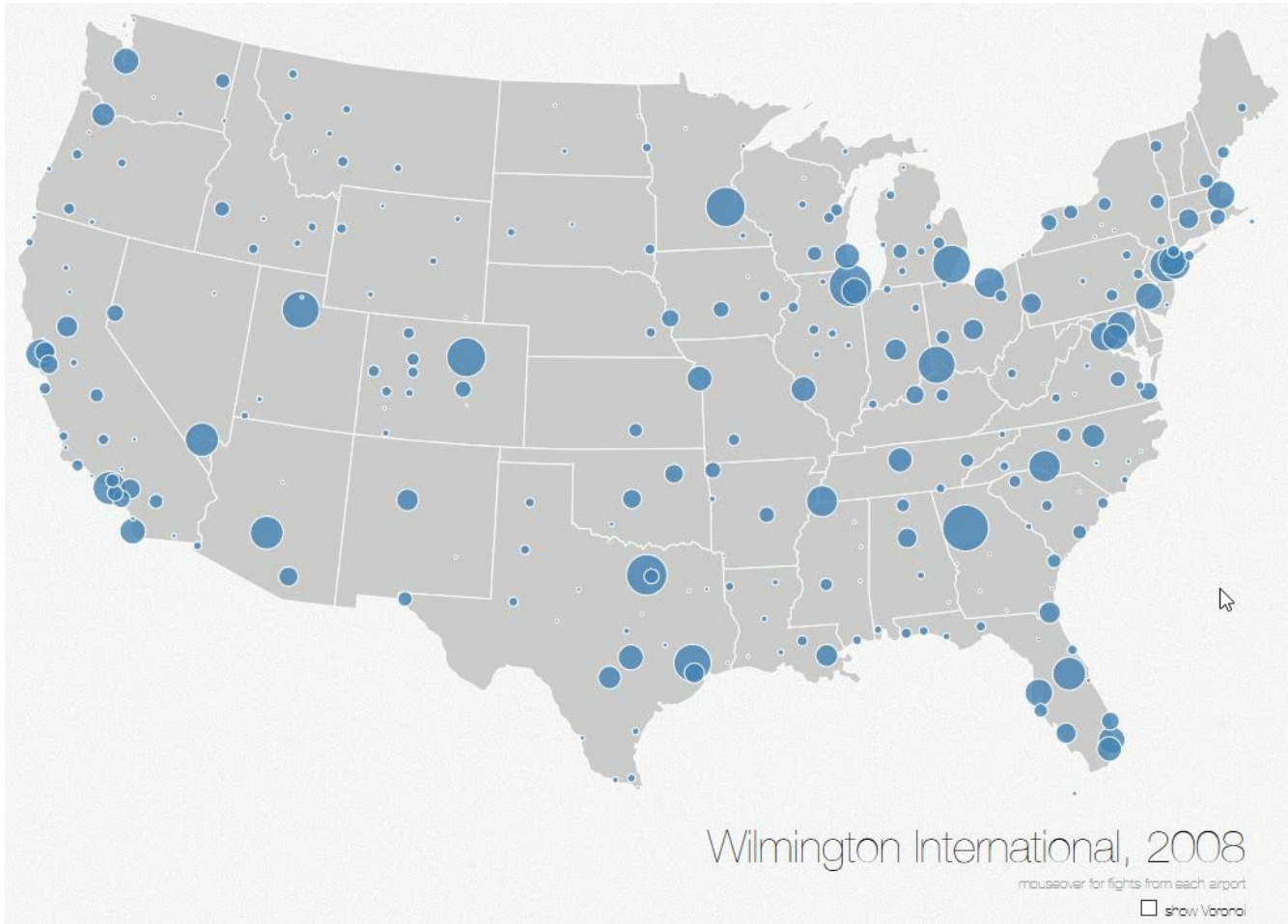
Touch / Tap

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





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



BASIC

Point Selection

Mouse Hover / Click

Touch / Tap

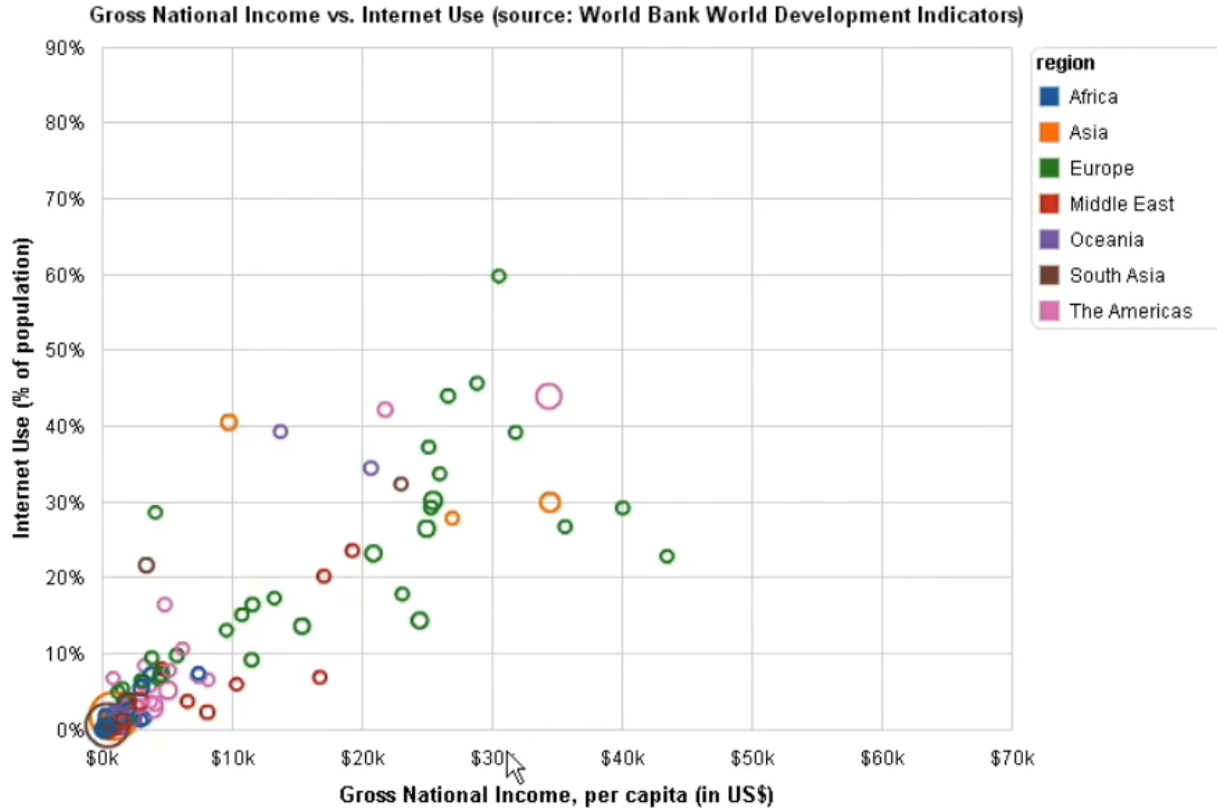
Select Nearby Element (e.g., Bubble Cursor)

Region Selection

Rubber-band or Lasso

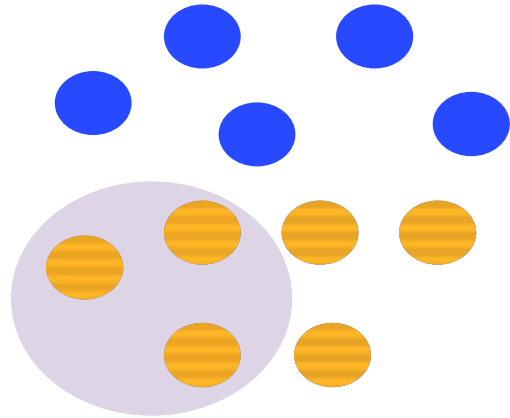
Area Cursors (“Brushes”)

RANGE

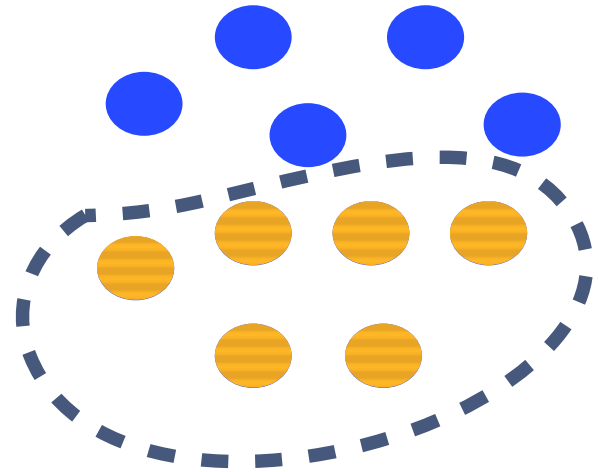


GENERALIZED SELECTION HEER ET AL. 2008

BRUSHES



LASSOS



WILLS' SELECTION TAXONOMY:

WILLS' SELECTION TAXONOMY

SELECTION MEMORY

MEMORY

25 < AGE < 35

COUNTRY = CANADA

**EDU LEVEL =
POSTSECONDARY**

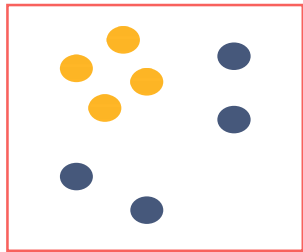
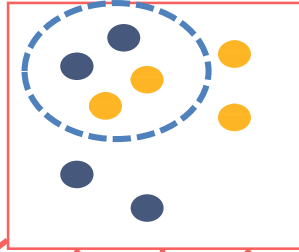
MEMORYLESS

25 < AGE < 35

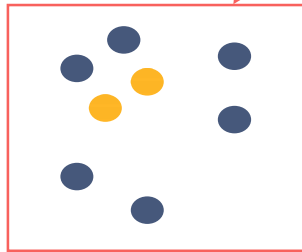
COUNTRY = CANADA

**EDU LEVEL =
POSTSECONDARY**

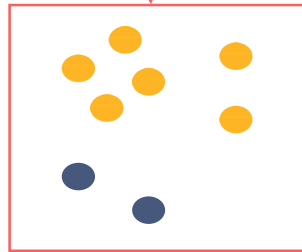
SELECTION OPERATIONS



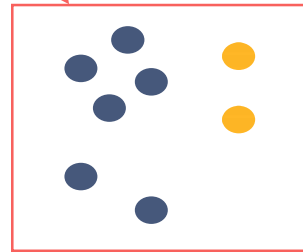
REPLACE



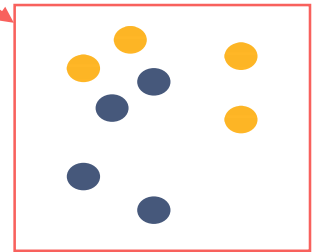
INTERSECT



ADD



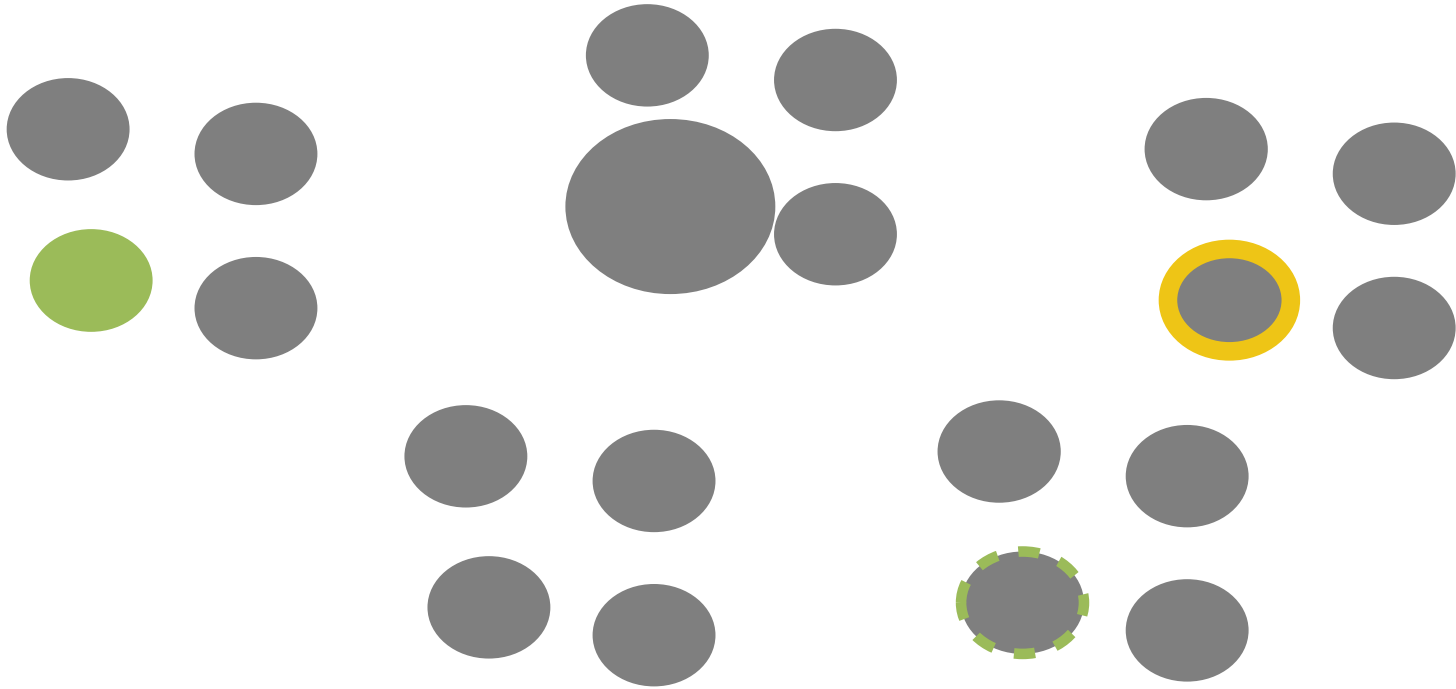
SUBTRACT



TOGGLE

HIGHLIGHTING

SELECTION + CHANGE IN APPEARANCE



SELECT

EXPLORE

FILTER

RECONFIGURE

ENCODE

ABSTRACT/ELABORATE

CONNECT

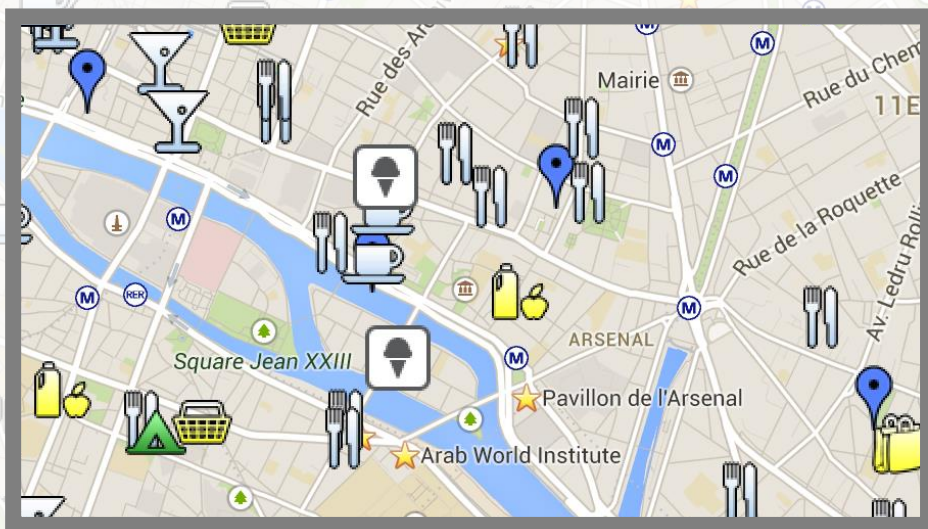
SHOW ME SOMETHING
ELSE

PROBLEM

Where am I?



NAVIGATION



PANNING



ZOOMING



NAVIGATION

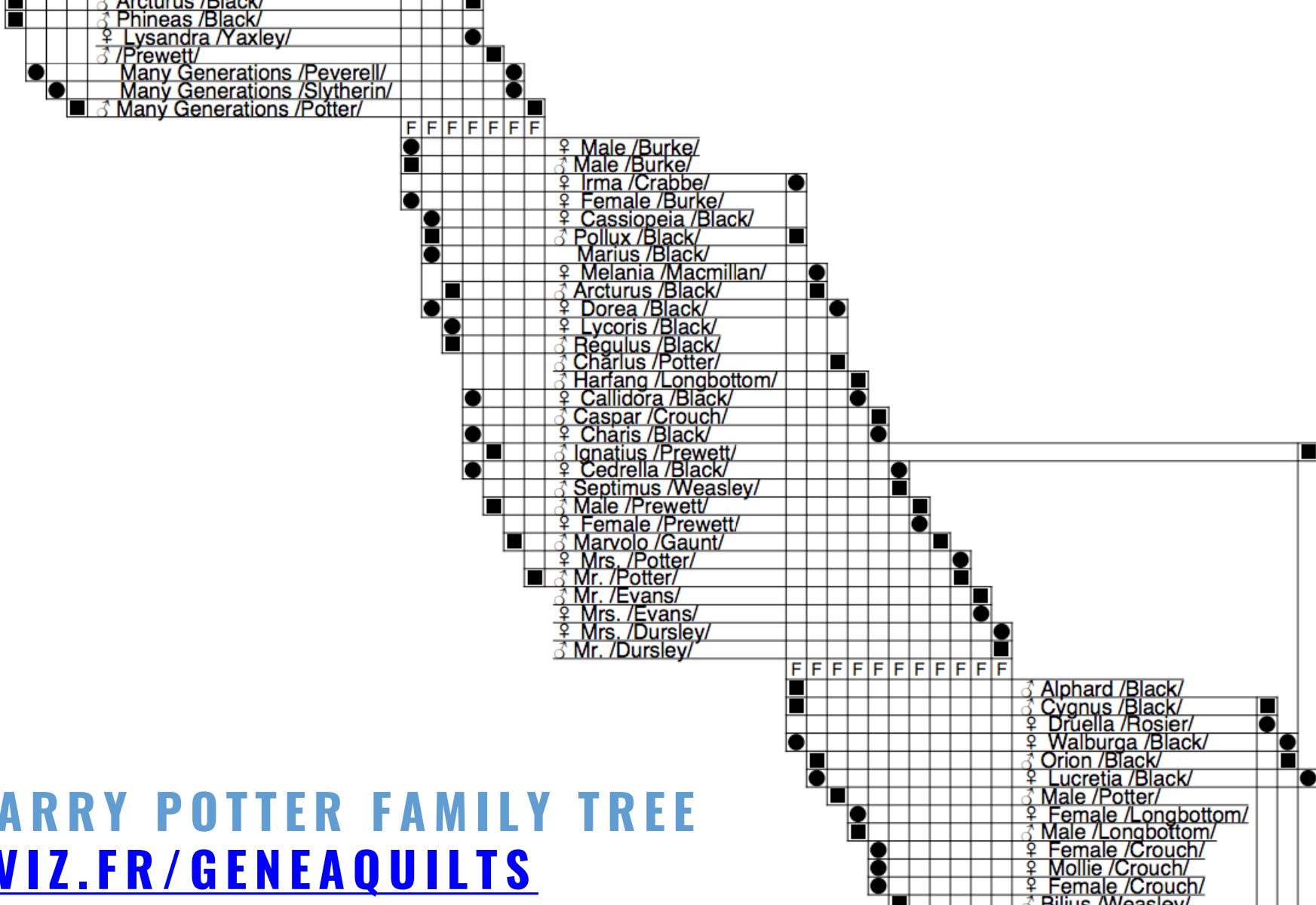


PANNING



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 > 2
garage == 2
bedrooms >= 3

REPLACING A QUERY WITH
“DYNAMIC QUERY WIDGETS”

Dynamic Browser : DC Home Finder

ID Number	Duelling Address	City
-----------	------------------	------

Dynamic Browser
Reset
Save
Dist to A:
1 19 30
Dist to B:
1 6 30
Bedrooms:
1 2 4 7
Cost:
\$50k 100k \$500k
Look at:
Hse TH Cnd
Features:
Gr9 Fp1
CAC New

The yellow dots above are homes in the DC area for sale. You may get more information on a home by selecting it. You may drag the 'A' and 'B' distance markers to your office or any other location you want to live near. Select distances, bedrooms, and cost ranges by dragging the corresponding slider boxes on the right. Select specific home types and services by pressing the labeled buttons on the right.

HOMEFINDER WILLIAMSON AND SCHNEIDERMAN 1992

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

Ben Shneiderman

COPYRIGHT © 1994 UNIVERSITY OF MARYLAND

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

COPYRIGHT © 1994 UNIVERSITY OF MARYLAND

CRIMESPOTTING



Report data last published by Oakland Police: 314 days ago

Home

Map

Crime Reports

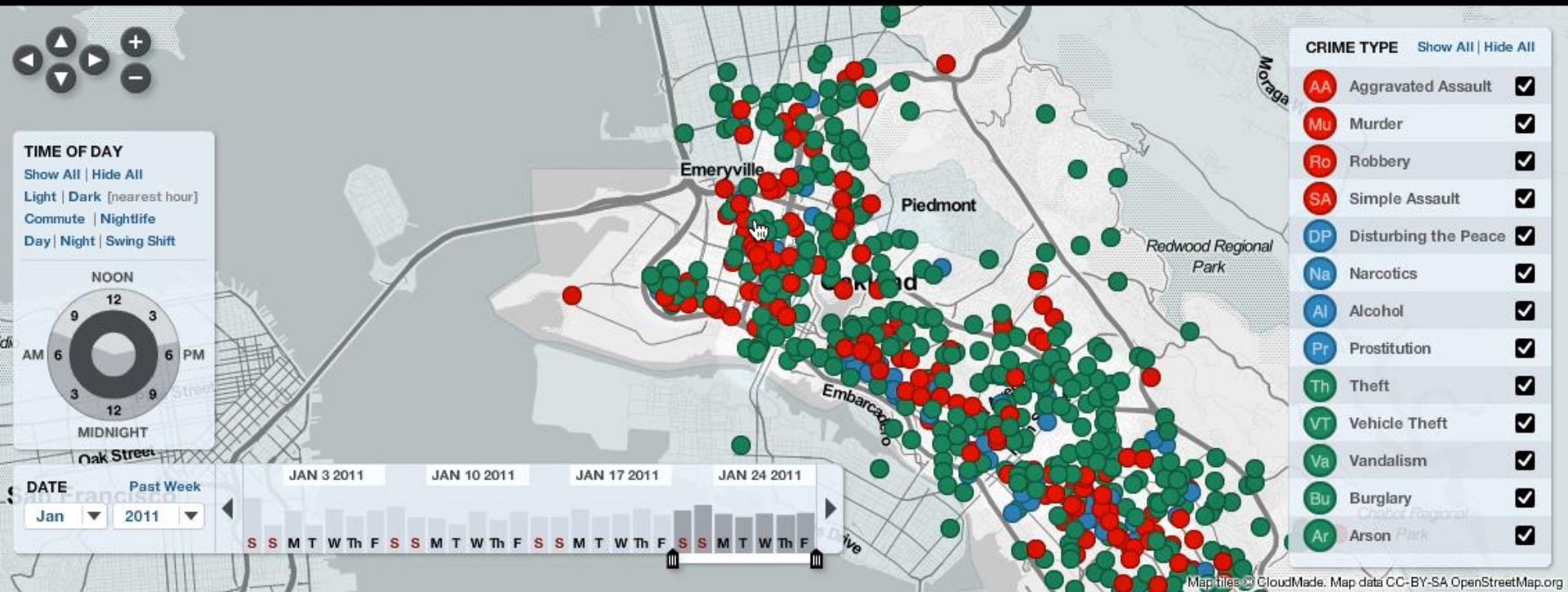
Police Beats

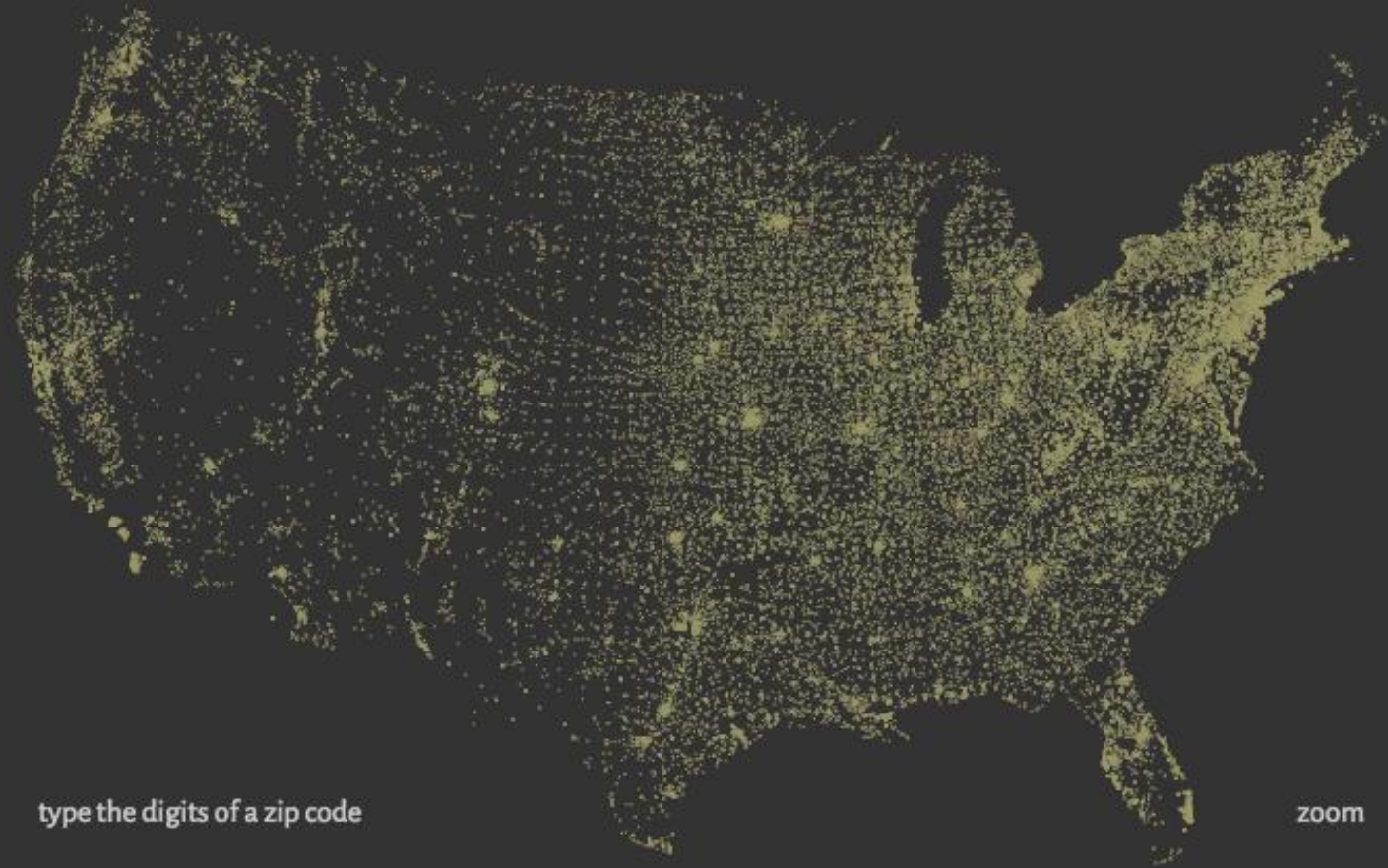
Alerts

API

About

Feedback





type the digits of a zip code

zoom

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

zipdecode

BEN FRY 1999

Baby Name >

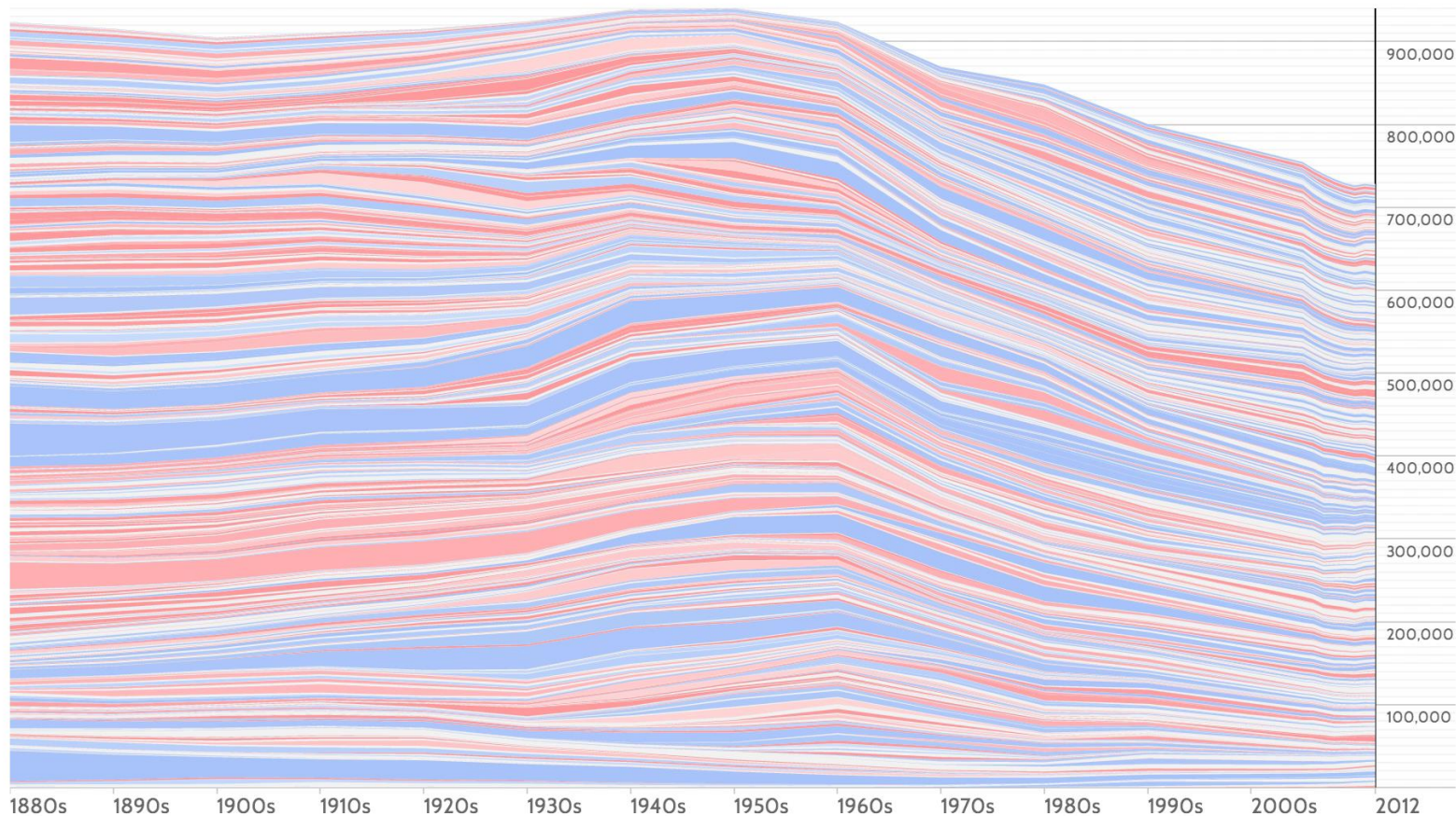
Both Boys Girls

Current rank: boys

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

girls

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



SELECT

EXPLORE

FILTER

SHOW ME A DIFFERENT
ARRANGEMENT

RECONFIGURE

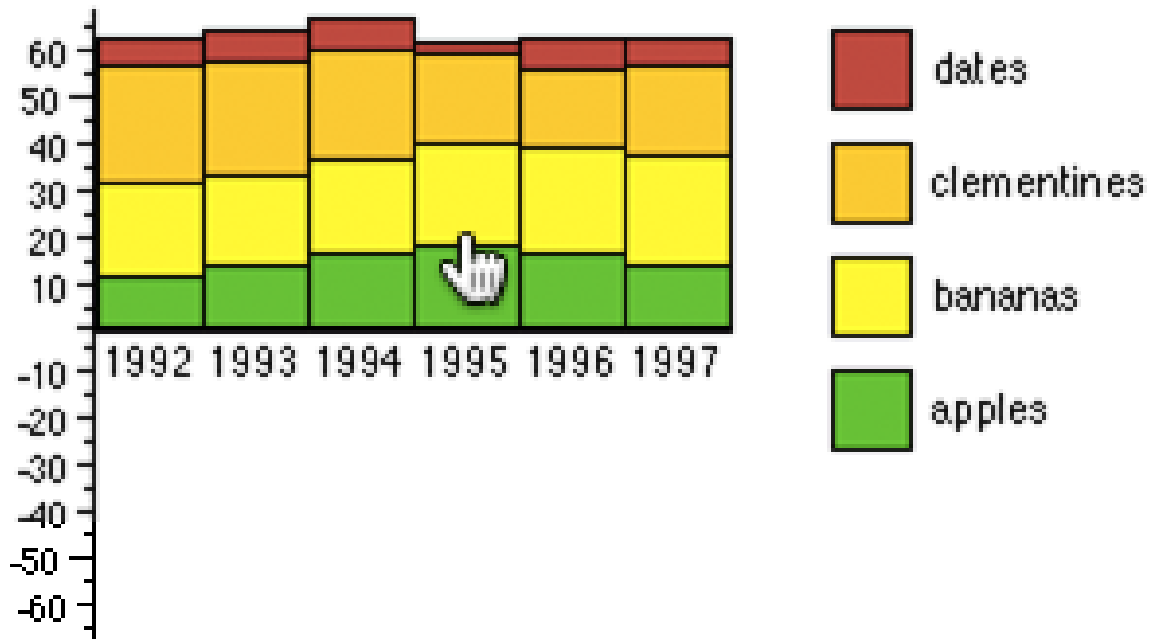
ENCODE

ABSTRACT/ELABORATE

CONNECT

RE-ARRANGING DATA

Fruit Sales 1992-1997



INTERACTIVE STACKED HISTOGRAMS [DIX & ELLIS, 1998]

Graph Viewer

Roll-up by:

All

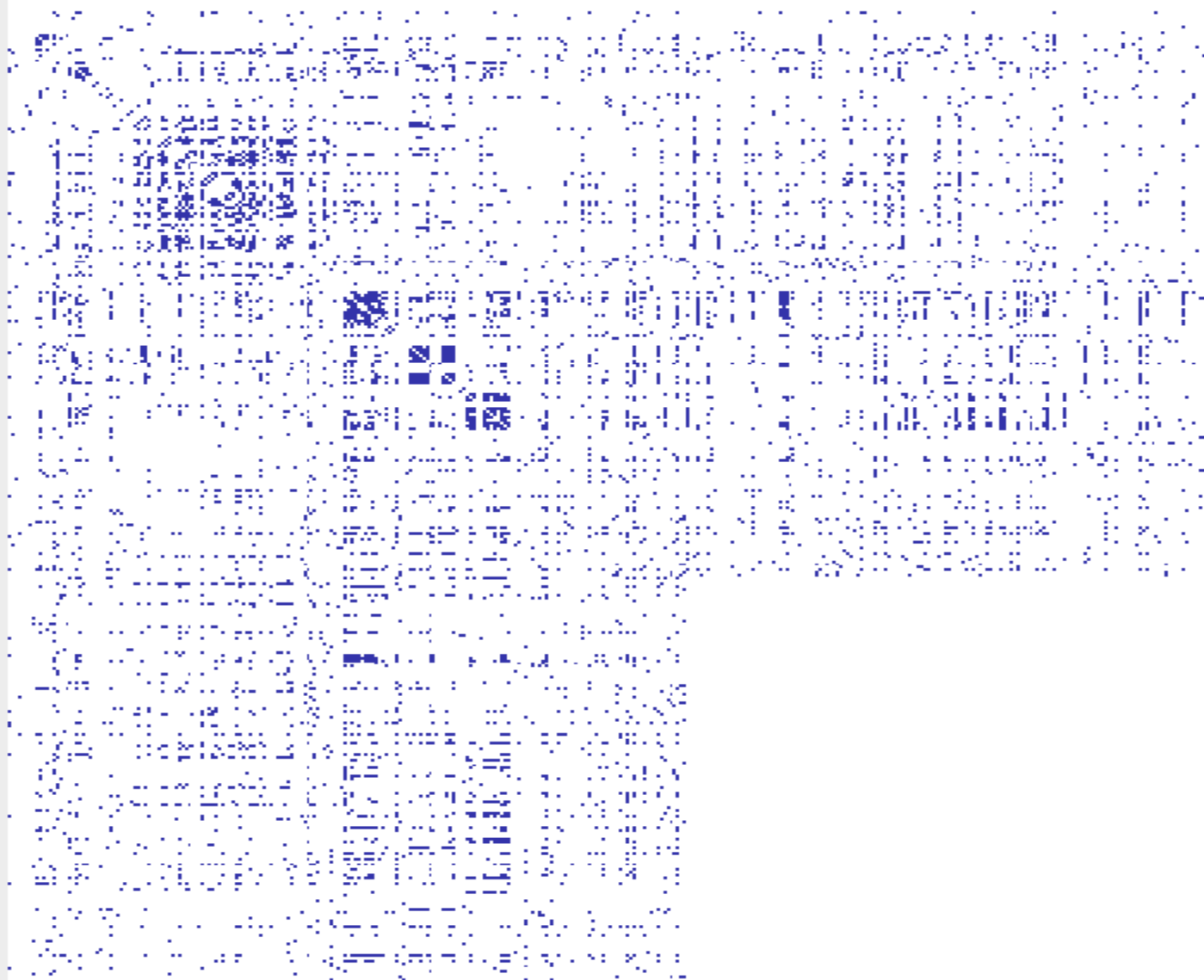
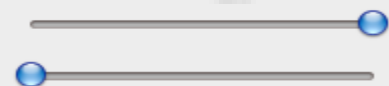
Visualization:

Matrix

Sort by:

None

Edge centrality threshold:



Graph Viewer

Roll-up by:

All

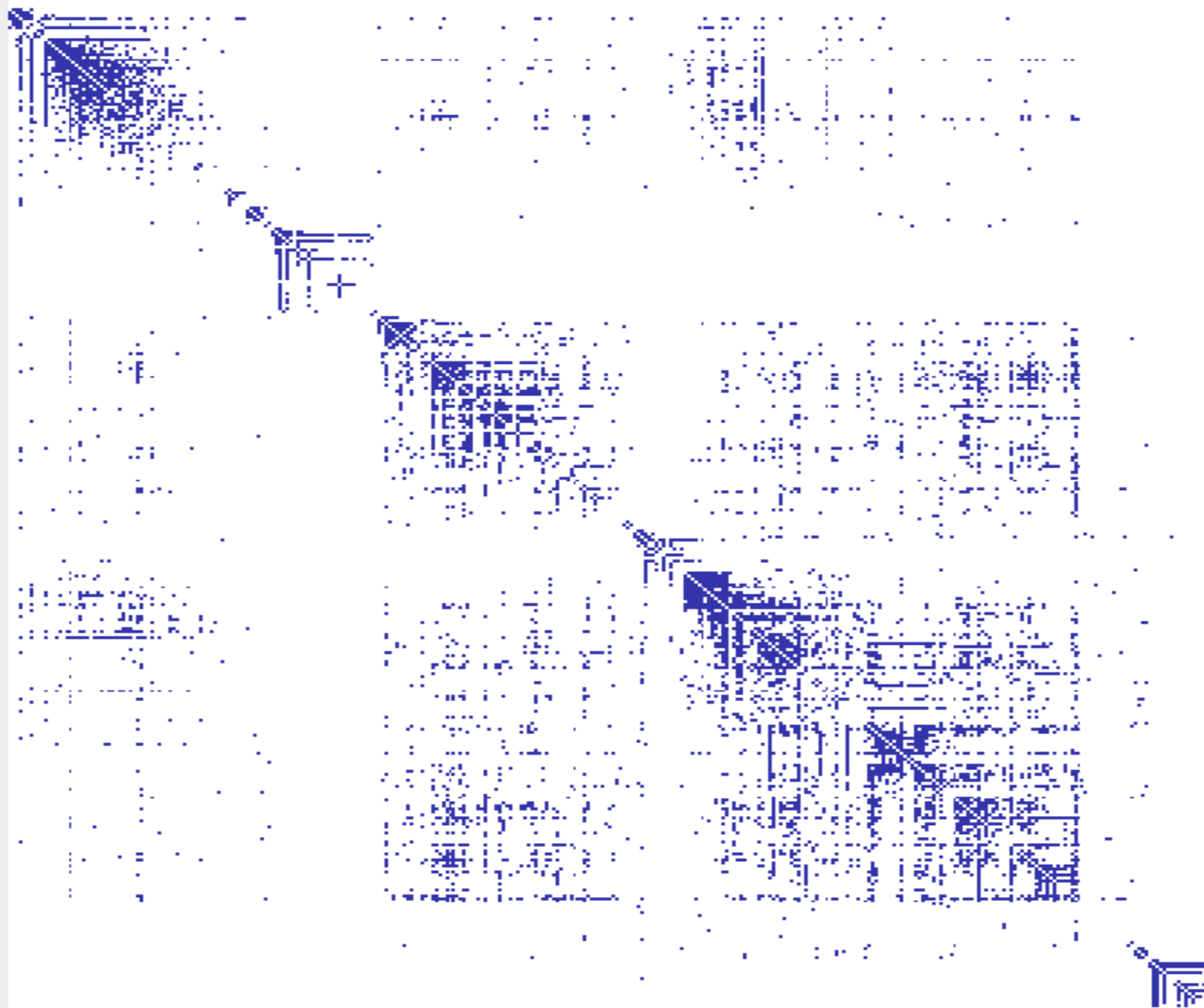
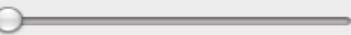
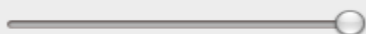
Visualization:

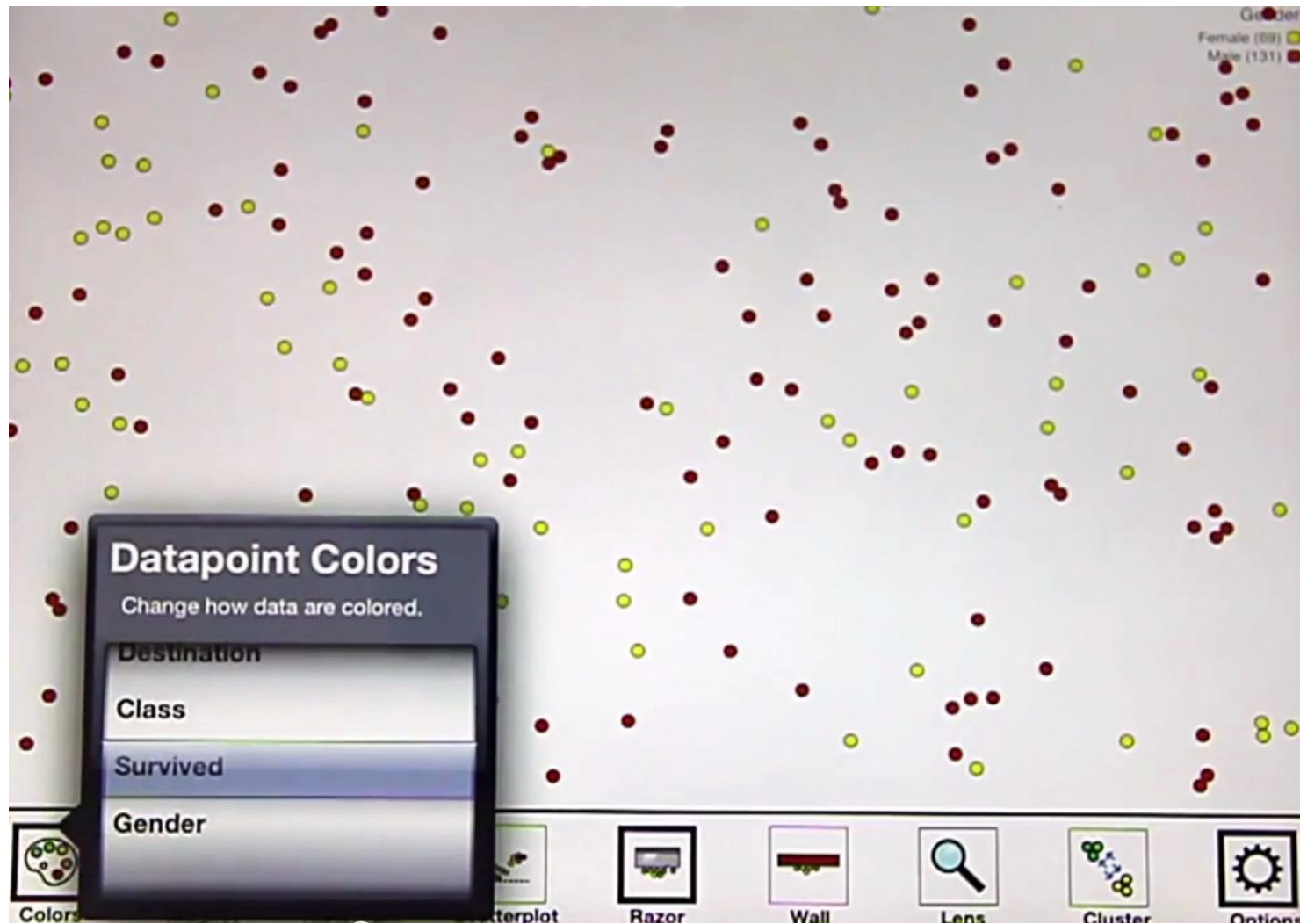
Matrix

Sort by:

Linkage

Edge centrality filters:





KINETICA [RZESZORTARKSI & KITTUR 2013]

SELECT

EXPLORE

FILTER

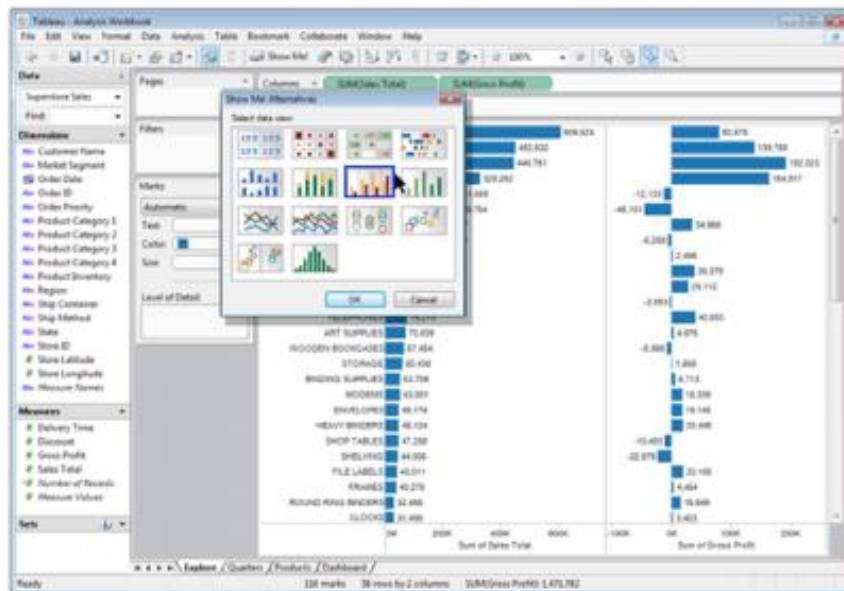
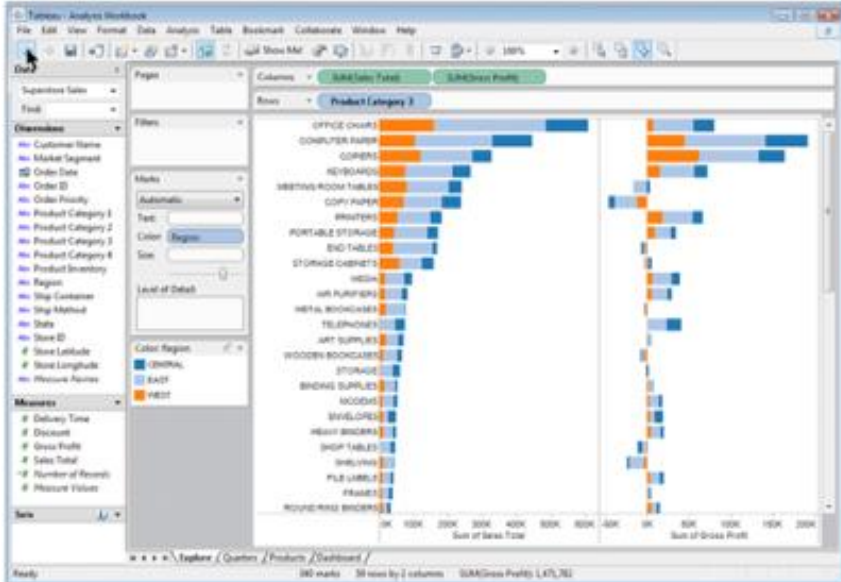
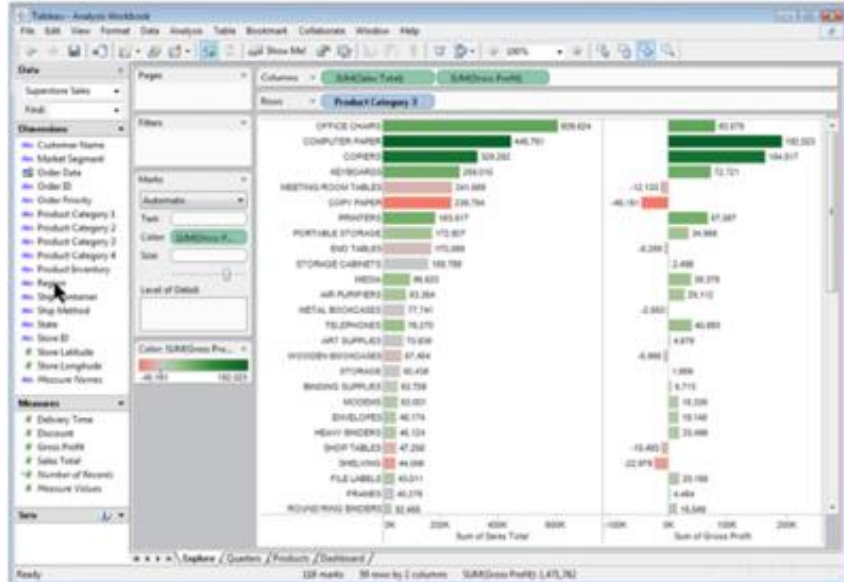
RECONFIGURE

ENCODE

ABSTRACT/ELABORATE

CONNECT

**SHOW ME A DIFFERENT
REPRESENTATION**



SELECT

EXPLORE

FILTER

RECONFIGURE

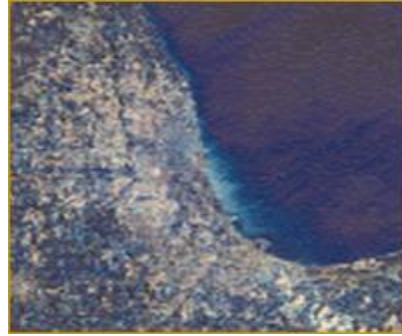
ENCODE

SHOW ME MORE
OR LESS DETAIL

ABSTRACT/ELABORATE

CONNECT

CHANGING LEVELS OF ABSTRACTION

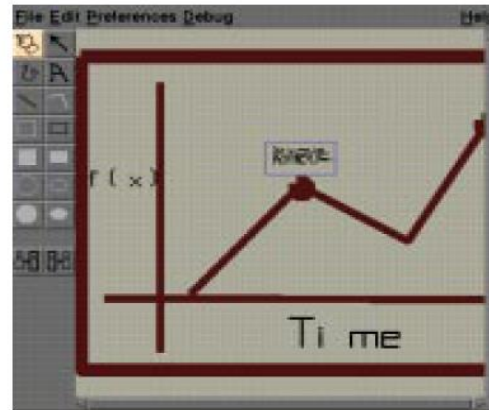
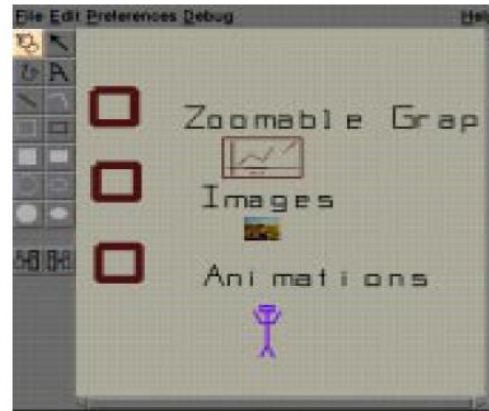
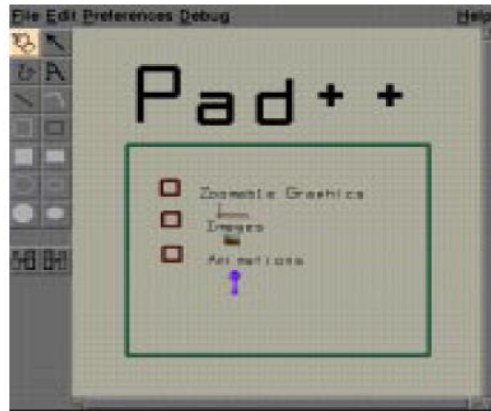
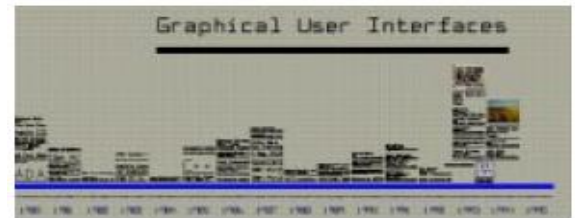
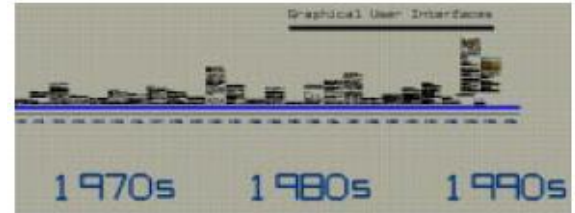


POWERS OF TEN RAY & CHARLES EAMES 1977



POWERS OF TEN

SEMANTIC ZOOMING



PAD++ BEDERSON AND HOLLAN 1994

LiveRAC

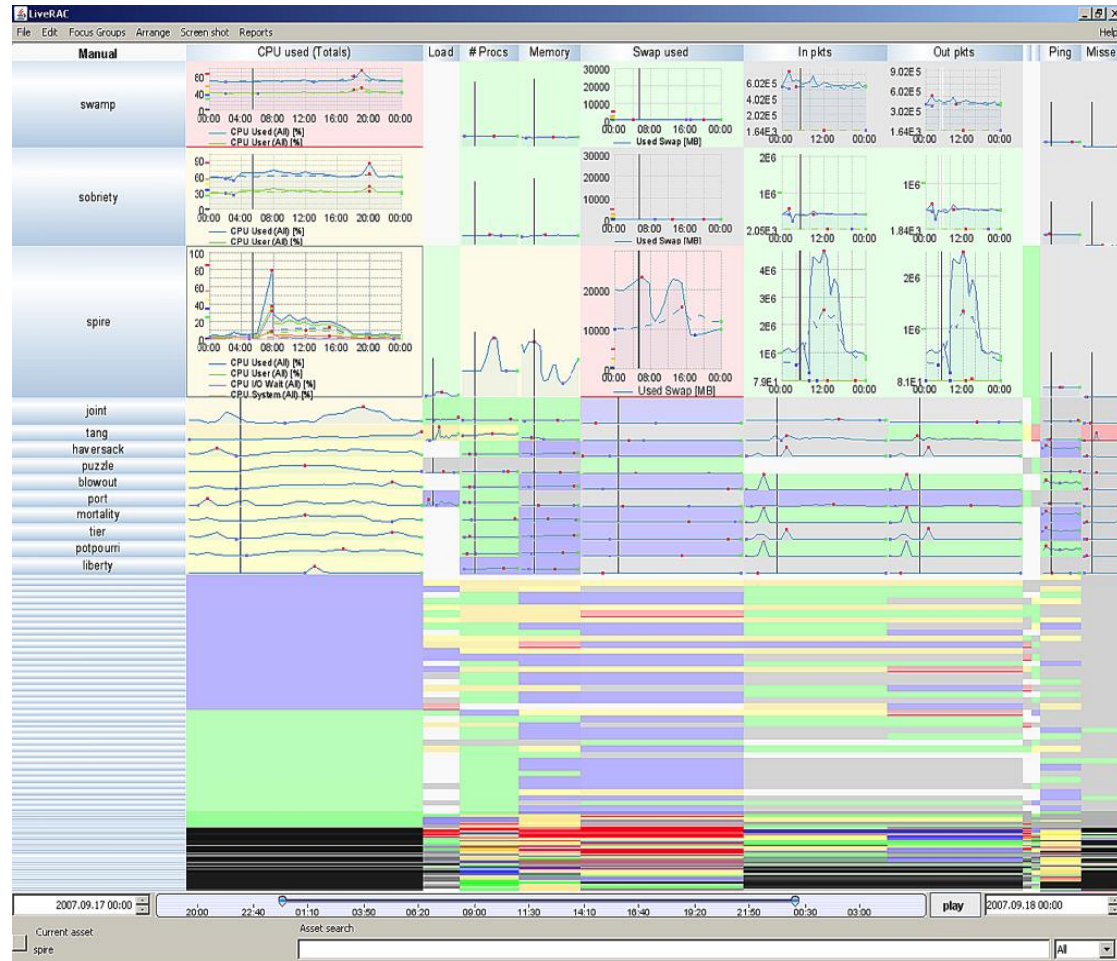
ENCODINGS CHANGE

—COLORED BOX

—SPARKLINE

—SIMPLE LINE CHART

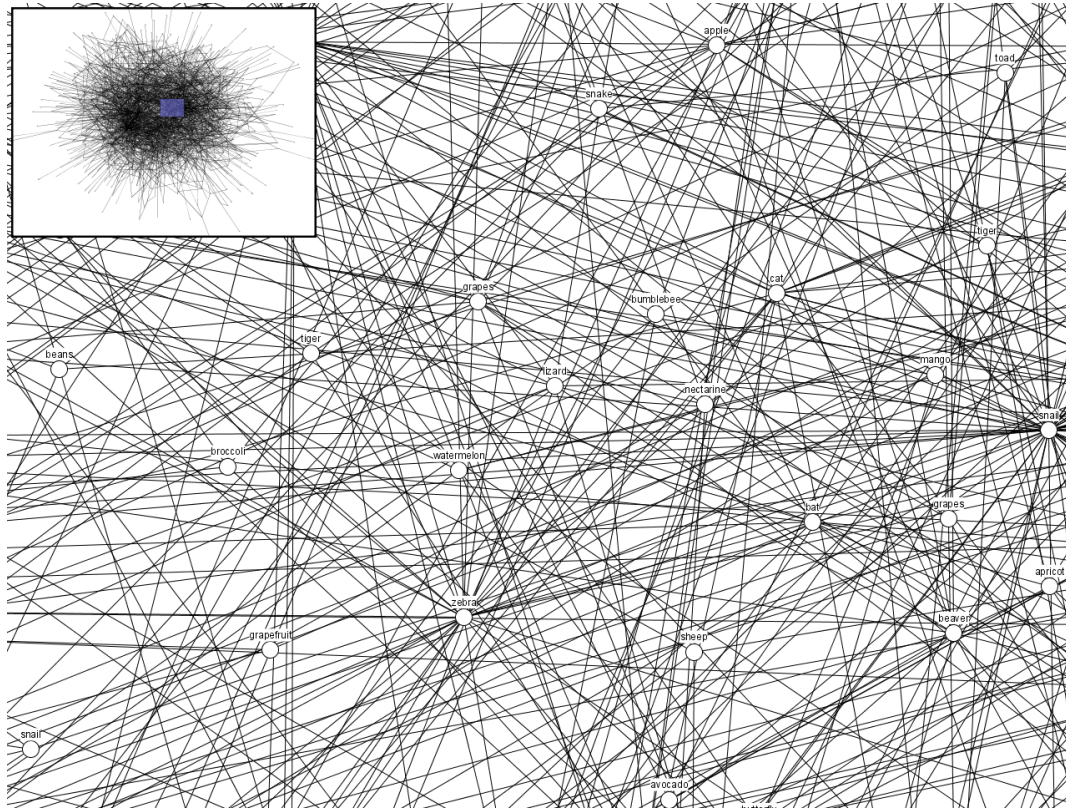
—FULL CHART: AXES AND TICKMARKS



MCLACHLAN ET AL. 2008

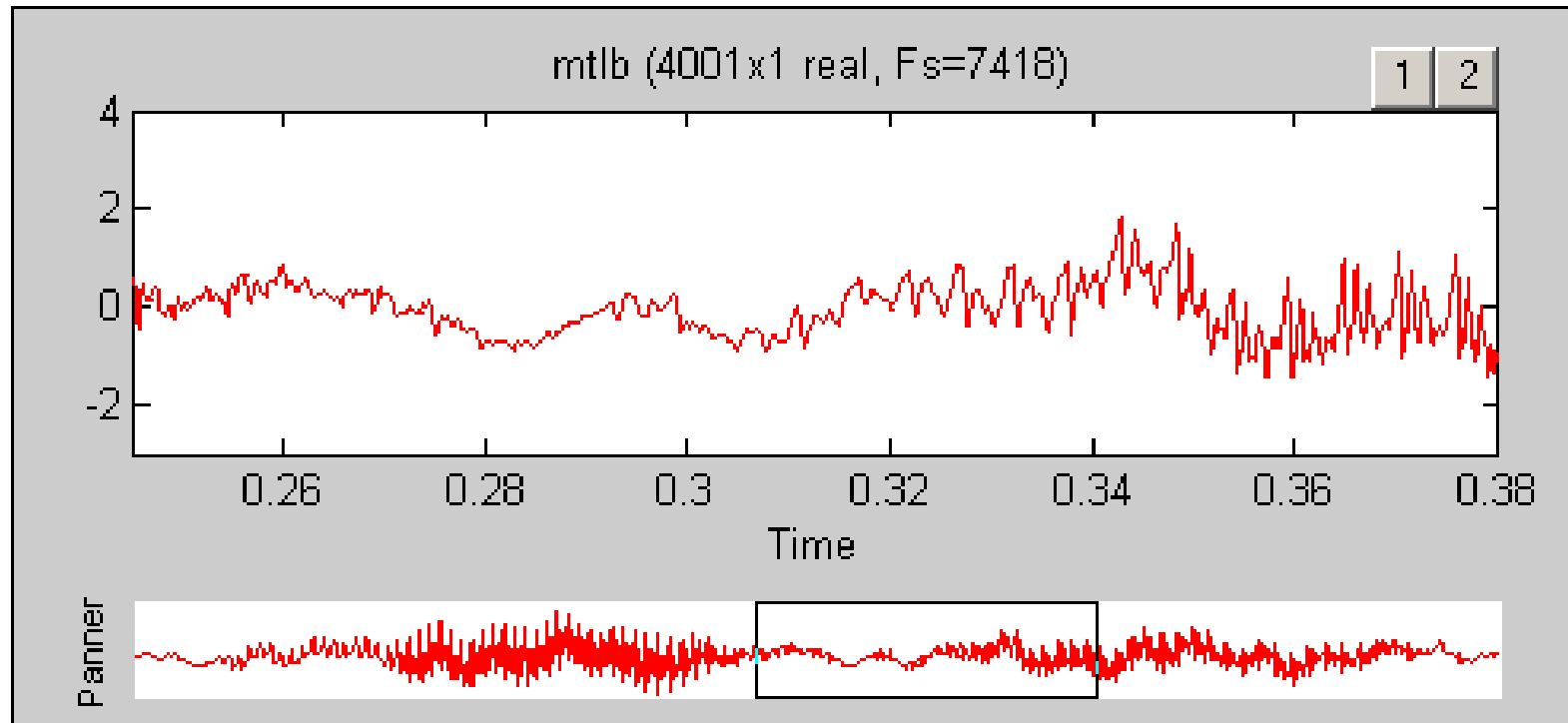
OVERVIEW + DETAIL

Panning a large graph



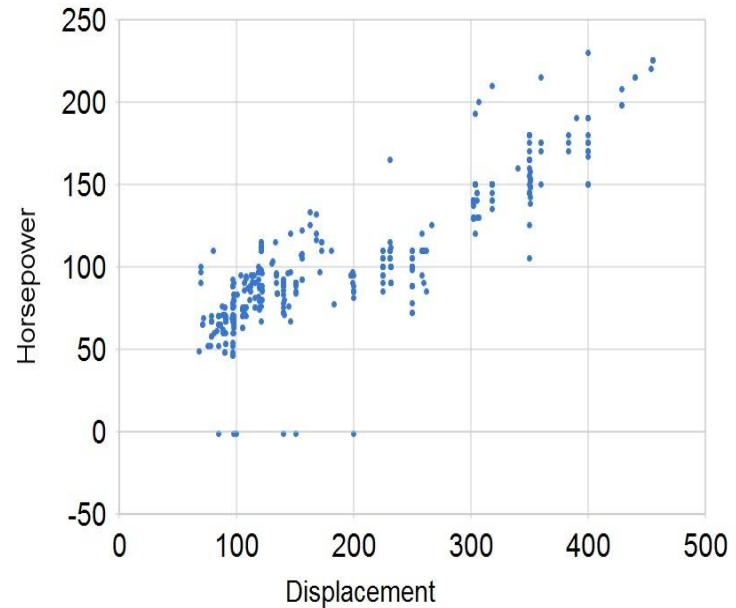
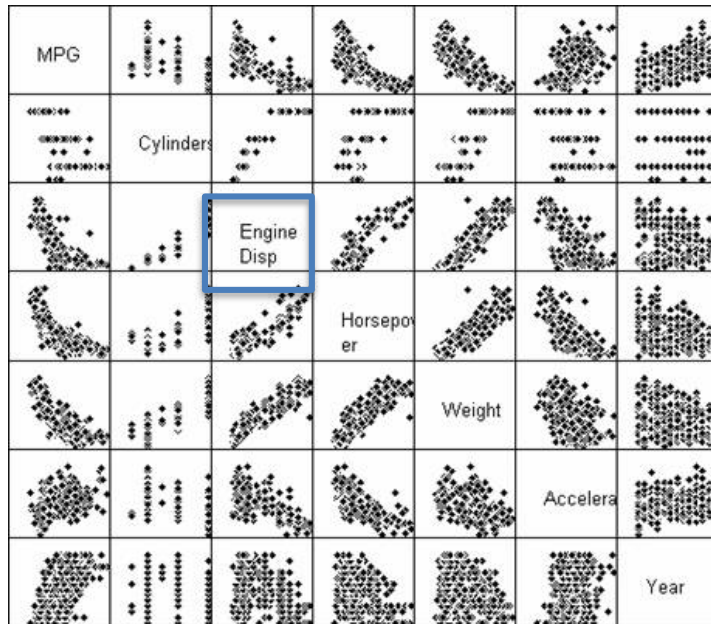
OVERVIEW + DETAIL

Panning a line chart



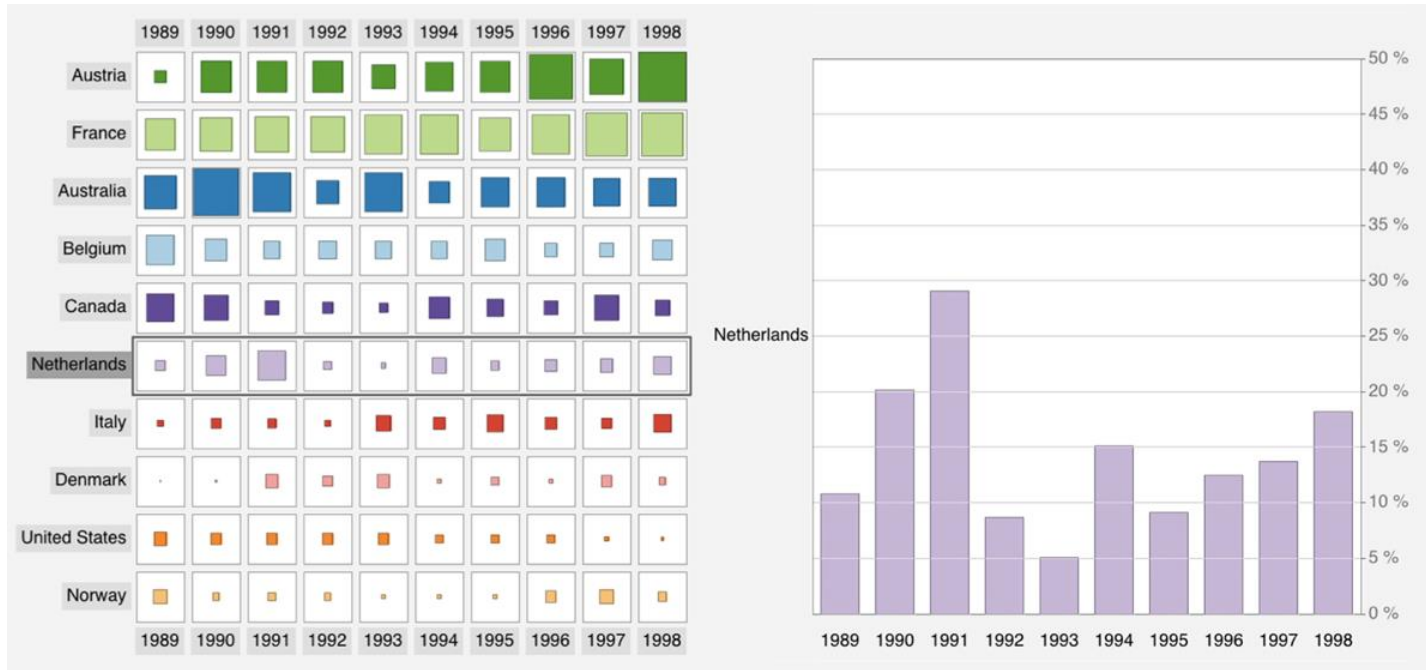
OVERVIEW + DETAIL

Browsing Multiple Views



OVERVIEW + DETAIL

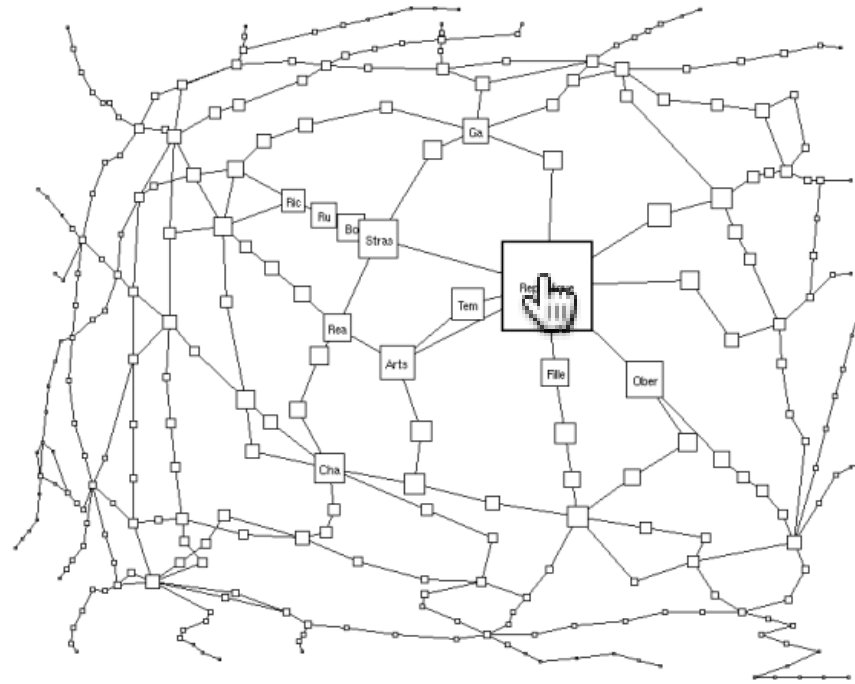
Browsing Multiple Views



FOCUS + CONTEXT

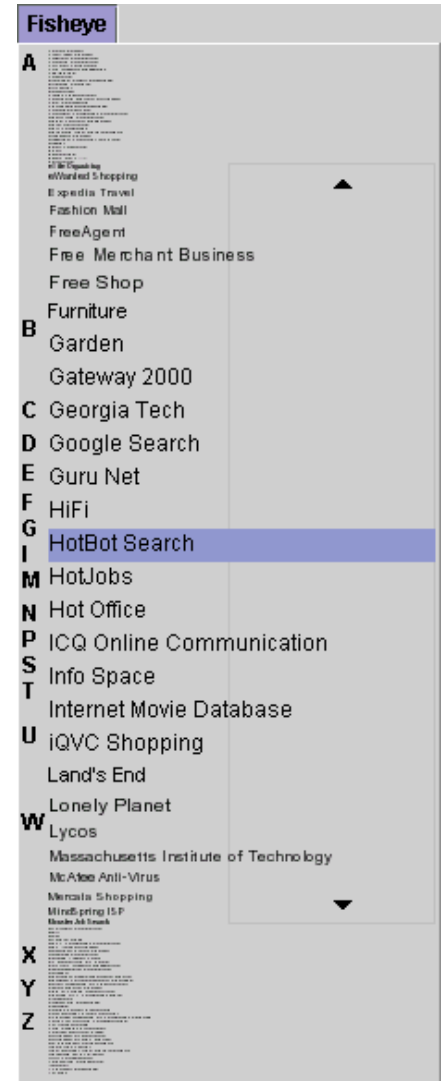
Space Distortion

1) Fisheye Views of Graphs



FOCUS + CONTEXT

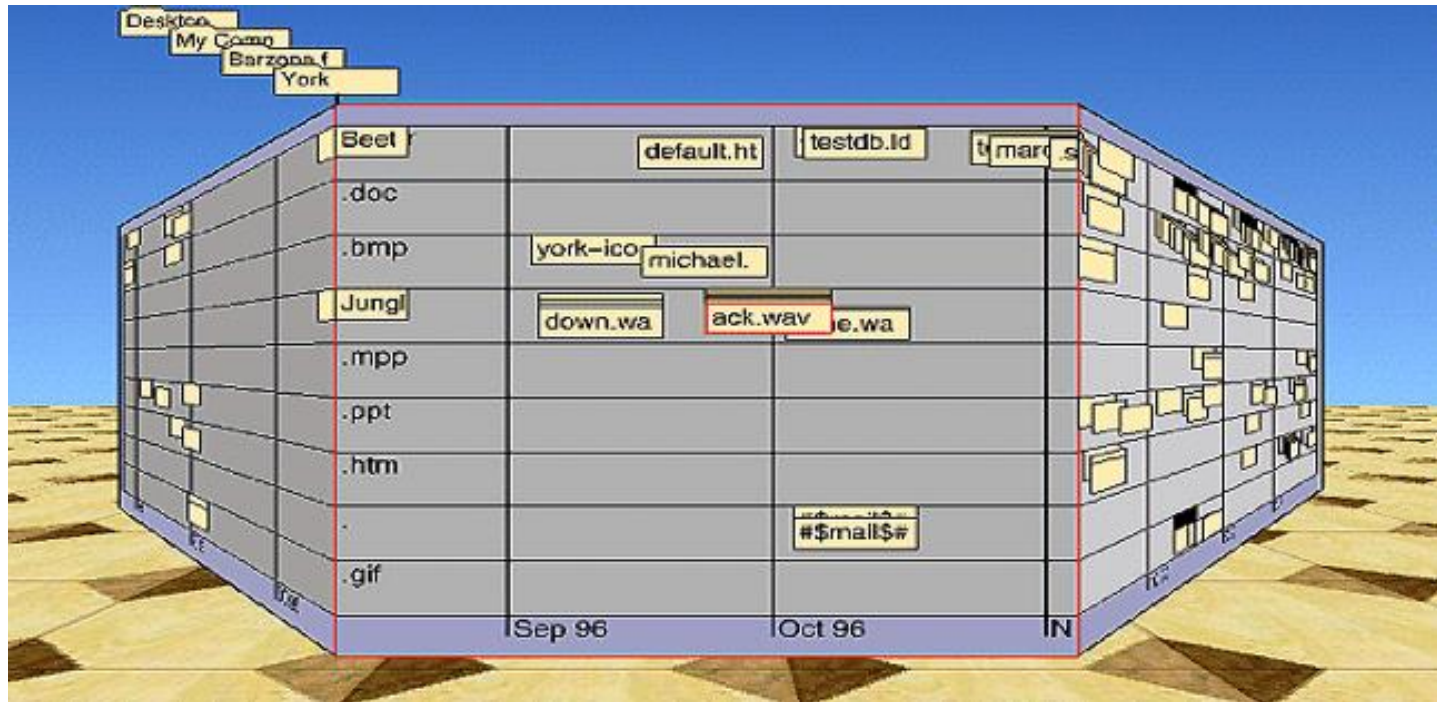
Space Distortion
2) Fisheye Menus



FOCUS + CONTEXT

Space Distortion

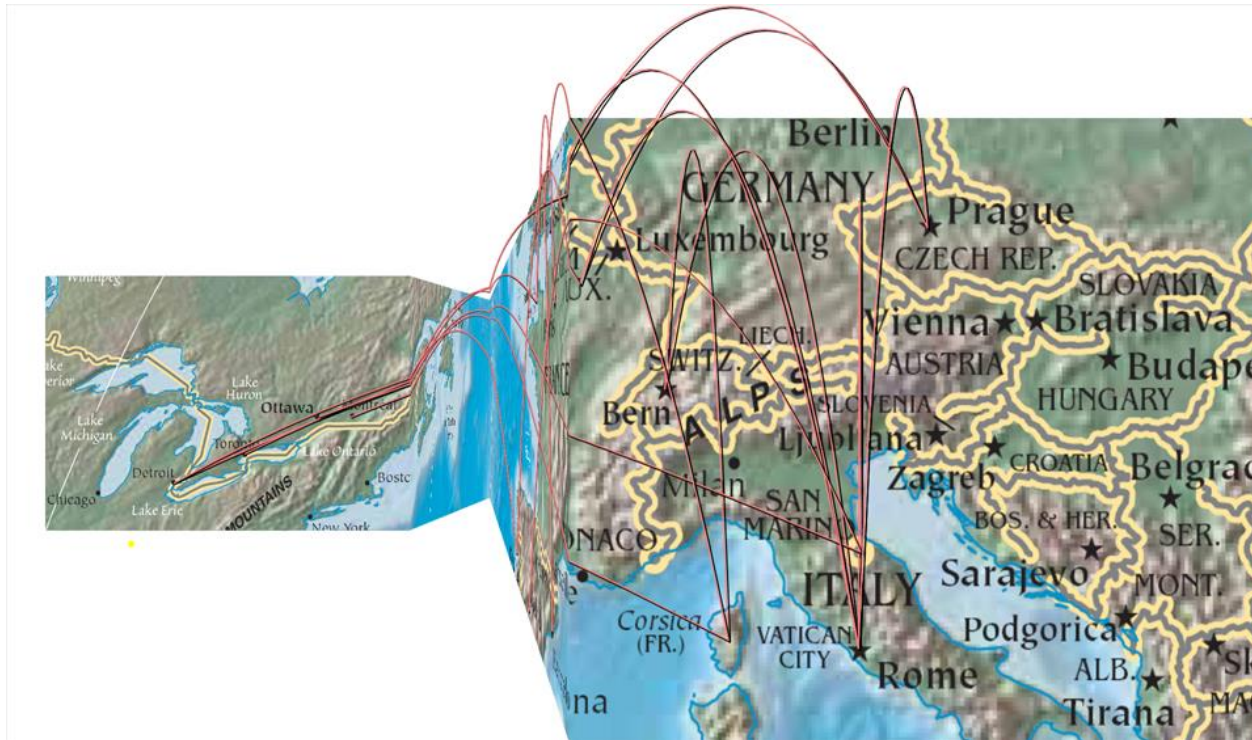
3) Perspective Wall



FOCUS + CONTEXT

Space Distortion

4) Melange



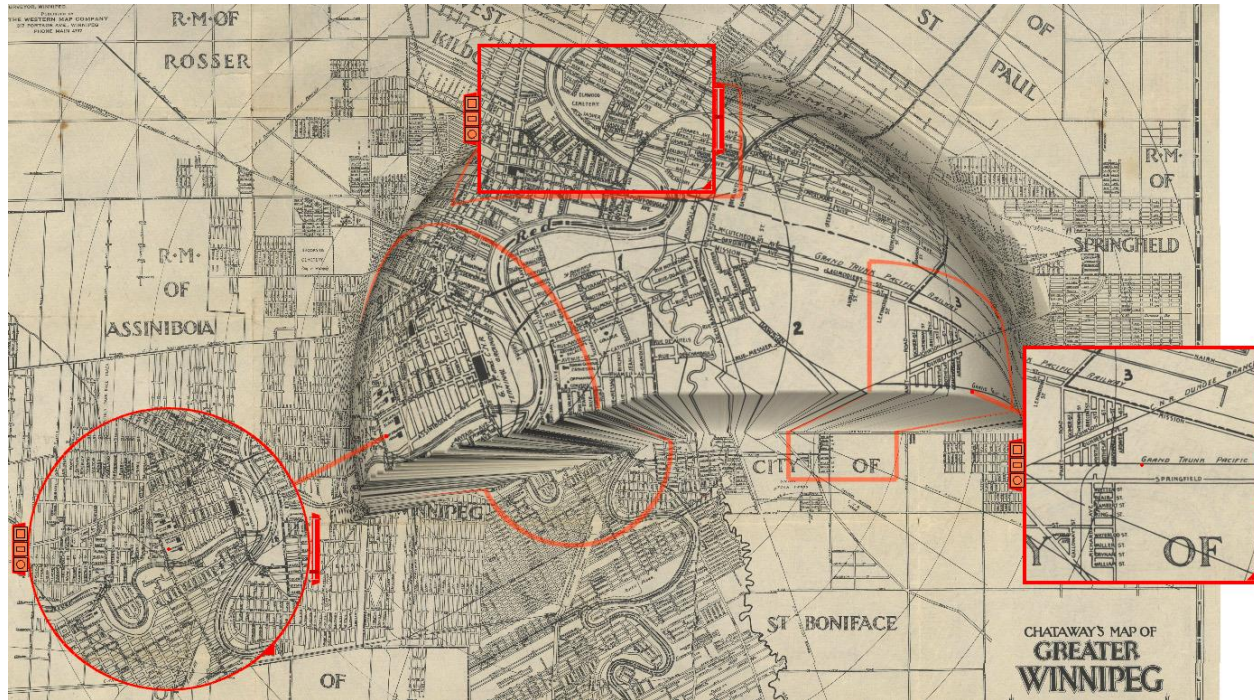
Mélange

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

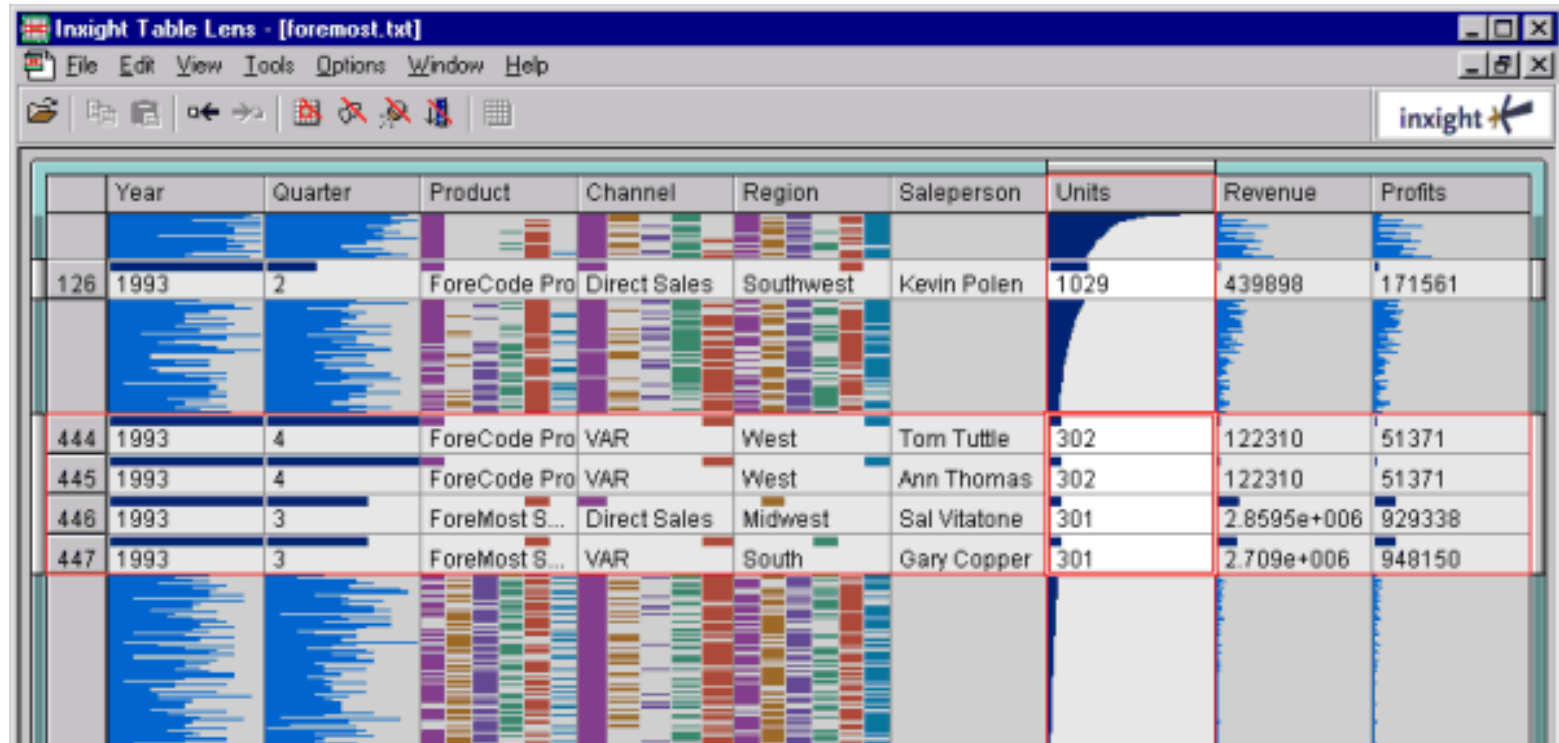
The Undistort Lens





FOCUS + CONTEXT

Table Lens



The screenshot shows the Inxight Table Lens application window. The title bar reads "Inxight Table Lens - [foremost.txt]". The menu bar includes "File", "Edit", "View", "Tools", "Options", "Window", and "Help". The toolbar contains various icons for navigation and editing. The main window displays a data table with columns: Year, Quarter, Product, Channel, Region, Salesperson, Units, Revenue, and Profits. A red rectangular lens highlights a specific row (row 444) and its corresponding data points in the Units, Revenue, and Profits columns. The lens also highlights the corresponding data points in the other columns for that row. The data for row 444 is as follows:

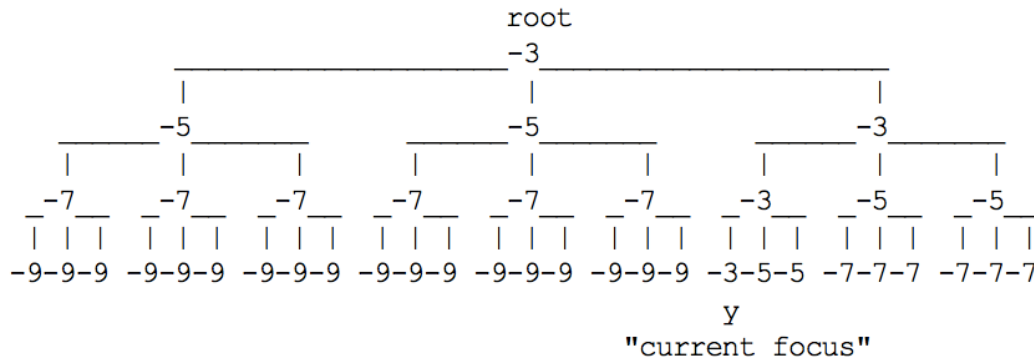
	Year	Quarter	Product	Channel	Region	Salesperson	Units	Revenue	Profits
126	1993	2	ForeCode Pro	Direct Sales	Southwest	Kevin Polen	1029	439898	171561
444	1993	4	ForeCode Pro	VAR	West	Tom Tuttle	302	122310	51371
445	1993	4	ForeCode Pro	VAR	West	Ann Thomas	302	122310	51371
448	1993	3	ForeMost S...	Direct 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:

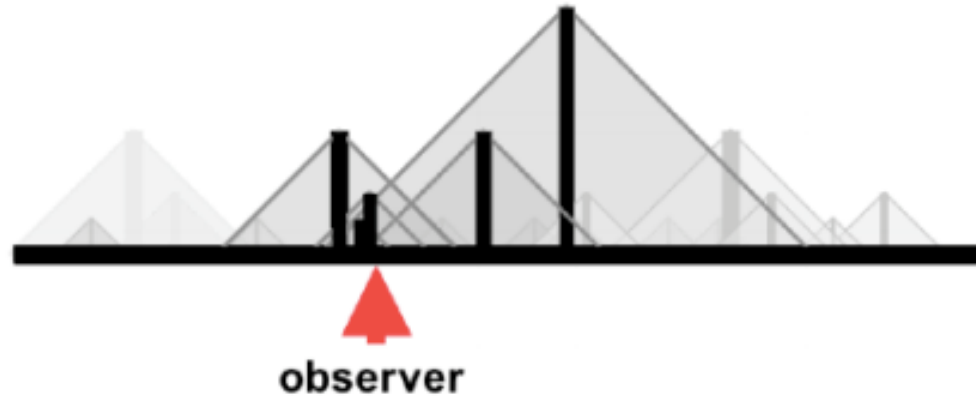
$$\begin{aligned} \text{DOI}_{\text{fisheye}(\text{tree})}(x|y) &= \text{API}(x) - D(x,y) \\ &= -(d_{\text{tree}}(x,y) + d_{\text{tree}}(x,\text{root})) \end{aligned}$$



FOCUS +

Generalized Fisheye Views

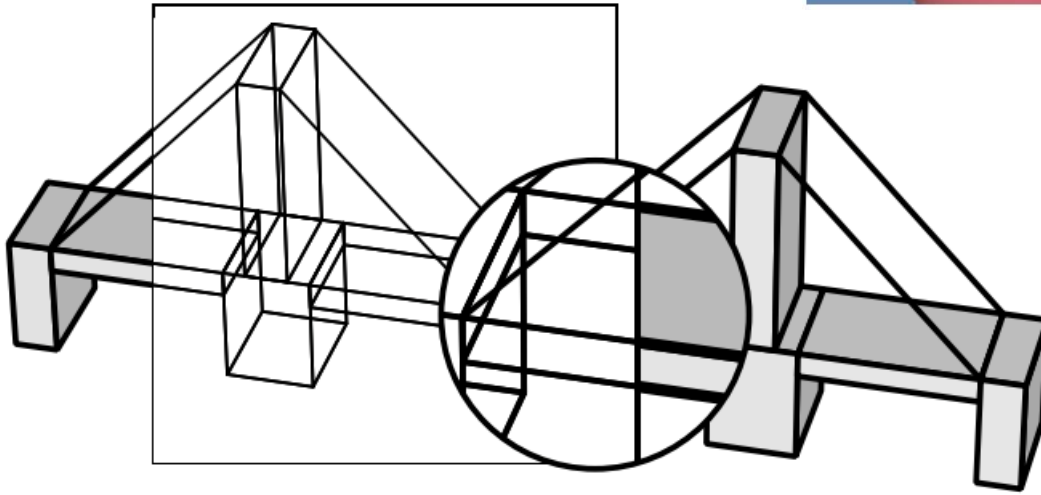
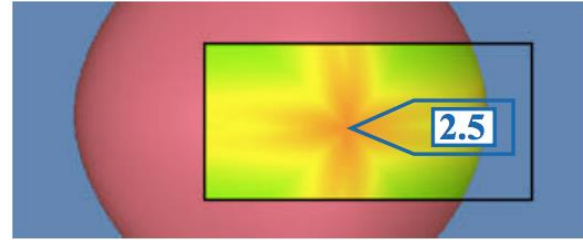
**Pattern of Influence
on the Observer:
Fisheye Subset of
entities**



Furnas, 2010

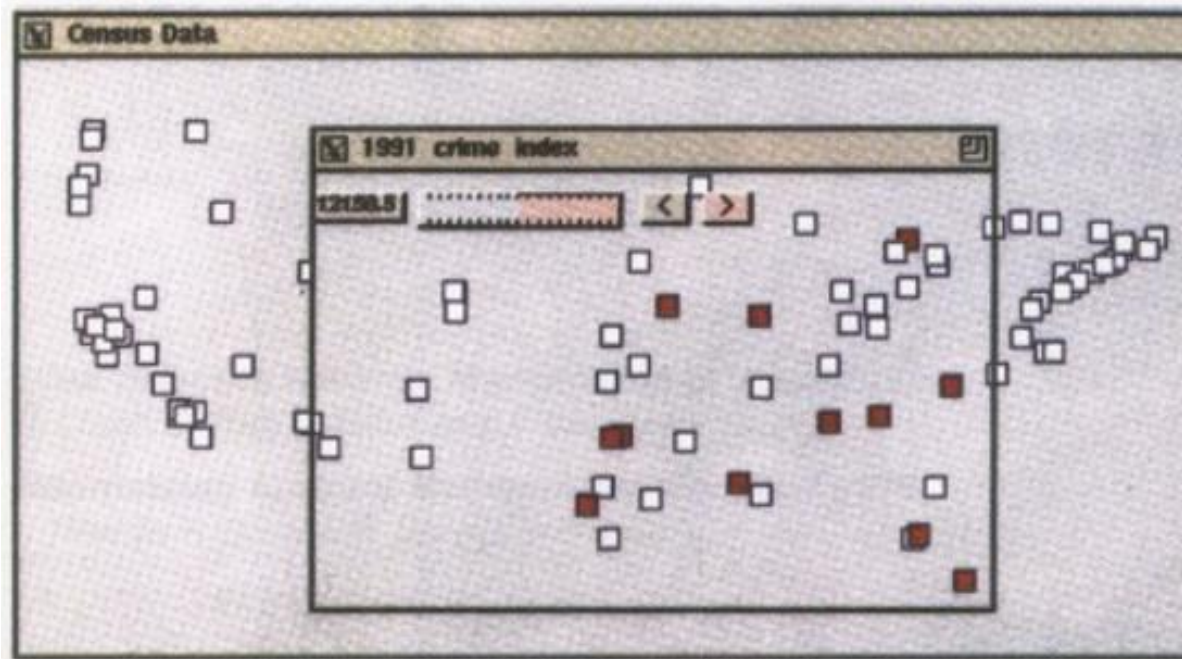
A Fisheye Follow-Up: Further Reflections on Focus + Context

MAGIC LENSES



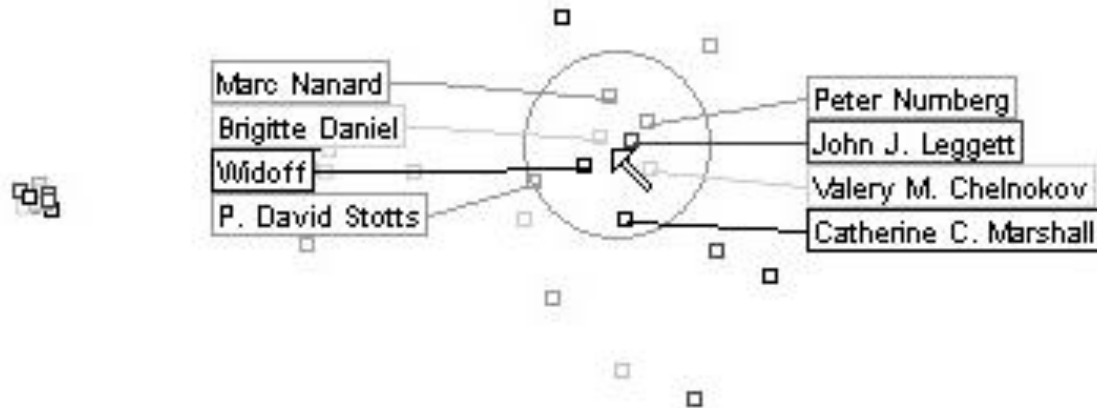
MAGIC LENSES

Movable filters for dynamic queries



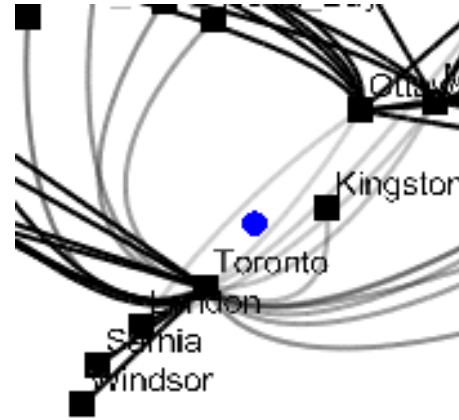
MAGIC LENSES

Exentric Labeling



MAGIC LENSES

Edge lenses



SELECT
EXPLORE
FILTER
RECONFIGURE
ENCODE
ABSTRACT/ELABORATE
CONNECT

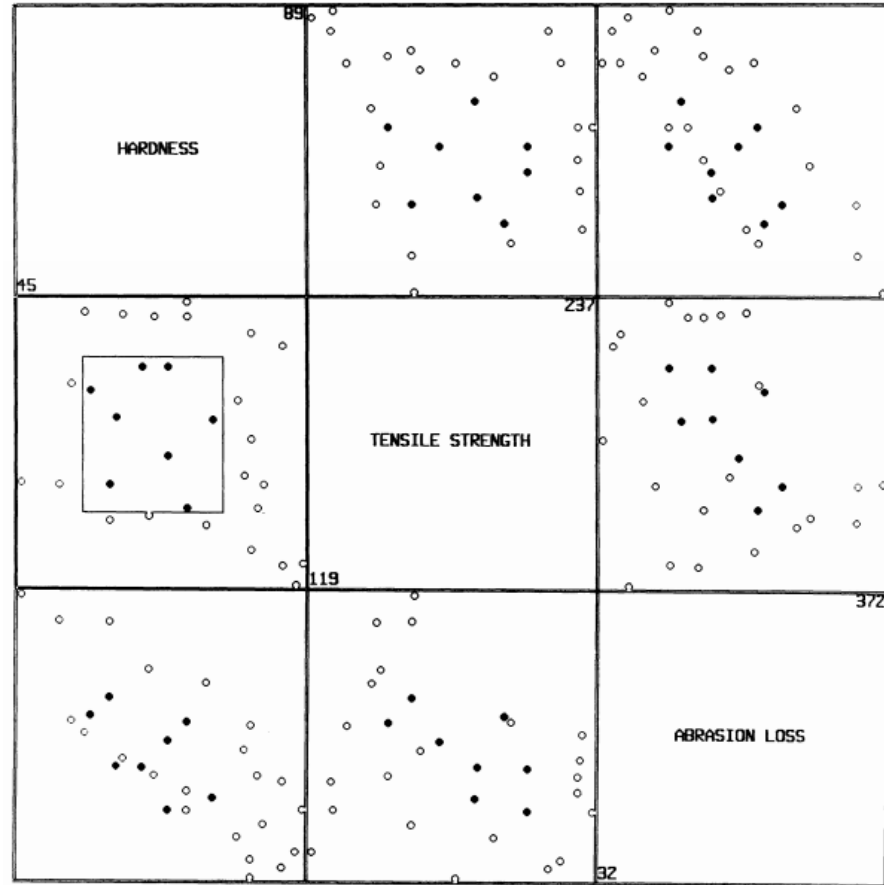
SHOW ME RELATED
ITEMS

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

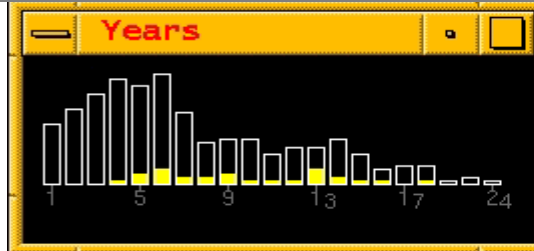


BRUSHING SCATTERPLOTS BECKER & CLEVELAND 1982

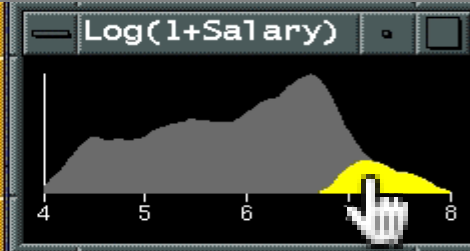
<p>100</p> <p>100</p>	<p>100</p> <p>100</p>	<p>100</p> <p>100</p>
<p>100</p> <p>100</p>	<p>100</p> <p>100</p>	<p>100</p> <p>100</p>
<p>100</p> <p>100</p>	<p>100</p> <p>100</p>	<p>100</p> <p>100</p>

BRUSHING & LINKING

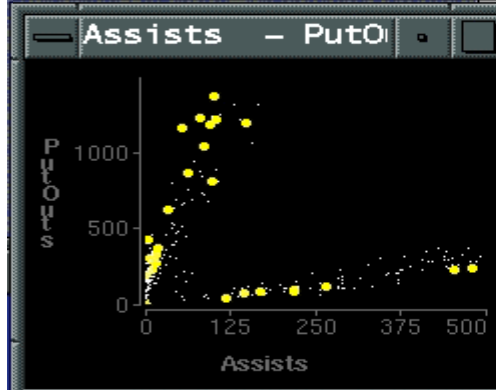
HOW LONG
IN MAJORS



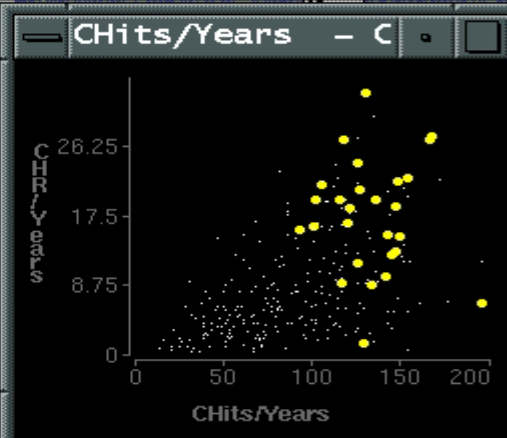
SALARIES



ASSISTS VS
PUTOUTS
(FIELDING
ABILITY)



HOME RUNS
VS HITS
(BATTING
ABILITY)

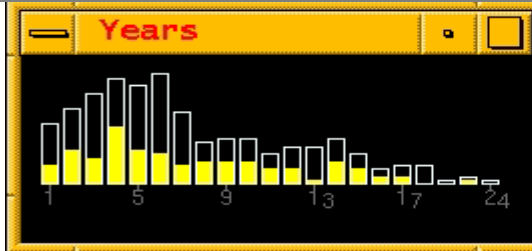


DISTRIBUTION
OF POSITIONS
PLAYED

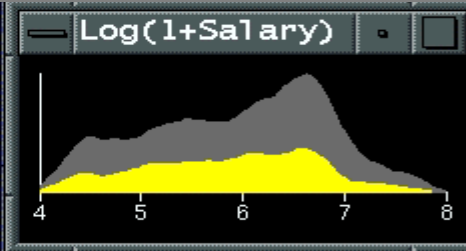


BRUSHING & LINKING

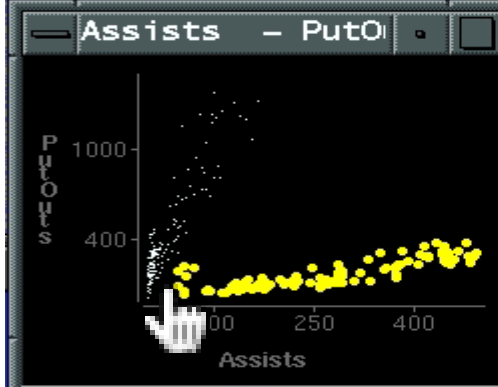
HOW LONG
IN MAJORS



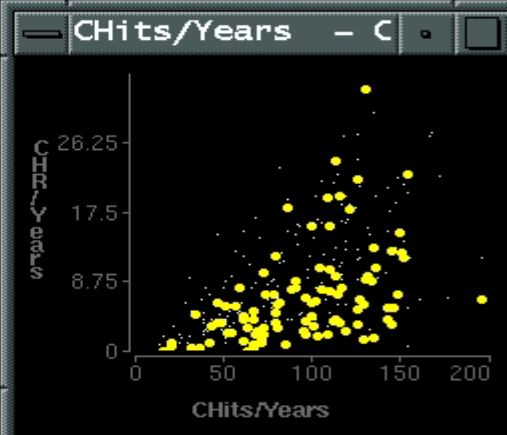
SALARIES



ASSISTS VS
PUTOUTS
(FIELDING
ABILITY)



HOME RUNS
VS HITS
(BATTING
ABILITY)



DISTRIBUTION
OF POSITIONS
PLAYED



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

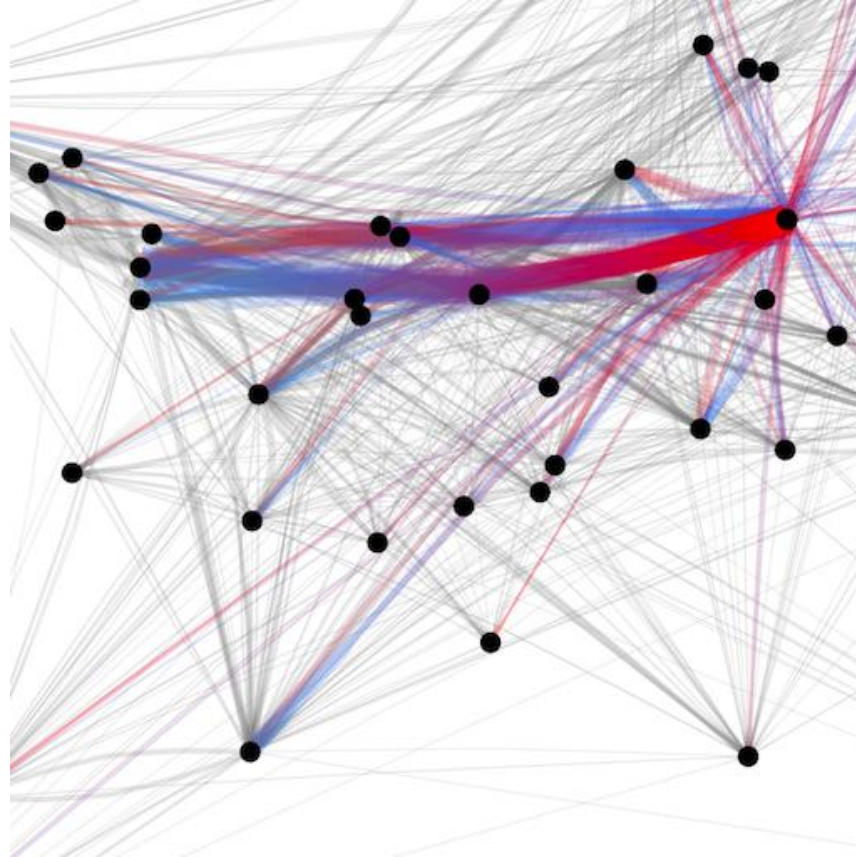
Input: mouse, touch, keyboard, speech,...

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

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

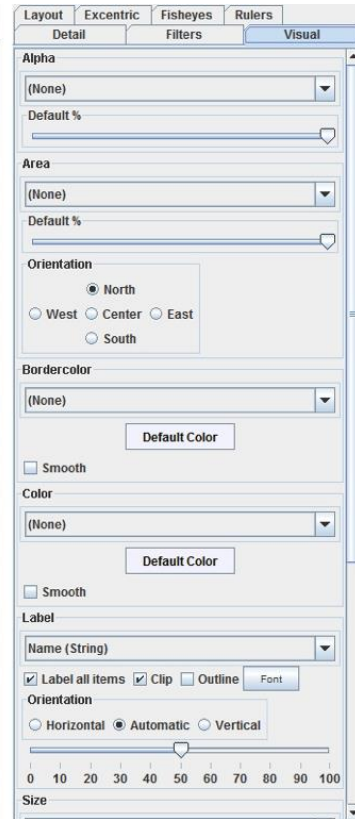
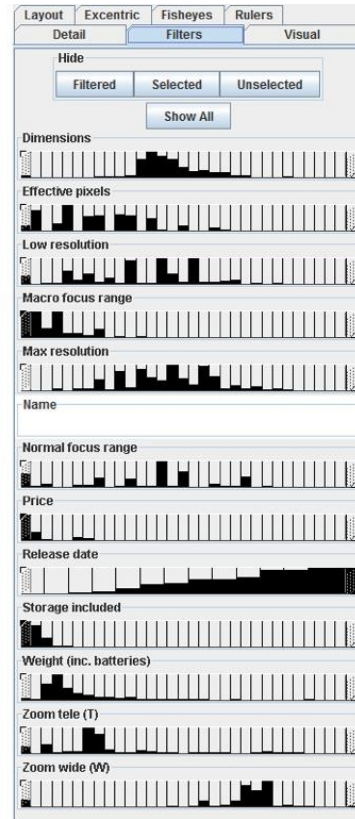
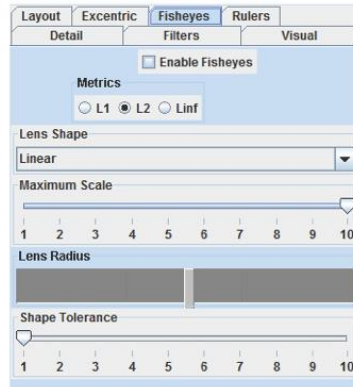
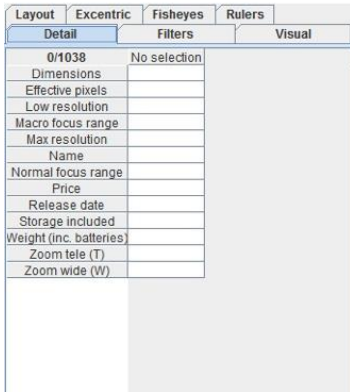
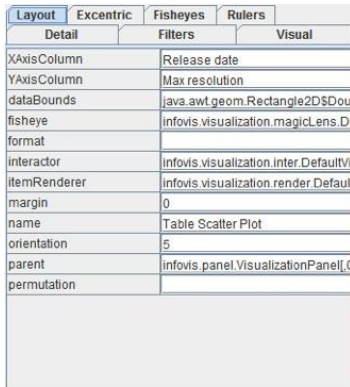
PITFALLS

#1 - Interaction has a cost



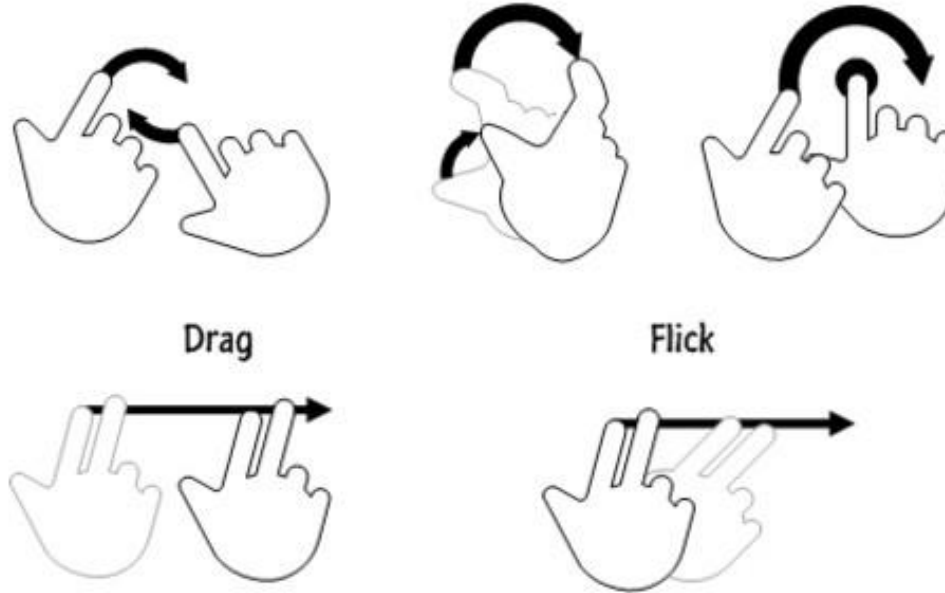
PITFALLS

#2 - Controls take screen real-estate



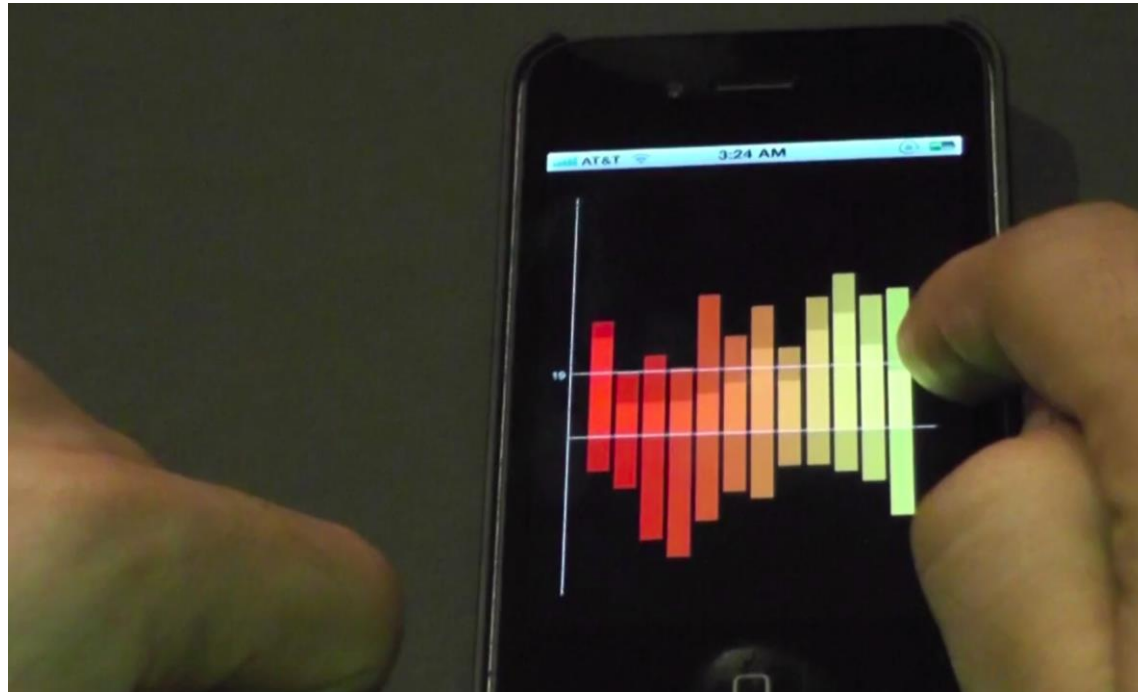
PITFALLS

#3 - Few techniques are self-explanatory



GOING BEYOND THE DESKTOP

TOUCH DEVICES



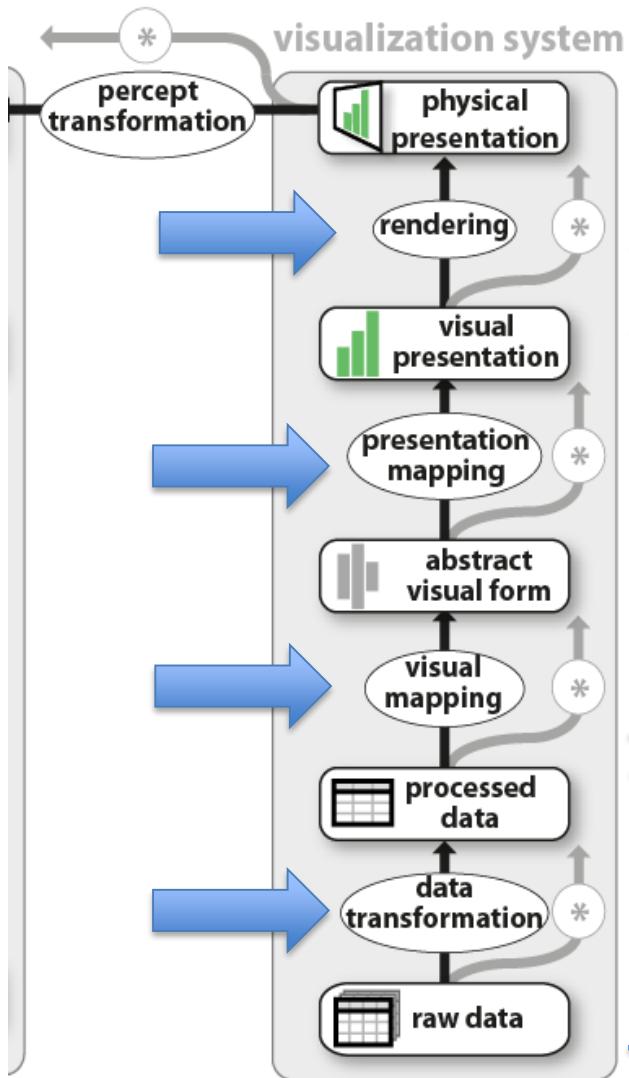
TABLETOP



WALL-SIZED DISPLAYS







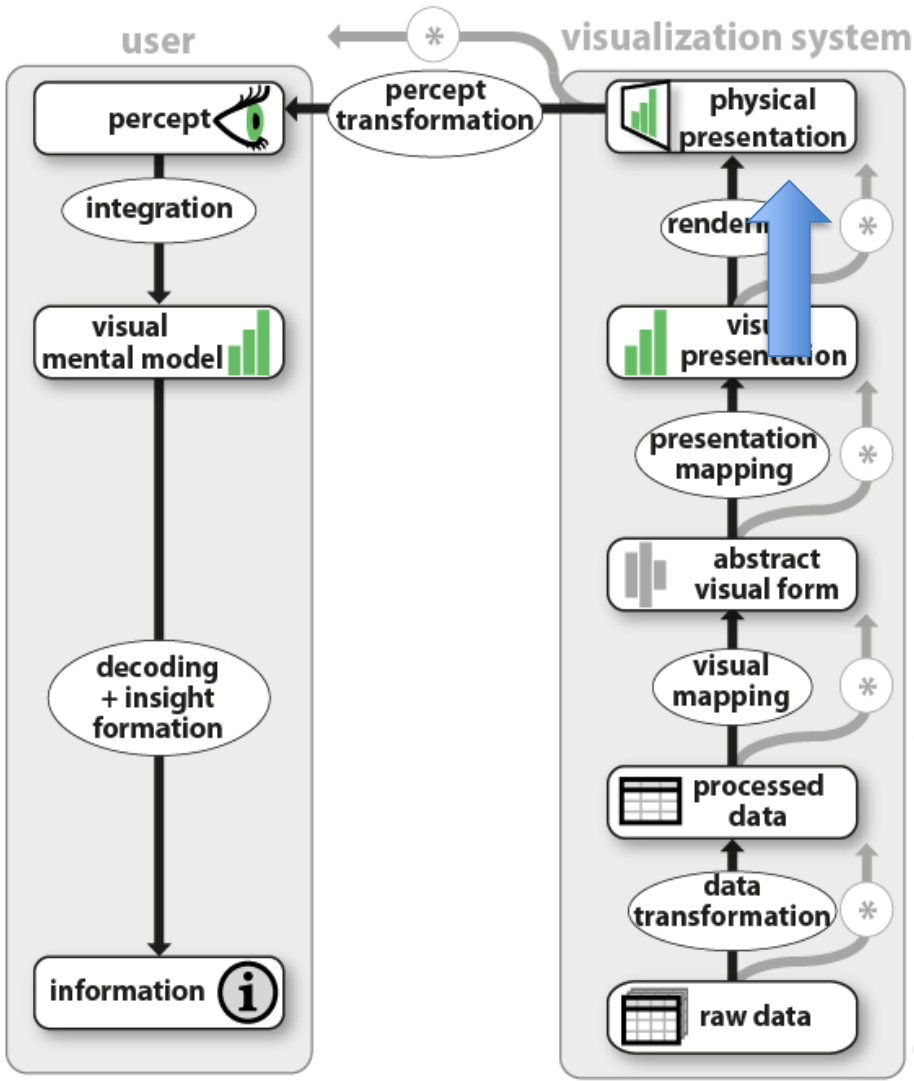
(view level)

(visual level)

(data level)



	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	AC										
1	Education and health expenditure	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										
2	Australia	4.7	3.3	2.0	2.6	2.8	3.0	1.1	1.2	1.1	2.0	2.4	2.5	2.1	4.8	5.0	4.5	4.1	3.9	3.4	4.7	3.8	2.3	3.9	2.1	2.9	2.9	2.8	2.8	2.7	2.3	1.4	1.1	1.0	0.7	0.1	1.2	1.2															
3	Austria	29	42	13	2.5	16	4.5	19	17	4.5	18	7.6	0.7	1.5	32	44	30	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2					
4	Belgium	85	84	11	11	11	19	27	22	20	20	6.8	4.5	1.6	3.7	2.7	3.4	2.8	2.4	2.0	2.2	1.8	1.9	1.8	1.7	2.2	1.4	1.5	2.0	2.1	2.0	2.1	2.0	2.2	2.0	2.6	2.0	1.9	2.1	2.5													
5	Canada	34	38	18	25	18.4	5.1	8.4	3.3	3.4	1.1	7.2	9.7	9.4	7.1	1.6	1.0	1.9	1.2	2.6	2.5	1.4	1.1	9.3	2.9	1.7	1.4	2.5	1.6	1.9	1.9	2.0	2.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6						
6	Denmark	100	100	14	19	5.6	1.5	3.8	1.4	8.2	9.5	1.4	0.5	5.8	1.0	3.7	3.3	3.7	4.6	1.5	1.9	1.4	1.1	1.3	4.2	7.8	4.3	1.1	4.9	1.3	5.5	8.2	9.6	2.1	5.6																		
7	Finland	30	14	1.2	2.5	1.6	1.5	8.6	3.7	3	4.8	5	4.5	3.5	7.9	6.2	3.7	3.1	6.8	3.6	8.8	5.3	10	5.3	11	8.6	1.4	1.3	1.2	1.4	1.5	3.4	1.0	8.4	7.6																		
8	France	63	64	47	33	38	38	40	39	42	45	30	33	38	35	34	26	30	28	32	34	38	36	38	40	33	39	43	44	47	38	37	41	42	41	40	38	37															
9	Germany	55	55	22	19	24	19	19	20	17	19	17	19	17	20	21	24	26	22	19	20	22	21	25	21	25	25	21	25	22	24	21	25	26	24	19	18	15	18														
10	Greece																																																				
11	Ireland																																																				
12	Italy																																																				
13	Japan	13	12	2.9	1.1	2.2	2.6	2.9	3.2	2.9	3.1	3.6	2.7	7.1	6	8.8	11	7.7	6.1	8.6	9.8	8.8	8.5	8	10	10	6.5	6.9	7.8	13	7.6	9.5	13	13	15	6.7	5.7	7.7															
14	Luxembourg																																																				
15	Netherlands																																																				
16	New Zealand																																																				
17	Norway																																																				
18	Portugal																																																				
19	Spain																																																				
20	Sweden																																																				
21	Switzerland																																																				
22	United Kingdom																																																				
23	United States																																																				
24																																																					



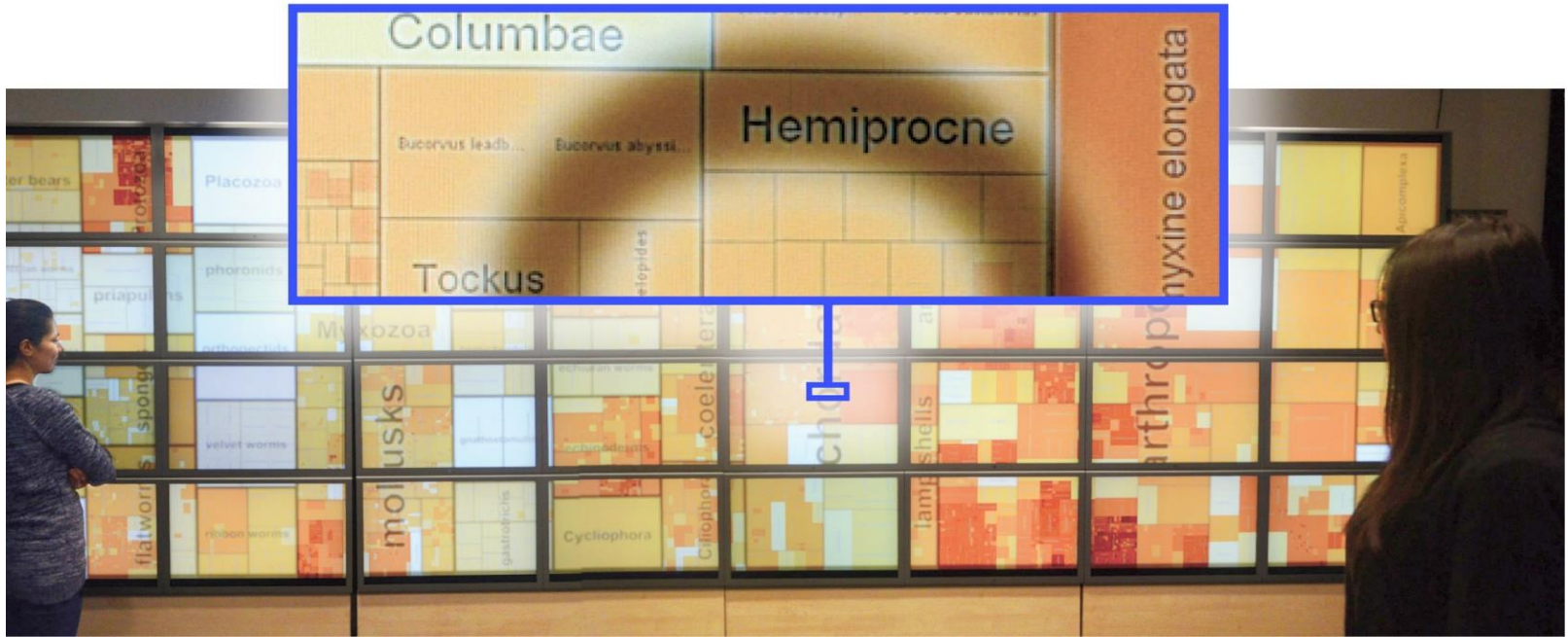
(view level)

(visual level)

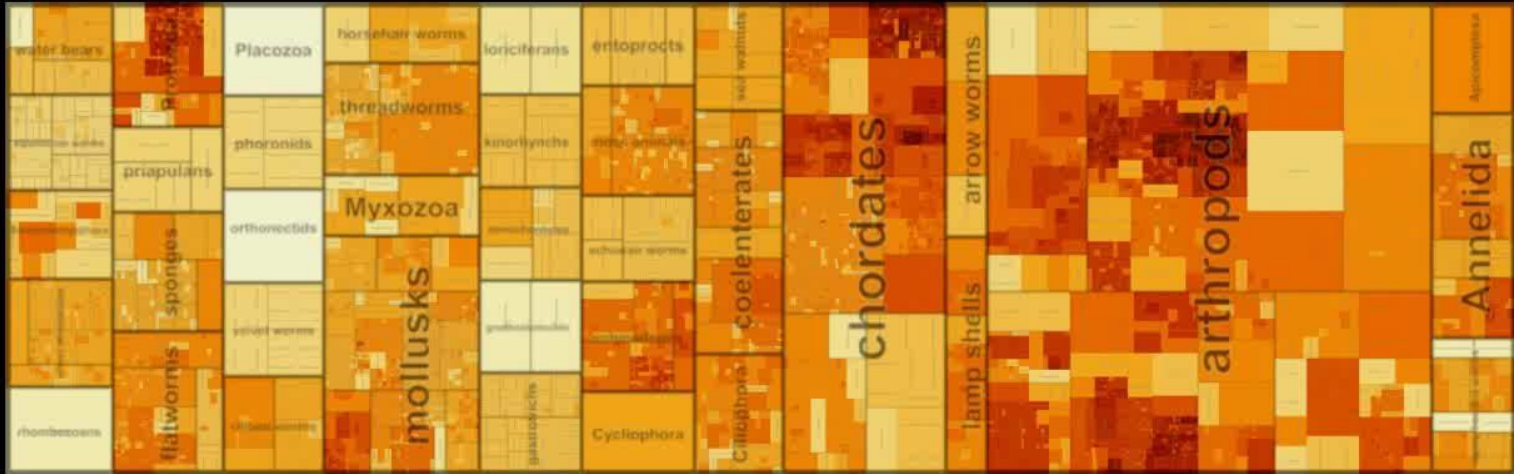
(data level)



Country	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Australia	2.7	3.9	2.6	3.6	3.0	1.1	1.2	1.1	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
2. Austria	25	42	13	2.5	1.6	4.9	1.9	1.7	4.5	1.8	7.6	0.7	1.5	3.2	4.4	3.0	3.2	1.6	1.2	3.2	3.1	3.2	3.1
3. Belgium	65	84	1.1	1.1	1.6	1.9	2.2	2.2	2.0	2.0	6.6	4.5	1.6	3.1	3.4	2.9	2.8	2.6	3.0	2.2	1.8	1.9	1.8
4. Canada	34	39	1.8	2.0	8.4	5.1	8.4	3.3	3.4	1.7	2.2	9.7	9.4	7.1	1.6	1.0	1.9	1.2	2.8	2.5	1.4	1.1	9.3
5. Denmark	100	100	1.4	1.9	5.8	1.5	3.8	1.4	9.2	8.5	4.1	0.5	1.8	1.0	3.7	3.7	4.0	1.5	1.9	1.6	1.1	1.2	4.2
6. Finland	30	34	1.4	2.0	1.5	1.5	0.6	3.7	3.1	4.8	5.4	4.5	3.5	7.9	6.2	5.7	2.1	6.8	3.8	5.8	5.3	1.0	5.3
7. France	63	64	4.7	3.1	3.8	3.8	4.0	3.8	4.2	4.5	3.0	3.8	3.8	3.4	3.8	3.0	2.8	3.4	3.6	3.8	4.0	3.3	3.8
8. Germany	55	55	2.2	1.9	2.4	1.9	2.0	1.7	1.9	1.7	2.0	2.0	2.1	2.4	2.6	2.2	1.8	2.2	2.1	2.1	2.5	2.1	2.5
9. Greece	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10. Ireland	20	36	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
11. Italy	13	12	2.9	1.1	2.2	2.6	2.9	3.2	2.9	3.1	3.5	3.7	7.1	6.8	11.7	6.5	8.6	9.8	8.8	8.5	8.1	10.1	6.5
12. Japan	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
13. Luxembourg	42	33	1.2	1.5	1.1	1.2	1.3	1.1	1.6	1.7	1.6	1.7	1.9	1.3	1.4	1.0	1.1	2.0	2.9	8.5	5.1	1.5	9.1
14. Netherlands	20	21	5.1	8.9	2.9	2.3	1.7	1.9	1.9	1.9	1.5	1.5	1.3	4.7	6.8	1.5	8.9	4.8	5.1	4.9	4.5	4.0	4.1
15. New Zealand	55	49	3.0	9.7	5.7	7.1	5.8	5.5	2.8	2.6	2.5	8.7	7.5	11.8	8.8	12.3	14.7	8.2	7.3	4.4	4.8	4.5	1.1
16. Norway	42	48	4.1	3.8	1.8	1.5	1.9	1.5	1.9	1.5	1.9	1.5	1.9	1.5	1.9	1.5	1.9	1.5	1.9	1.5	1.9	1.5	1.9
17. Portugal	33	23	1.5	1.4	2.1	1.8	1.7	2.1	1.7	6.8	1.6	1.7	1.2	1.1	1.6	1.3	1.5	6.5	8.7	14.7	7.6	9.7	1.1
18. Spain	47	48	1.2	1.5	8.7	1.1	1.0	1.9	1.0	1.3	1.3	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
19. Sweden	50	32	1.6	1.8	0.9	0.7	2.0	1.3	1.8	2.1	2.7	1.9	1.6	1.3	2.6	1.7	1.9	2.0	1.8	1.9	1.3	1.6	1.2
20. Switzerland	69	64	1.0	1.8	6.2	7.5	7.1	1.2	1.9	5.9	7.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
21. United Kingdom	68	64	1.0	1.8	6.2	7.5	7.1	1.2	1.9	5.9	7.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
22. USA	68	64	1.0	1.8	6.2	7.5	7.1	1.2	1.9	5.9	7.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1

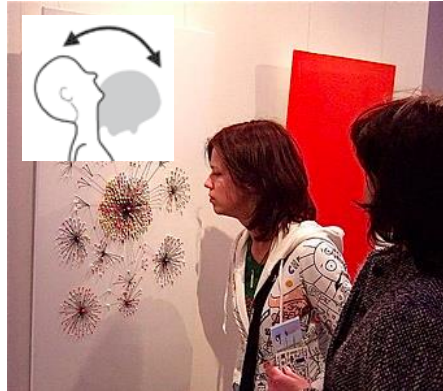
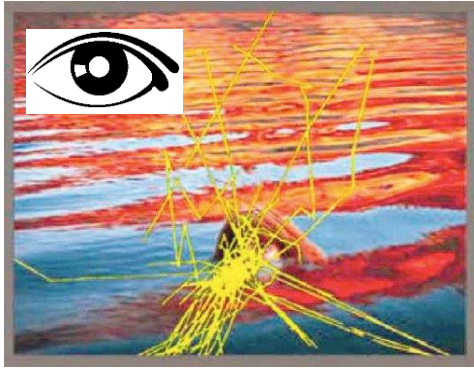


[Isenberg et al. , Hybrid Images for Large Viewing Environments, InfoVis'13]

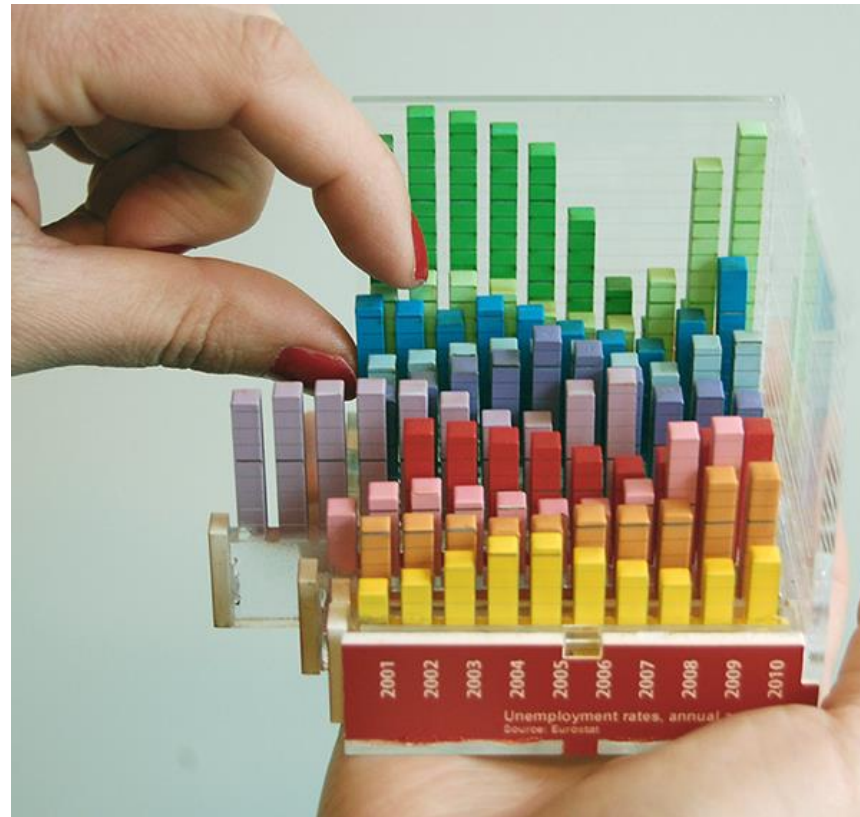


[Isenberg et al. , Hybrid Images for Large Viewing Environments, InfoVis'13]

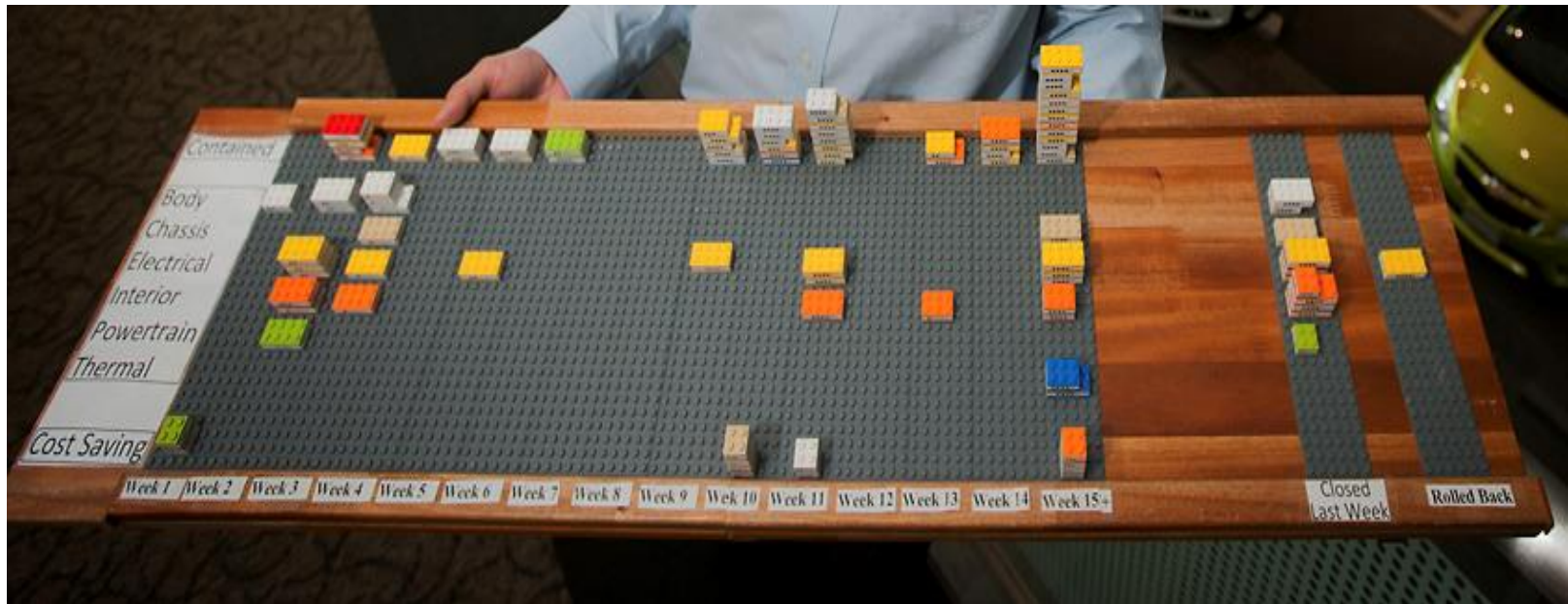
INTERACTION WITH THE PHYSICAL WORLD



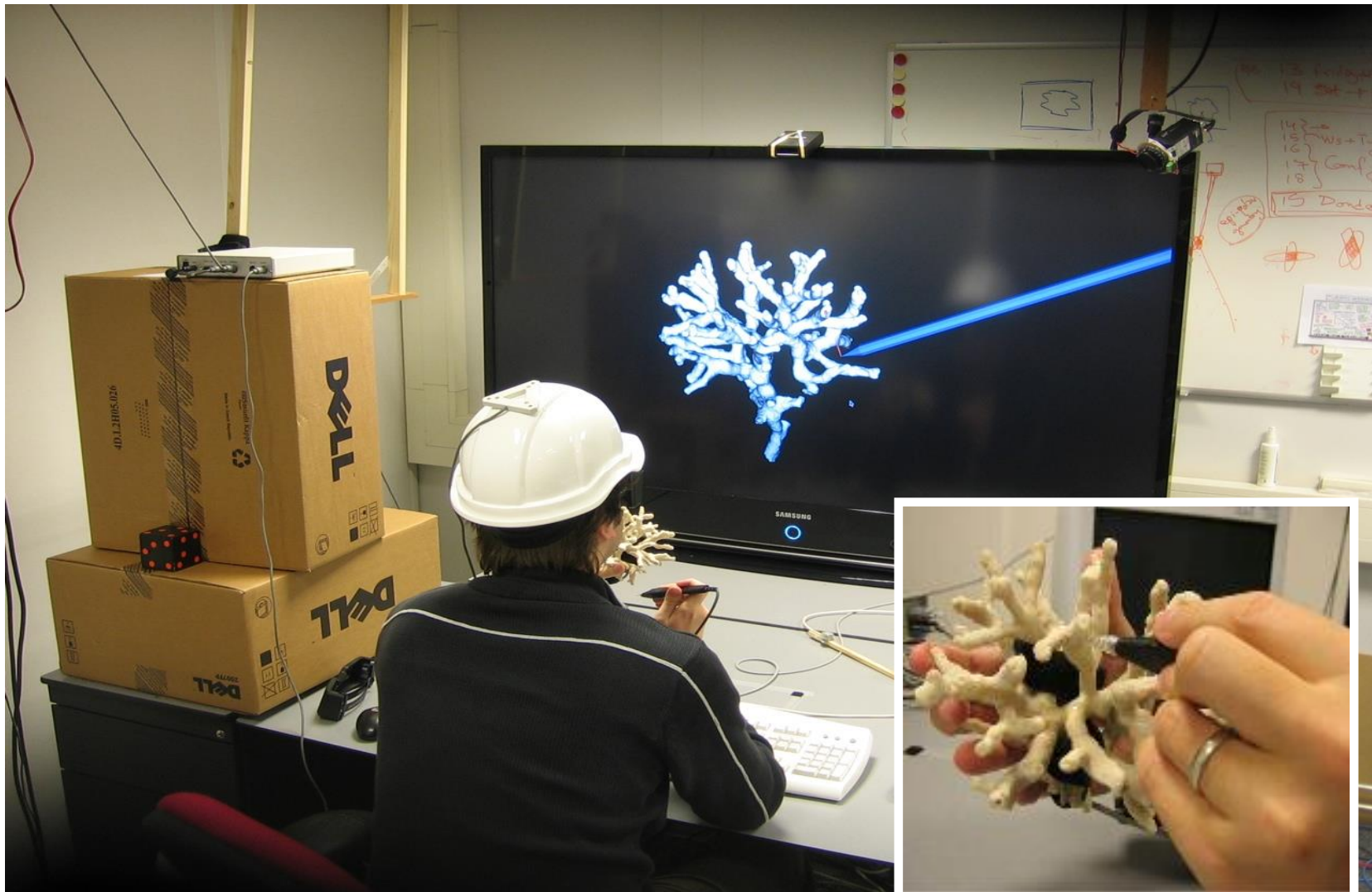
PHYSICAL VISUALIZATIONS



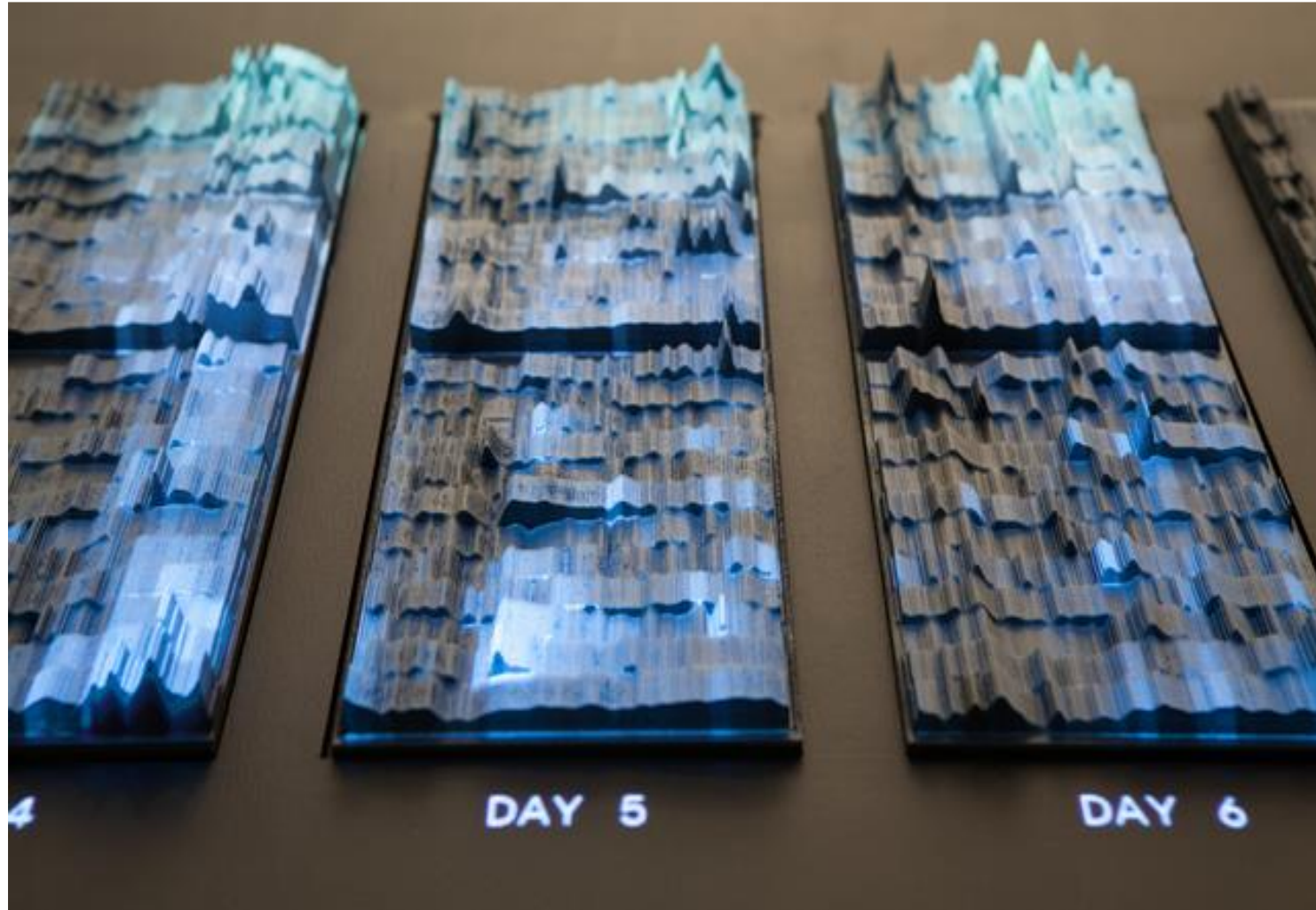
tinyurl.com/physvis



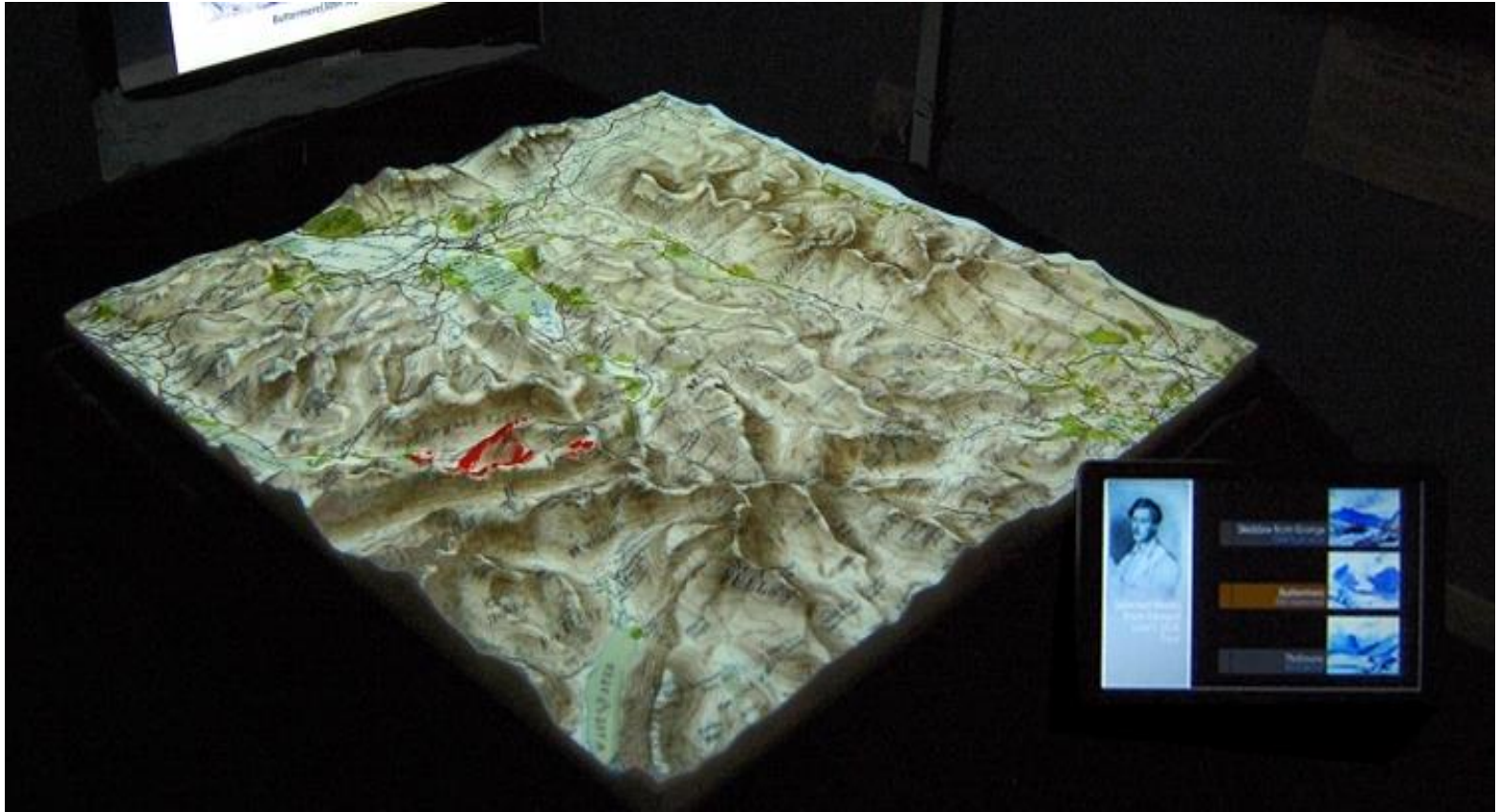
[Mark Wilson. How GM is saving cash using legos as a data viz tool. April 2012]



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



[Stefaner & Hemmert, emoto data sculpture, <http://www.nand.io/visualisation/emoto-installation>]



[PARM: Projected Augmented Relief Models, University of Nottingham, 2012]





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- Pierre Dragicevic (Inria)