http://www.ifs.tuwien.ac.at/~silvia/wien/vu-infovis/

188.305 - 2 st. VO
188.308 - 1 st. UE

informations-visualisierung

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Part 1

Definitions of Information Visualization

Outline

Motivation - Examples

Definitions and Goals

Knowledge Crystallization

Visualization Reference Model(s)

Exploration Techniques

Visual Encoding Techniques

Summary

Example 1 – Multiplication

Working Memory of Human Mind is Restricted

E.g. Mental Multiplication

6 X 7 = ? 42 Piece of Cake!

317 x 432 = ? Yuk! No, thanks!

But with pencil and paper:

317 x 432
634
[illegible]10
12[illegible]0
137.944

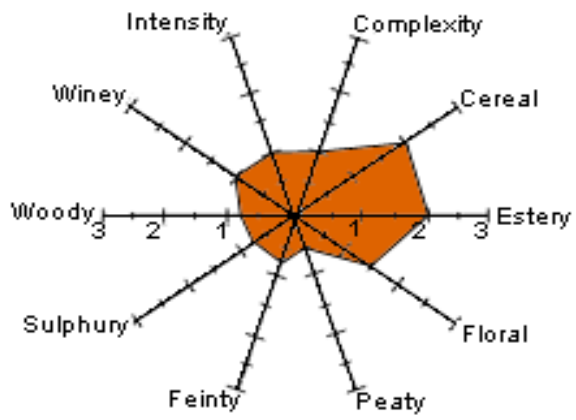
No Problem!

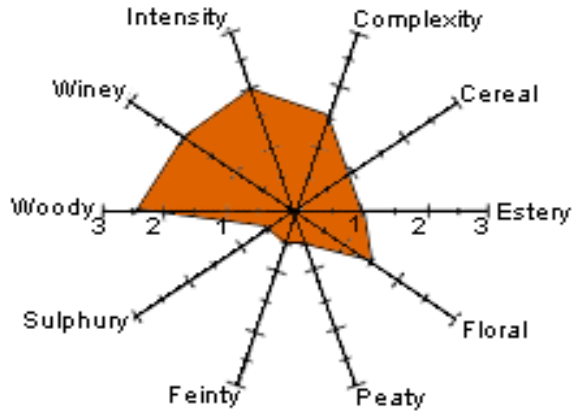
Example 2 – Taste

E.g., Whisky-Tasting

- Taste is Very Abstract
- 10 Basic Tastes: Intensity: [0, 3]
- Intensity
  - Wheel Chart
  - Points - Form a Polygon
  - Polygon's Properties Give Quick Access to the Represented Taste

Glenfiddich



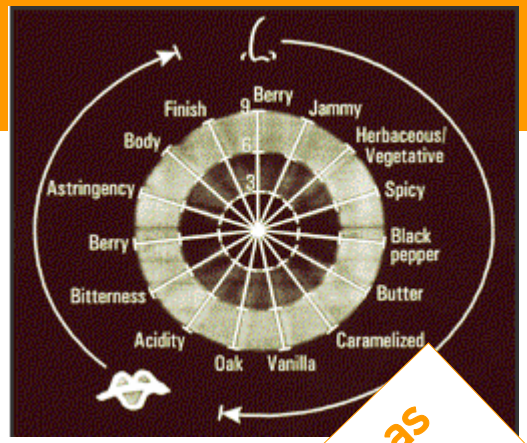


The Balvenie (12 y.)

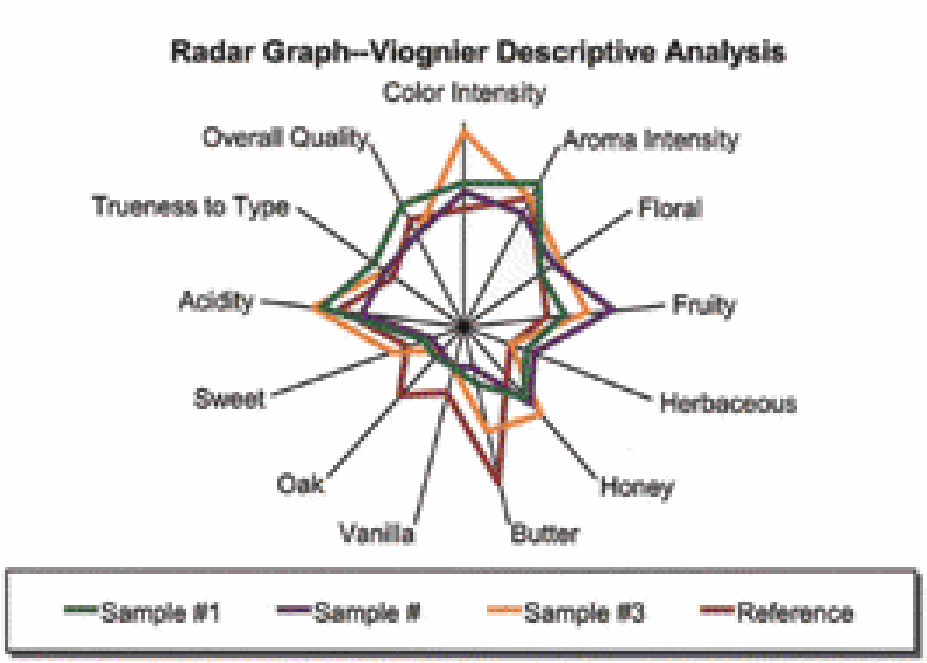
[cite http://www.scotchwhisky.com]

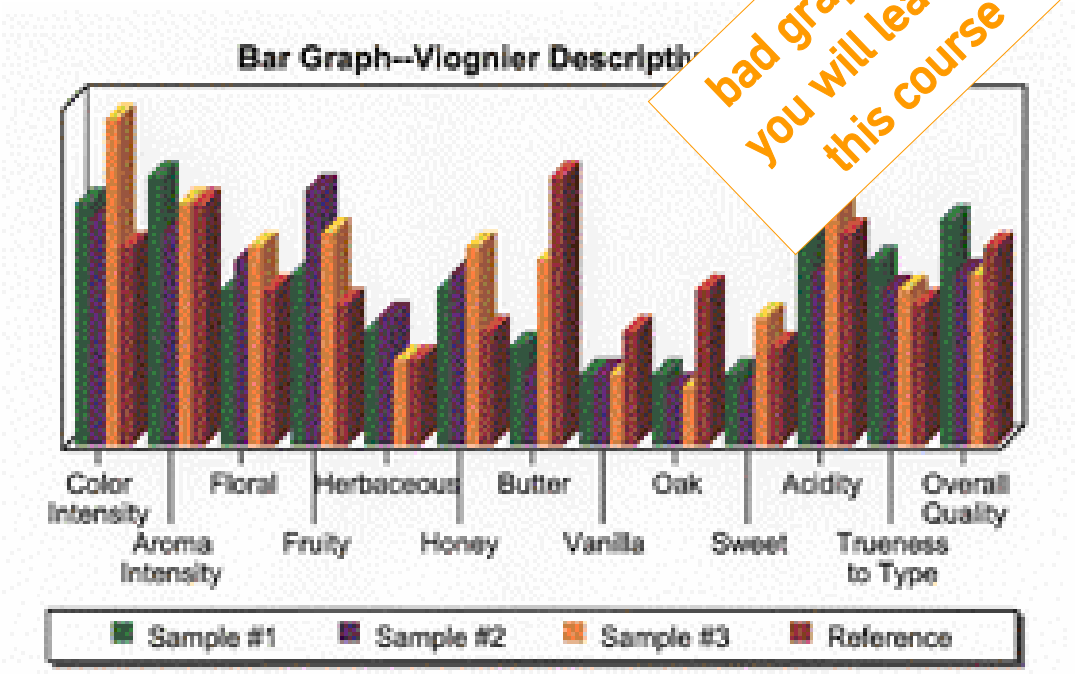
Example 2b – Taste

E.g., Wine-Tasting



bad graphic as you will learn in this course





Example 3 – Chemical Elements

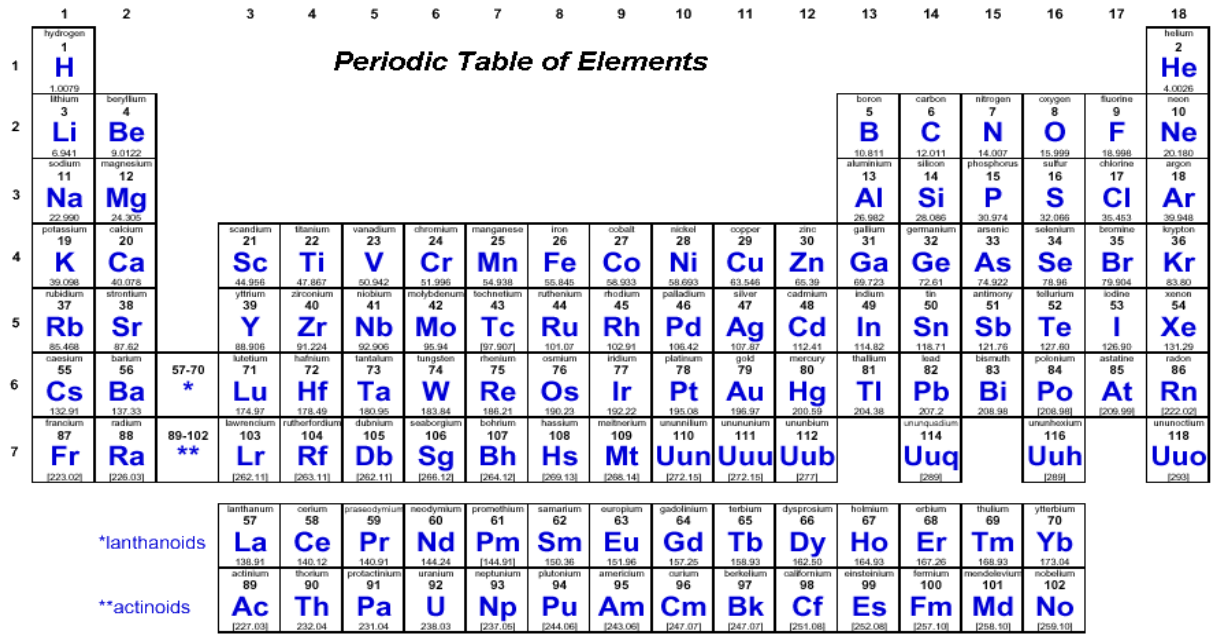
Dimitiri Mandeleyev (1834-1907)

Periodic Table

Invented by Dimitri Mendeleyev

Structured and Classified Representation of All Chemical Elements and Their Properties

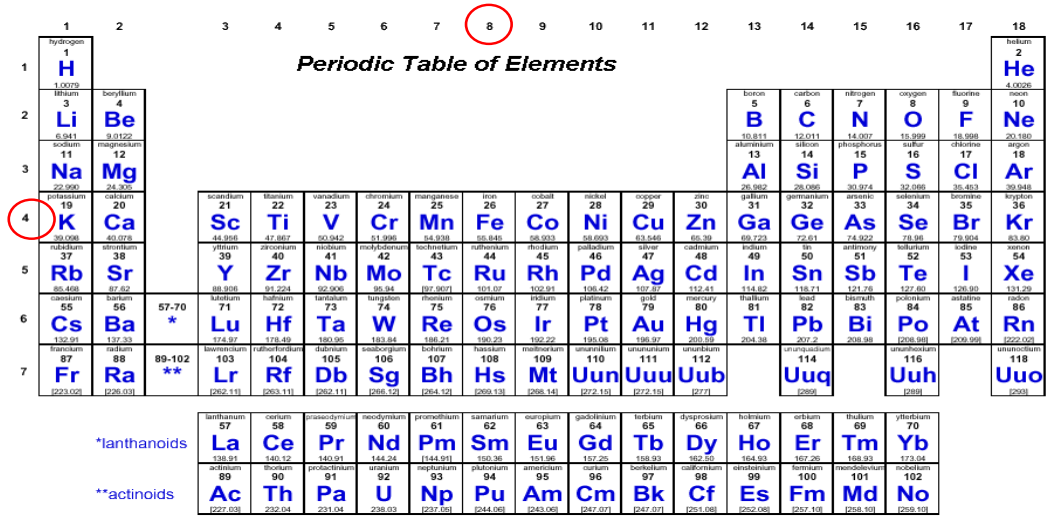
Predicted the Existence of Several Elements Before They Were Discovered



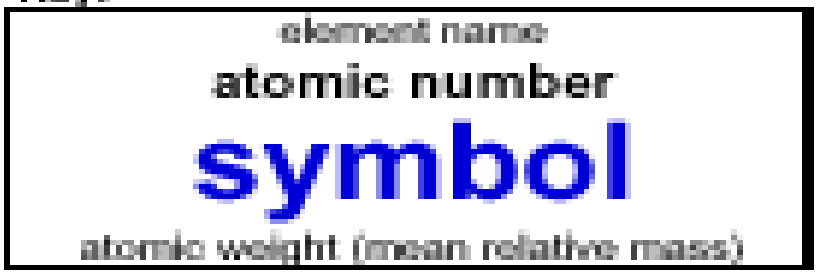
Example 3 – Chemical Elements

Main-Group

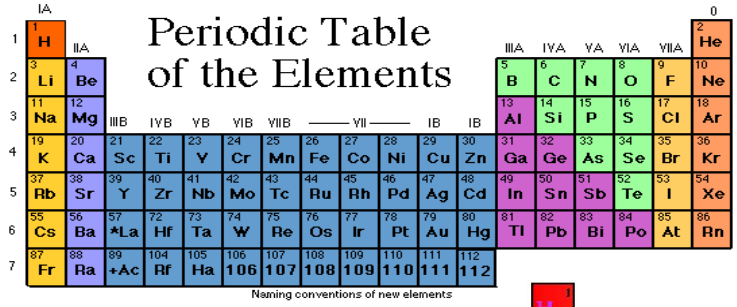
Period

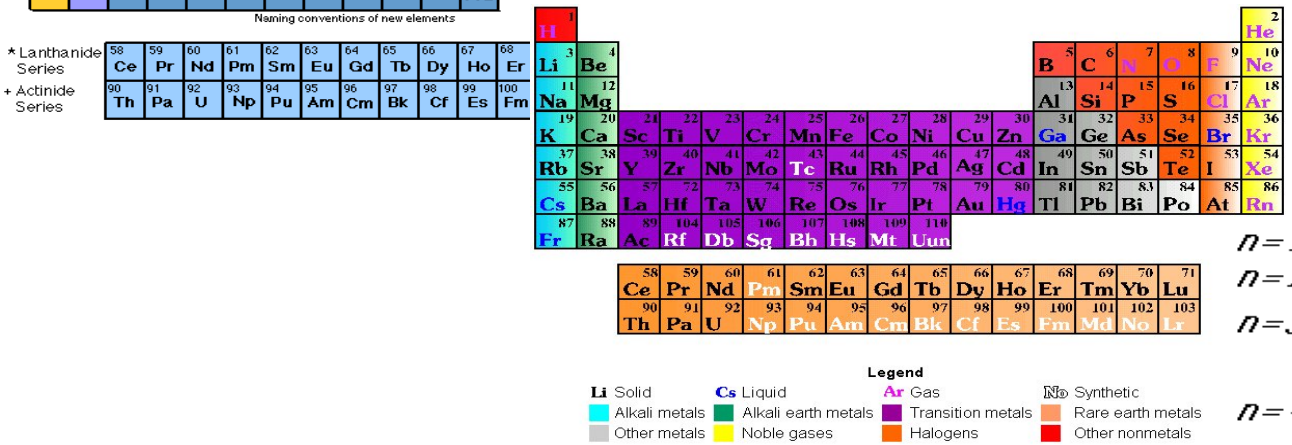


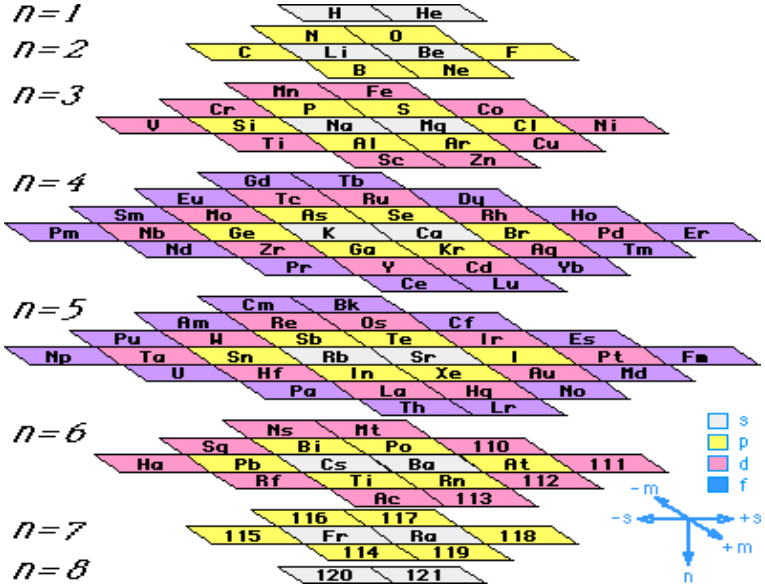
Key:



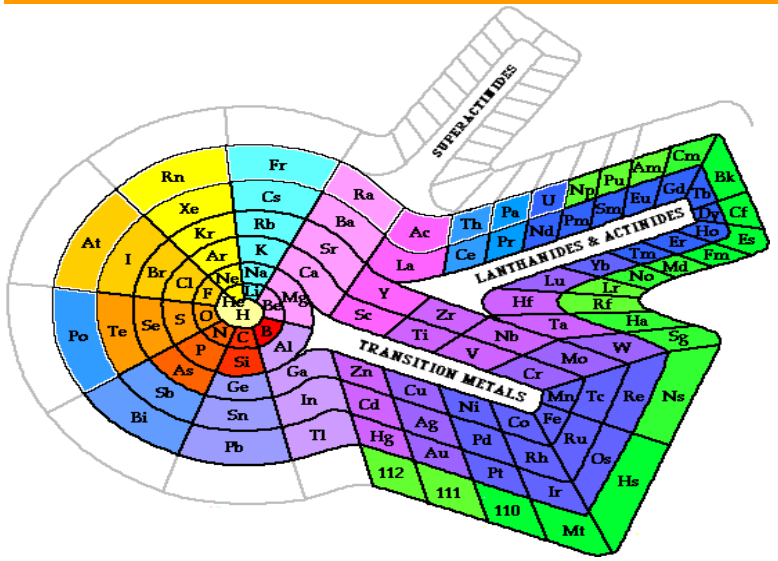
Example 3 – Chemical Elements

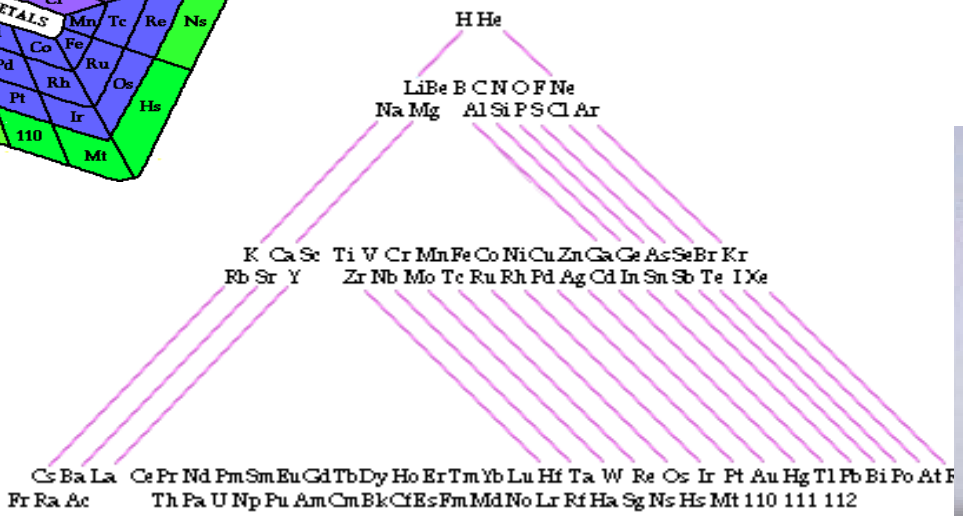


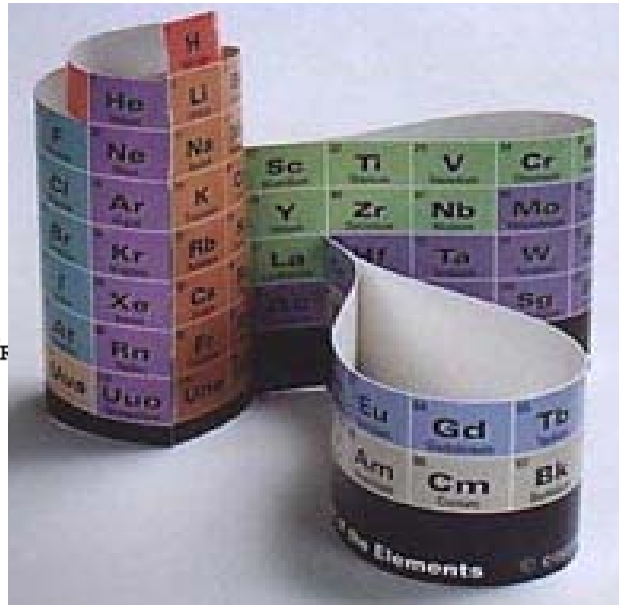




Example 3 – Chemical Elements



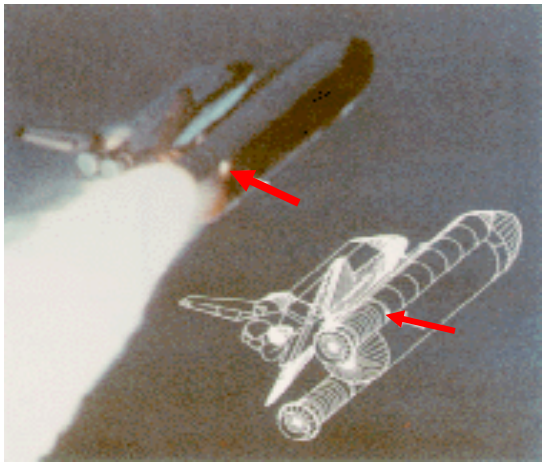


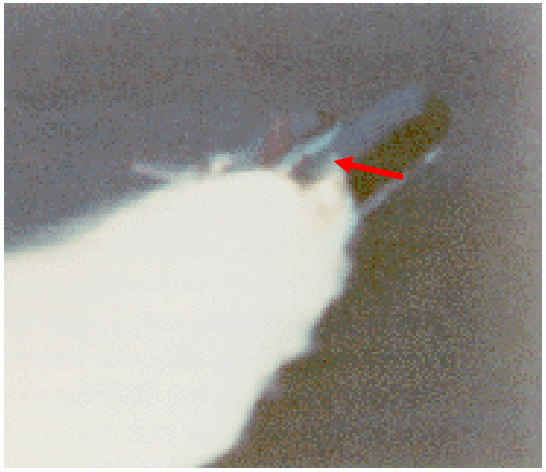


Example 4

The Challenger Disaster

January 27, 1986:
US-Space Shuttle *Challenger* Explodes
72 Seconds After Launch





Reason:

Sealing-Rings in the Right Booster Were Damaged Due to Weather Conditions

Reliability-Problems of the so Called O-Rings Were Known

Example 4

The Challenger Disaster

The manufacturer of the boosters warned NASA before launch that the expected cold temperatures might be an extra risk.

NASA did not see any correlation between the failing of O-Rings and the temperatures.

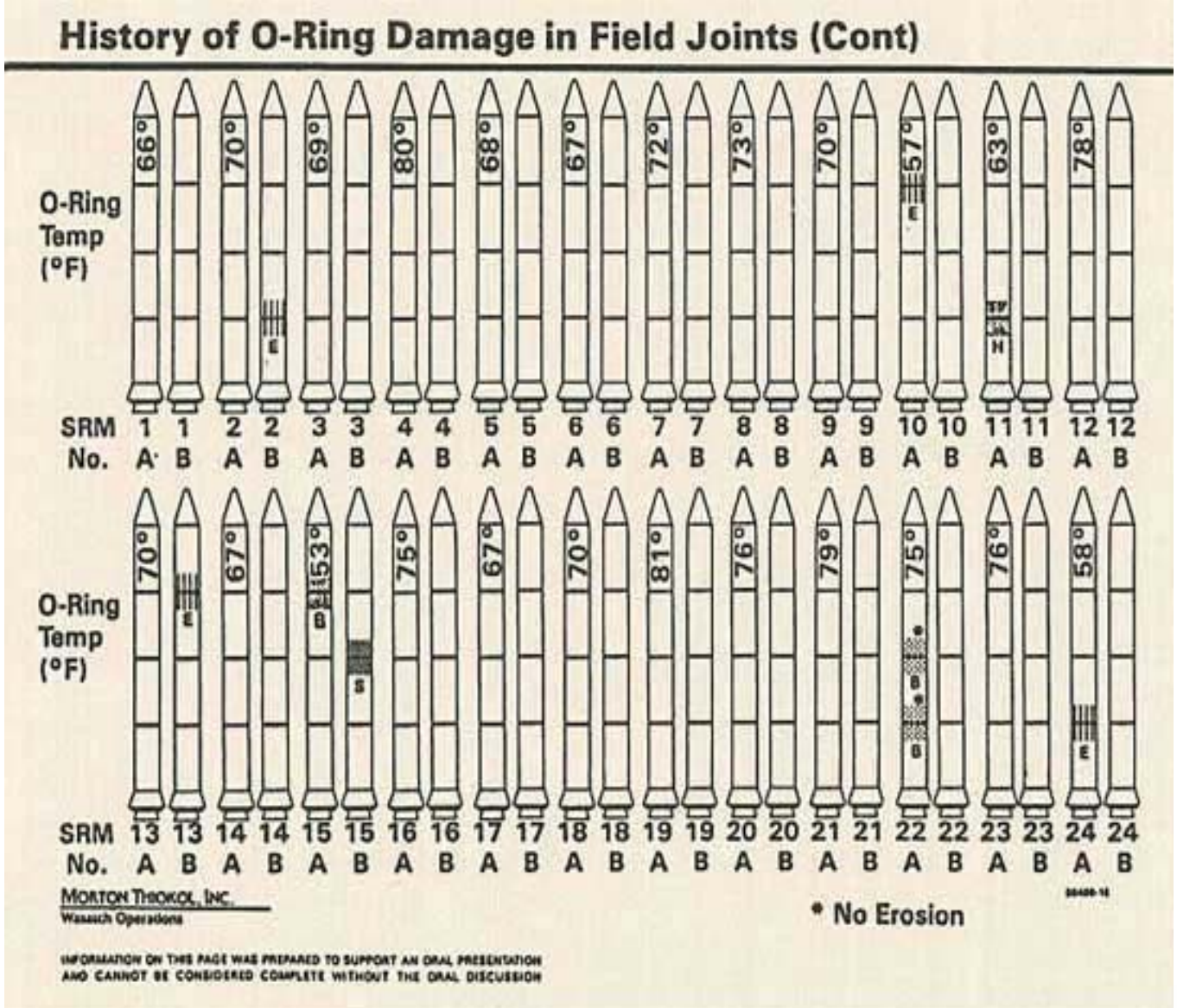
This was wrong!

Edward R. Tufte showed that the risk would have been obvious to NASA engineers if a better visualization would have been used

[Tufte's Re-Visualization]

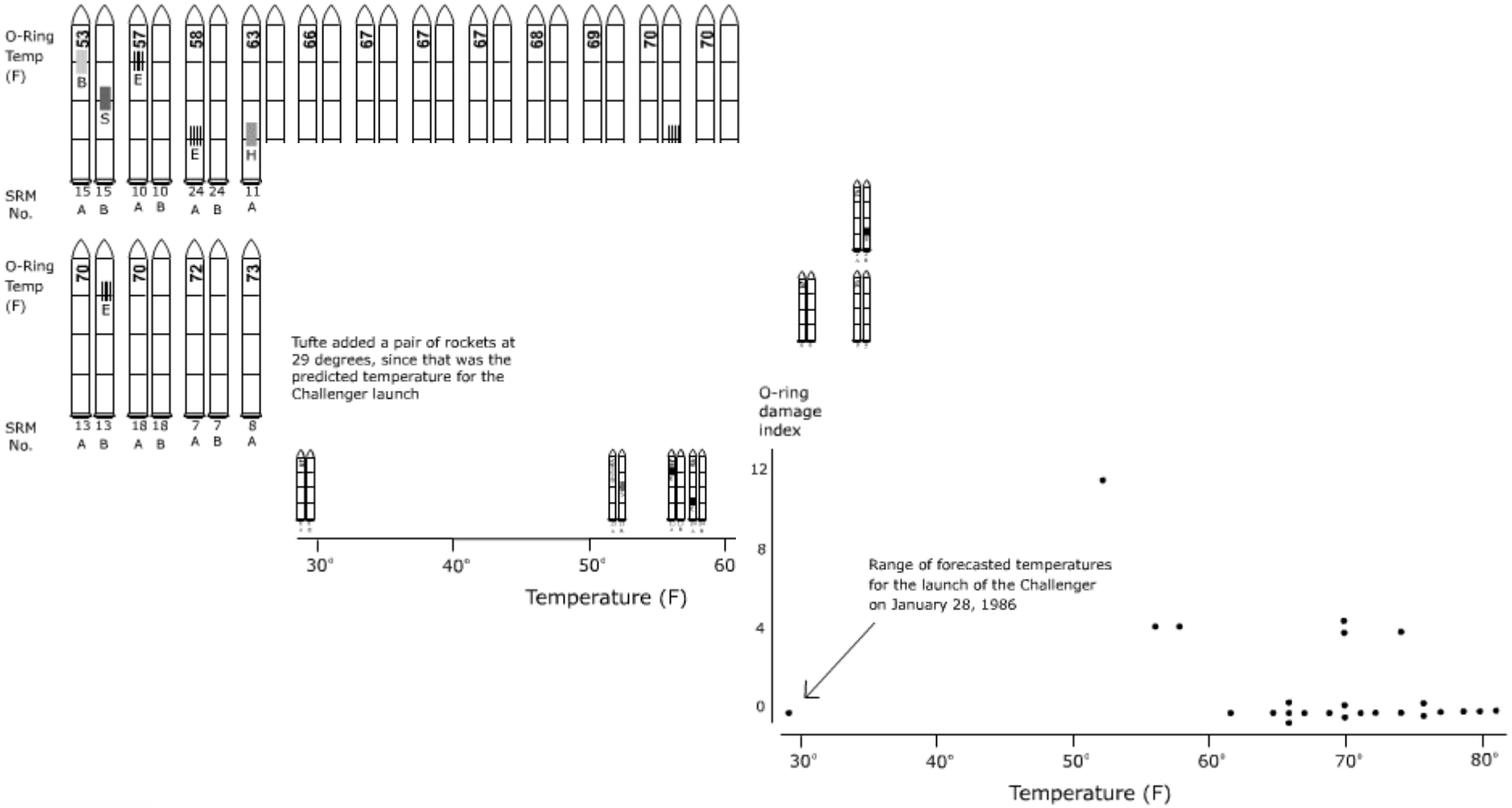
Example 4

Tufte's Re-Visualization



Example 4

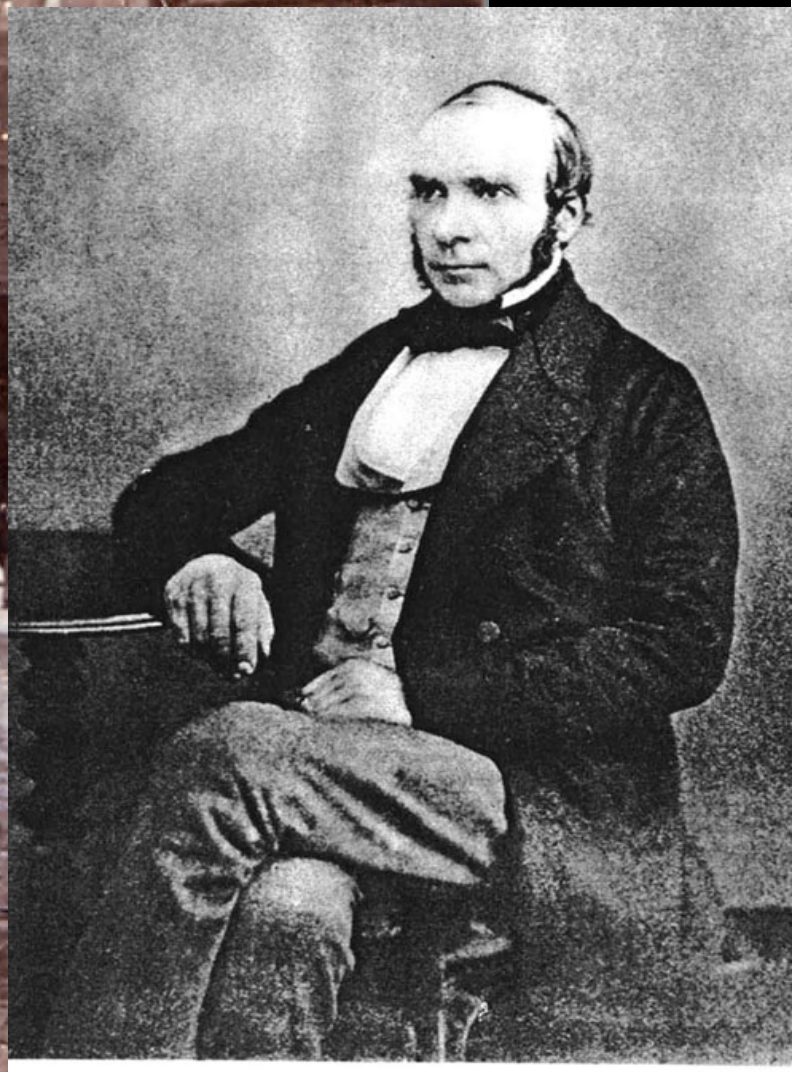
Tufte's Re-Visualization



[Tufte, 1997]
adapted from [Hearst , 2004]

Visualization Success Story

Mystery: what is causing a cholera epidemic in London in 1854?



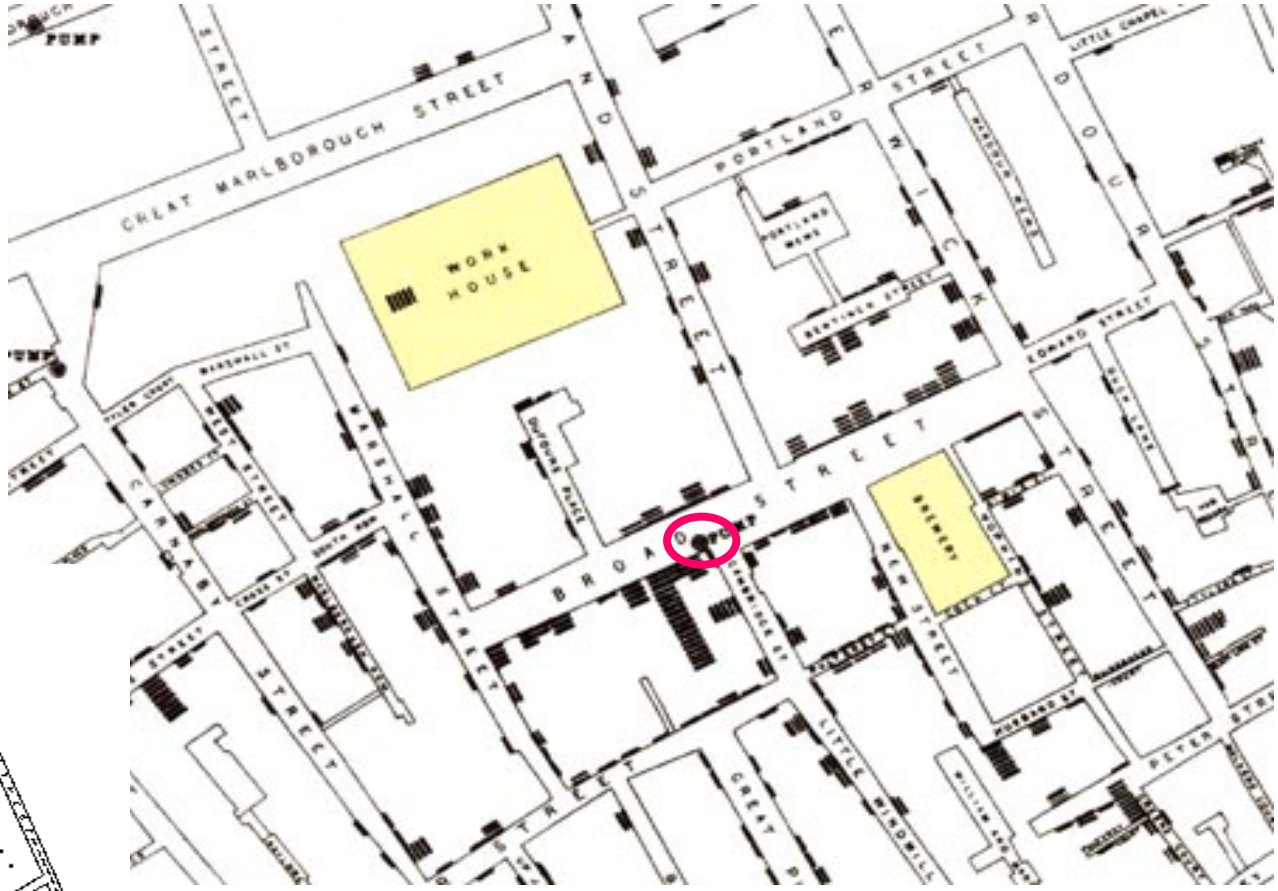
John Snow

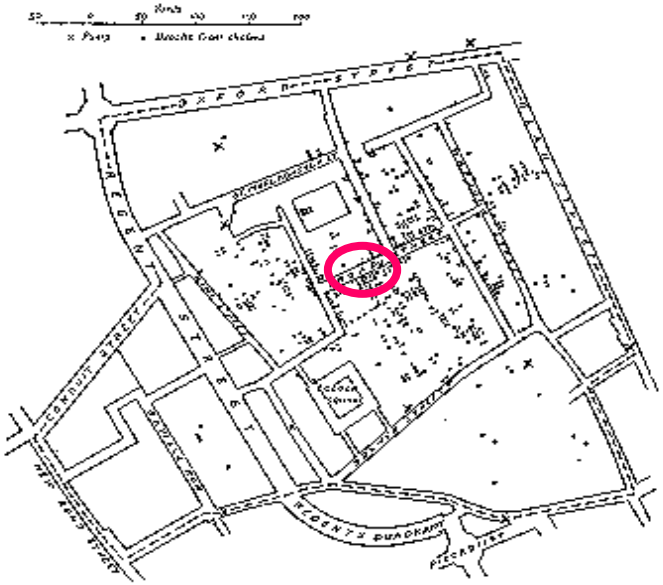
Visualization Success Story

[Tufte, 1997]
adapted from [Hearst , 2004]

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

Horizontal lines indicate location of deaths.





From Visual Explanations by Edward Tufte, Graphics Press, 1997

Cycle Plot

[Cleveland, Dunn, and Terpenning, 1978]; [Robbins, 2008]

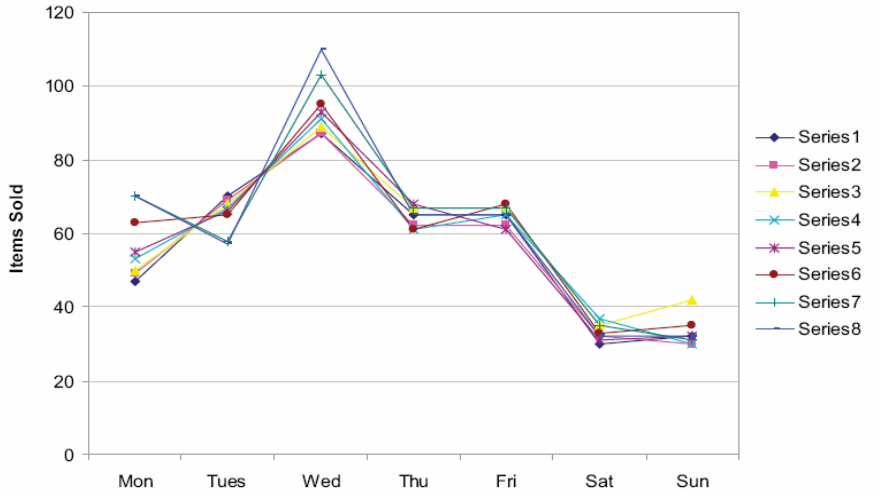


Figure 1: This line chart uses one line per week to display the sales of a hypothetical company by the day-of-the-week over an eight week period.

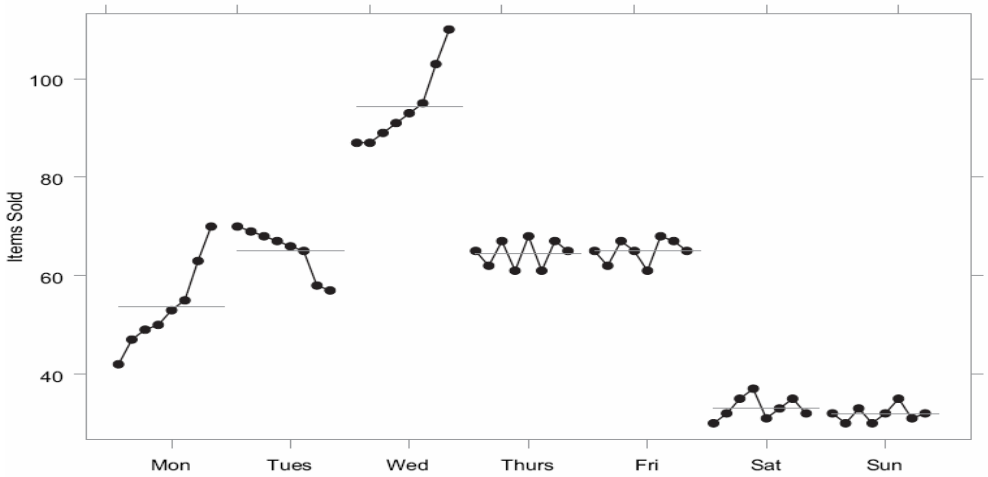


Figure 3: This cycle plot first plots the first Monday, the second Monday, and on through the eighth Monday. Then it plots the first Tuesday, second Tuesday, and so on. The horizontal lines show the means for each day of the week. Trends that were much more difficult to see in Figures 1 and 2 show up clearly in this figure.

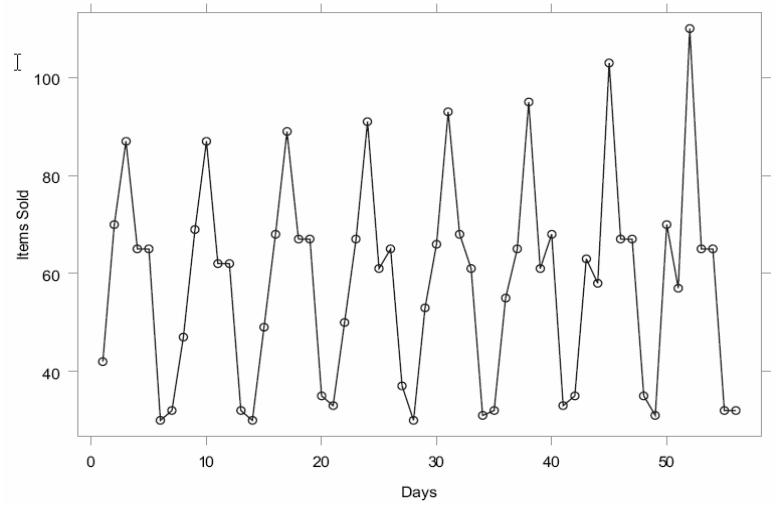


Figure 2: This time series chart shows the data of Figure 1 over the eight week period. Note that it is much more difficult to determine sales for a particular day, for example for Tuesdays.

Data Set

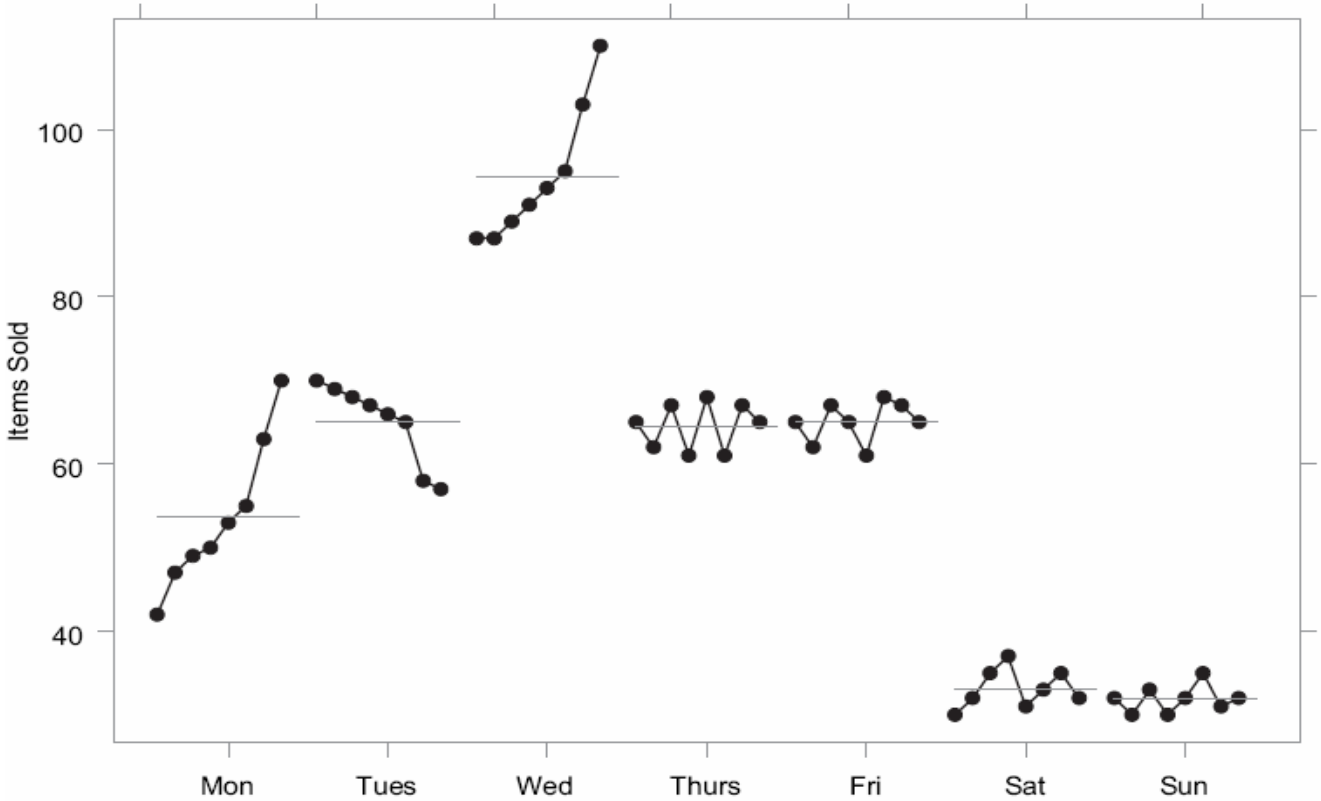
Sales of a hypothetical company by the day-of-the-week over an eight week period

3 Visualizations

1) Line Chart – day-of-the-week
2) Line Chart – over an eight weeks
3) Cycle Plot

Cyclic Plot

[Cleveland, Dunn, and Terpenning, 1978]; [Robbins, 2008]



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Benefits
(compared to Line Chart)

Sales/Changes each data more visible

Mo / We: increase

Tu: decrease

Other days: less variable and fluctuated around their means

Repeating Time-oriented Pattern Detection

Visualization for Problem Solving

1	599	693	26	541	558	51	318	527	76	196	467	101	246	606
2	525	693	27	542	531	52	321	489	77	192	482	102	230	693
3	541	662	28	527	606	53	243	510	78	134	473	103	196	693
4	542	611	29	505	693	54	250	497	79	94	568	104	230	660
5	527	579	30	469	693	55	253	508	80	318	558	105	196	579
6	505	529	31	409	660	56	246	493	81	321	531	106	318	527
7	469	553	32	321	579	57	230	423	82	243	606	107	321	489
8	409	558	33	318	527	58	196	467	83	250	693	108	243	606
9	321	531	34	321	489	59	192	482	84	253	693	109	250	693
10	318	606	35	243	510	60	134	473	85	246	660	110	253	693
11	321	693	36	250	497	61	94	568	86	230	579	111	246	660
12	243	693	37	253	508	62	541	558	87	196	527	112	230	579
13	250	660	38	246	493	63	542	531	88	318	489	113	230	527
14	253	579	39	230	423	64	527	606	89	321	510	114	196	489
15	246	527	40	196	467	65	505	693	90	243	497	115	318	510
16	230	489	41	192	482	66	469	693	91	250	508	116	321	497
17	196	510	42	134	473	67	409	660	92	253	493	117	243	508
18	192	497	43	94	568	68	321	579	93	246	423	118	250	493
19	134	508	44	541	558	69	318	527	94	230	467	119	253	423
20	94	493	45	542	531	70	321	489	95	196	482	120	246	467
21	25	423	46	527	606	71	243	510	96	318	473			
22	87	467	47	505	693	72	250	497	97	321	568			
23	128	482	48	469	693	73	253	508	98	243	482			
24	183	473	49	409	660	74	246	493	99	250	473			
25	163	568	50	321	579	75	230	423	100	253	568			

Outline

Motivation - Examples

Definitions and Goals

Knowledge Crystallization

Visualization Reference Model(s)

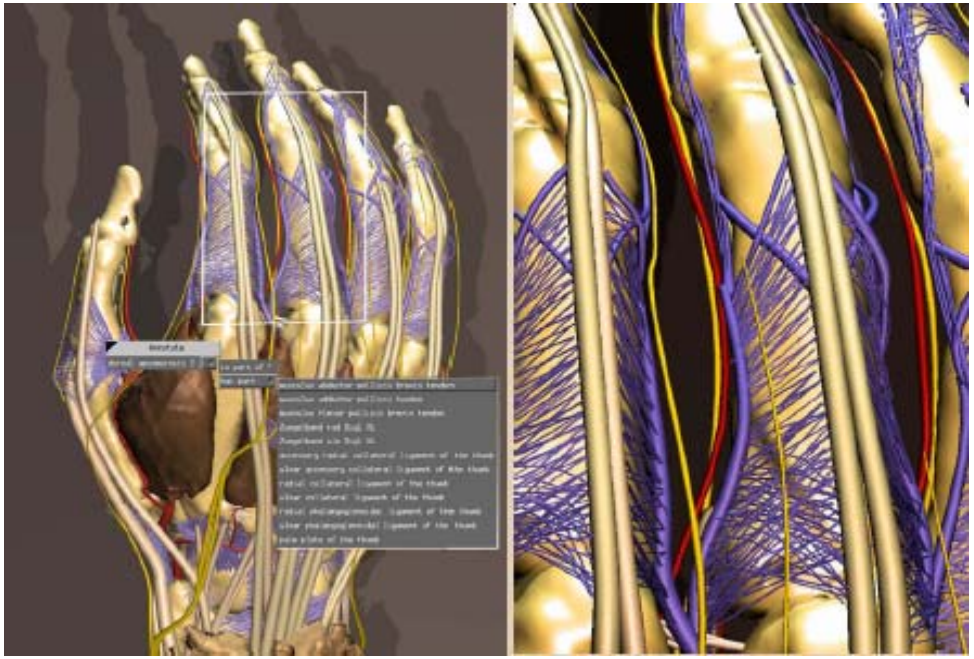
Exploration Techniques

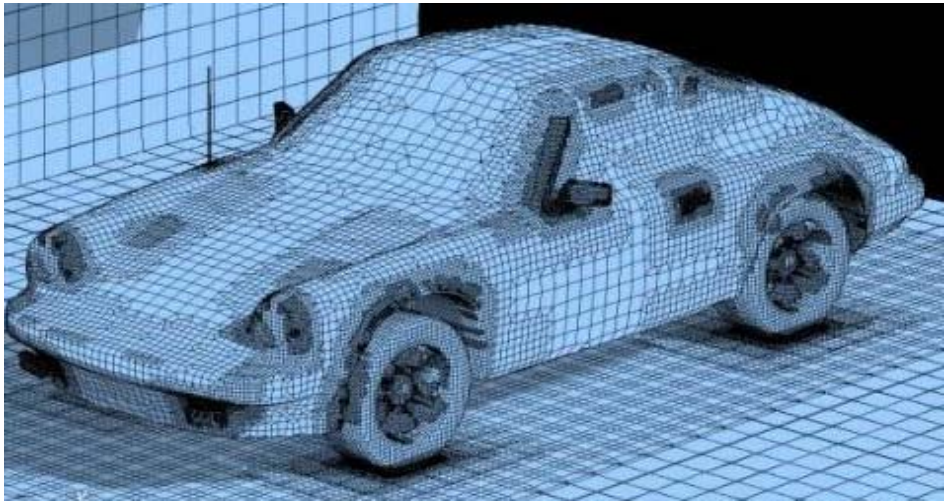
Visual Encoding Techniques

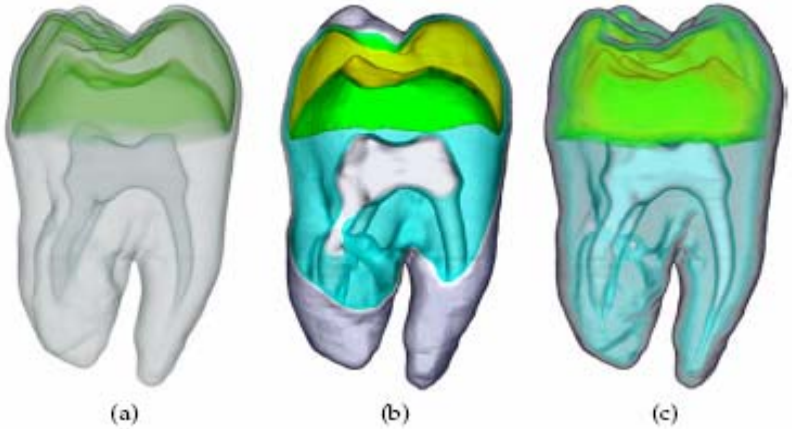
Summary

Visualization: Classical Areas

Volume Visualization

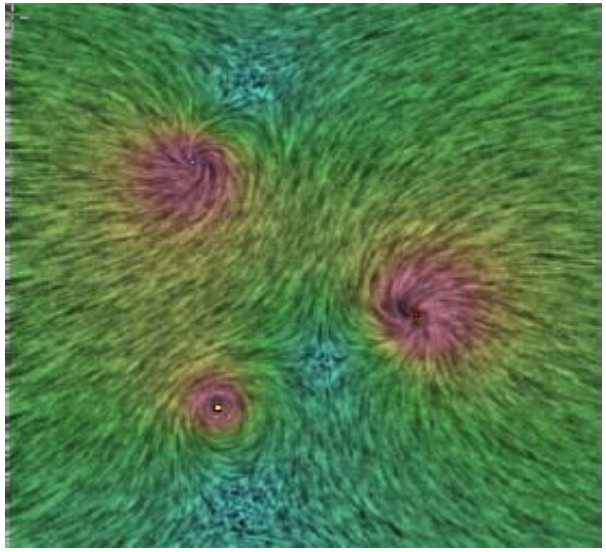


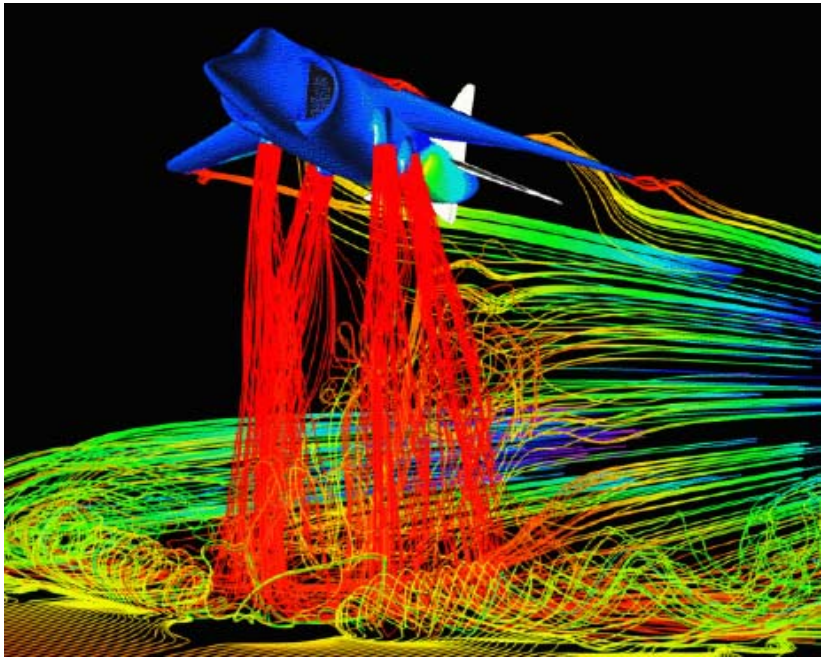




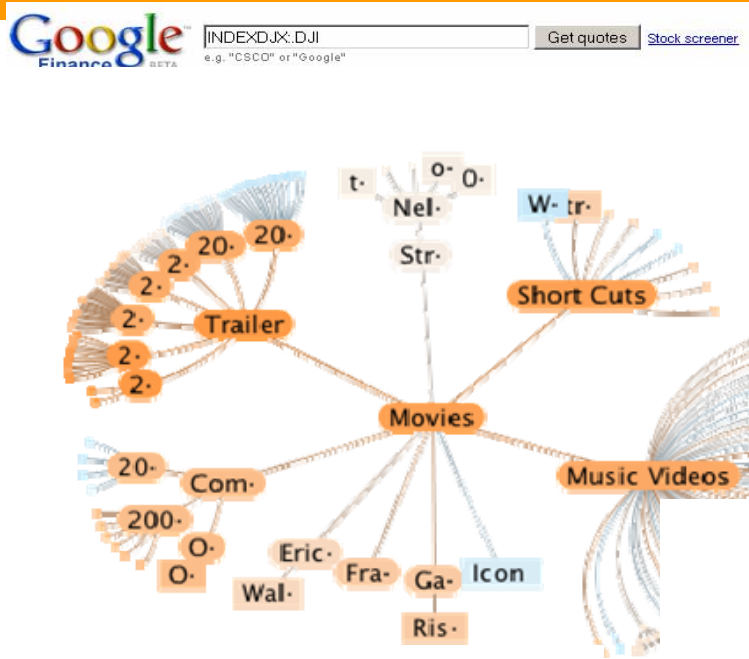
Visualization: Classical Areas

Flow Visualization

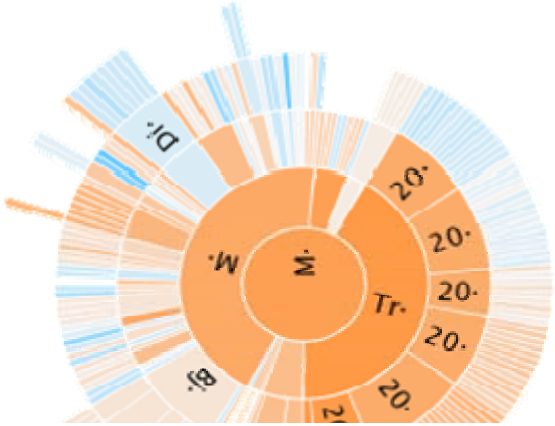


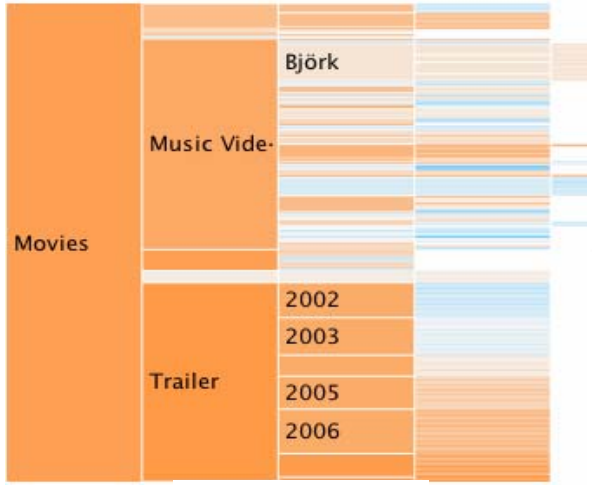


Visualization: Classical Areas

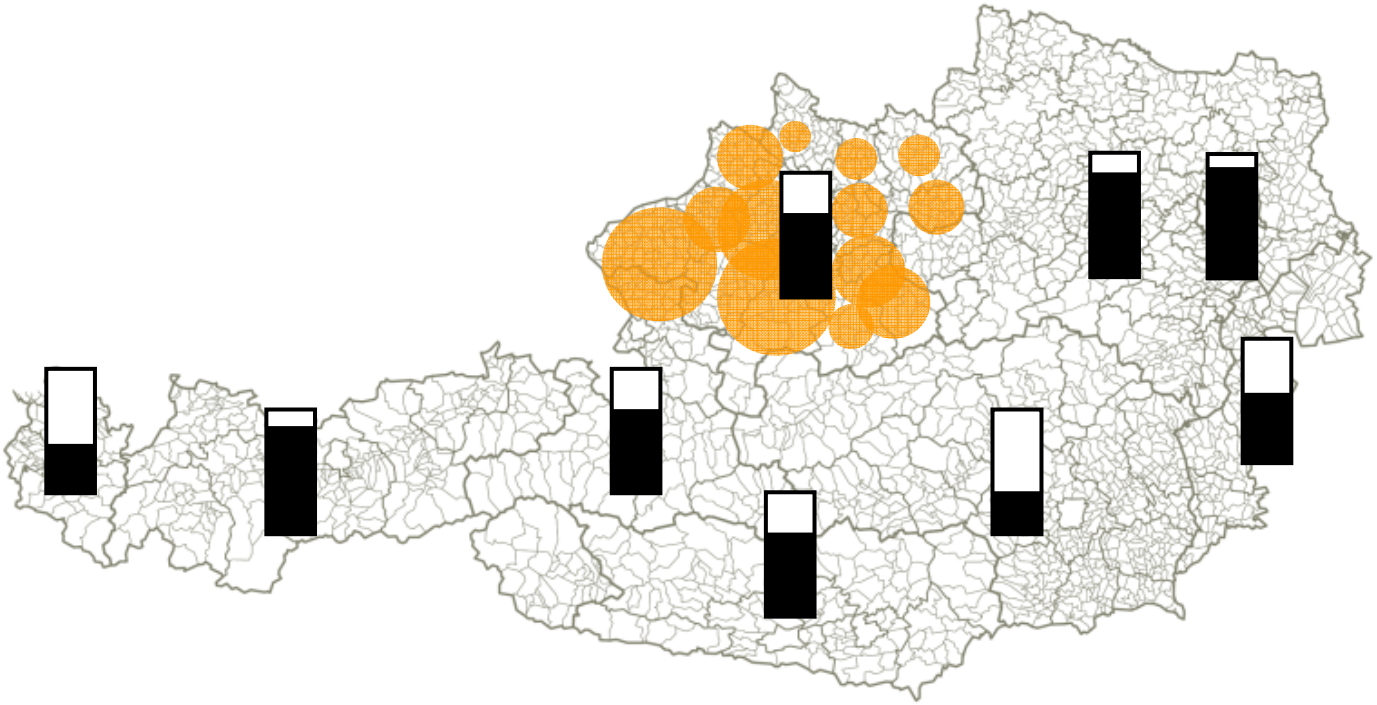


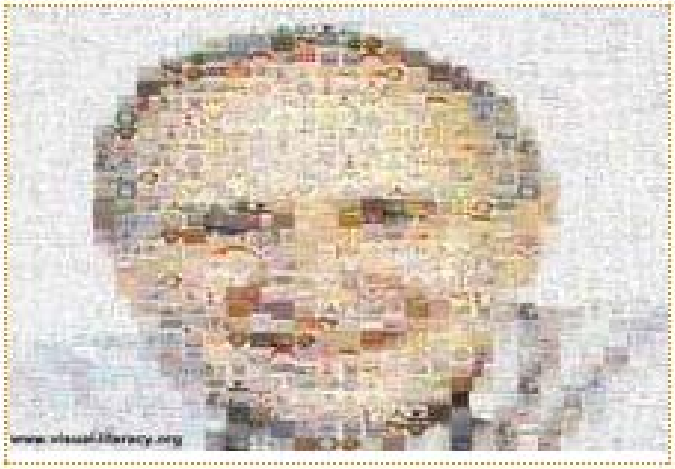
Hyperbolic Tree





Icicle Tree





Interactive Homage to Ben Shneiderman

Visualization: 3 Classical Areas

Volume Visualization

Flow Visualization

Information Visualization

? *Scientific Visualization*

? *Scientific Visualization*

? *Scientific Visualization*

Visualization: 3 Areas

Volume
Visualization
Flow
Visualization …

} Scientific Visualization

Information
Visualization

Information – Flow/Volume Visualization

"Abstract" Data

- Usually No Inherent Spatial Structure
- Heterogeneous Data

nD

Prime Goals

- Users & Tasks
- Visual Metaphor
- Flexible User Interaction Mechanisms
- **Exploration**, Analysis, Presentation

"Concrete" Data

- Inherent Spatial Structure

2 or 3D / temporal ?

Prime Goals

- 3D-Rendering
- Fast Rendering
- Exploration, **Analysis**, Presentation

Example: Data about Cars

[UCI Machine Learning Repository]

Attribute:	Values:
1. **risk**:	-3, -2, -1, 0, 1, 2, 3.
2. **make**:	alfa-romero, audi, bmw, chevrolet, dodge, honda, isuzu, jaguar, mazda, mercedes-benz, mercury, mitsubishi, nissan, peugot, plymouth, porsche, renault, saab, subaru, toyota, volkswagen, volvo.
3. **fuel-type**:	diesel, gas.
4. **num-of-doors**:	four, two.
5. **body-style**:	hardtop, wagon, sedan, hatchback, convertible.
6. **num-of-cylinders**:	eight, five, four, six, three, twelve, two.
7. **horsepower**:	continuous from 48 to 288.
8. **price**:	continuous from 5118 to 45400.

Kinds of …

[Keim, 1996/2001]

Explorative Analysis

Starting Point: data without hypotheses about the data

Process: interactive, usually undirected search for structure, trends, etc.

Result: visualization of the data, which provides hypotheses about the data

Confirmative Analysis

Starting Point: hypotheses about the data

Process: goal-oriented examination of the hypotheses

Result: visualization of the data, which allows to confirm or reject the hypotheses

Presentation

Starting Point: facts to be presented are fixed a priori

Process: choose the appropriate presentation method

Result: high-quality visualization of the data presenting the facts

Data Exploration

[Keim, 1996/2001]

Definition

Data Exploration is the process of searching and analyzing databases to find implicit but potentially useful information.

more formally:

Data Exploration is the process of finding a

- subset D' of the database D and
- hypotheses $H_U(D', C)$

that a *user U* considers *useful* in an *application context C*.

Definitions ...

[Card, et al., 2000, Gershon, et al. 1998]

Visualization

"the act or process of interpreting in visual terms or of putting into visual form"

Information Visualization

"the process of transforming *data*, *information*, and *knowledge* into visual form making use of humans' natural visual capabilities"

"the computer-assisted use of visual processing to gain understanding (insights)"

Definitions ...

[Schreiber, et al., 1999]

Data

"input signals to sensory and cognitive processes"

Information

"data with an associated meaning"

Knowledge

"the whole body of data and information together with cognitive machinery that people are able to exploit to decide how to act, to carry out tasks and to create new information"

Some Definitions of Visualization

"The use of computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results."

[McCormick, et al. 1987]

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

[Card, et al., 1999]

"The purpose of computing is insight, not numbers."

[Hamming, 1962]

"The purpose of visualization is insight, not numbers."

Goals

To Ease *Understanding* and to Facilitate *Cognition*

To Promote a *Deeper Level of Understanding* of the Data and Information under Investigation

To Foster **New Insight** into the Data AND the **Underlying** ***Process***

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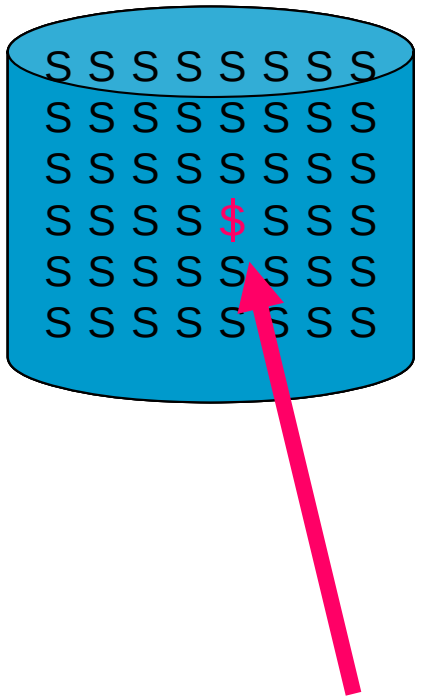
Motivation: An Information Gap

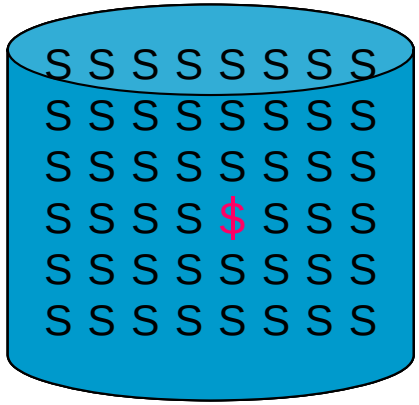
[Card, et al. 1999]

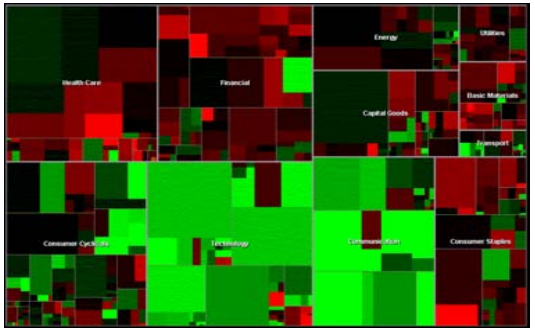


Somewhere in the data there is valuable information.

One Approach: Visualization

[Card, et al. 1999]



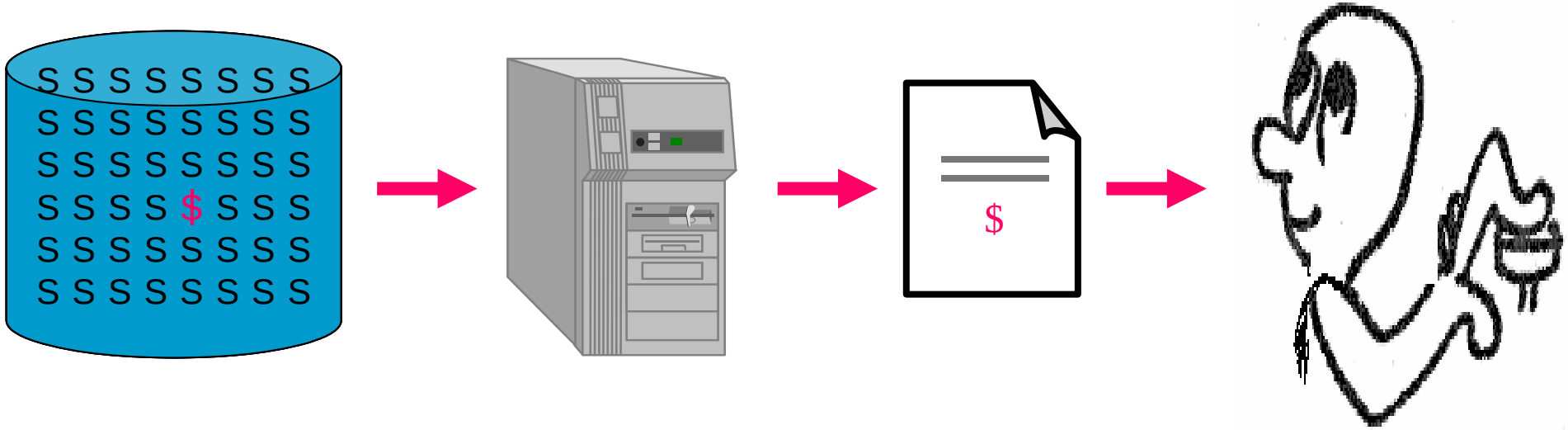


Tap the Power of Human Perception

- Complex View of the Data
- Interactive Controls to Explore Data and See Patterns

Competing Approach: Data Mining

[Card, et al. 1999]



Tap the Power of the Computer

- Complex Statistical Analysis
- Simple Report

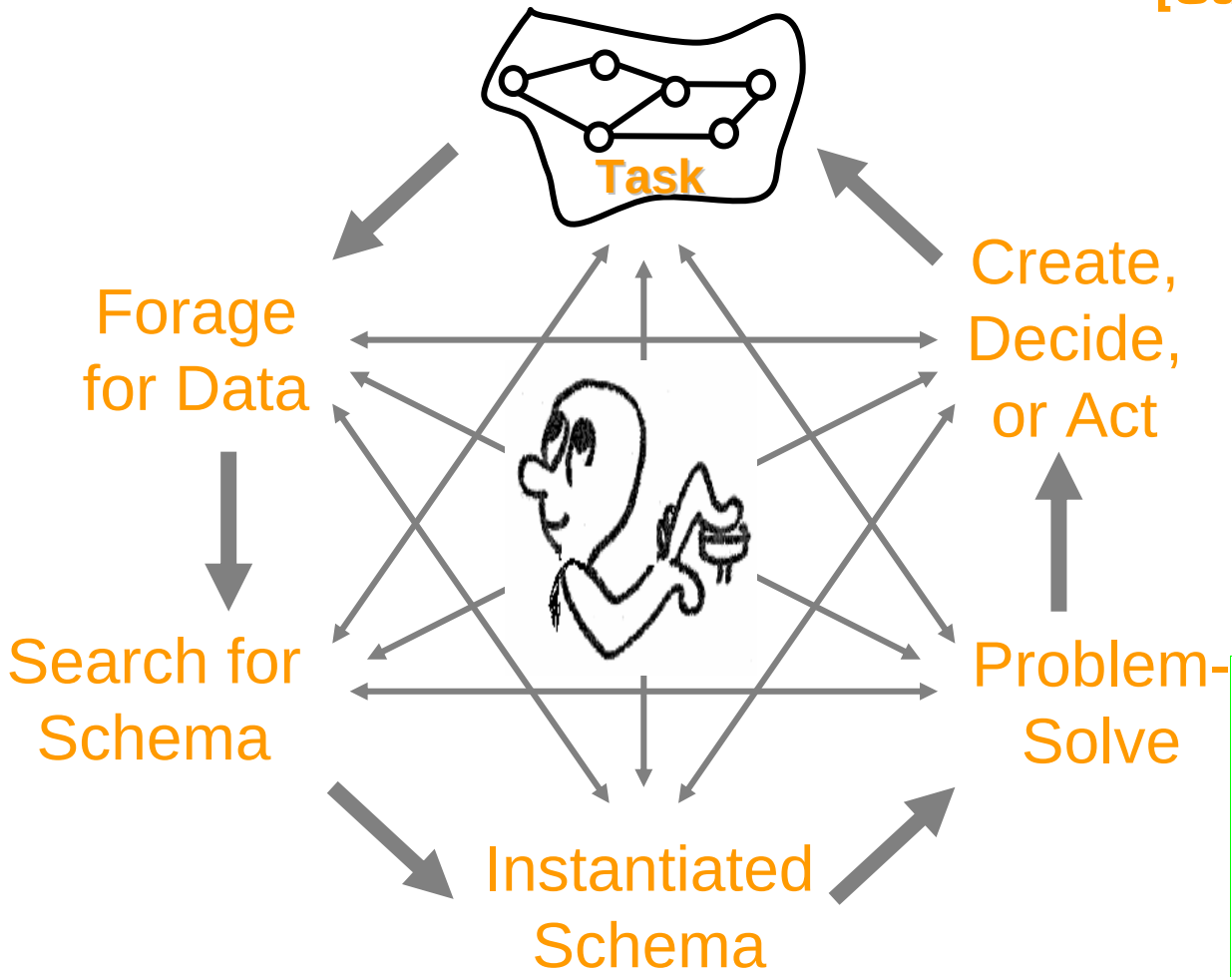
Knowledge Crystallization Loop

Sub-tasks

[Card, et al. 1999]

Overview
Zoom
Filter
Details
Browse
Search query

Extract
Compose
Present

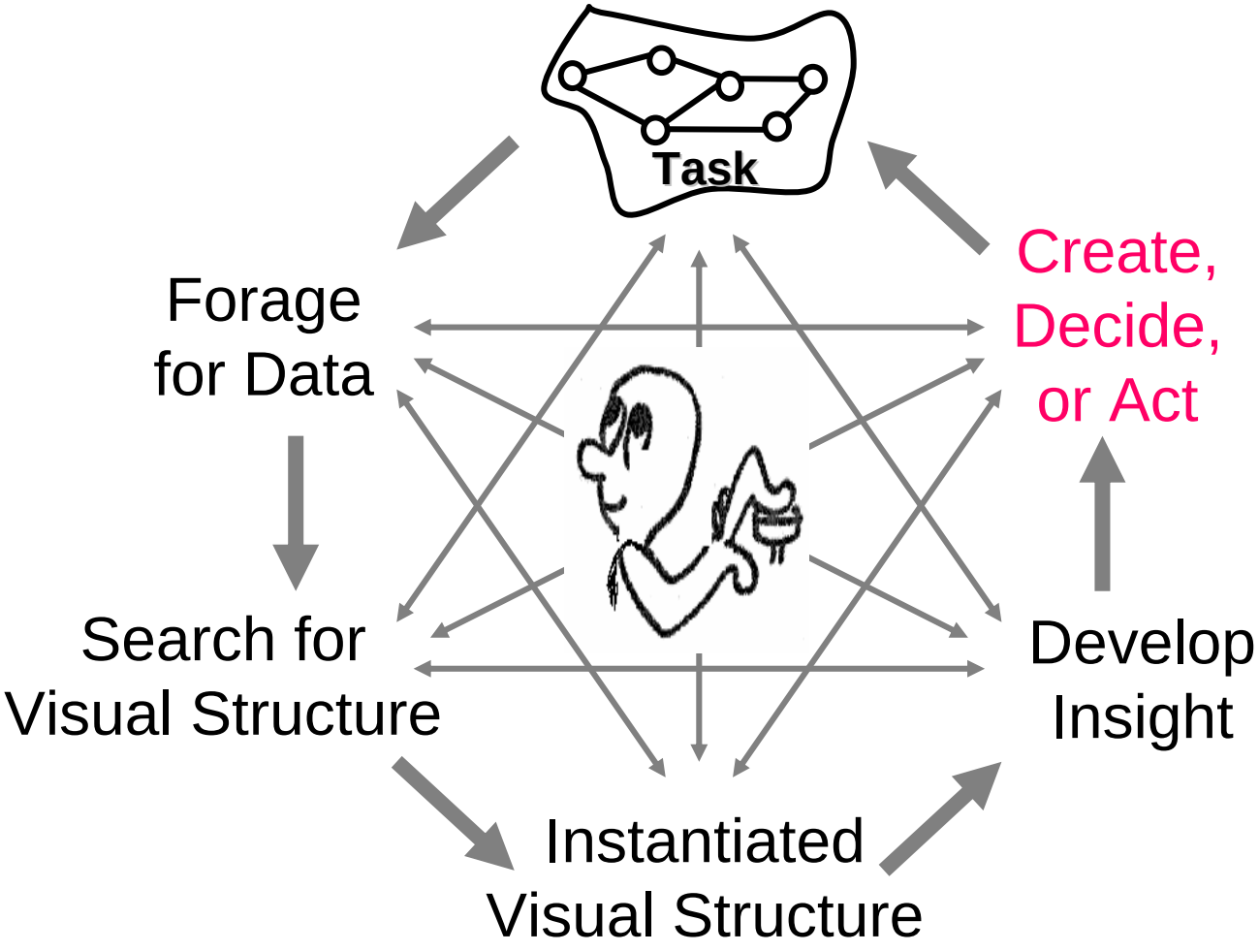


Reorder
Cluster
Class
Average
Promote
Detect pattern
Abstract

Create
Delete
Manipulate
Read fact
Read pattern
Read compare

Knowledge Crystallization Loop ::: Visualization

[Card, et al. 1999]



Knowledge Crystallization 1

The Task

You want to buy a new Computer!

But where?

Which Model?

Aaaargh... HELP!

Solution

What do you do?

>> Knowledge Crystallization <<

Knowledge Crystallization 2

Information Foraging

- Collect Information about the Task, i.e.:
  - Articles
  - Tests
  - Advertising
  - etc.
  - ... About Computers

Knowledge Crystallization 3

Search for a Schema

Identify Attributes of Computers You Want to Use for Comparison, e.g.:

- MHz
- RAM
- Disc-Space
- CD-Rom/DVD-Rom Speed
- Brand
- Warranty
- or Even Color?

Knowledge Crystallization 4

- Instantiate Schema
  - Make a Table
    - List Computers and Their Attributes
  - Information That Does Not Fit into Schema:
    - If Not Essential
      - Remove
    - If Essential
      - Go to Step Two and Find Better Schema
  - In General
    - Remove Redundant Information

Knowledge Crystallization 5

Problem-Solving / Find Trade-off

Set Priorities in the Features You Want

Re-order the Columns and Rows of Your Table, Respectively

Remove Computers That Are Already Out of the Running

Knowledge Crystallization 6

Search for a More Compact Schema

Simplify Your Trade-off

E.g.,

Group the Computers Regarding to Attributes You Are Interested in

Remove All These Computers but the Best One or Two in Each Group

Knowledge Crystallization 7

Communicate Found Pattern or Act Resp.

- You Found a Pattern in Your Input Data
  - i.e. You Found a Compromise or Several Alternatives
- Bring It in a More „Crystallized“ Form of Representation
- Use this Representation to Communicate Your Result to Others…
- … or To Make a Decision on Your Own

Your Task Is Solved

Facilitation of Cognition

[Card, Mackinlay & Shneiderman 1999]

There are six ways how visualization can facilitate cognition

- By increasing the memory and processing resources available to the user
- By reducing the search for information
- By using visual representations to enhance the detection of patterns
- By enabling perceptual inference operations
- By using perceptual attention mechanisms for monitoring
- By encoding information in a manipulable medium

Outline

Motivation - Examples

Definitions and Goals

Knowledge Crystallization

Visualization Reference Model(s)

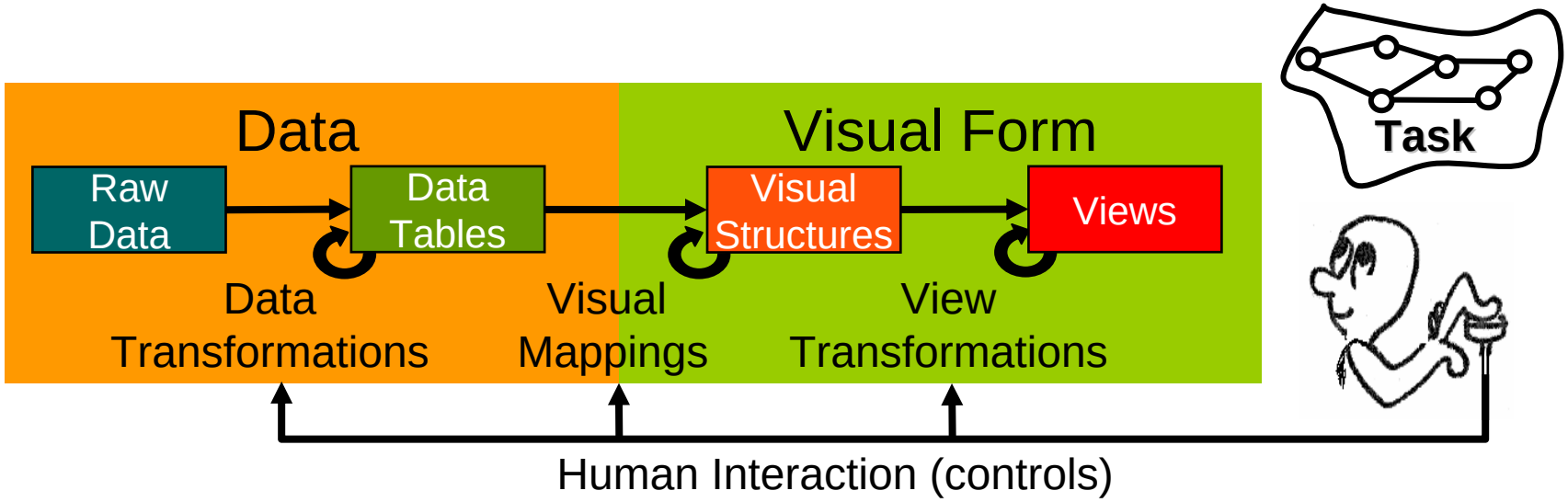
Exploration Techniques

Visual Encoding Techniques

Summary

Visualization Reference Model

[Card, et al., 1999]



Data Transformations

Mapping raw data into an organization fit for visualization

Visual Mappings

Encoding abstract data into a visual representation

View Transformations

Changing the view or perspective onto the visual representation

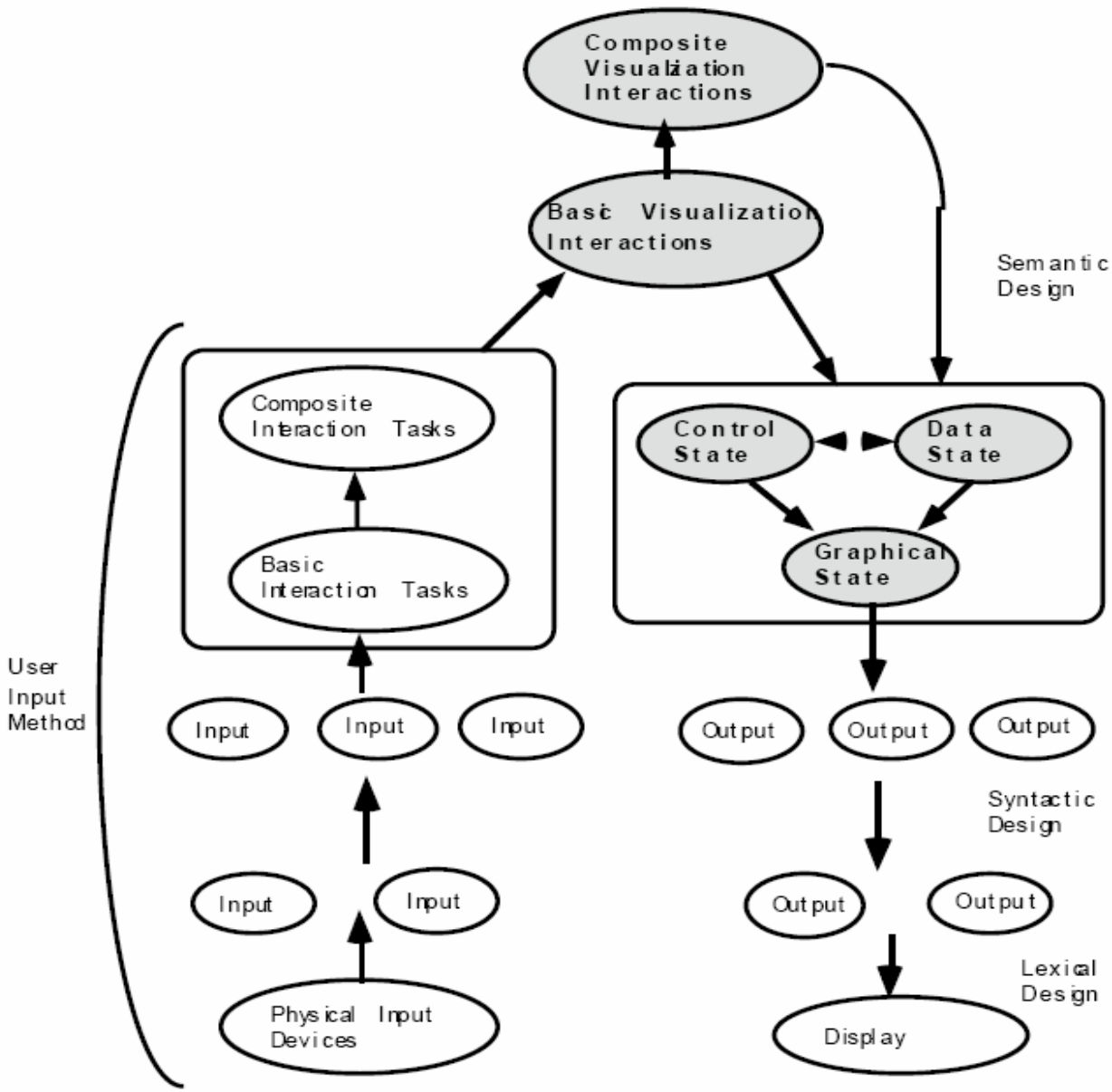
User interaction can feed back into any level

Basic Visualization Interactions *(BVI)*

[Chuah & Roth. 1996]

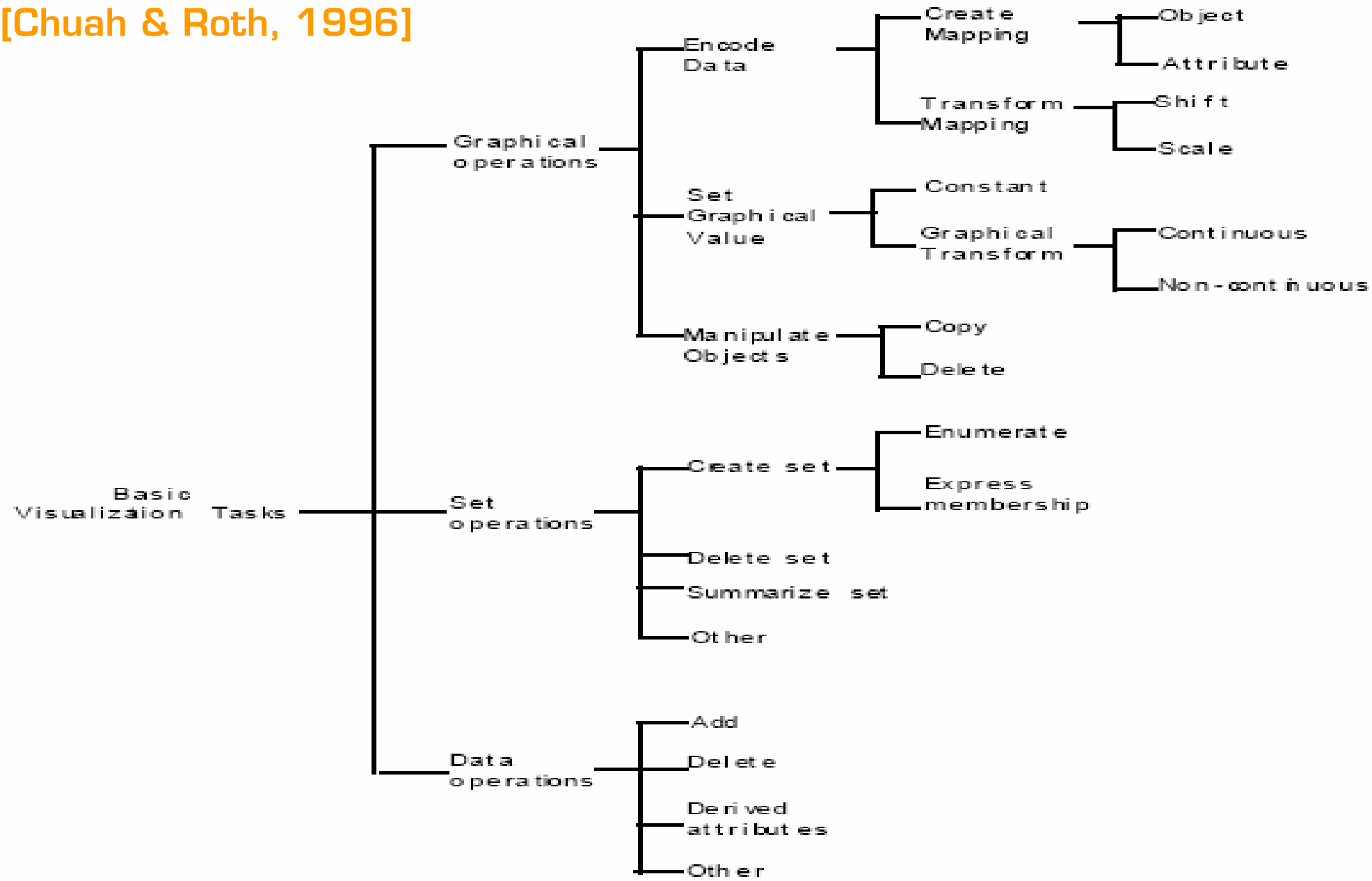
Described by its Input, Output, and Operation

- Graphical Operations (Graphical State)
- Set Operations (Control State)
- Data Operations (Data state)



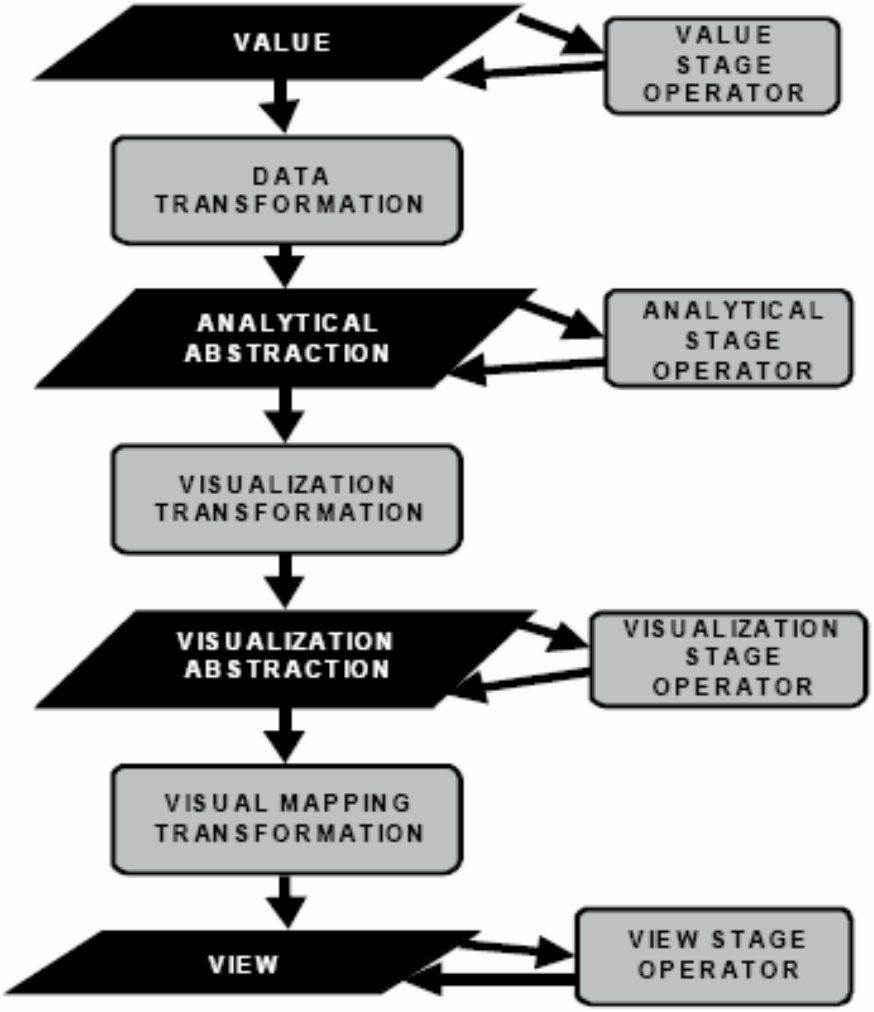
Basic Visualization Interactions *(BVI)*

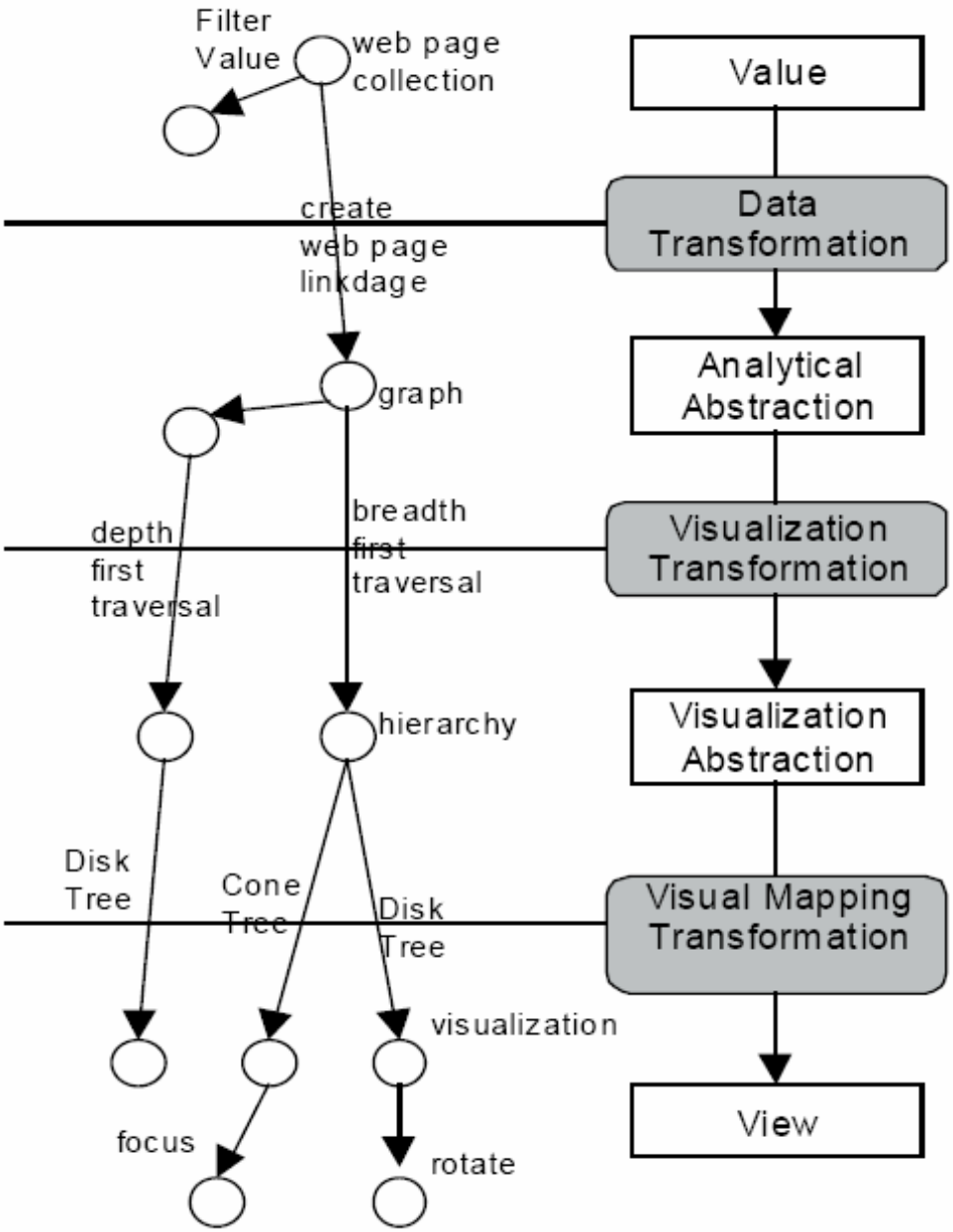
[Chuah & Roth, 1996]



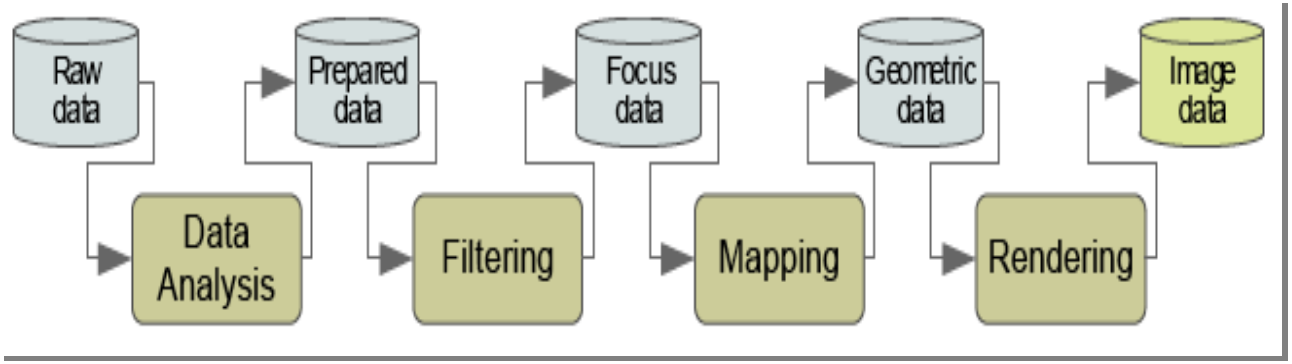
Chi's Data State Reference Model

[Chi 2000]

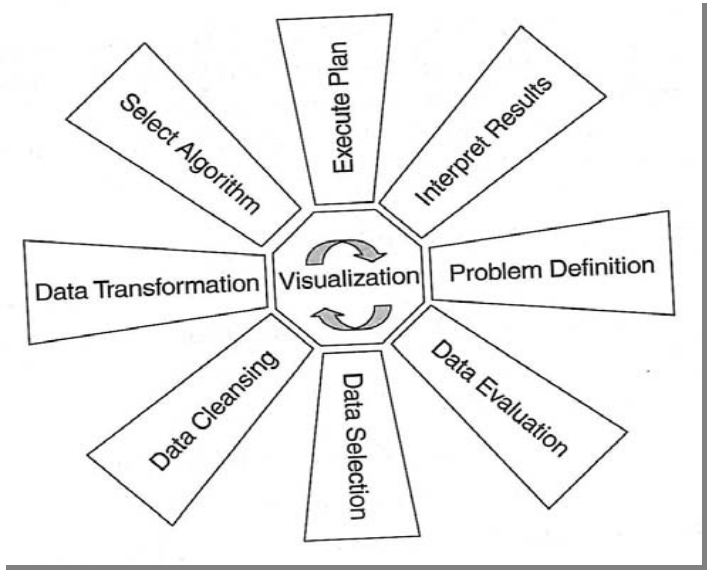




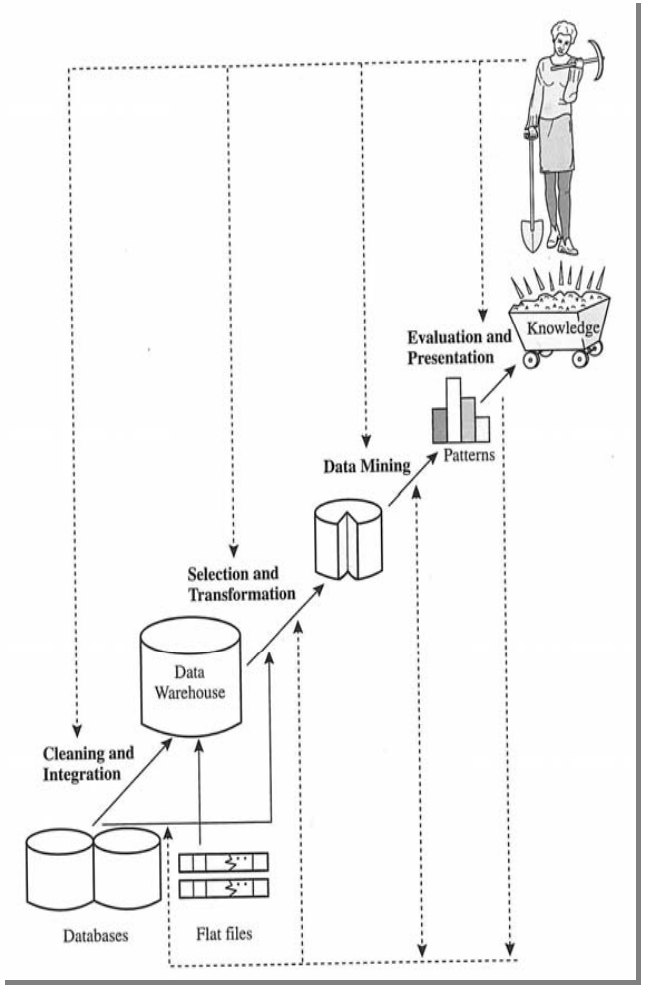
Some More …



[dos Santos and Brodlie, 2004]



[Fayyad, Grinstein, and Wierse, 2001]



[Han and Kamber, 2005]

Outline

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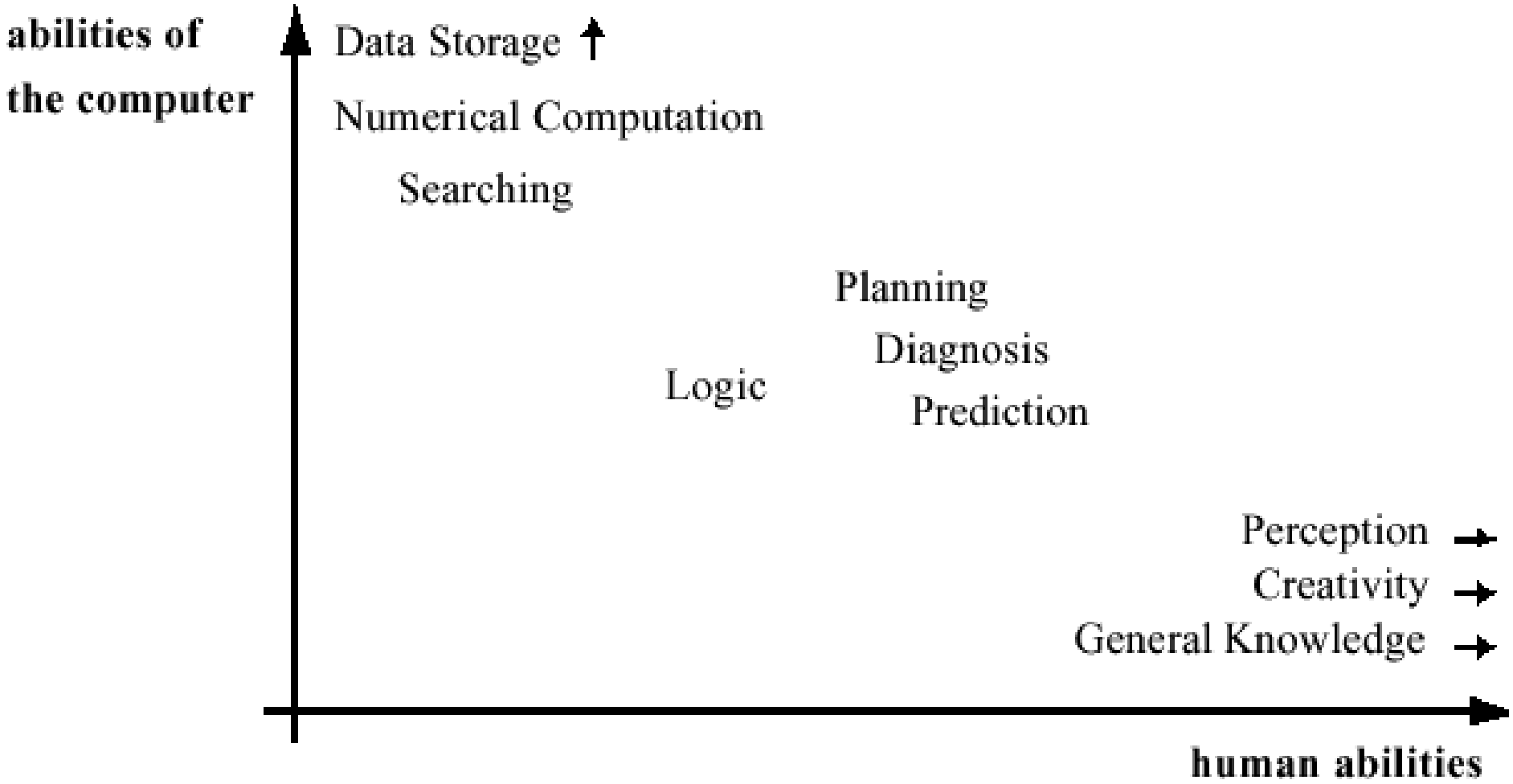
Human Abilities versus Computers

[Keim 2001]



A Task by Data Type Taxonomy

[Shneiderman, 1996]

InfoVis Tasks

- Overview
- Zoom
- Filter
- Details-on-demand
- Relate
- History
- Extract

Data Types

- 1-D Linear (document lens, SeeSoft, IM)
- 2-D Map (GIS, ThemeScape)
- 3-D World (CAD, Visible Human)
- Temporal (Perspective Wall, LifeLines)
- Multi-dimensional (SpotFire, HomeFinder)
- Tree (Cone trees, Hyperbolic trees)
- Network (Netmap, SemNet)
- Documents (Digital Library)

Tasks Taxonomy

High-level Tasks

[Shneiderman, 1996]

1	overview	gain an overview of the entire set of data
2	zoom	adjust the size of items of interest
3	filter	remove uninteresting items
4	details-on-demand	select one or more items and get details
5	relate	identify relationships between items
6	history	keep a history of actions to support undo/redo
7	extract	extract subsets of items for separate analysis

Data Types & Tasks taxonomy

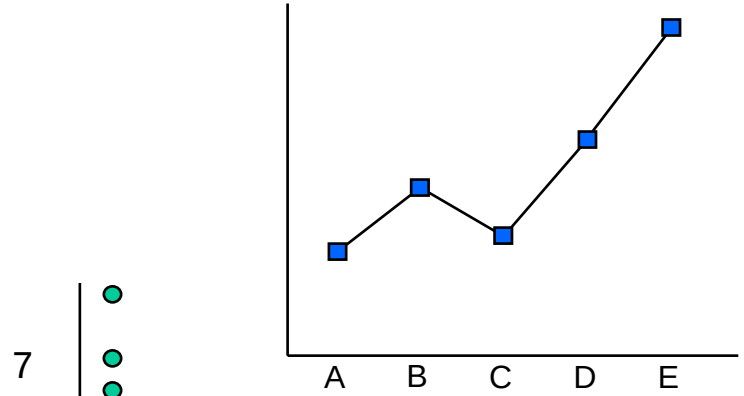
[Shneiderman, 1996]

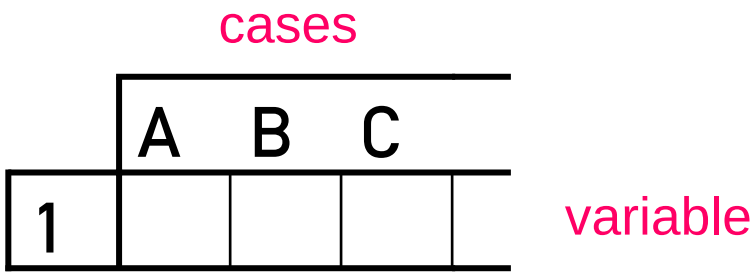
Data Types

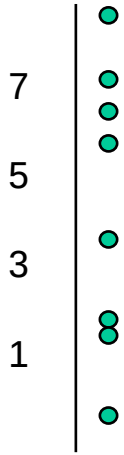
1	1-dimensional	alphabetic lists, source code, text/documents
2	2-dimensional	planar or map data, photos
3	3-dimensional	molecules, human body, buildings
4	temporal	{start, finish}, e.g., medical records, project management, historical presentations
5	multi-dimensional	n attribute => points in n-dimensional space, e.g., relational DB
6	tree	Hierarchies or tree structured, e.g., file directories, business organizations
7	network	connected as graph(s), e.g., telecommunications network, www

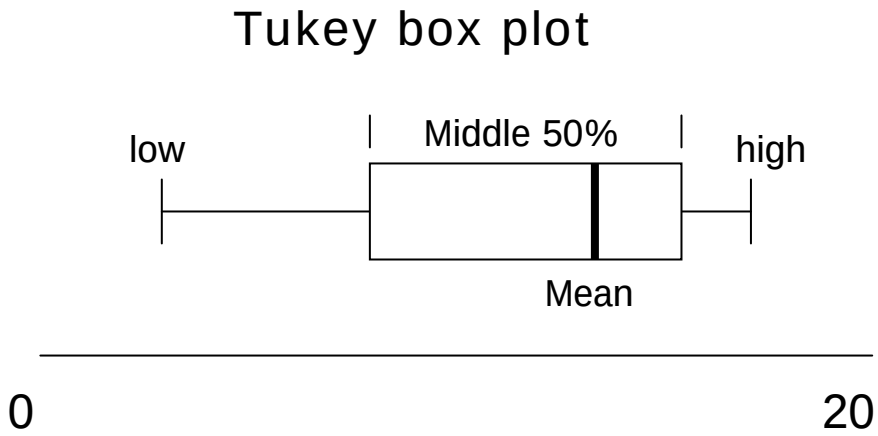
Univariate Data

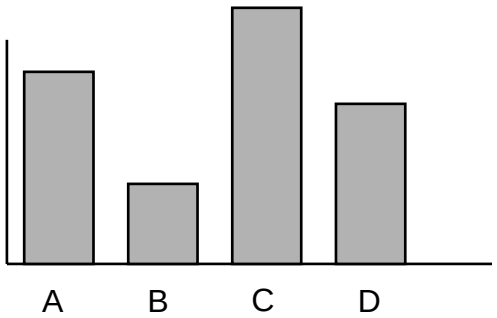
[Mackinlay, 2000]







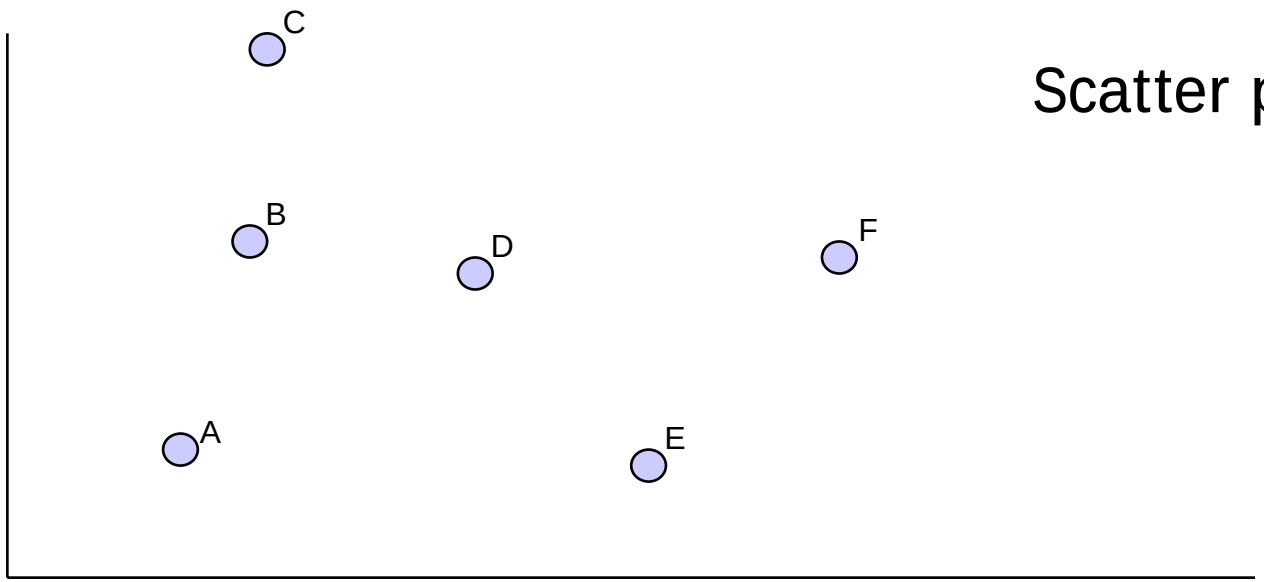




Bivariate Data

[Mackinlay, 2000]

	A	B	C	
1				
2				

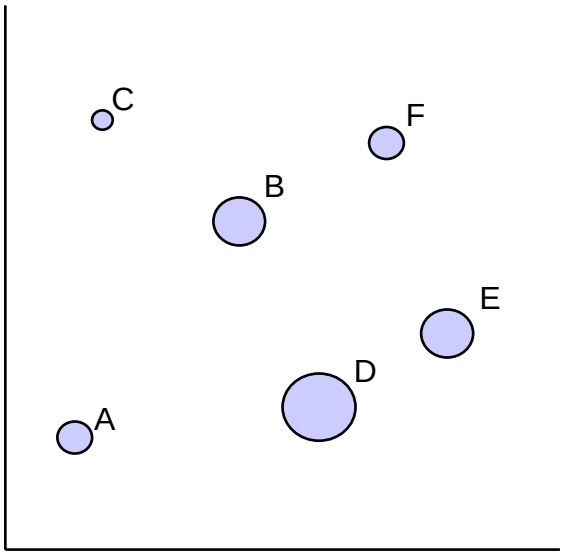


Scatter plot is common

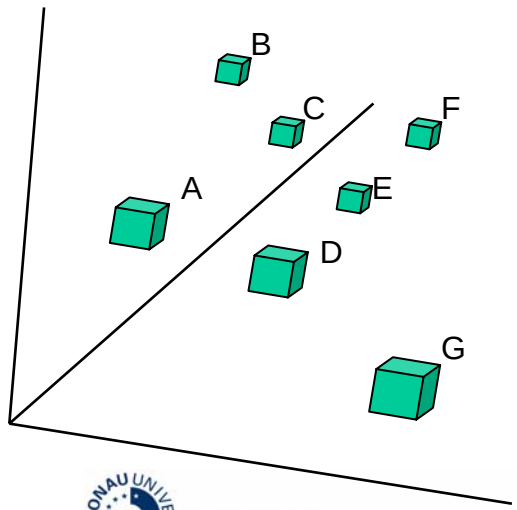
Trivariate Data

[Mackinlay, 2000

	A	B	C	
1				
2				
3				



3D scatter plot is possible



Based on John Stasko slide

Multivariant

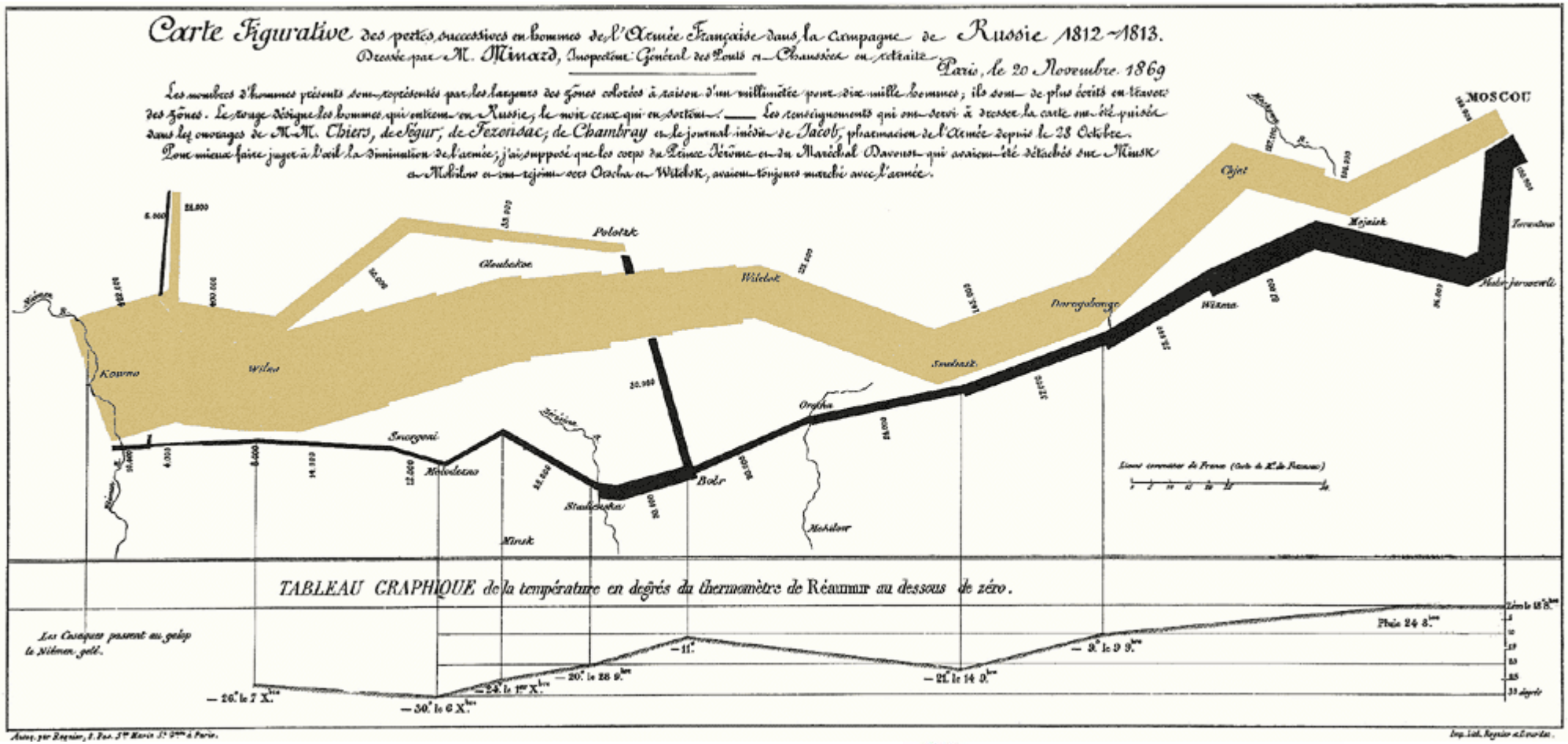
[Mackinlay, 2000]

	A	B	C	
1				
2				
3				
4				
5				
6				
7				
8				

Composition/Decomposition

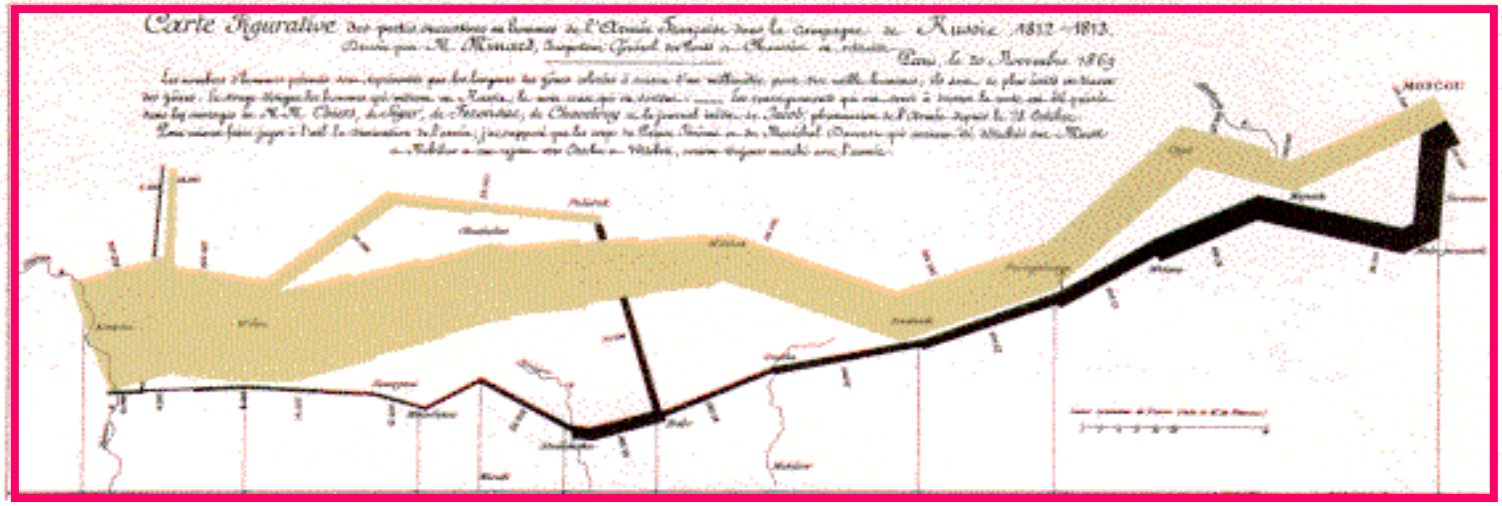
Tufte – [Mackinlay, 2000]

Minard's 1869 Napoleon's March



Single Axis Composition

[Mackinlay, 2000]



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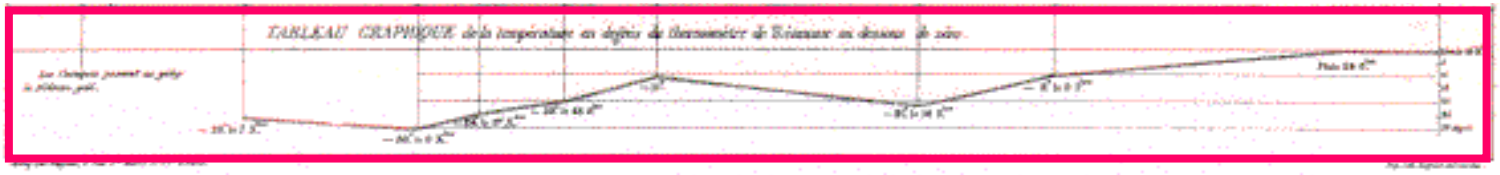
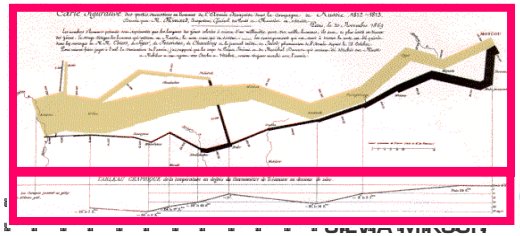
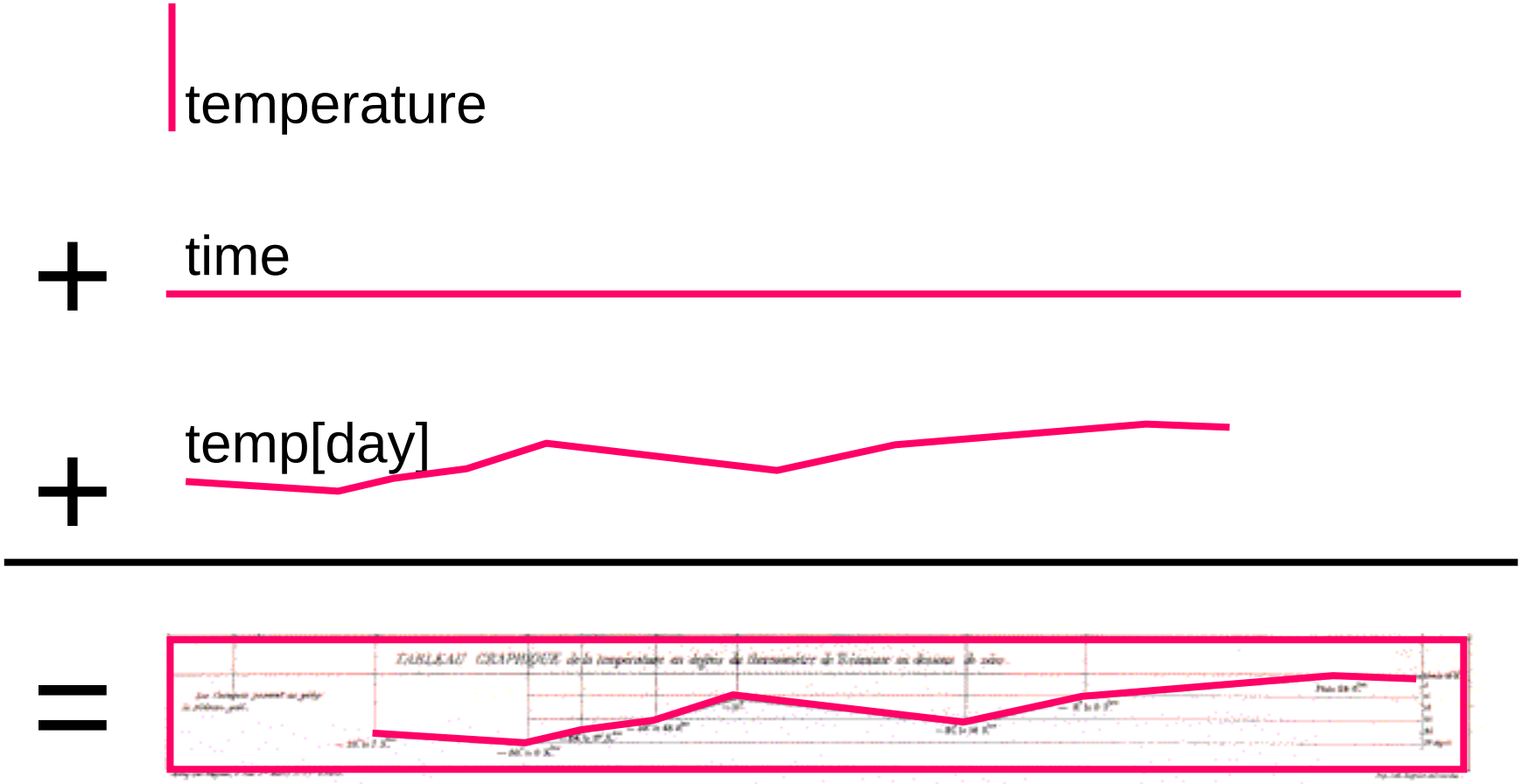


=



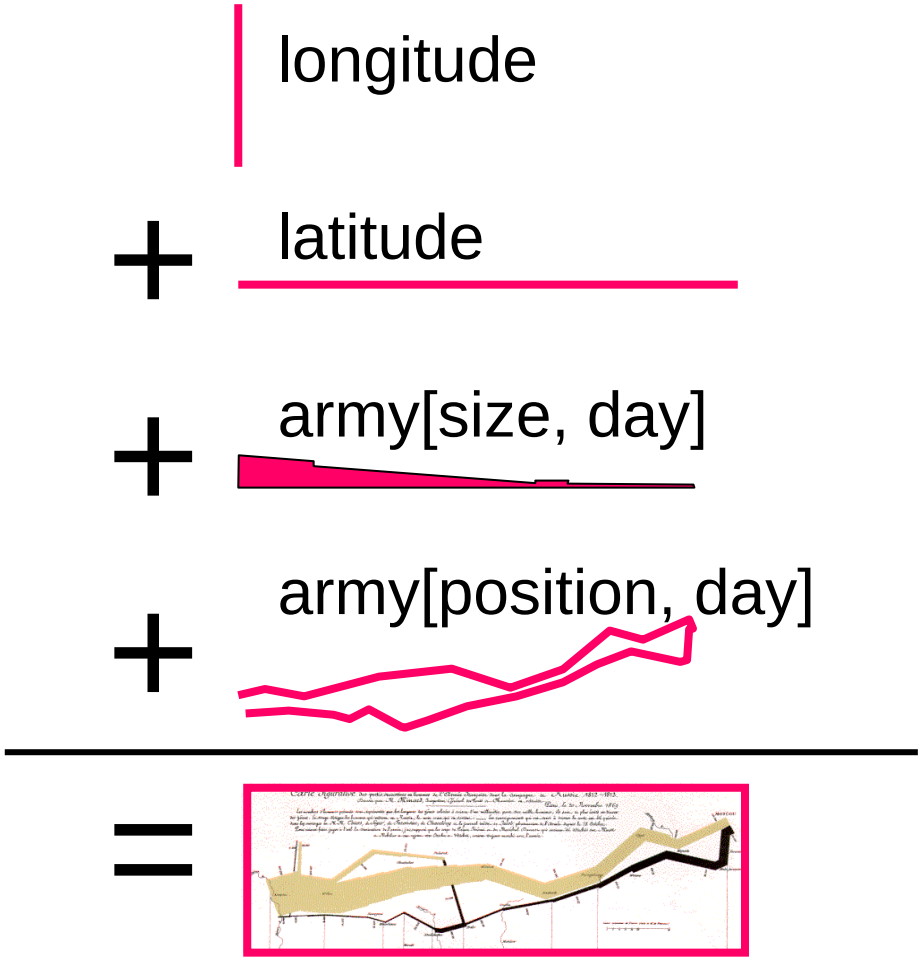
Mark Composition

[Mackinlay, 2000]



Mark Composition

[Mackinlay, 2000]



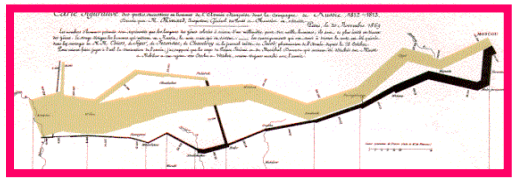
[Mackinlay, 2000]

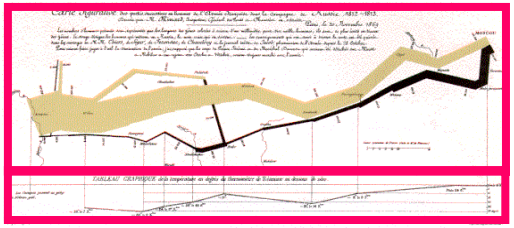
longitude

latitude

army[size, day]

army[position, day]

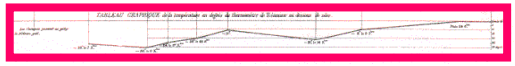




temperature

time

temp[day]

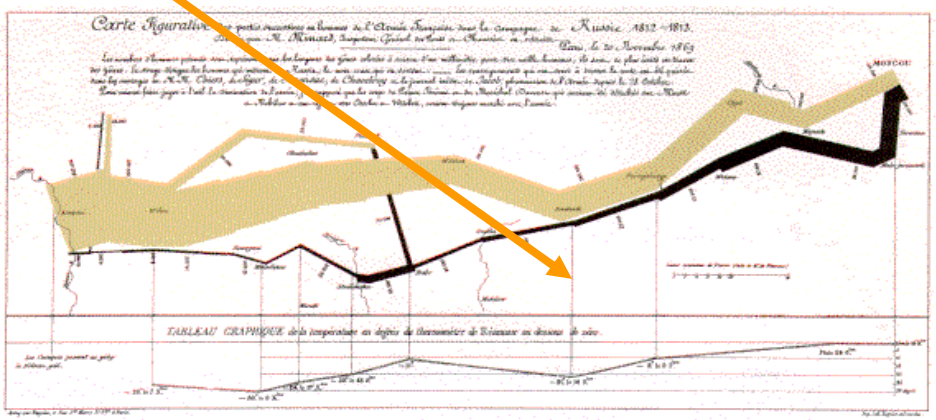


Minard's Data Table and Synoptic

[Mackinlay, 2000]

	Day1	Day2	
Army size			
Army longitude			
Army latitude			
Temperature			

Issue: Seeing the Relationships



Visual Information Seeking Mantra

[Shneiderman, 1996]

overview first, zoom and filter, then details-on-demand

overview first, zoom and filter, then details-on-demand

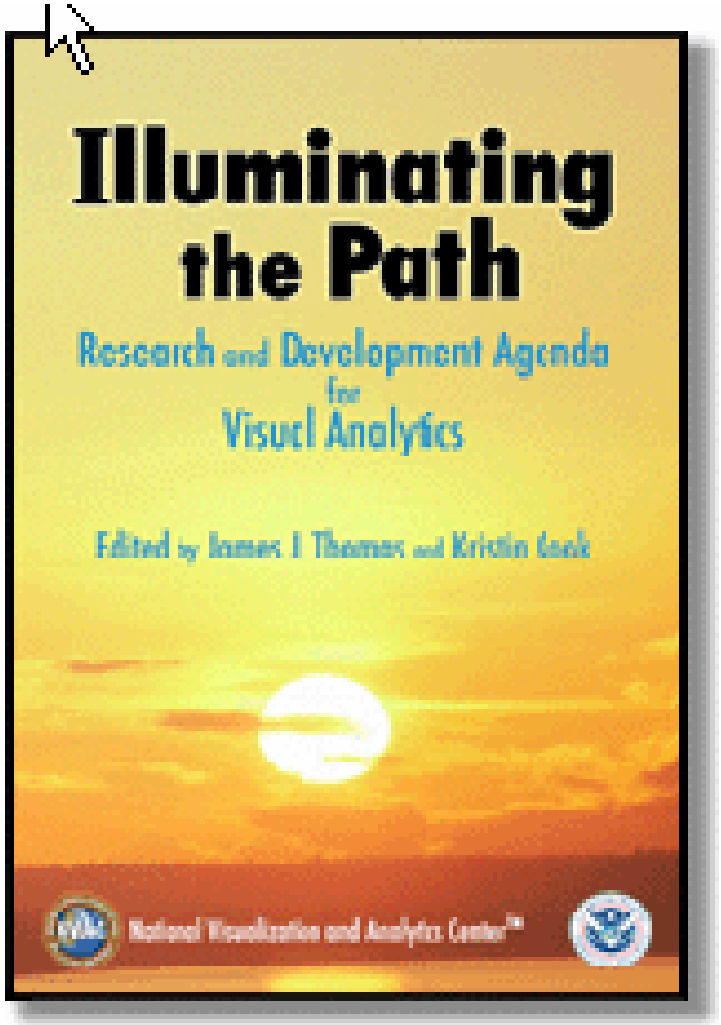
overview first, zoom and filter, then details-on-demand

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

... 10 times ...



Illuminating the Path: The Research and Development Agenda for Visual Analytics

James J. Thomas and Kristin A. Cook

http://nvac.pnl.gov/

National Visualization and Analytics Center™

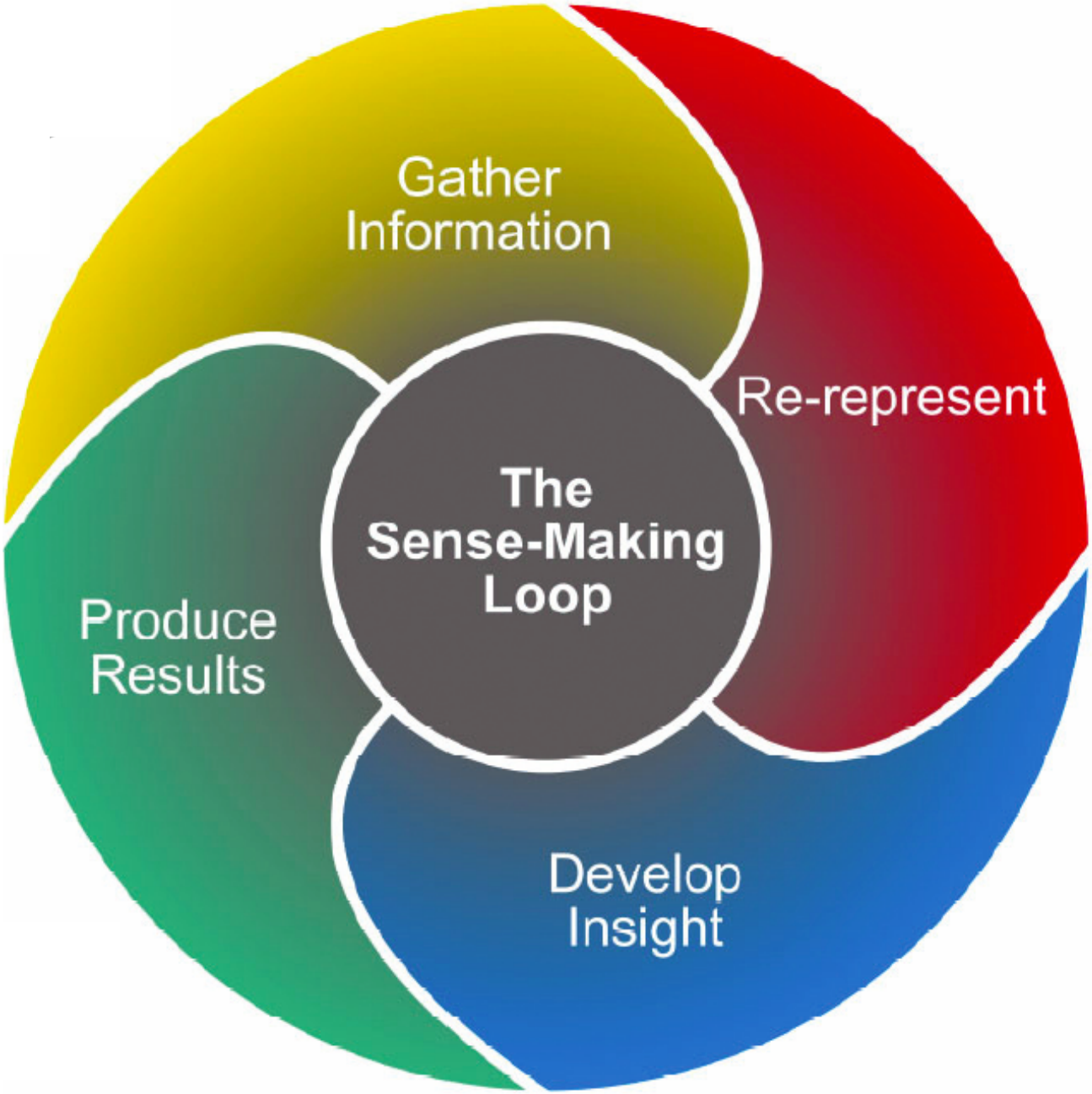
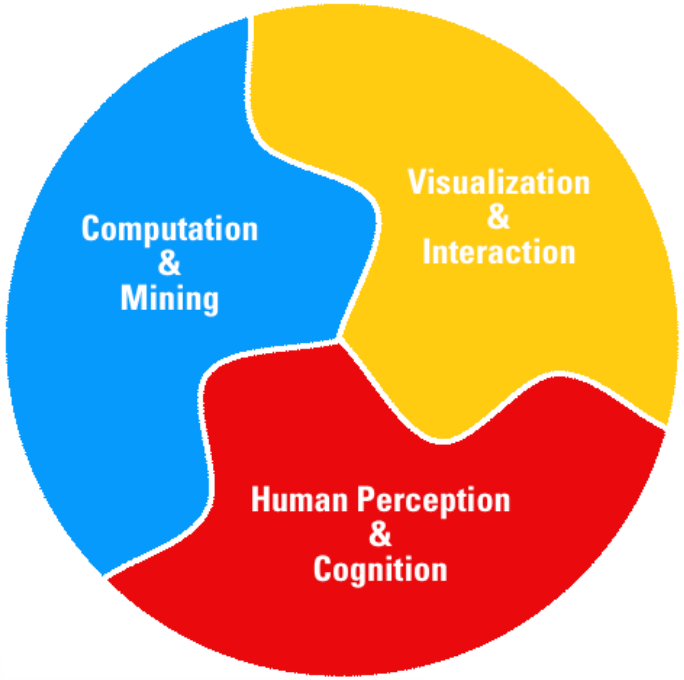
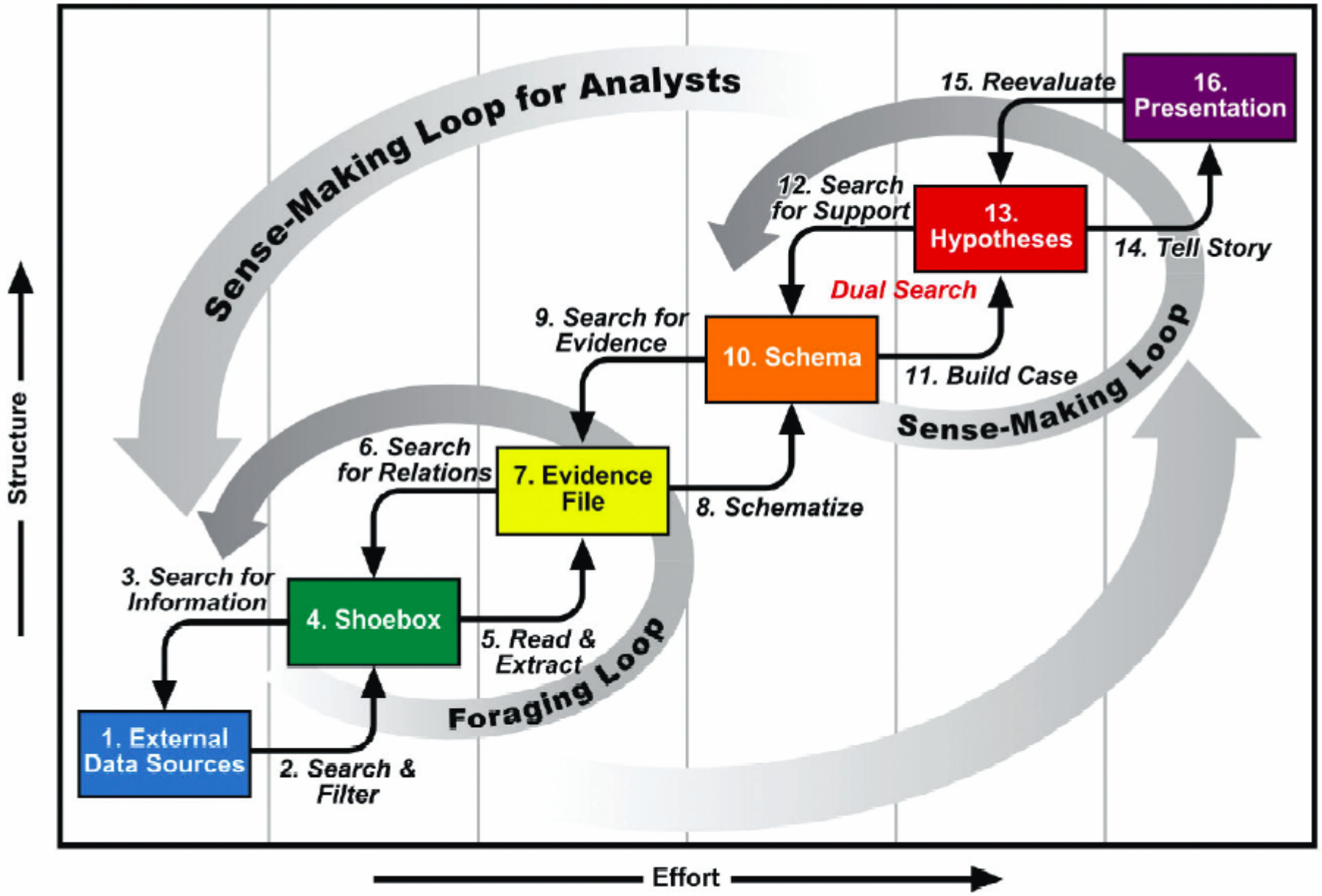


Figure 2.1. The analytical reasoning process.

[Thomas & Cook 2005]

"Visual analytics is the science of analytical reasoning facilitated by interactive visual interfaces."



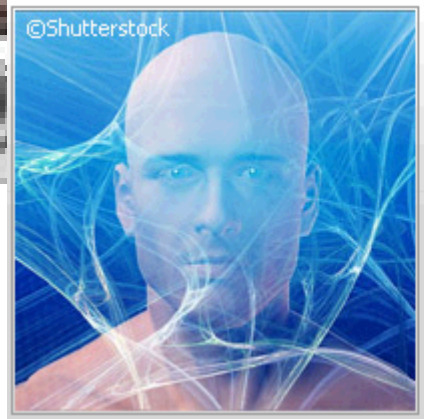


[Thomas & Cook 2005]

Figure 2.2. Nominal sense-making loop for some types of intelligence analysts.

Video

VisMaster
Visual Analytics - Mastering the Information Age



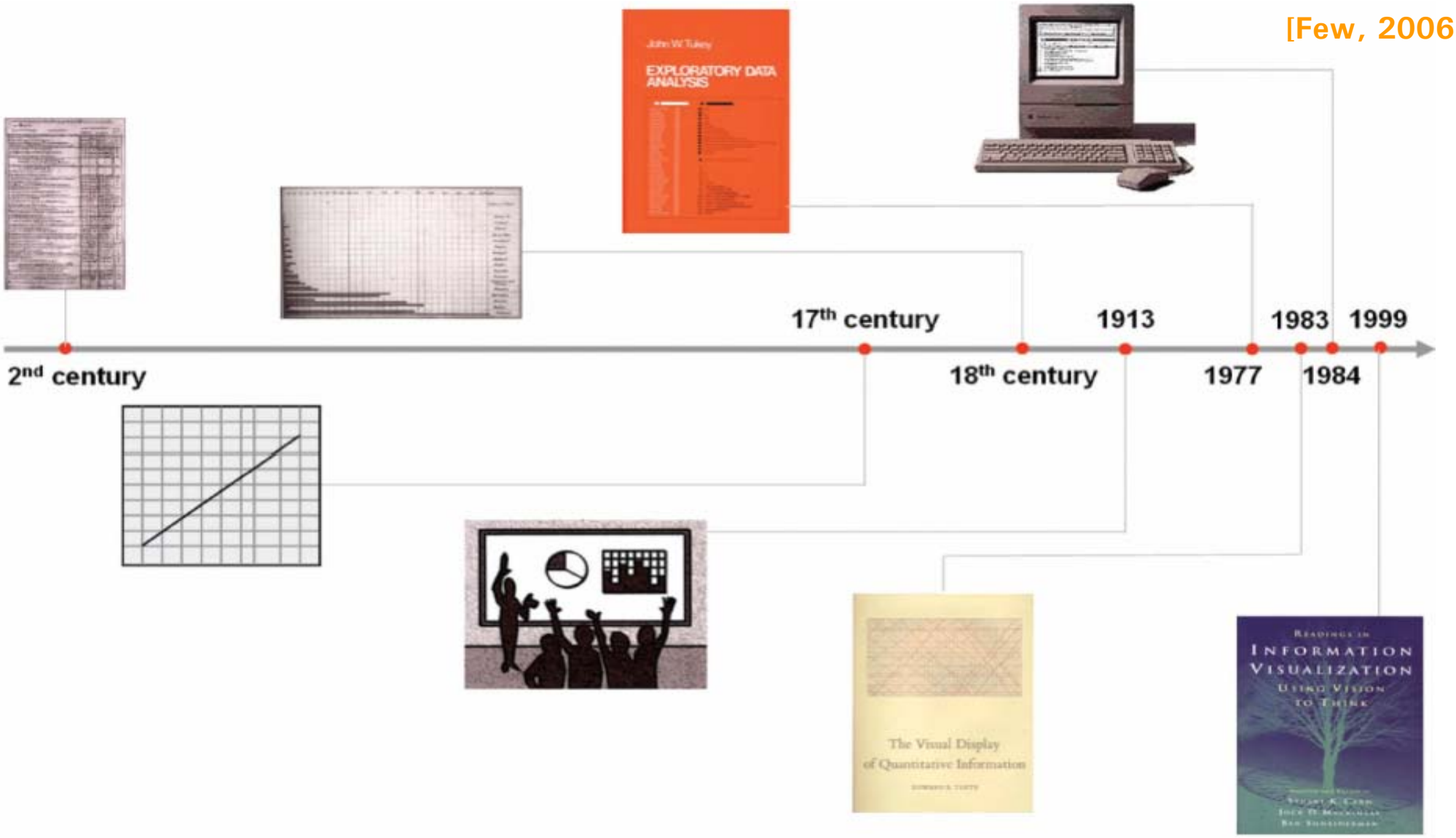
NEWS

VISMASTER drives visual analytics and technology in Europe

The EU CORDIS site just released a news headline on VisMaster in different languages!

A Brief History of Data Visualization

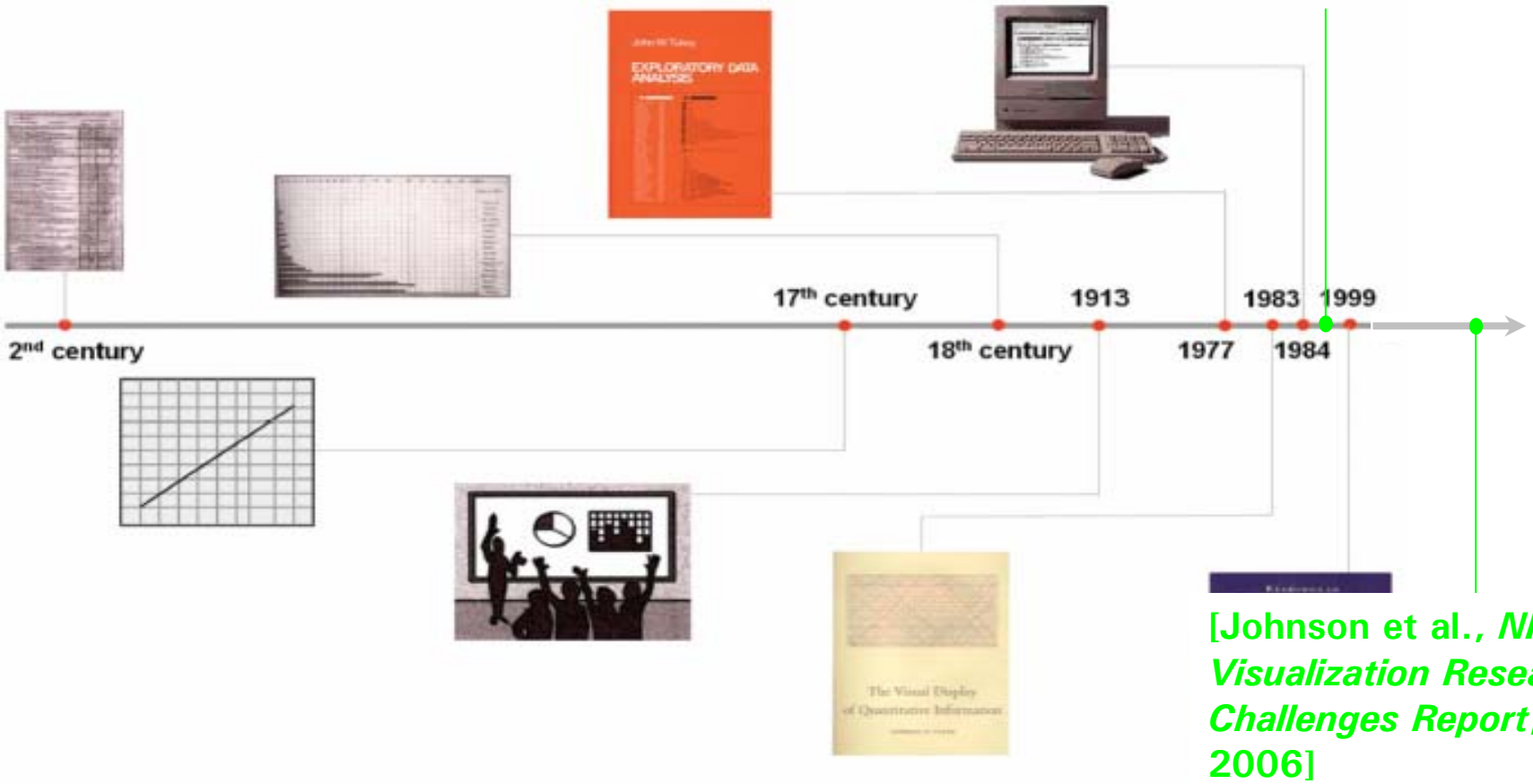
[Few, 2006]



A Brief History of Data Visualization

[Few, 2006]

[McCormick, DeFanti, Brown, *Visualization in Scientific Computing,* Computer Graphics 21(6):1-14,1987]

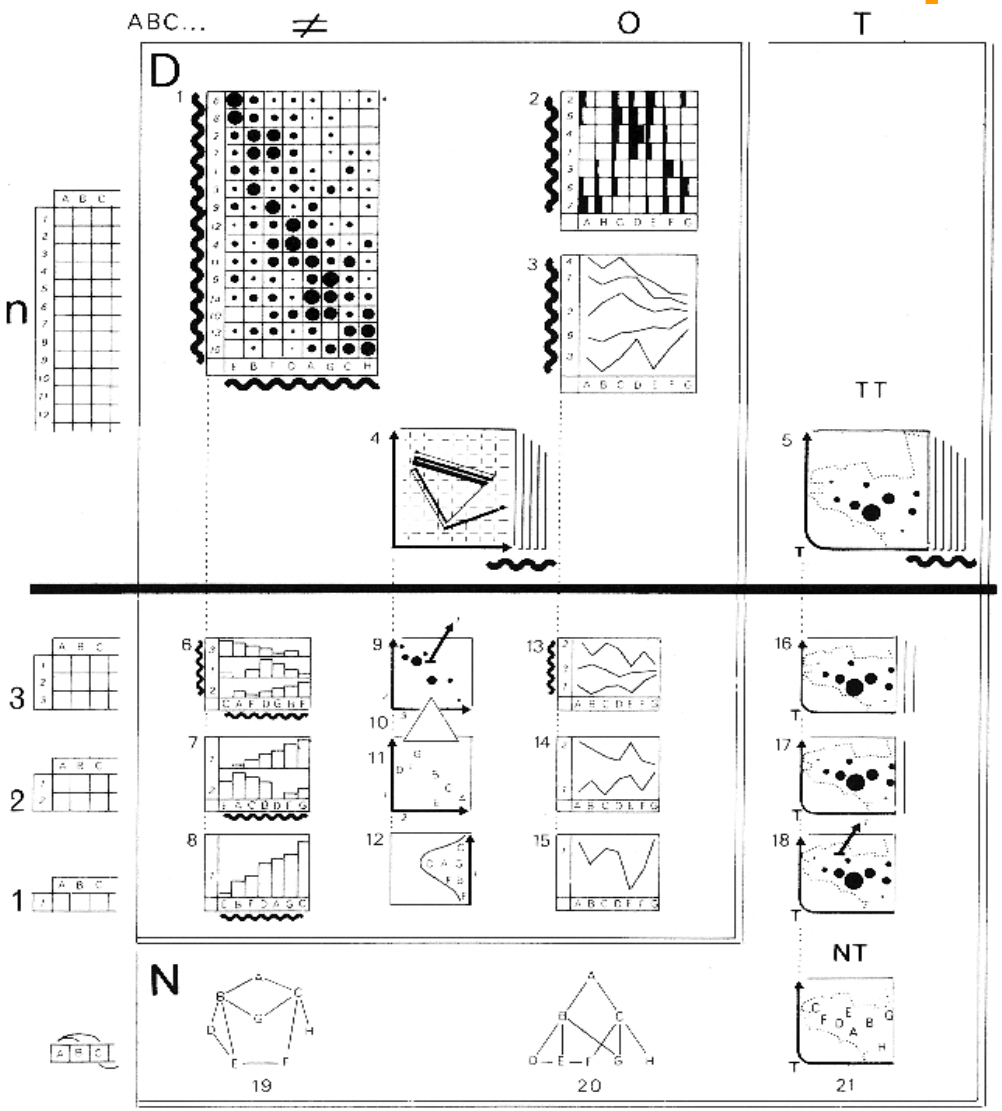


[Johnson et al., *NIH-NSF Visualization Research Challenges Report*, IEEE Press, 2006]

Jacques Bertin

[Card, et al. 1999]

Semiology of Graphics



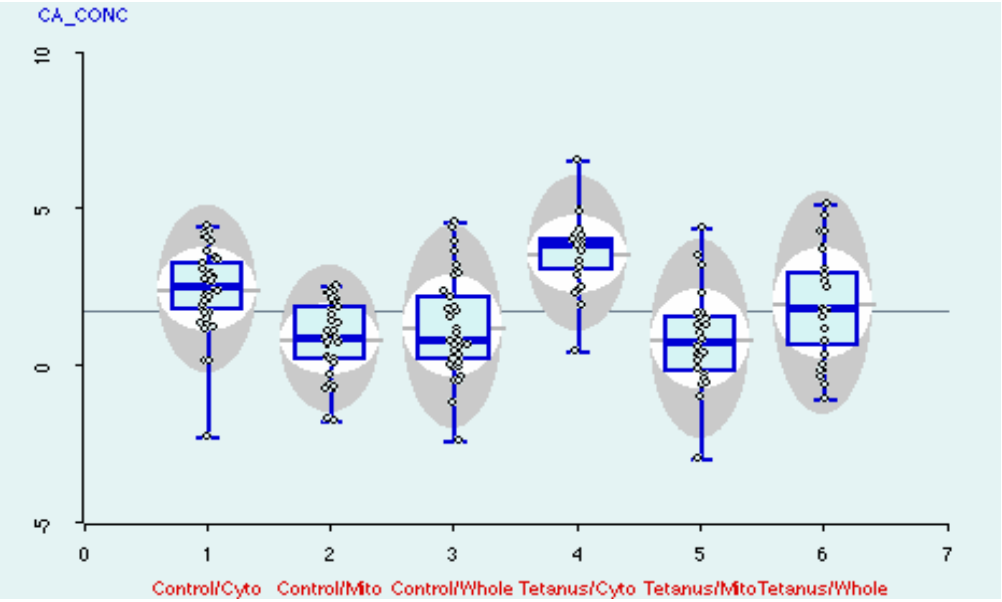
- 1967

John Tukey

[Card, et al. 1999]

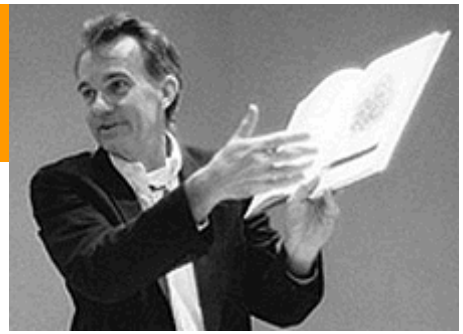
Exploratory Data Analysis

3	4
4	0
5	7 2 7
6	0 7 9 0 3 9 9
7	1
8	9

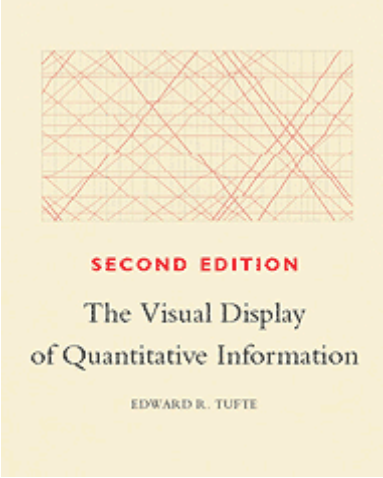


- 1977 Stem&Leaf, Box&Whisker

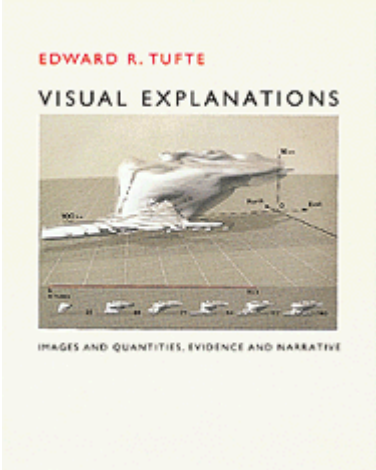
Eduard Tufte



2006



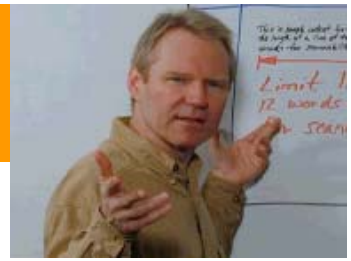
2001

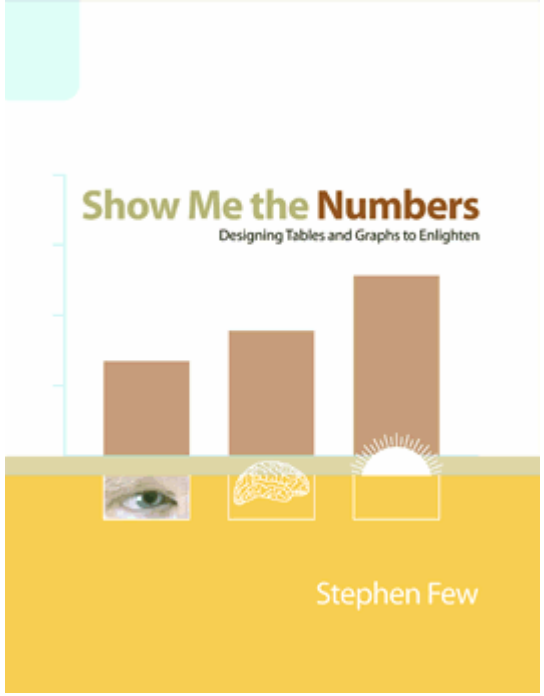


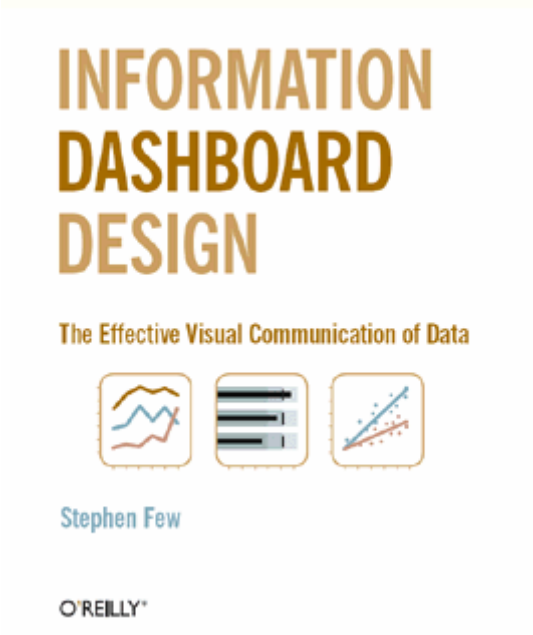
1990

1997

Stephen Few





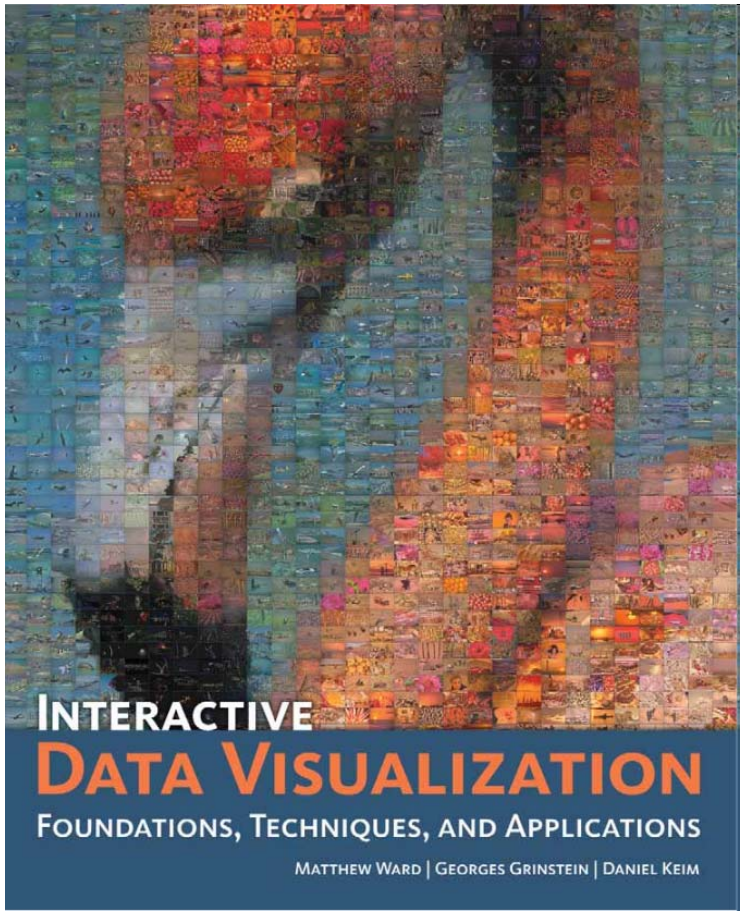


Show Me the Numbers: Designing Tables and Graphs to Enlighten, Analytics Press, 2004

Information Dashboard Design: The Effective Visual Communication of Data, O'Reilly Media, 2006

Now You See It: Simple Visualization Techniques for Quantitative Analysis, Analytics Press, 2009

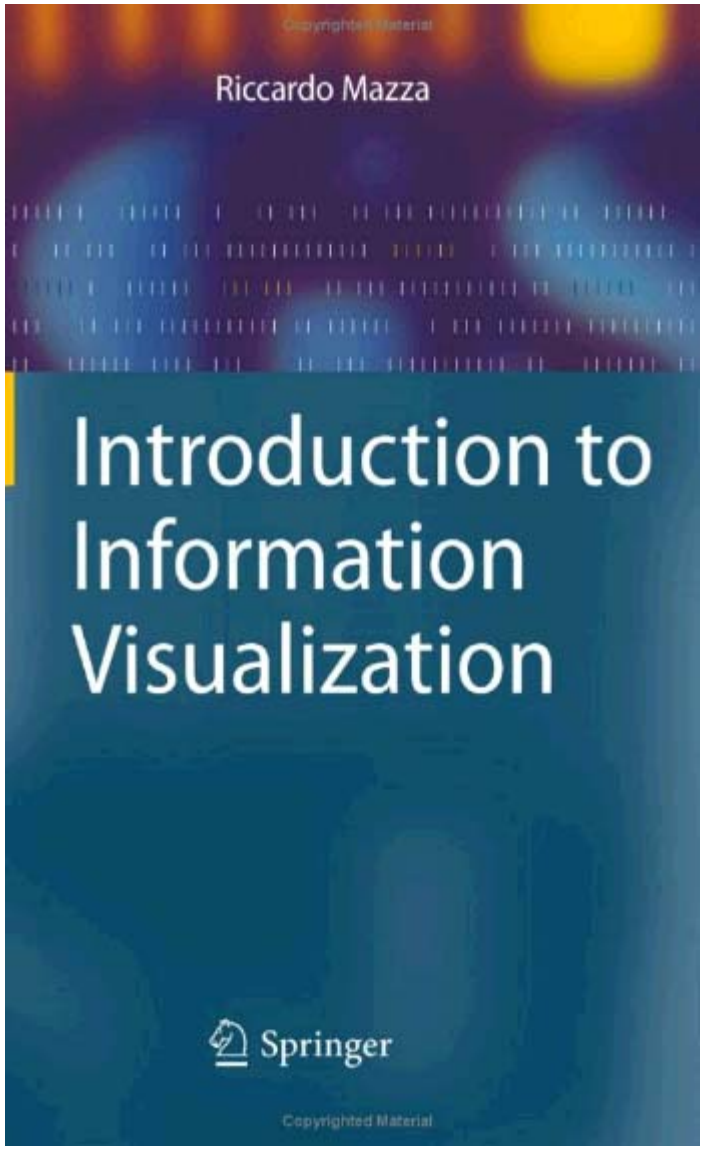
Matthew Ward, Georges Grinstein, Daniel Keim



A.K. Peters LTD, May 2010

http://www.idvbook.com/

Riccardo Mazza

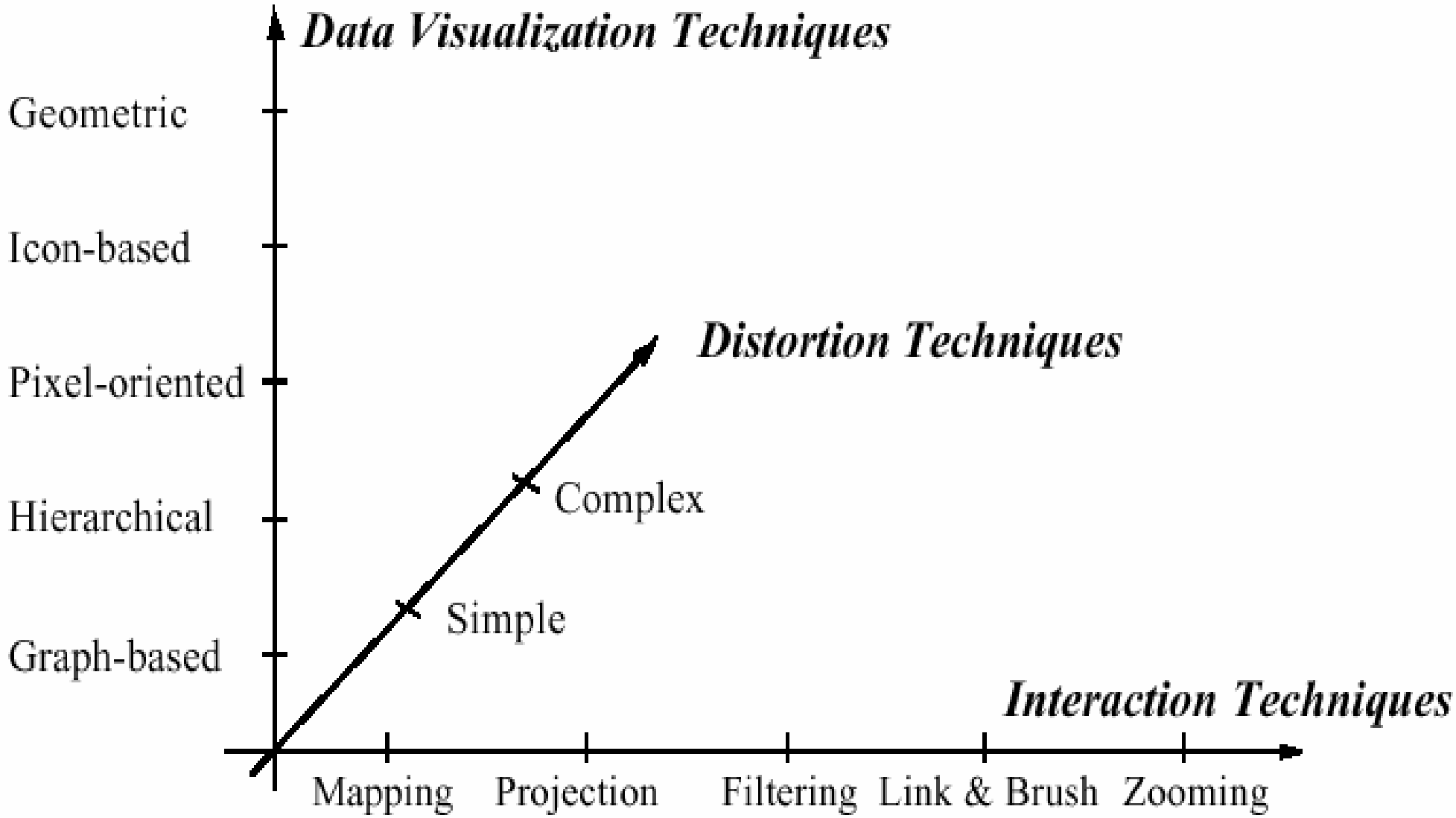


Mazza, R.: Introduction to Information Visualization, Springer, 2009.

http://www.springerlink.com/content/978-1-84800-218-0#section=43657&page=1

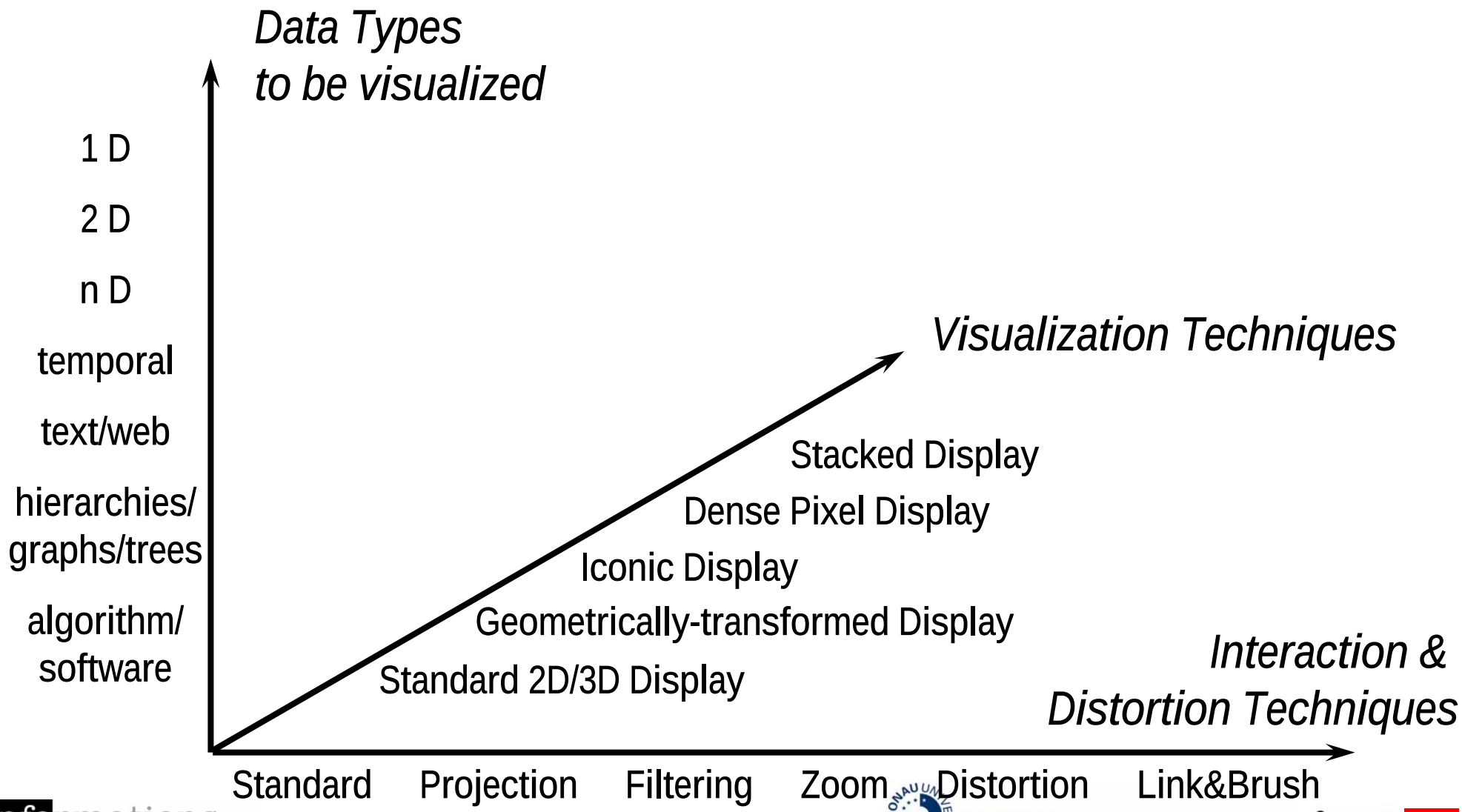
Dimensions of Exploratory Data Visualizations

[Keim, 2001]

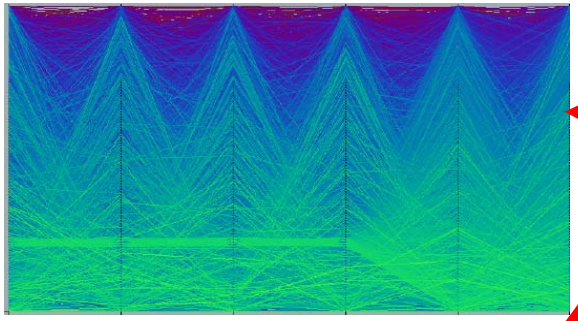


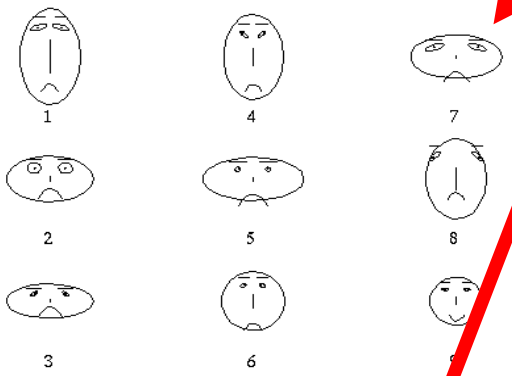
Dimensions of Exploratory Data Visualizations

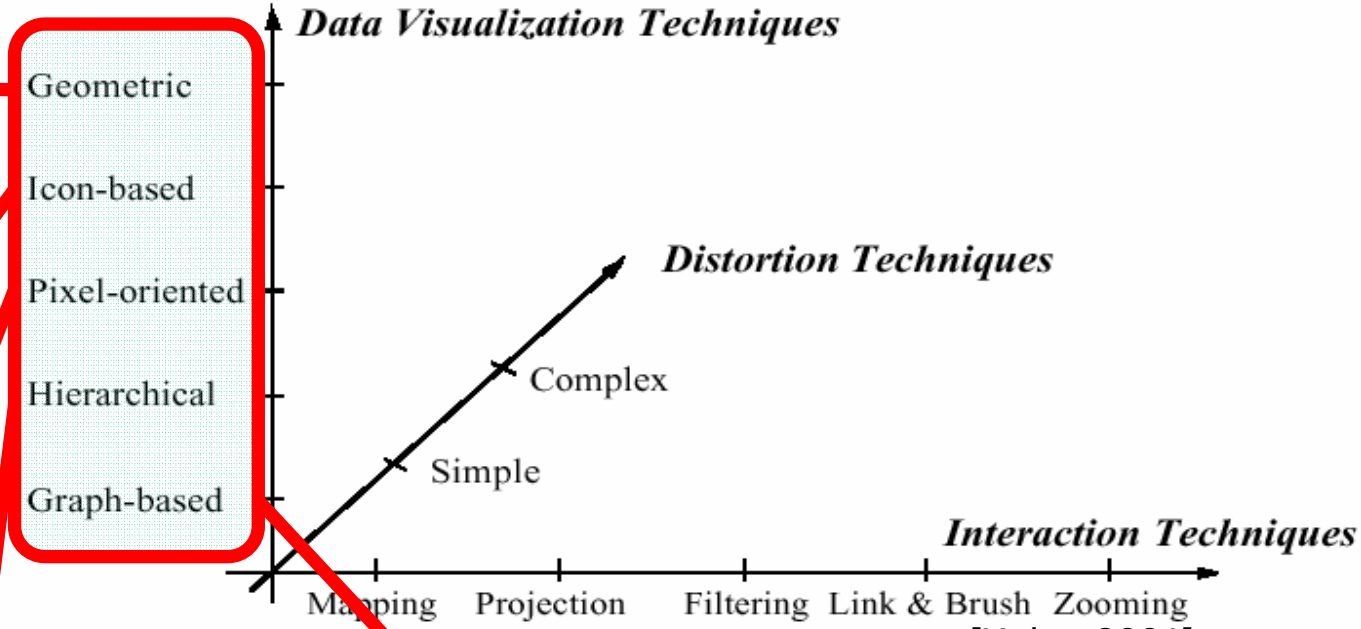
adapted from [Keim, 2001]



Classification

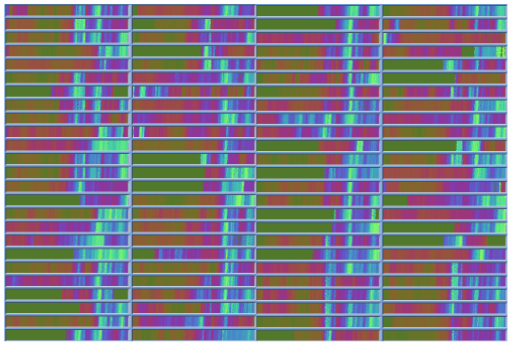


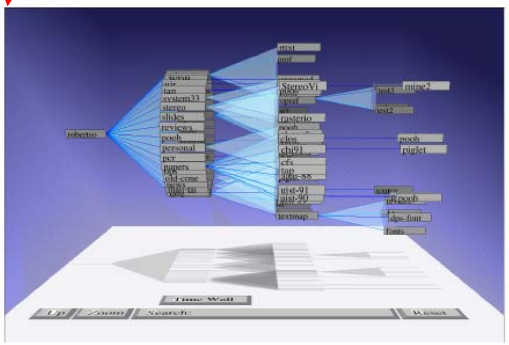


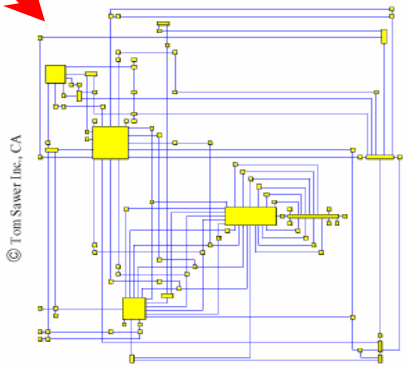


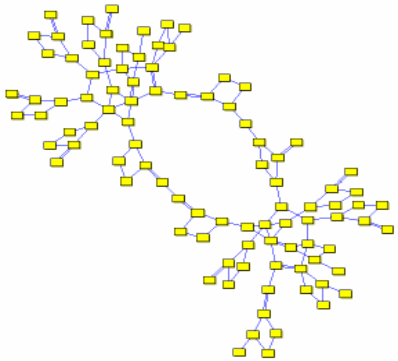
[Keim, 2001]

Recursive Pattern: FAZ-Index (Jan. '74 - Apr. '95)



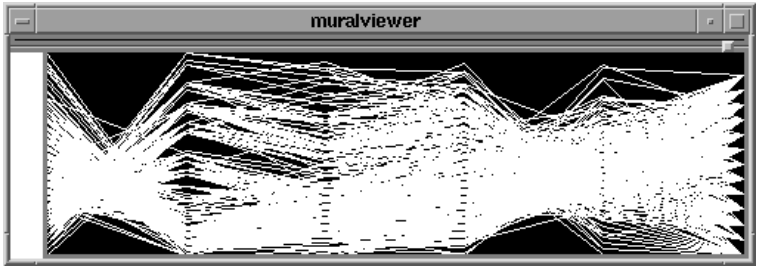




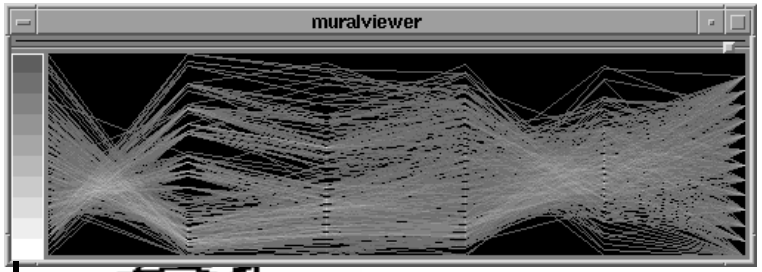


Geometric Techniques

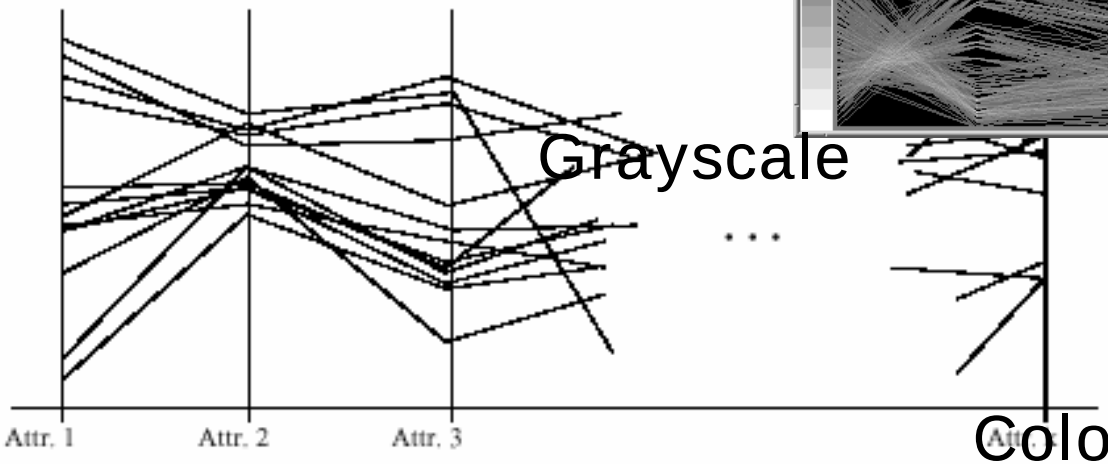
Parallel Coordinates



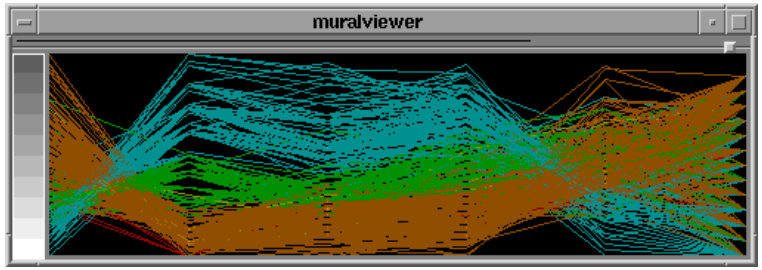
Basic



Grayscale



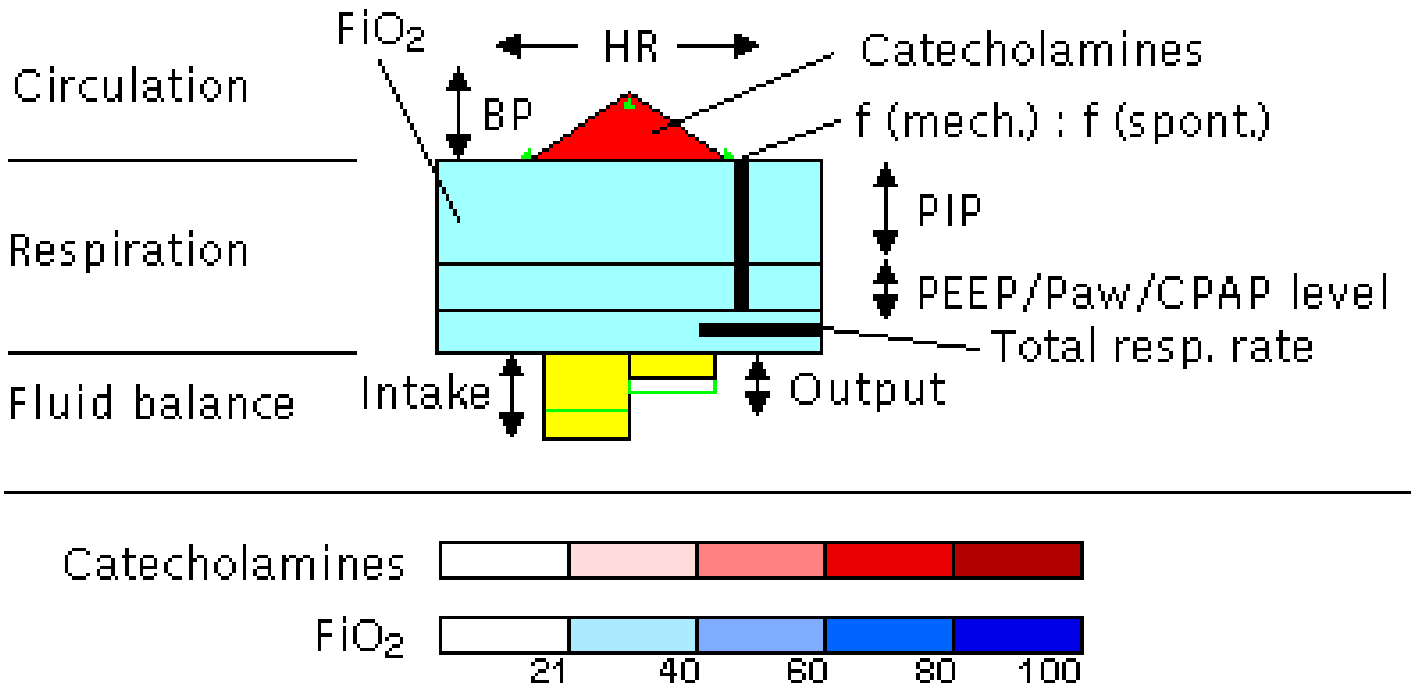
...

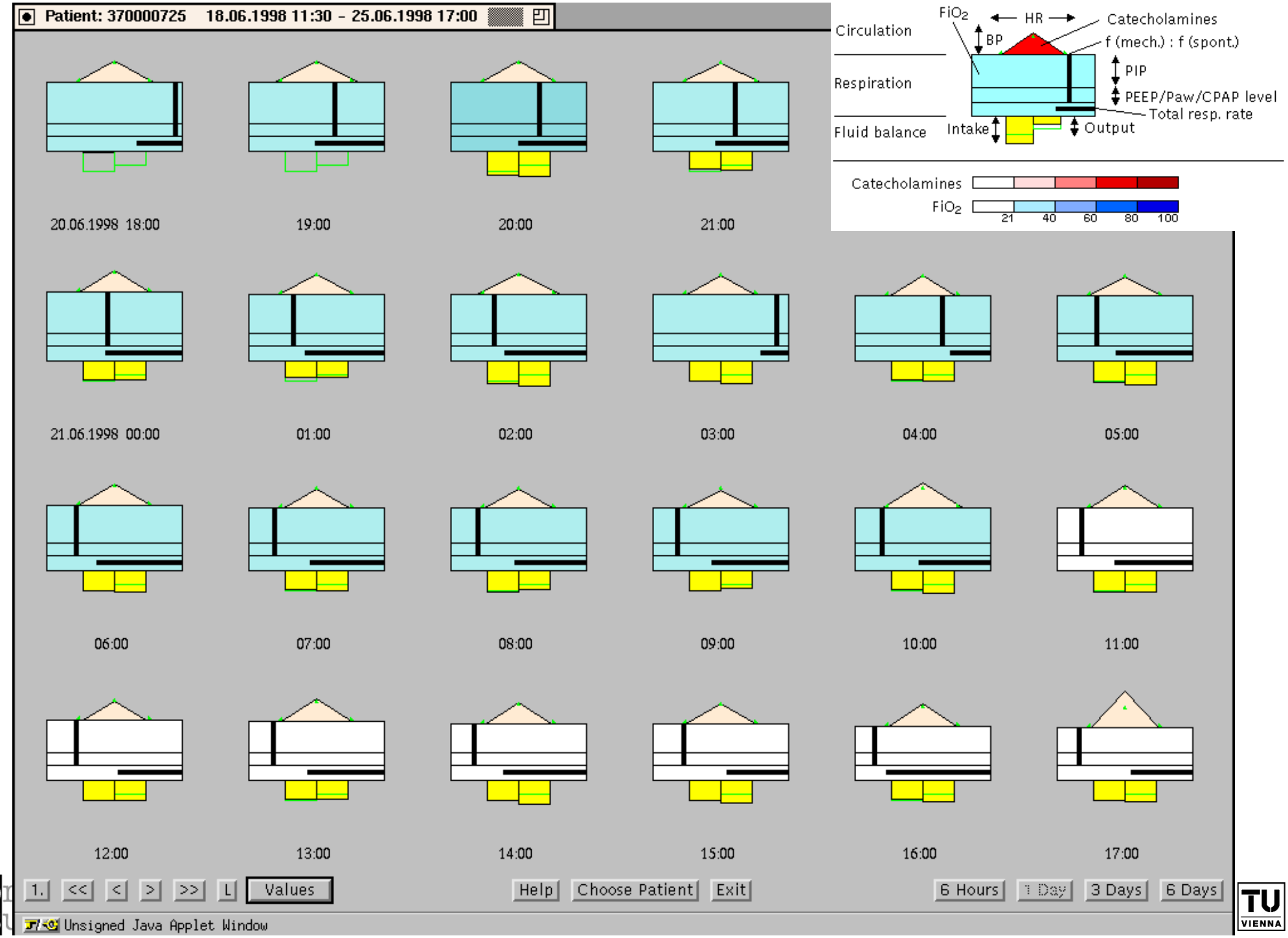


Color

Icon-based Techniques

VIE-Visu *[Horn, et al. 1998]*

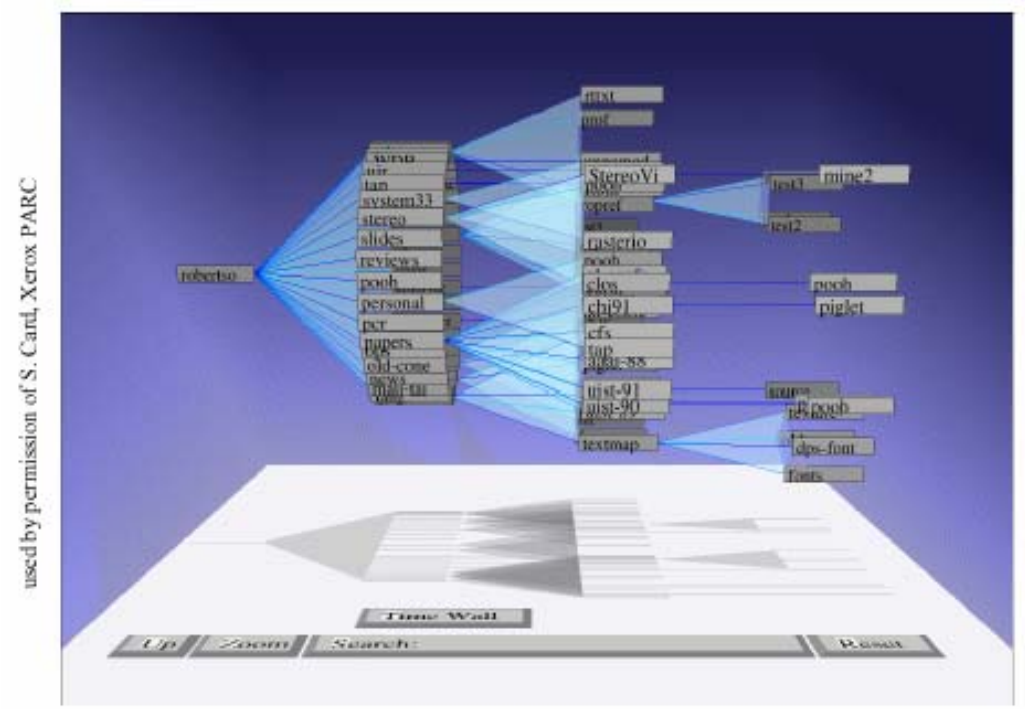



Patient: 370000725 18.06.1998 11:30 - 25.06.1998 17:00
Circulation
Respiration
Fluid balance
FiO2
HR
BP
Catecholamines
f (mech.) : f (spont.)
PIP
PEEP/Paw/CPAP level
Total resp. rate
Intake
Output
Catecholamines
FiO2
21
40
60
80
100
20.06.1998 18:00
19:00
20:00
21:00
21.06.1998 00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
1.
<<
<
>
>>
L
Values
Help
Choose Patient
Exit
6 Hours
1 Day
3 Days
6 Days
Unsigned Java Applet Window

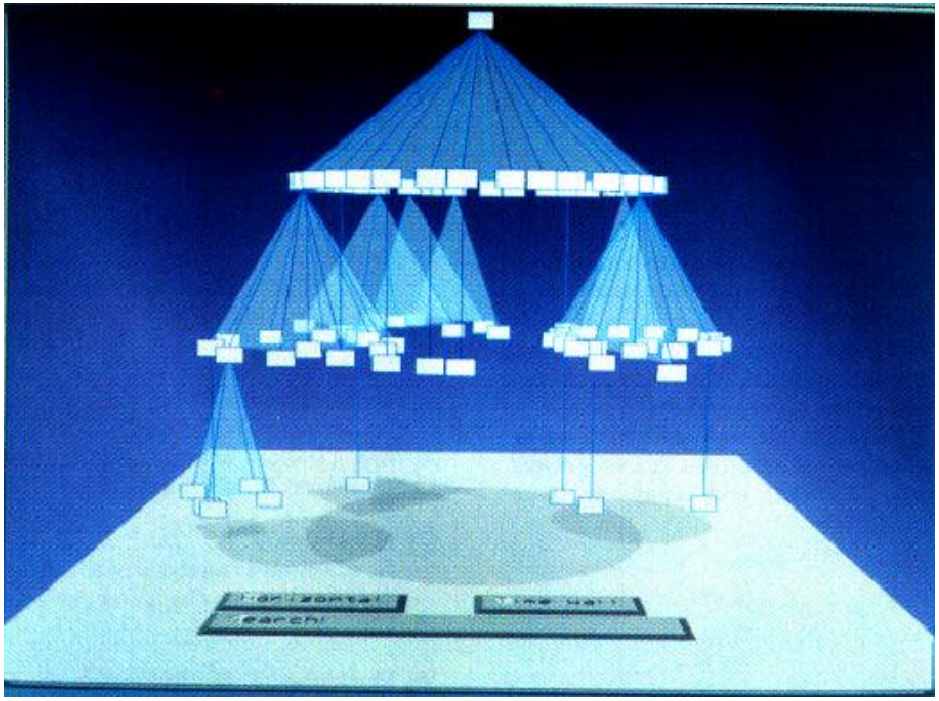
Hierarchical Techniques

[Robertson et al. 1991]

Cone Trees

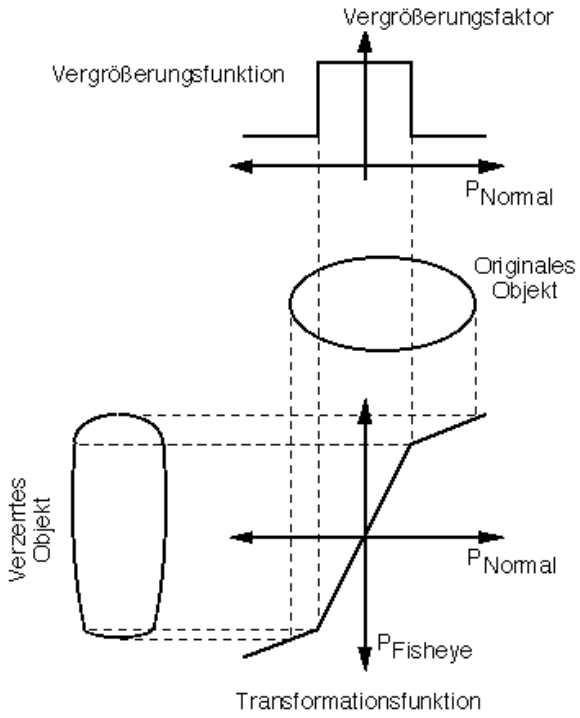


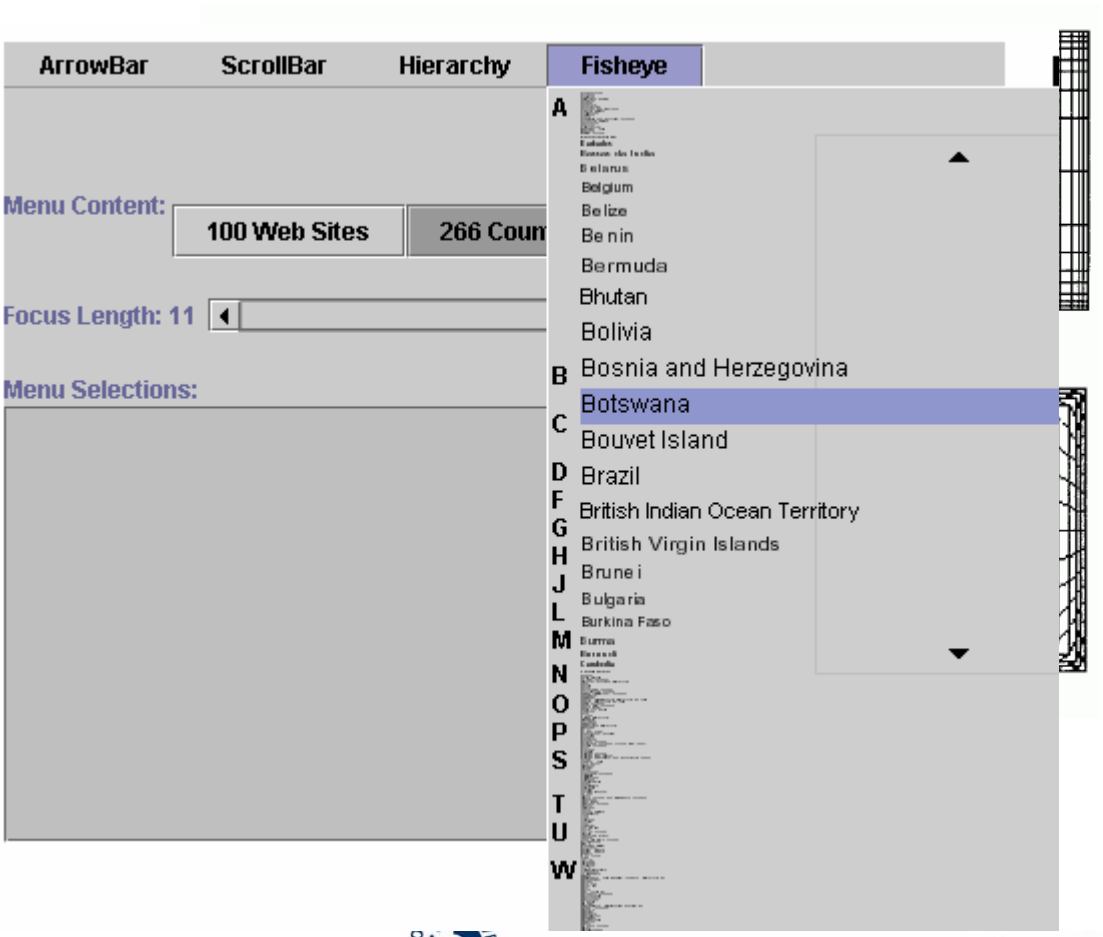
Cam Trees



Distortion Techniques

Fisheye View *[Furnas, 1986]*





Dynamic/Interactive Techniques

Adapted from J. Mackinlay slide

Linking & Brushing

Baseball Data

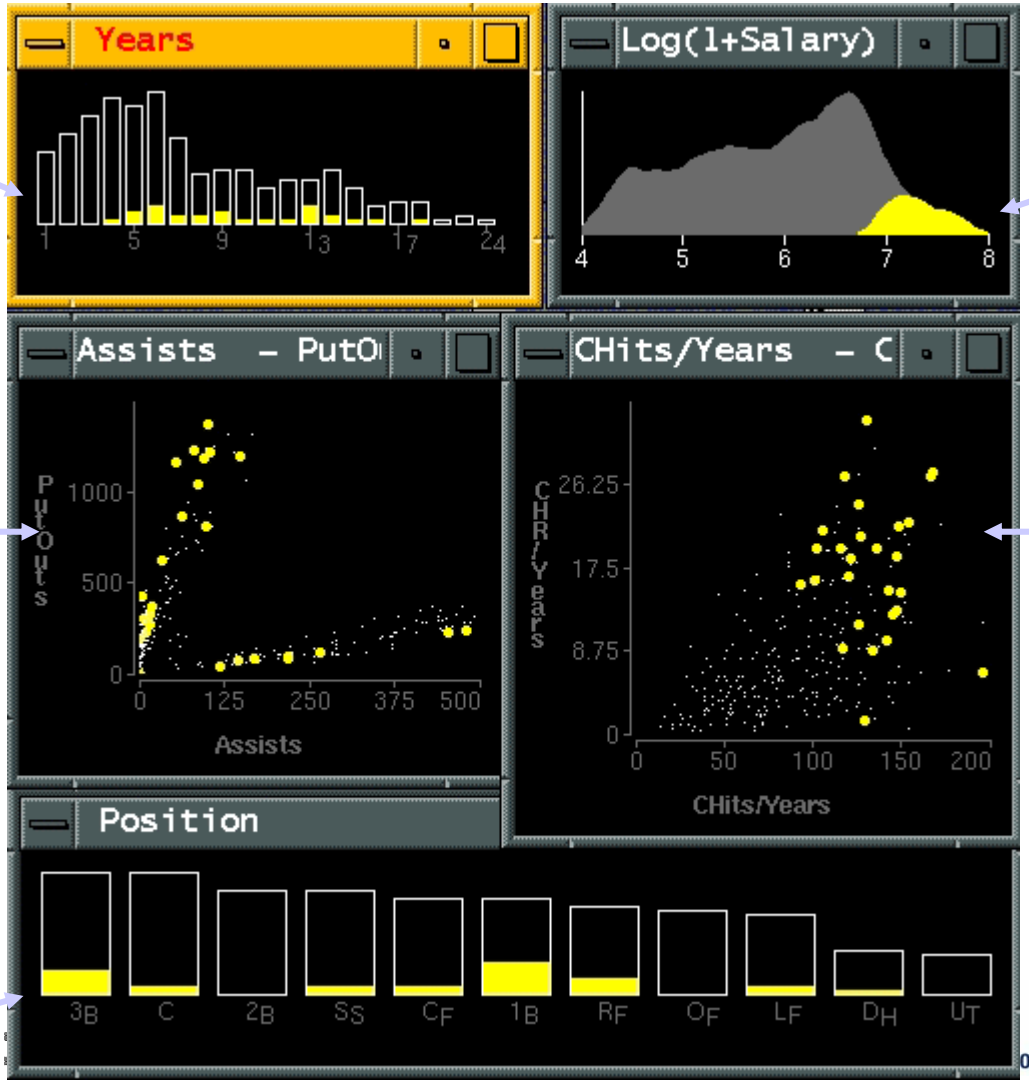
how long in majors

select high salaries

avg assists vs avg putouts (fielding ability)

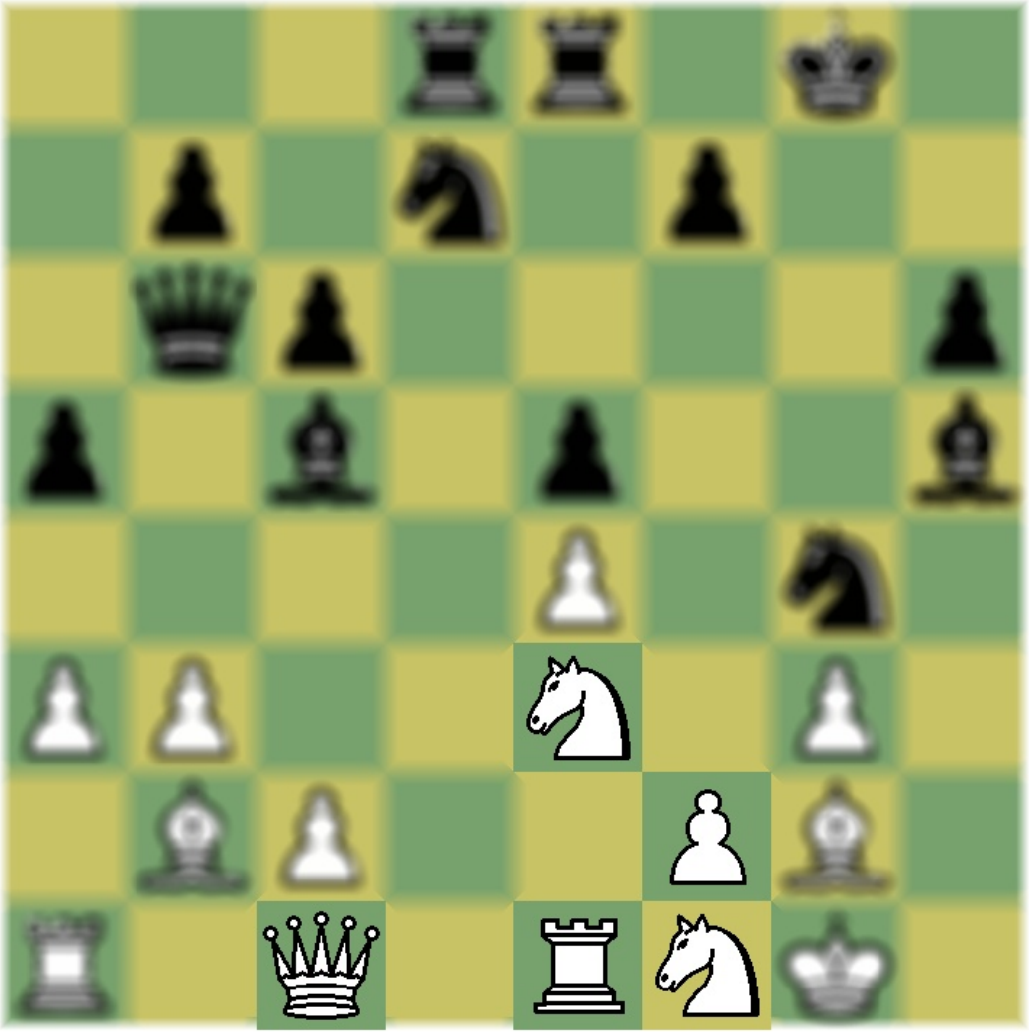
avg career HRs vs avg career hits (batting ability)

distribution of positions played



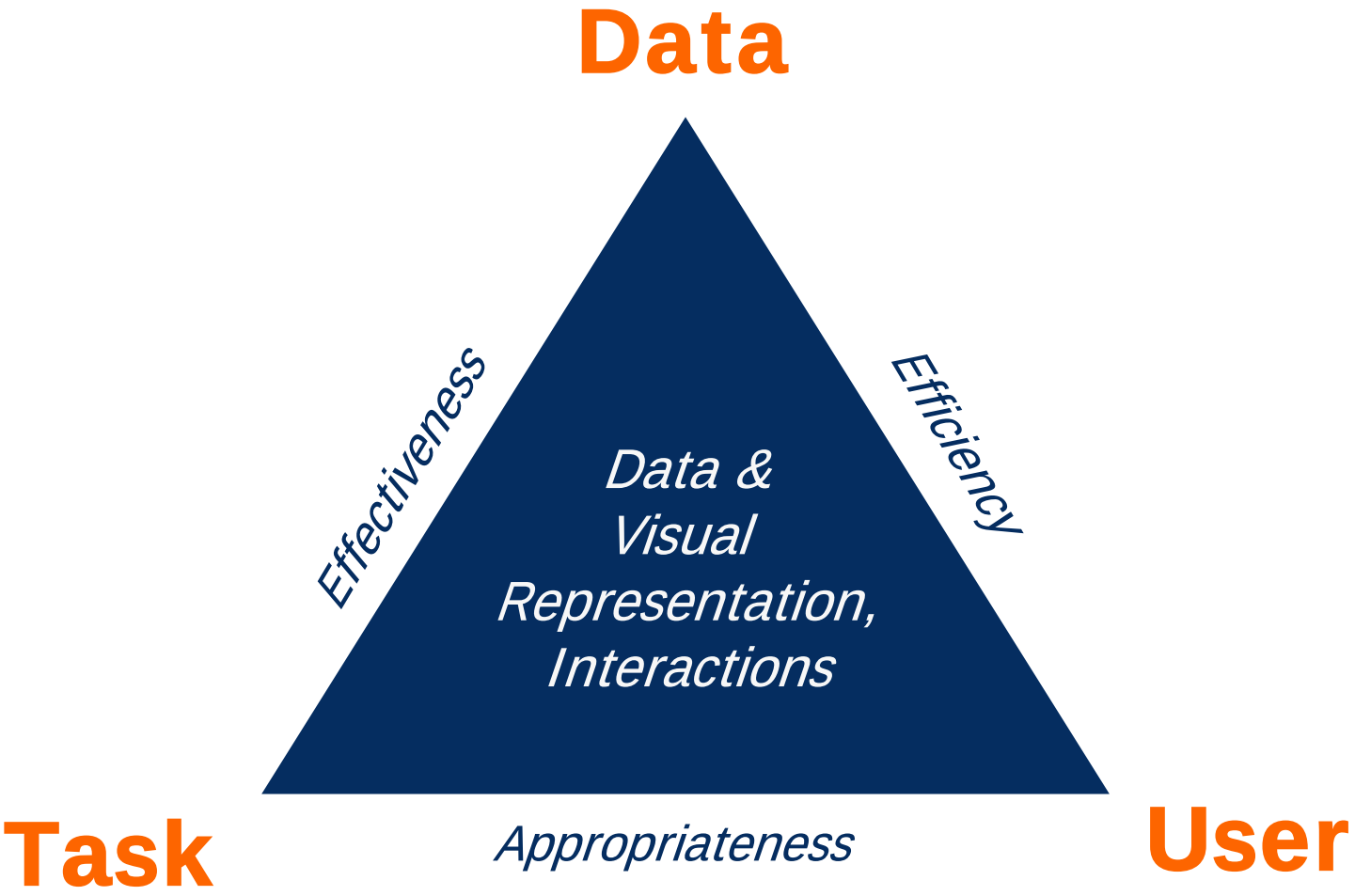
Focus and Context: Covers?

[Kosara, et al. 2001]



Information Visualization Design

[Aigner; Presentation 2009]



Outline

Motivation - Examples

Definitions and Goals

Knowledge Crystallization

Exploration Techniques

Visual Encoding Techniques

Summary

Visual Encoding Techniques 1

[Card, Mackinlay & Shneiderman 1999]

Different ways in encoding information visually:

- space (absolute dominant)

five main techniques, we will talk about later

Visual Encoding Techniques 1

[Card, Mackinlay & Shneiderman 1999]

Different ways in encoding information visually:

- space (absolute dominant)
- marks (in space)

points
lines
areas
volumes

Visual Encoding Techniques 1

[Card, Mackinlay & Shneiderman 1999]

Different ways in encoding information visually:

- space (absolute dominant)
- marks (in space)
- connections & enclosures
- retinal properties
- temporal changes
- viewpoint transformations

crispness
shape
resolution
transparency
color (value, hue & saturation)
grayscale

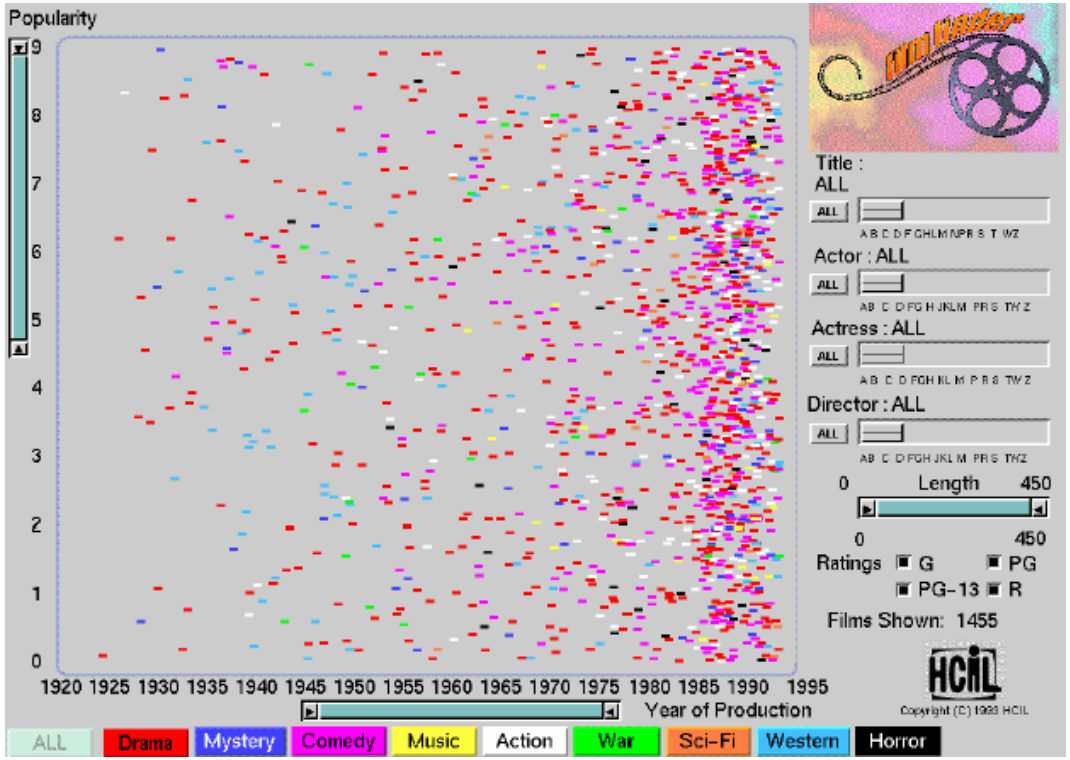
Visual Encoding Techniques 2

[Card, Mackinlay & Shneiderman 1999]

Five major spatial encoding techniques:

- Composition

The orthogonal placement of axes, creating a 2D metric space

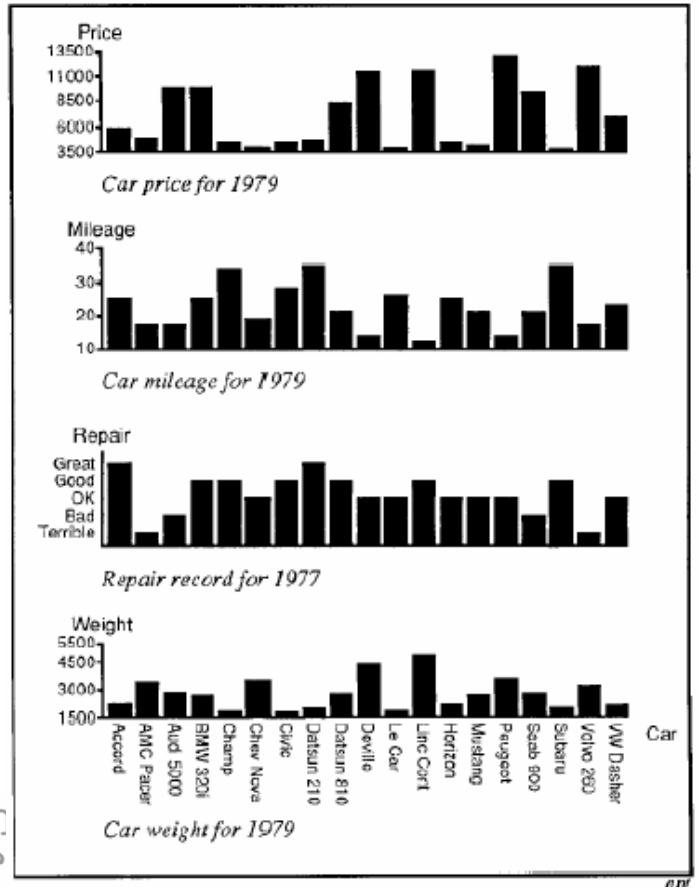


Visual Encoding Techniques 2

[Card, Mackinlay & Shneiderman 1999]

Five major spatial encoding techniques:

- Composition
- Alignment



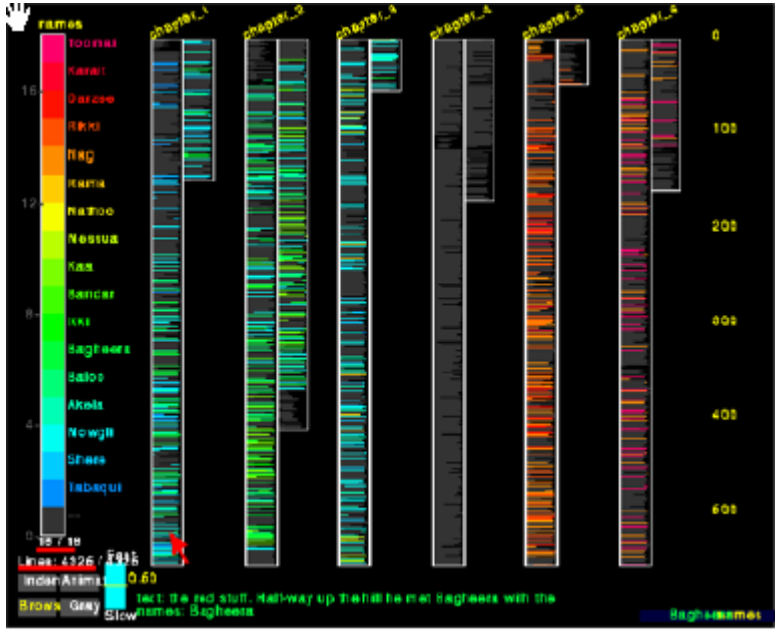
The repetition of an axis at a different position in the space

Visual Encoding Techniques 2

[Card, Mackinlay & Shneiderman 1999]

Five major spatial encoding techniques:

- Composition
- Alignment
- Folding



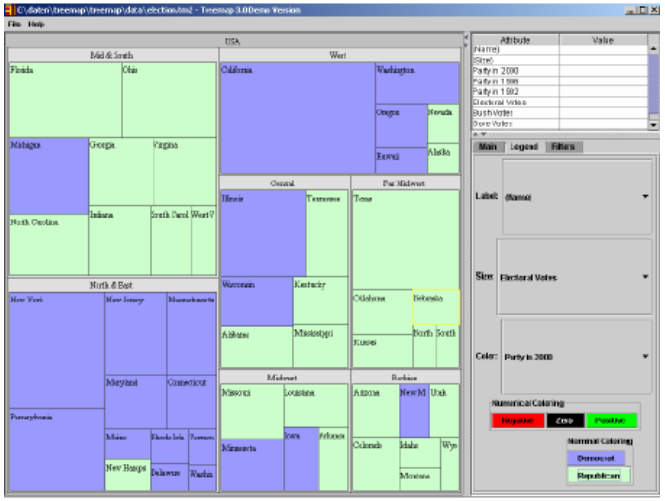
The continuation of an axis in an orthogonal direction

Visual Encoding Techniques 2

[Card, Mackinlay & Shneiderman 1999]

Five major spatial encoding techniques:

- Composition
- Alignment
- Folding
- Recursion



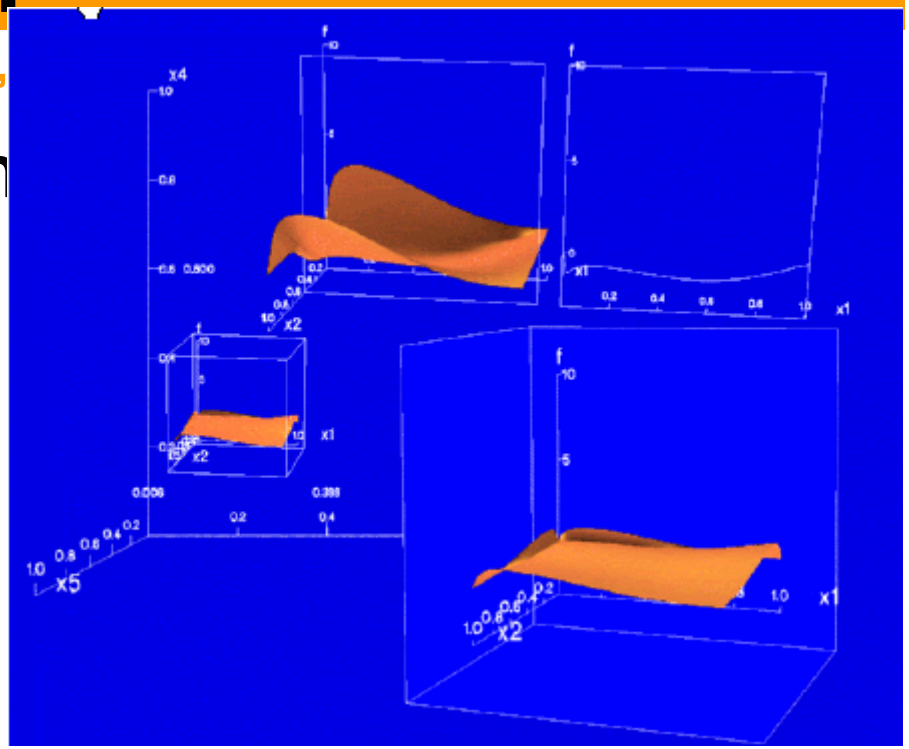
The repeated subdivision of space

Visual Encoding Techniques 2

[Card,

Five major spatial encoding tech

- Composition
- Alignment
- Folding
- Recursion
- Overloading



The reuse of the same space for the same Data Table

Outline

Motivation - Examples

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Visual Encoding Techniques

Summary

Summary: InfoVis...

... is a very complex task

... can help to get insight into data more quickly

... requires preparation and sensible handling of the information

... should make use of the properties of human visual perception

... requires sensible handling, relative to the task

... is a big challenge, if you want to do it good