Visual Analytics

Hunting down unknown unknowns, and opening the black box of bioinformatics

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Overview of lecture

A. Why visual analytics?

B. Data visualization

   - Data foundations
   - Human perception foundations
   - Visualization foundations and techniques

C. Visualization evaluation

D. Tools of the trade

E. Examples

Overview of lecture

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F. Exercises

A. What’s the problem?

hypothesis-driven -> data-driven

Scientific Research Paradigms (Jim Gray, Microsoft)

1st	1,000s years ago	empirical
2nd	100s years ago	theoretical
3rd	last few decades	computational
4rd	today	data exploration

I have an hypothesis -> need to generate data to (dis)prove it.
I have data -> need to find hypotheses that I can test.

What does this mean?

- immense **re-use** of existing datasets

- biologically interesting signals may be **too poorly understood** to be analyzed in automated fashion

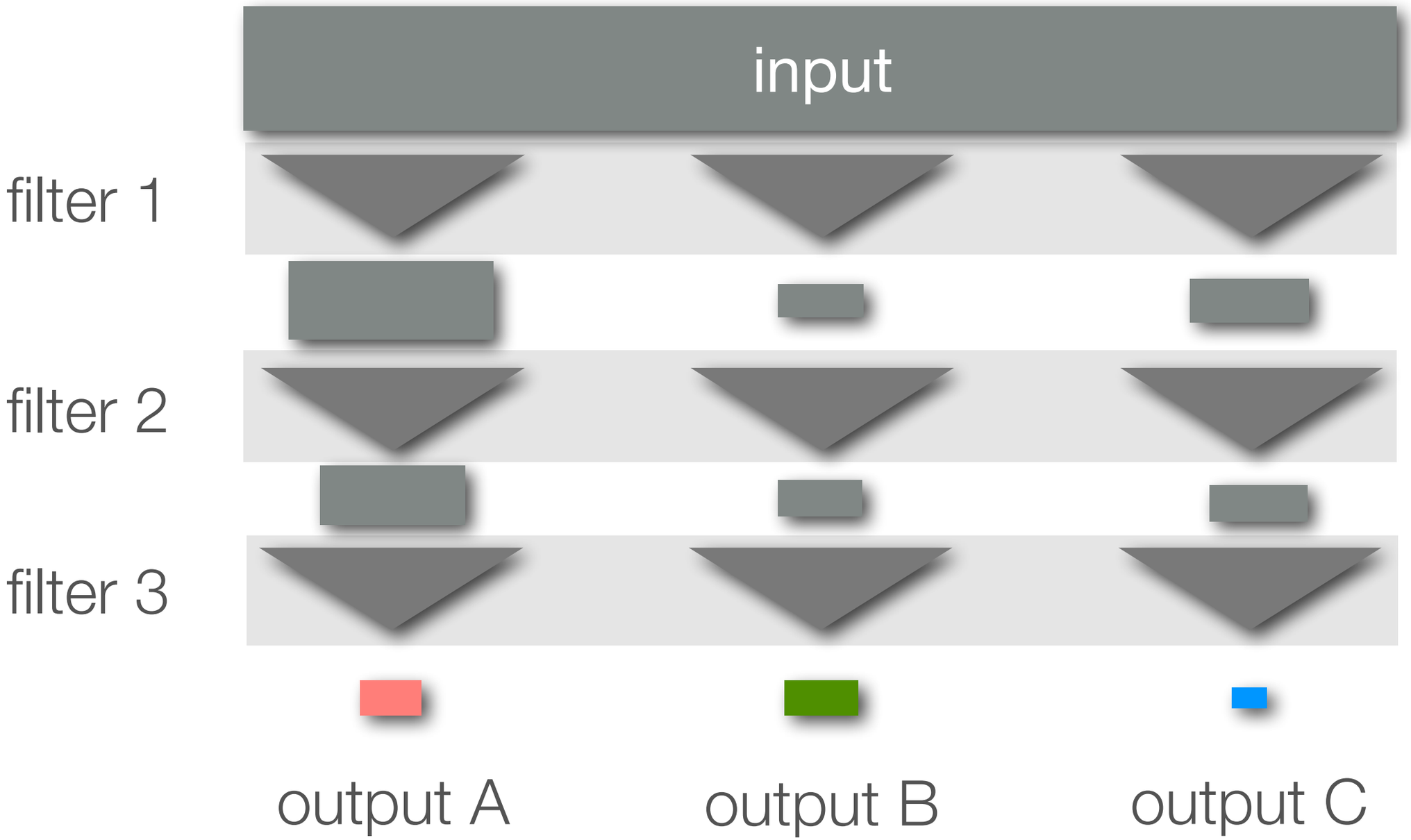
- much of initial analysis is **exploratory** in nature => what's my **hypothesis**?
  => searching for **unknown unknowns**

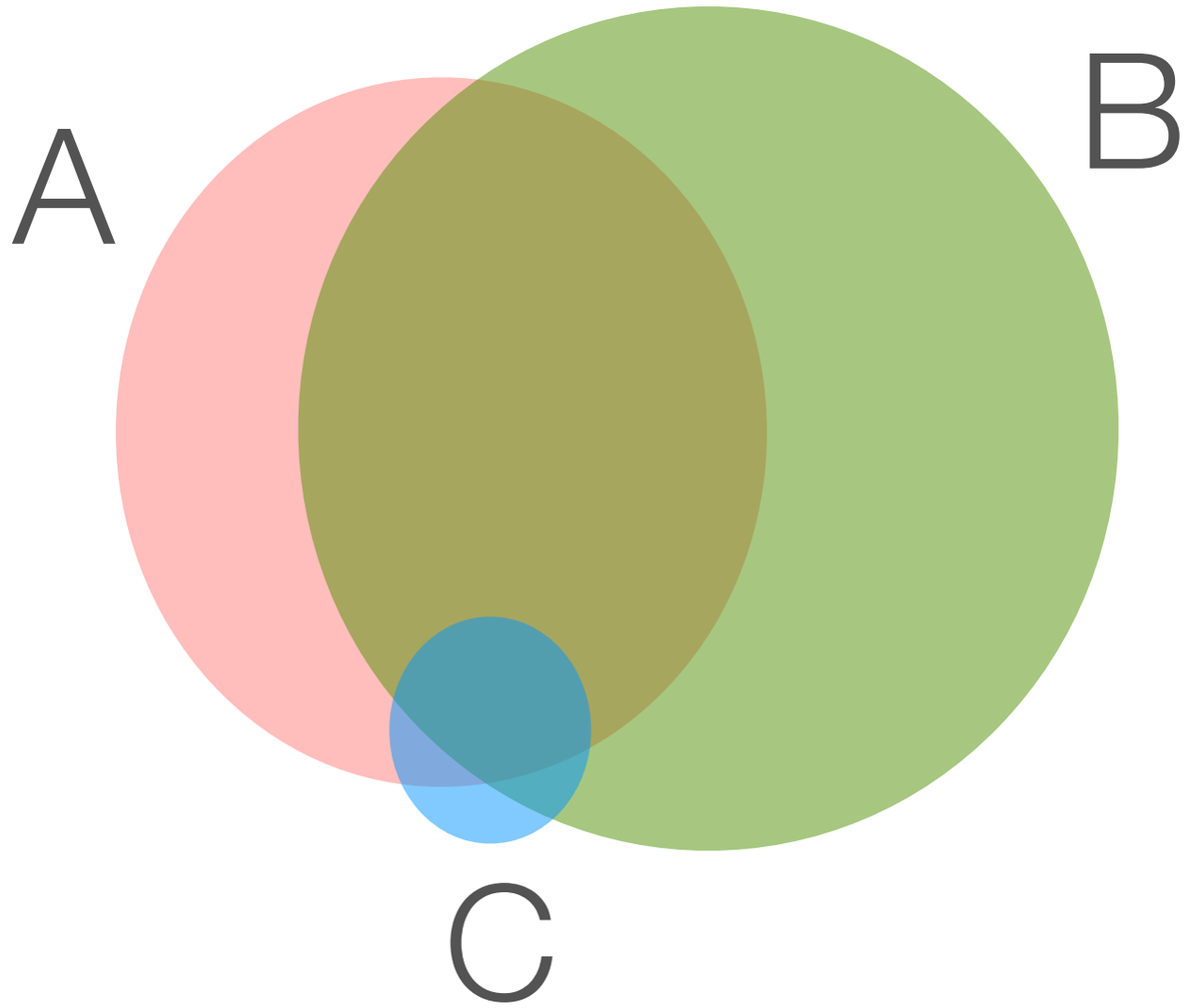
- automated algorithms often act as **black boxes** => biologists must have blind faith in bioinformatician (and bioinformatician in his/her own skills)

For domain expert: what's my hypothesis?

Martin Krzywinski

For developer and domain expert: opening the black box

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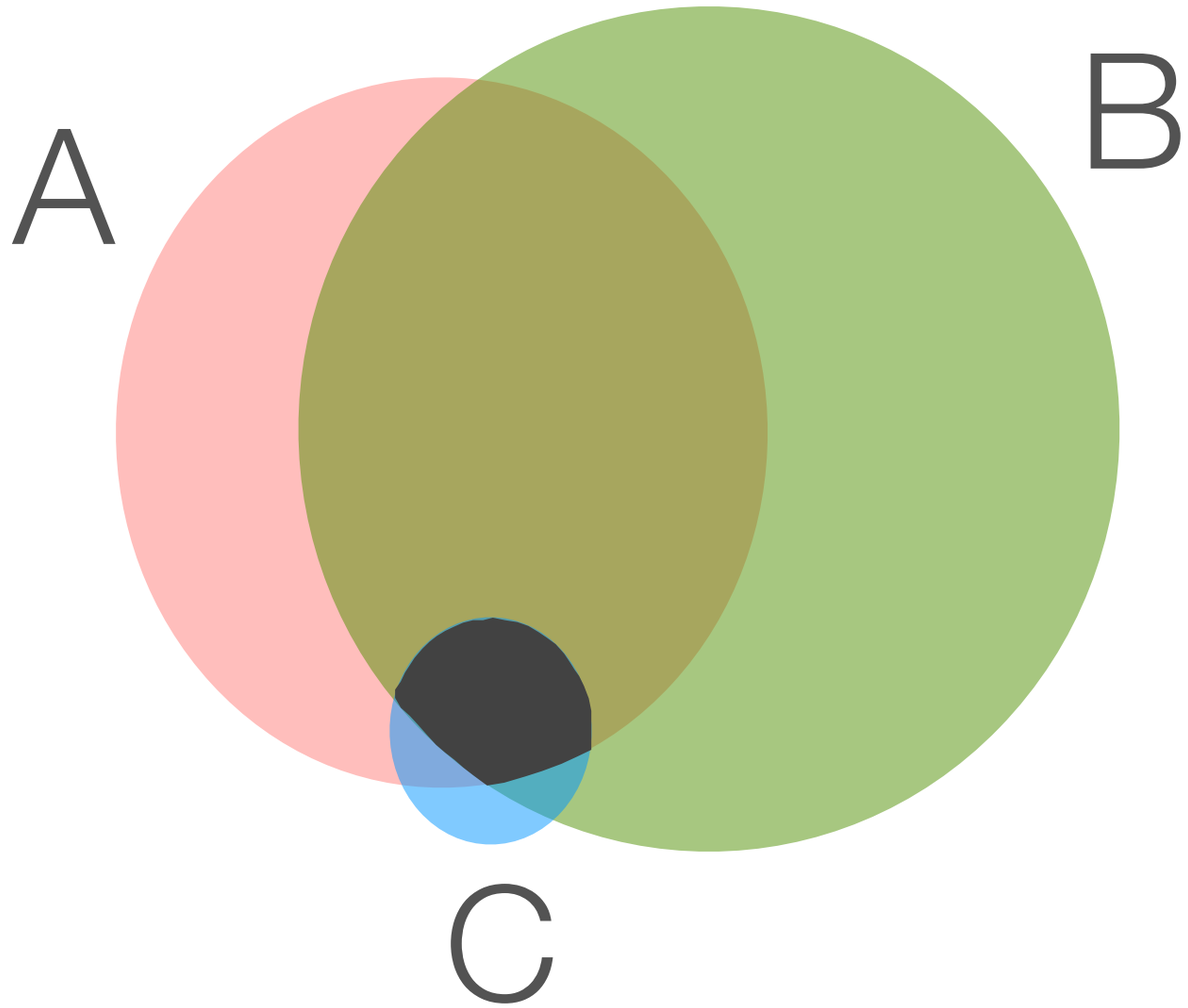
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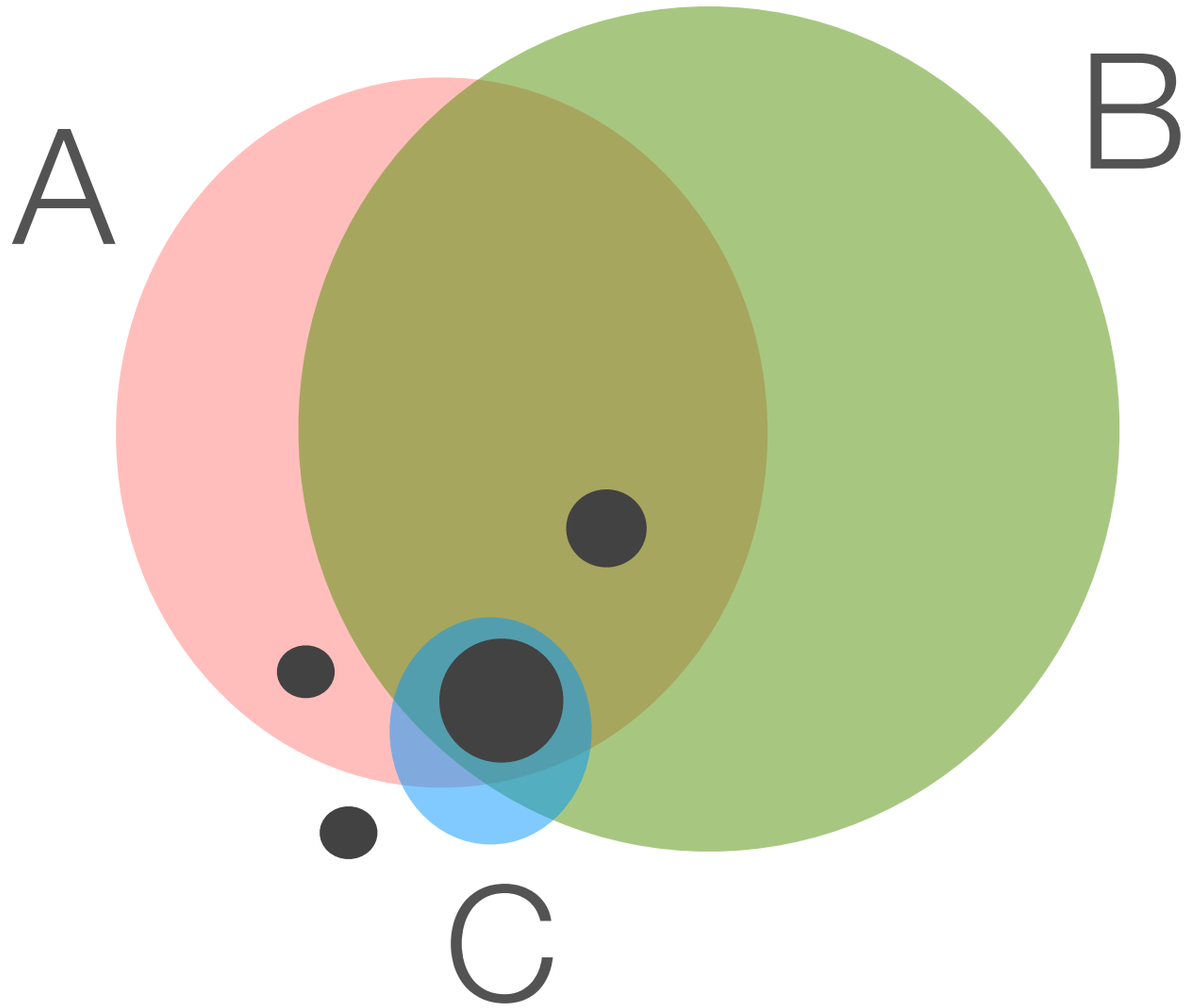
A
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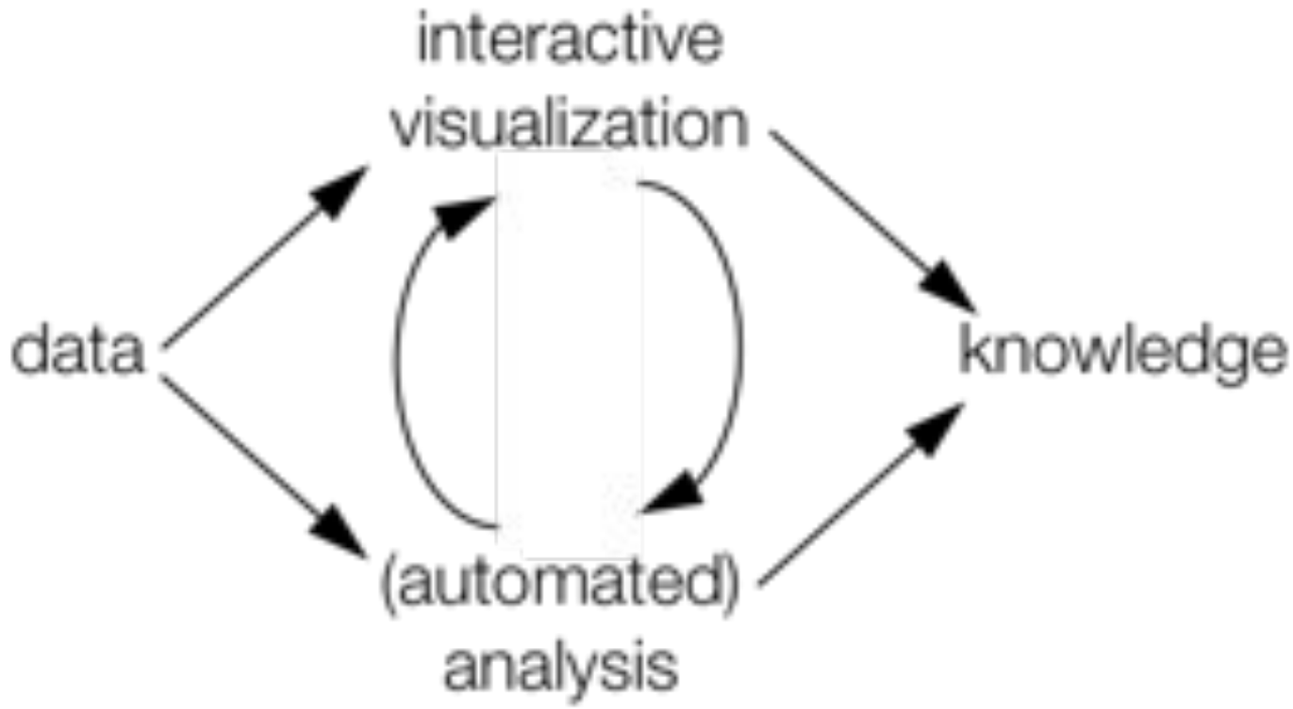
Visual Analytics to the rescue



Our research interest:
visual design + interaction design + backend

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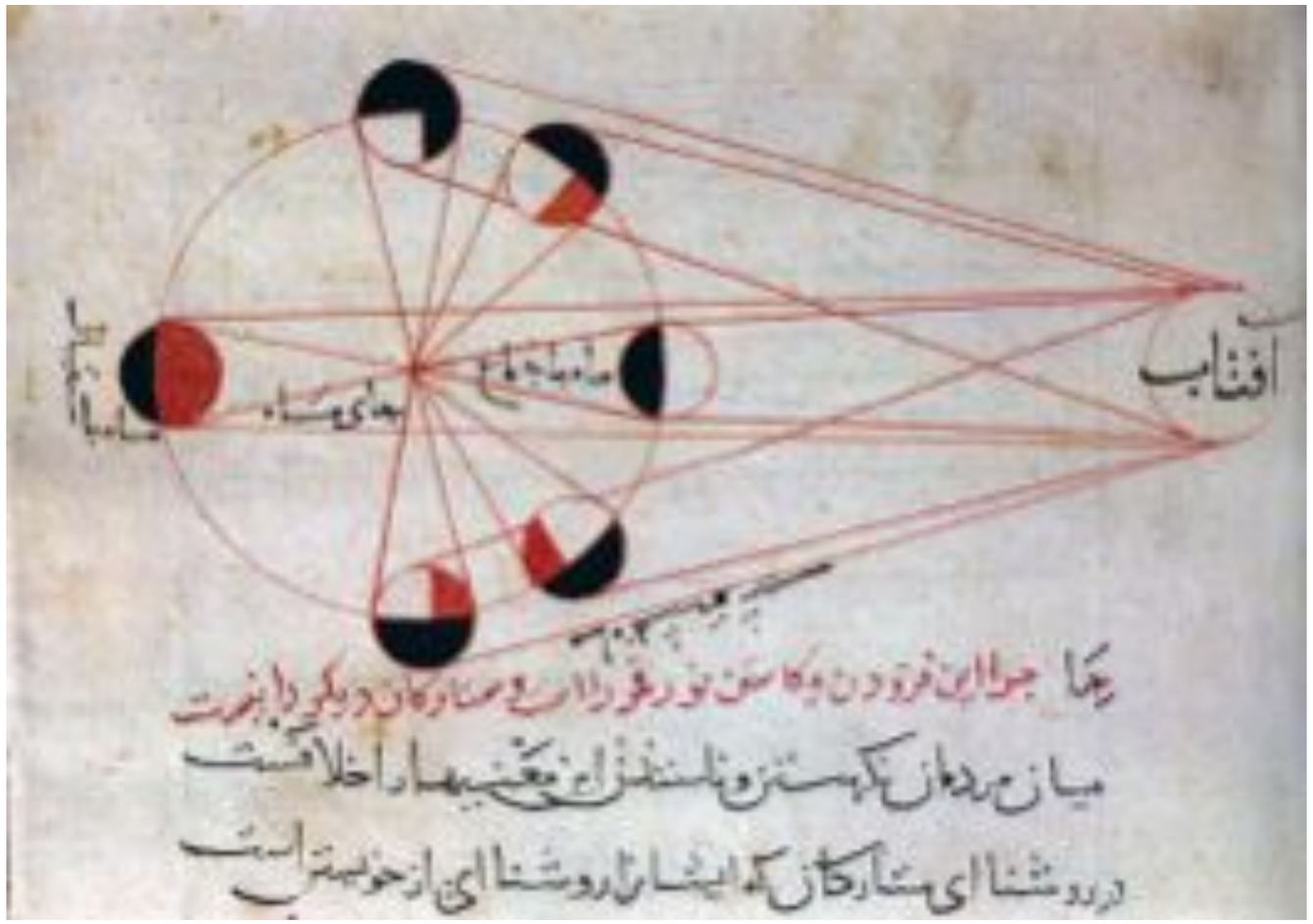
B. Data Visualization

Historical perspective

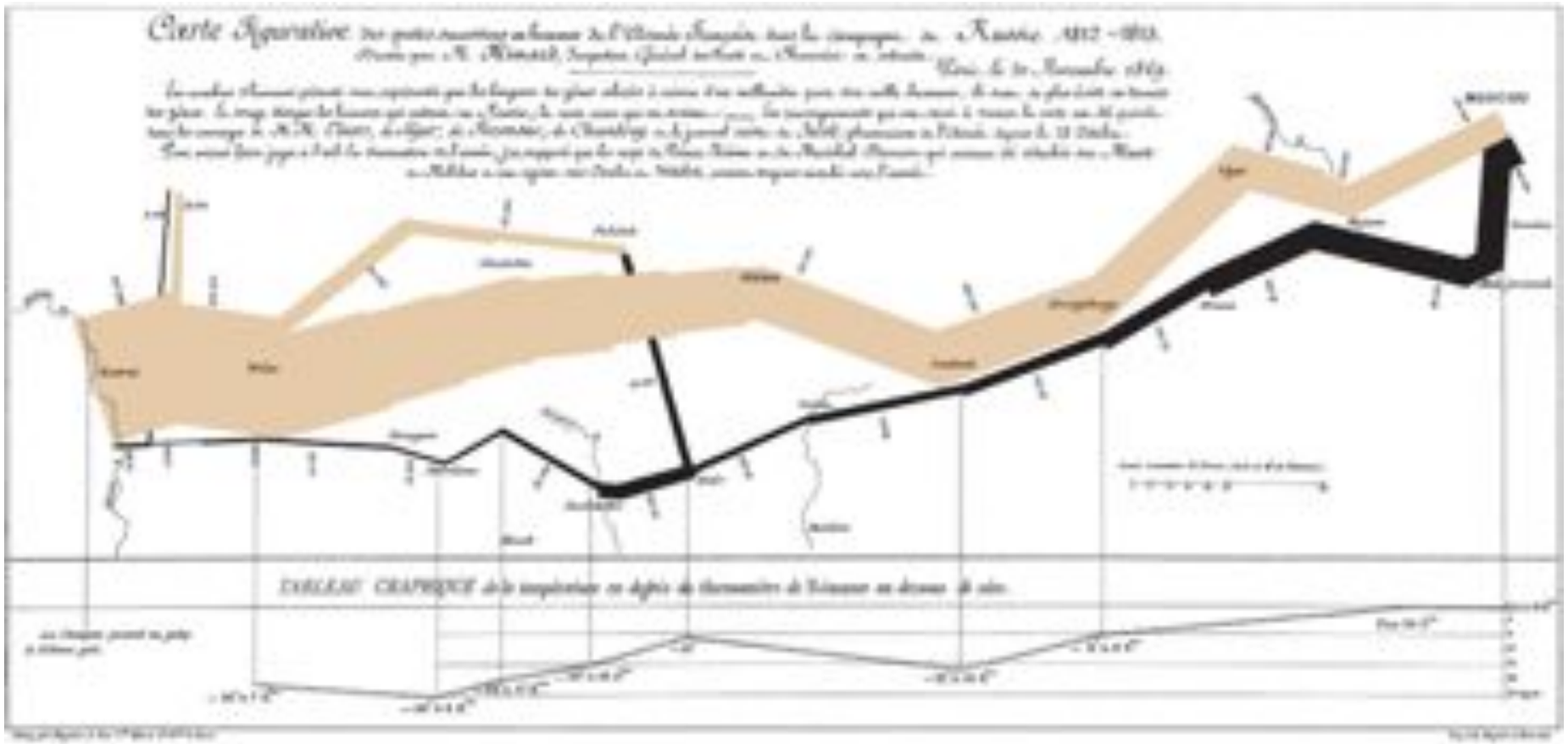


Biruni - time series visualization: phases of the moon in orbit (circa 1030)

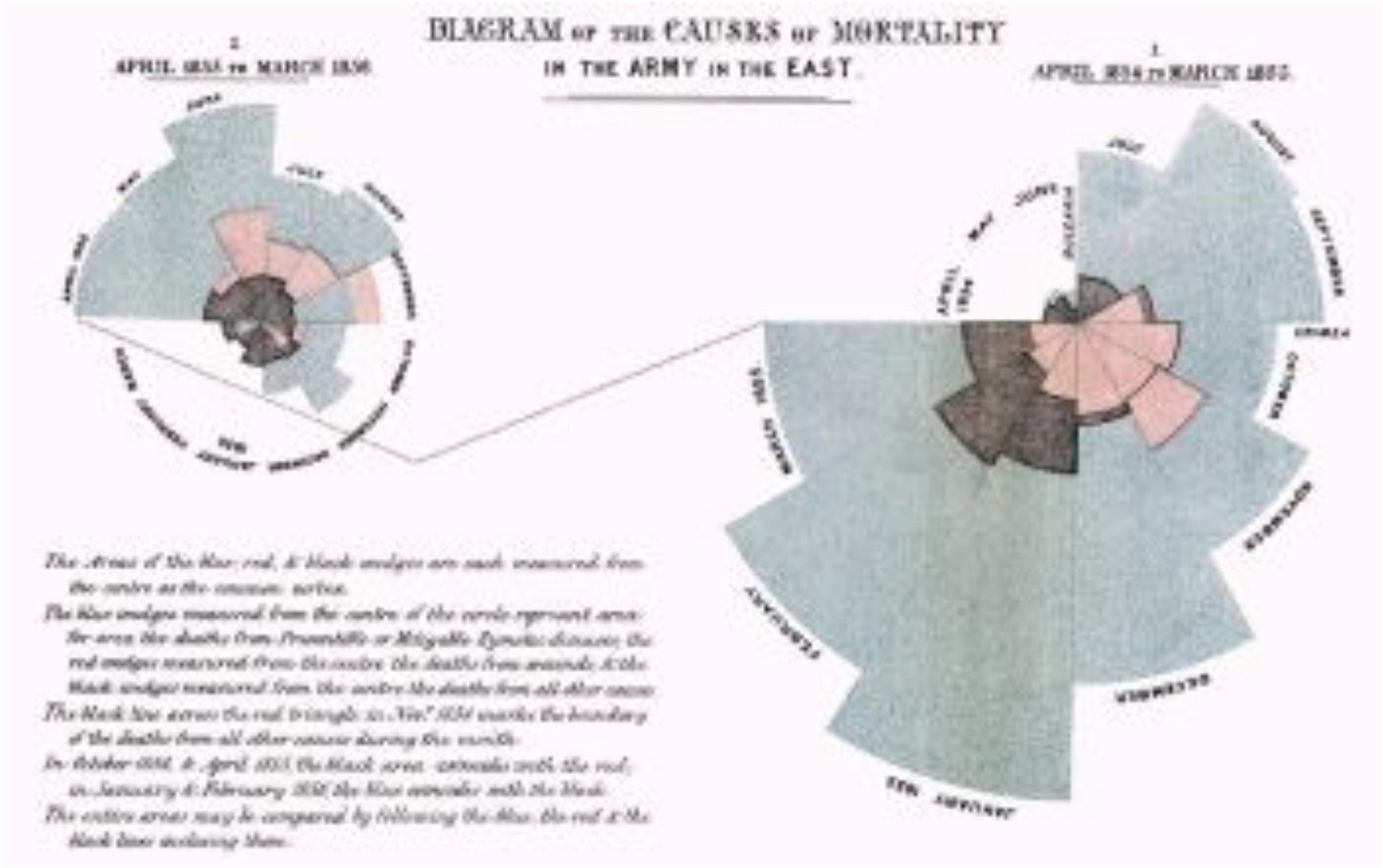
Hereford map - largest surviving map of the Middle Ages (1280s)

Peutinger Map - roads in Roman Empire, 1570
Abraham Ortelius (Flemish cartographer)

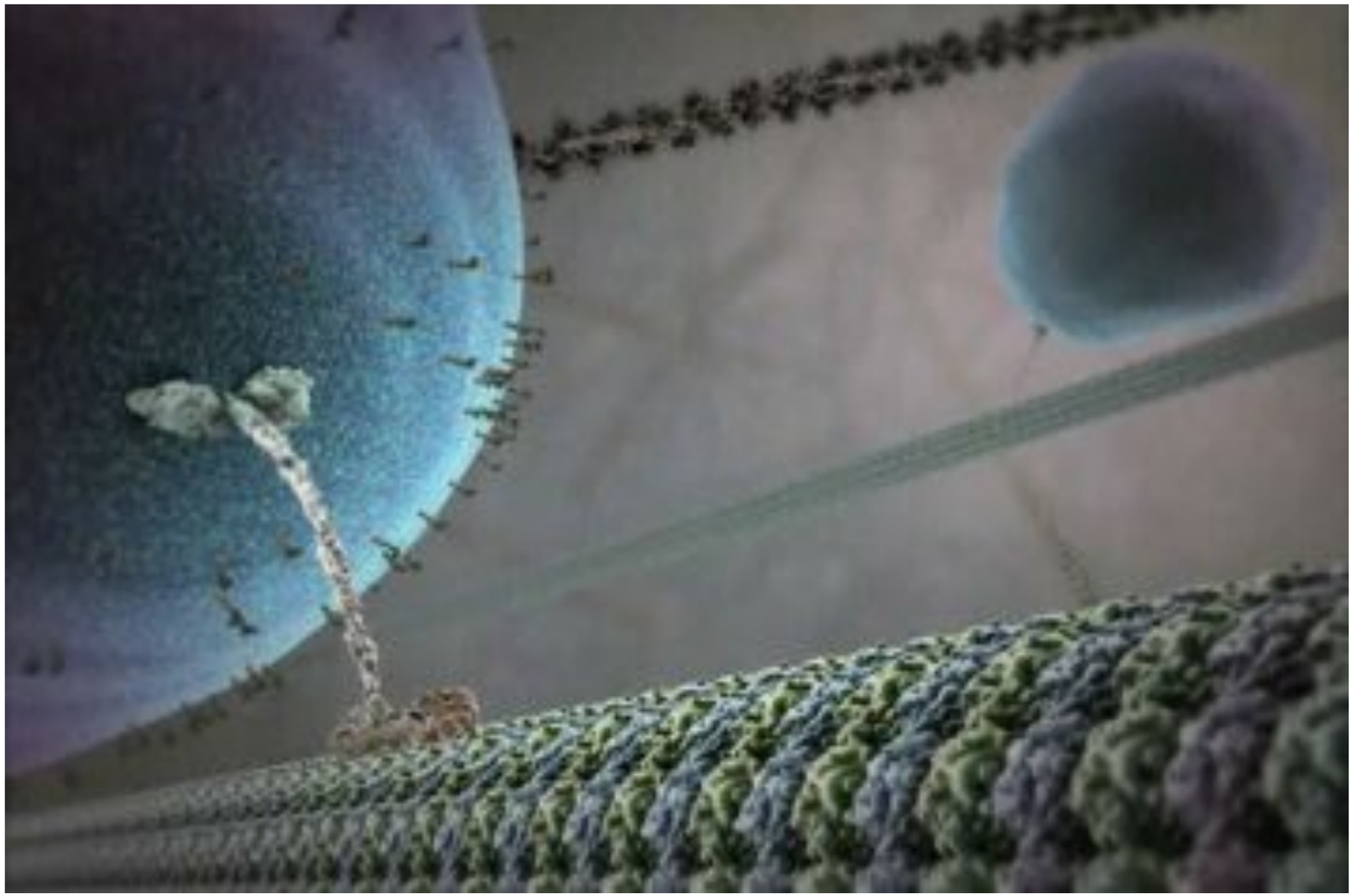
John Snow - cases of cholera in London (1663)



Charles Joseph Minard (1781-1870) - Napoleon’s march on Moscow



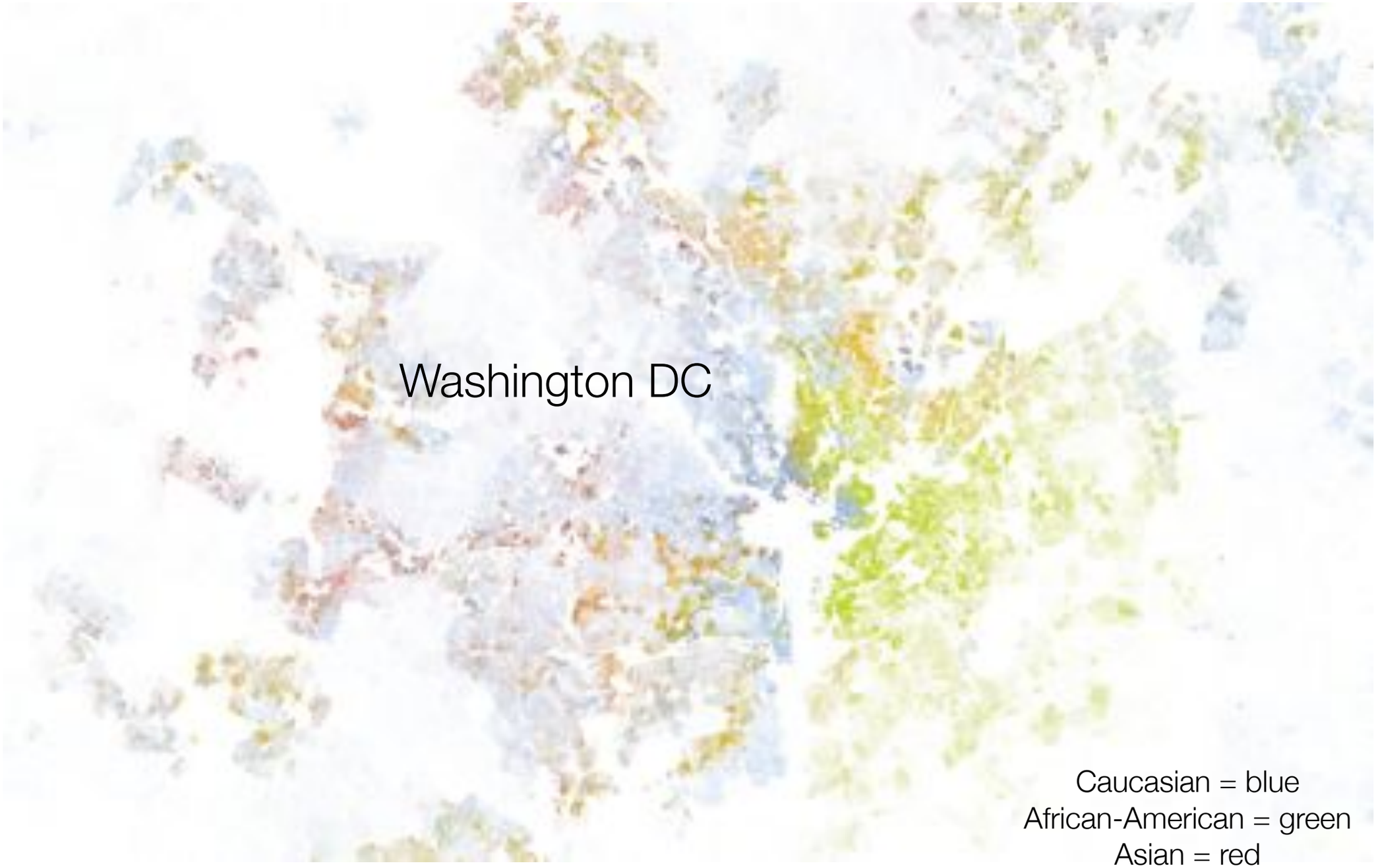
Florence Nightingale (1820-1910)
coxcomb chart monthly deaths from battle and other causes



http://multimedia.mcb.harvard.edu/anim_innerlife.html

Shape of Songs: “Like a Prayer” (Madonna)

Martin Wattenberg

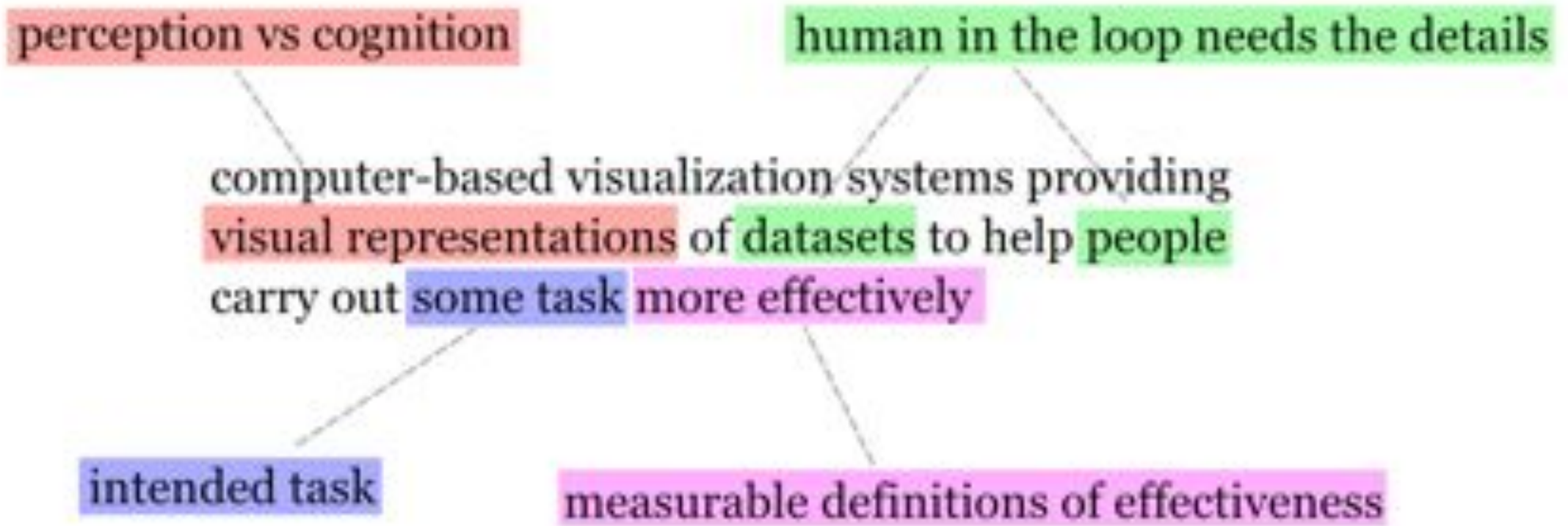


Caucasian = blue
African-American = green
Asian = red
Hispanic = orange
other = brown

Racial dot map: one dot per person in the US, coloured by ethnicity

source:http://www.coopercenter.org/demographics/Racial-Dot-Map

What is data visualization?


perception vs cognition
human in the loop needs the details
computer-based visualization systems providing visual representations of datasets to help people carry out some task more effectively
intended task
measurable definitions of effectiveness

T. Munzner

perception vs cognition

human in the loop needs the details

cognition <=> perception

cognitive task => perceptive task

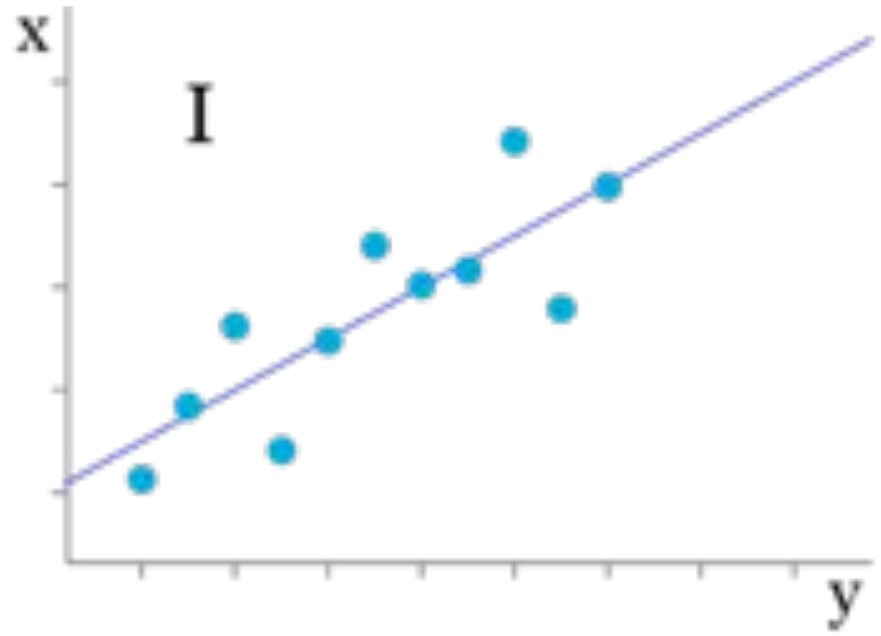
identify anomalies, clusters, trends

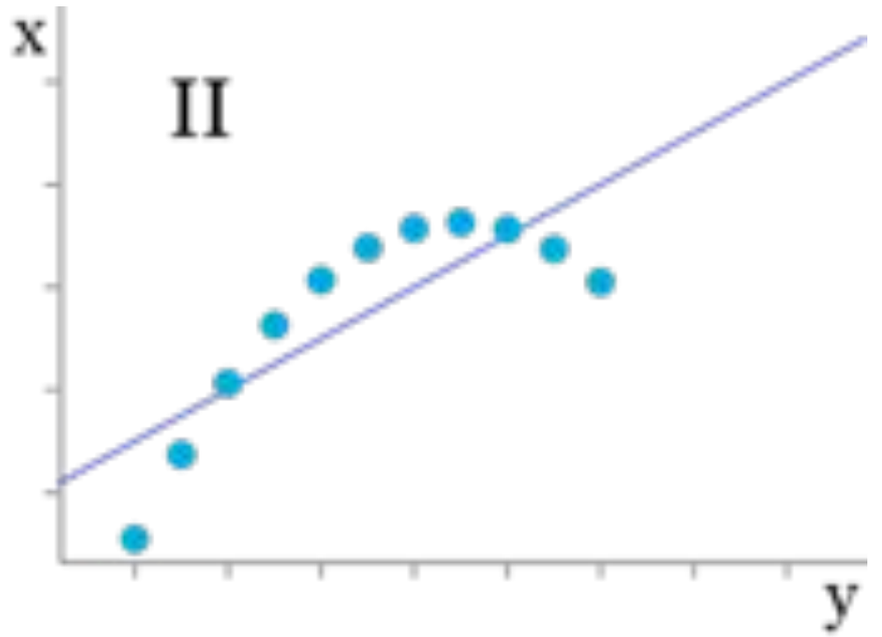
T. Munzner

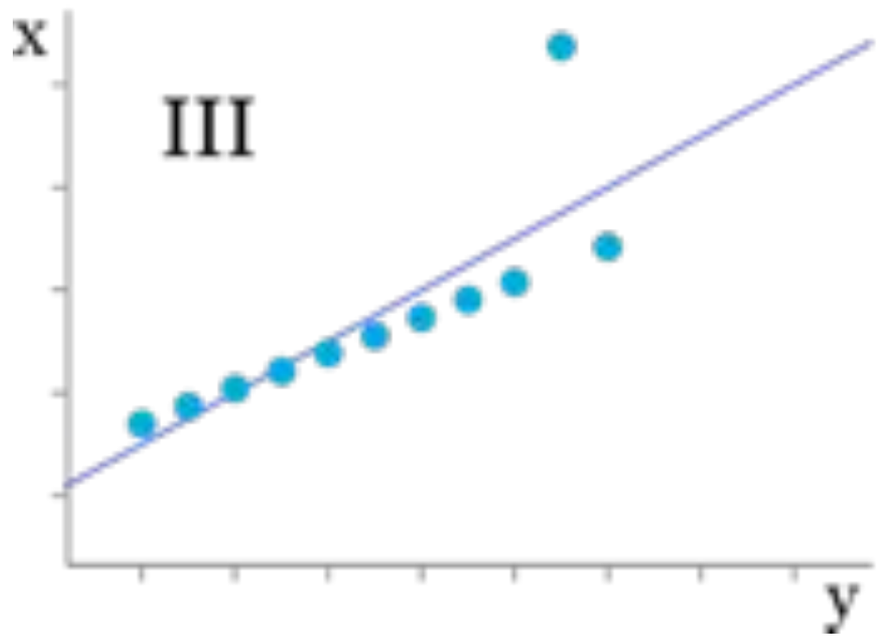
I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.80

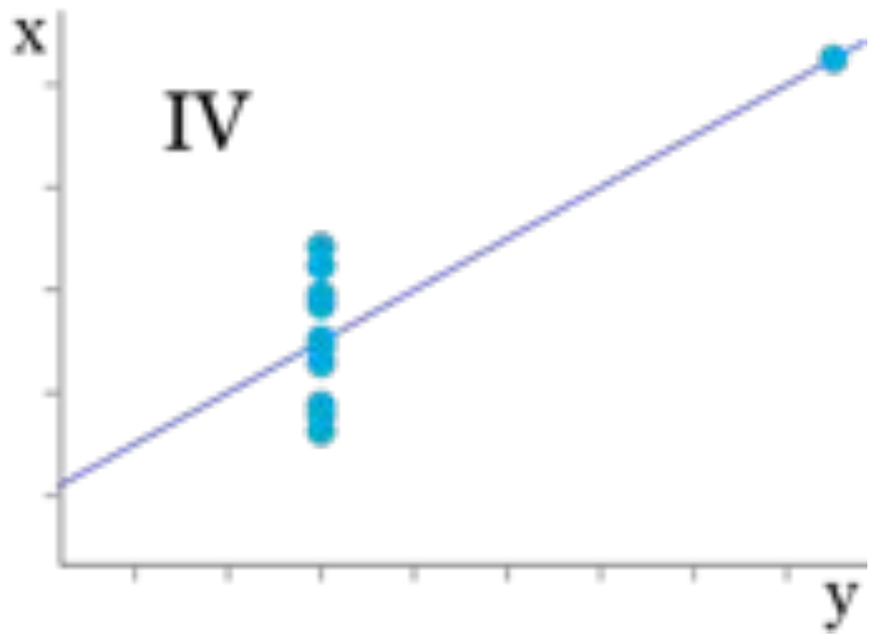
n = 11

mean x = 9.0 variance x = 11.0 correlation x & y = 0.816
mean y = 7.5 variance y = 4.12 regression line: y = 3+0.5x


x
I
y


x
II
y


x
III
y


x
IV
y

Misunderstandings visual design

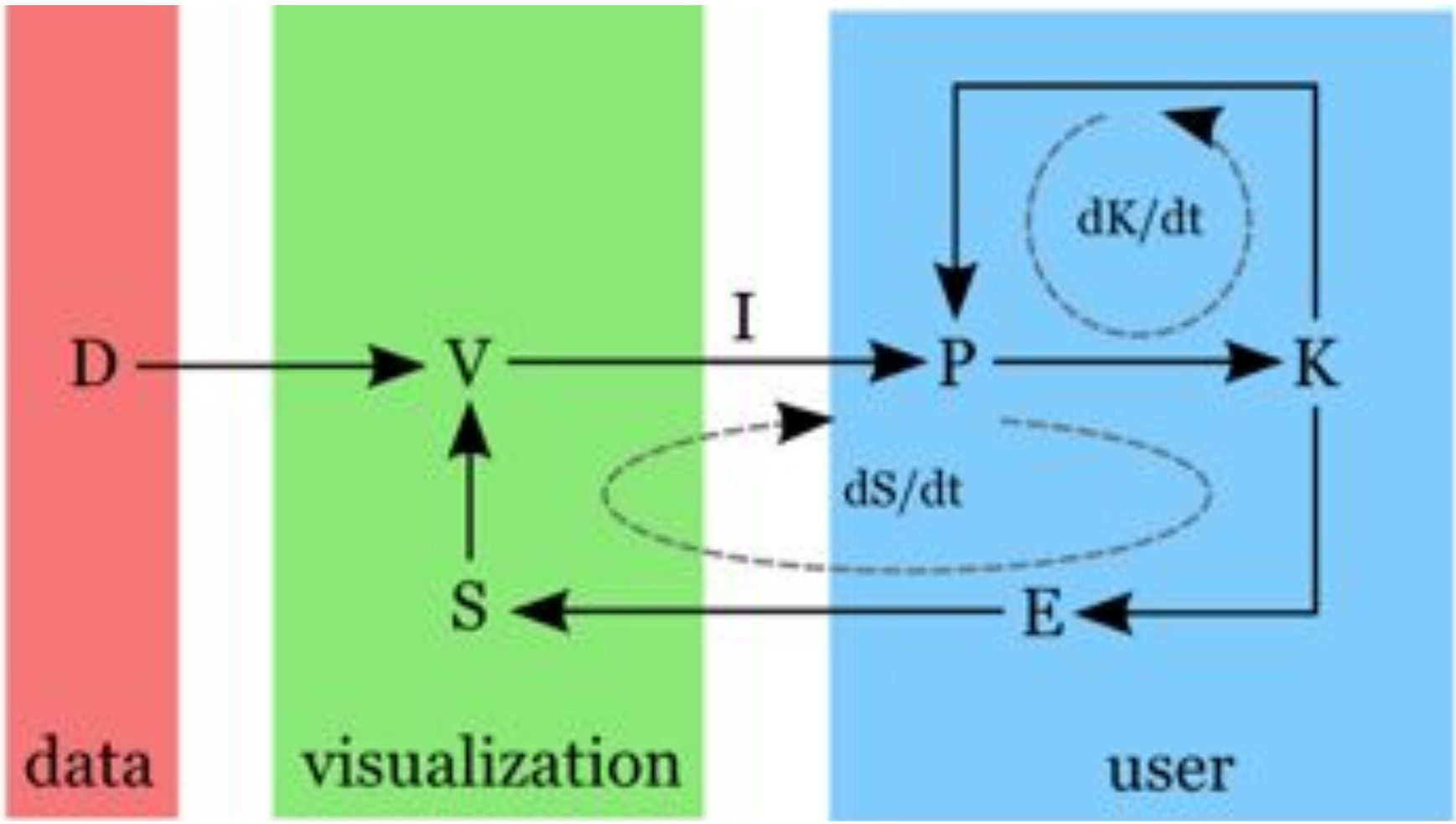
- Is it a matter of talent? creativity? inspiration? aesthetics? taste?

- practice => anyone can learn (to some extent)

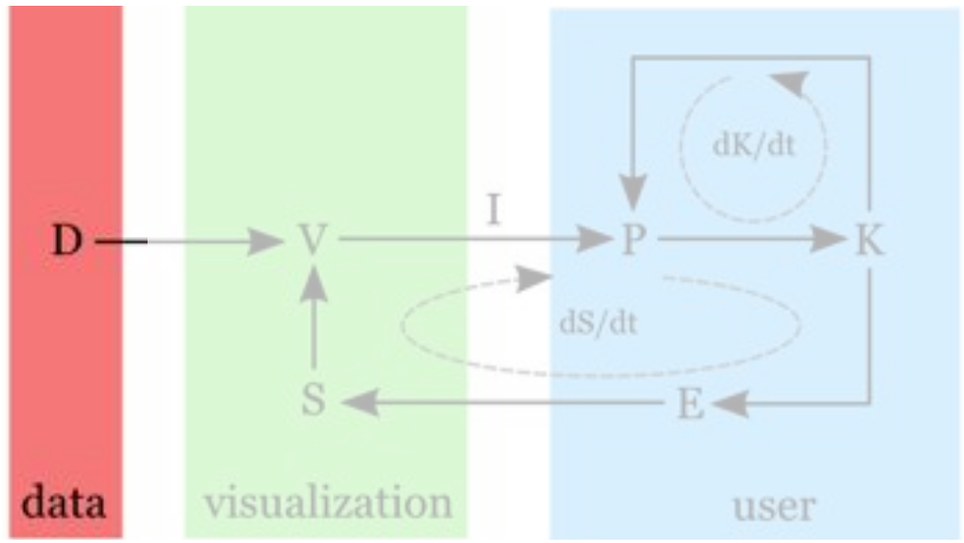
- be rational

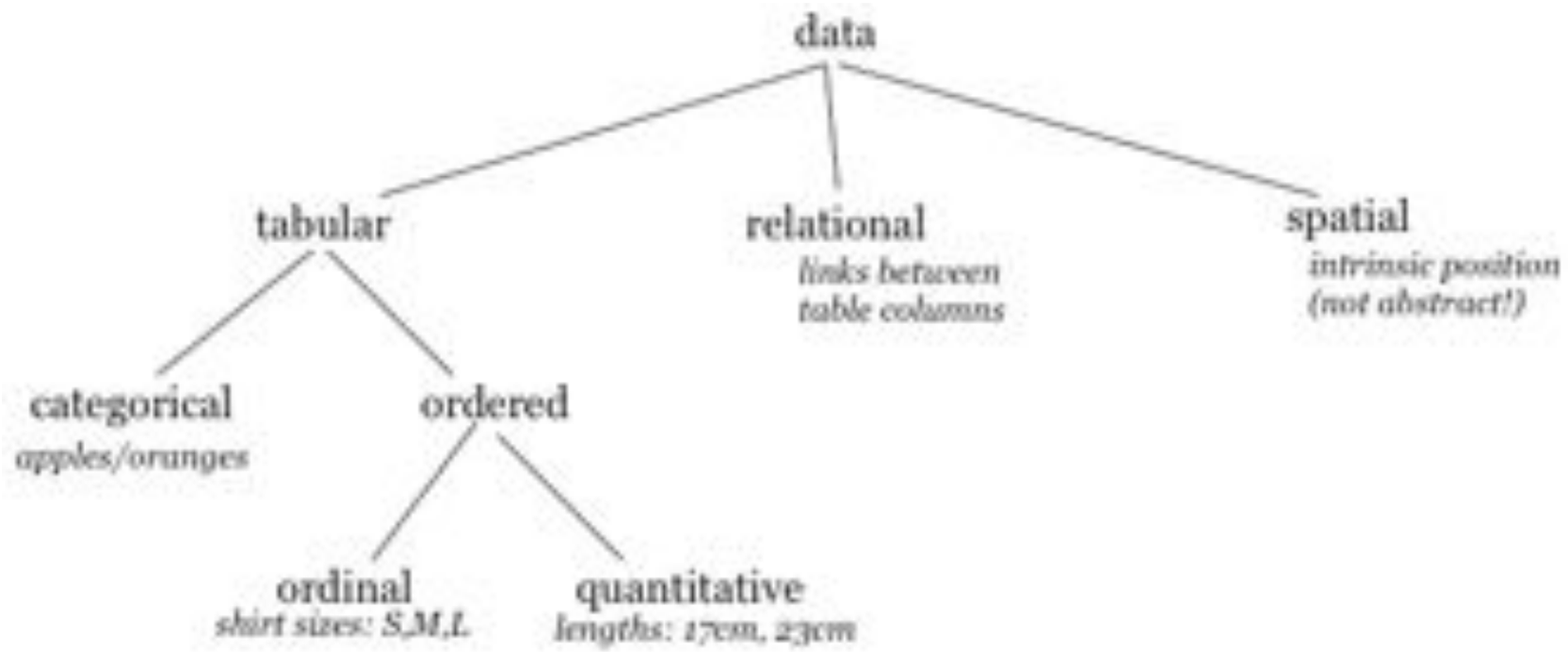
- aim at usability => beauty/aesthetics often follows

Components



Data foundations



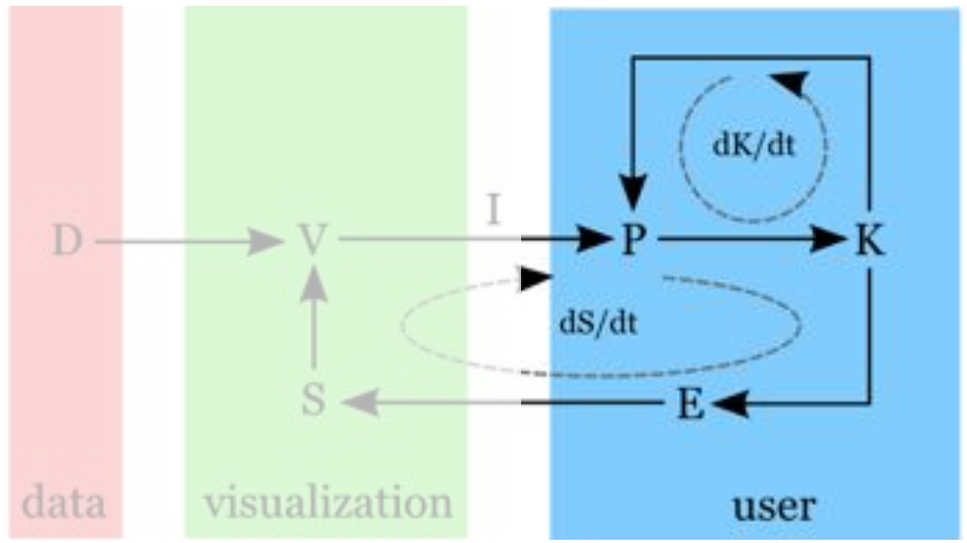


S Stevens “On the theory of scales and measurements” (1946)

Data type taxonomy (?) (Schneiderman, 2006):

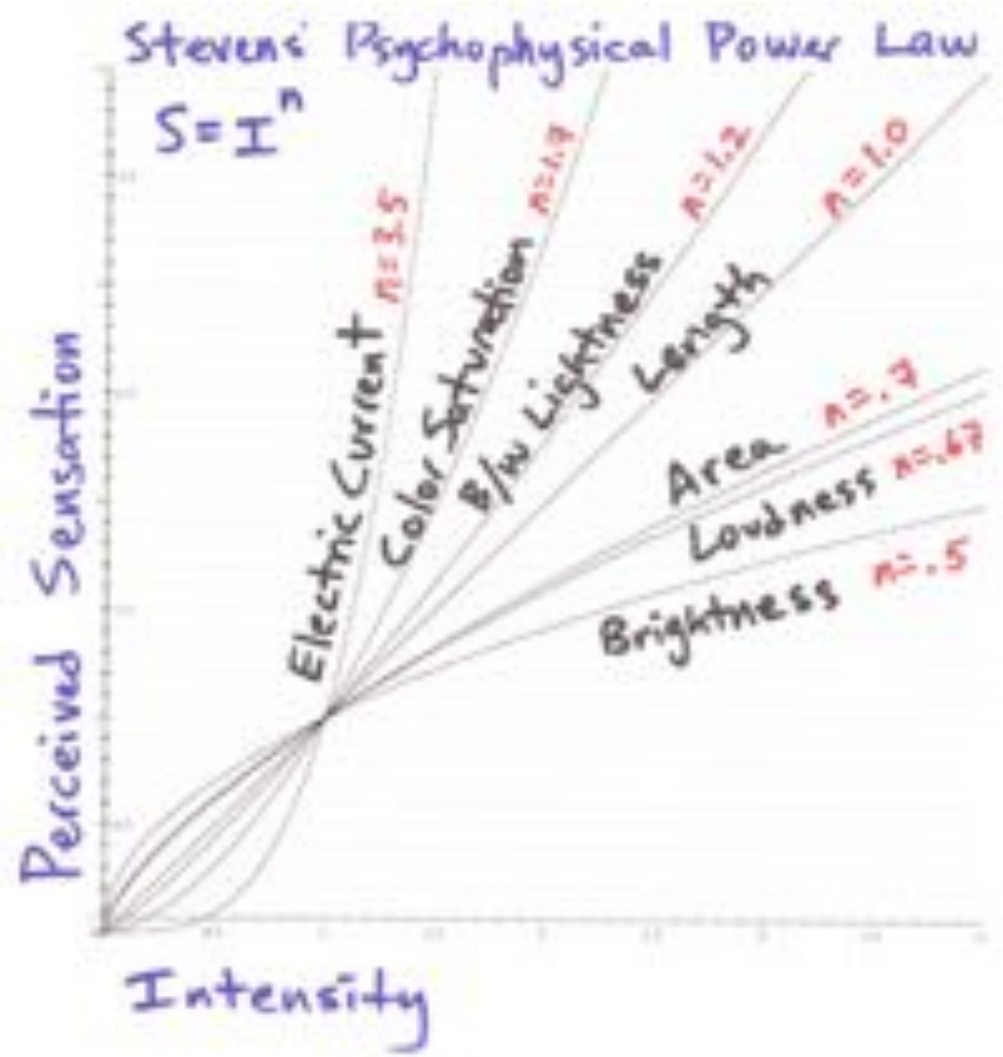
- 1D (*e.g.* DNA sequences)
- temporal (*e.g.* time series gene expression)
- 2D (*e.g.* distribution maps)
- 3D (*e.g.* anatomical structures)
- nD (*e.g.* Fisher's iris dataset; what if 1,000s of dimensions?)
- trees (*e.g.* phylogenies)
- networks/graphs (*e.g.* metabolic pathways)
- text & documents (*e.g.* publications)

Human perception foundations



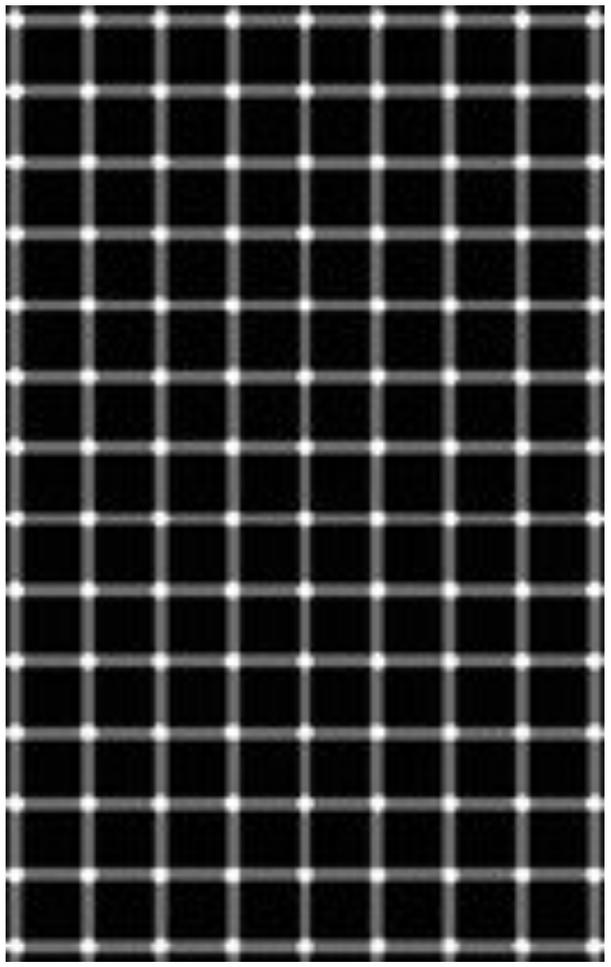
Steven's psychophysical law

= proposed relationship between the magnitude of a physical stimulus and its perceived intensity or strength



Gestalt laws - interplay between parts and the whole (Kurt Koffka)

series of principles



Hermann grid illusion

Election results Florida:

- black = Bush
- white = Gore

Gestalt - Principle of Simplicity

Every pattern we see is seen such that we see a strcture that is as simple as possible.

Gestalt - Principle of Proximity

Things that are close to each other are seen as belonging together (=> clusters)

Gestalt - Principle of Similarity

Things that are similar in some way are perceived as belonging together.

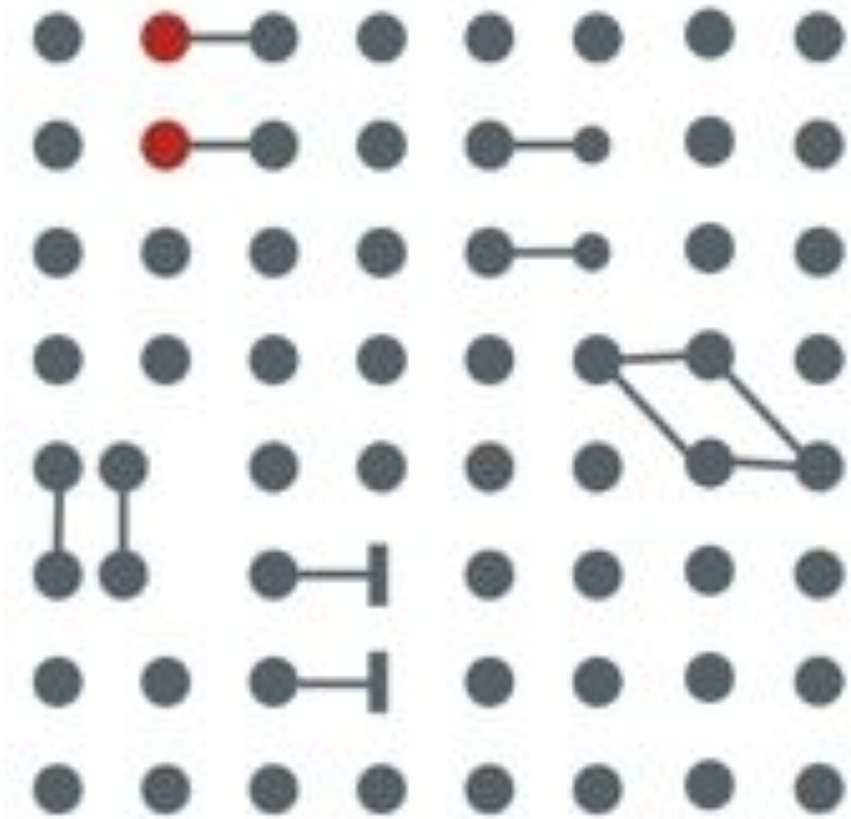
Gestalt - Principle of Closure

You will try to complete a pattern.

Kanizsa illusion

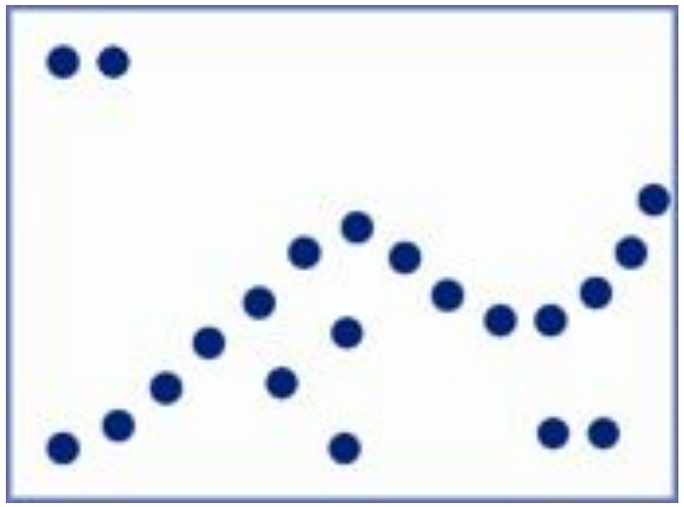
Gestalt - Principle of Connectedness

Things that are connected are perceived as belonging together. This encoding is stronger than similarity, shape, colour, and size.



Gestalt - Principle of Good Continuation

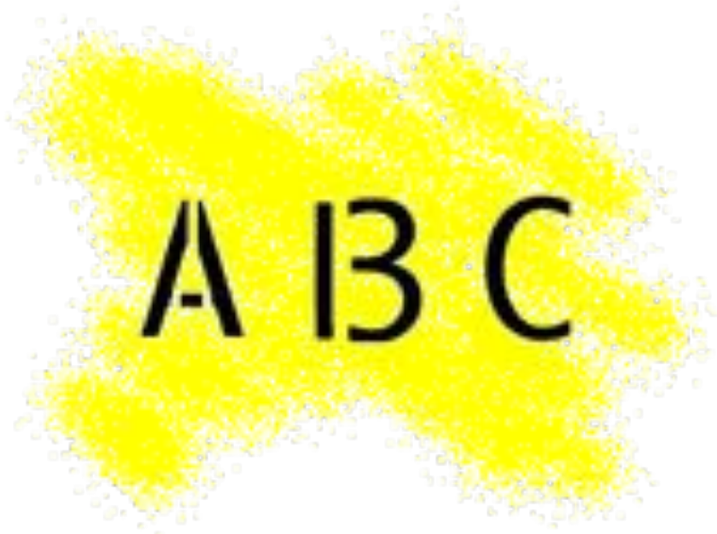
Objects that are arranged in a straight or smooth line tend to be seen as a unit.



Gestalt - Principle of Common Fate

Objects that move in the same direction tend to be seen as a unit.

Gestalt - Principle of Familiarity

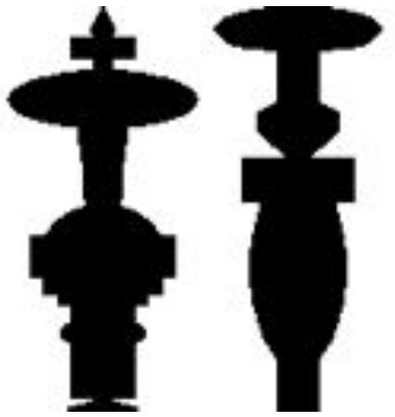


13

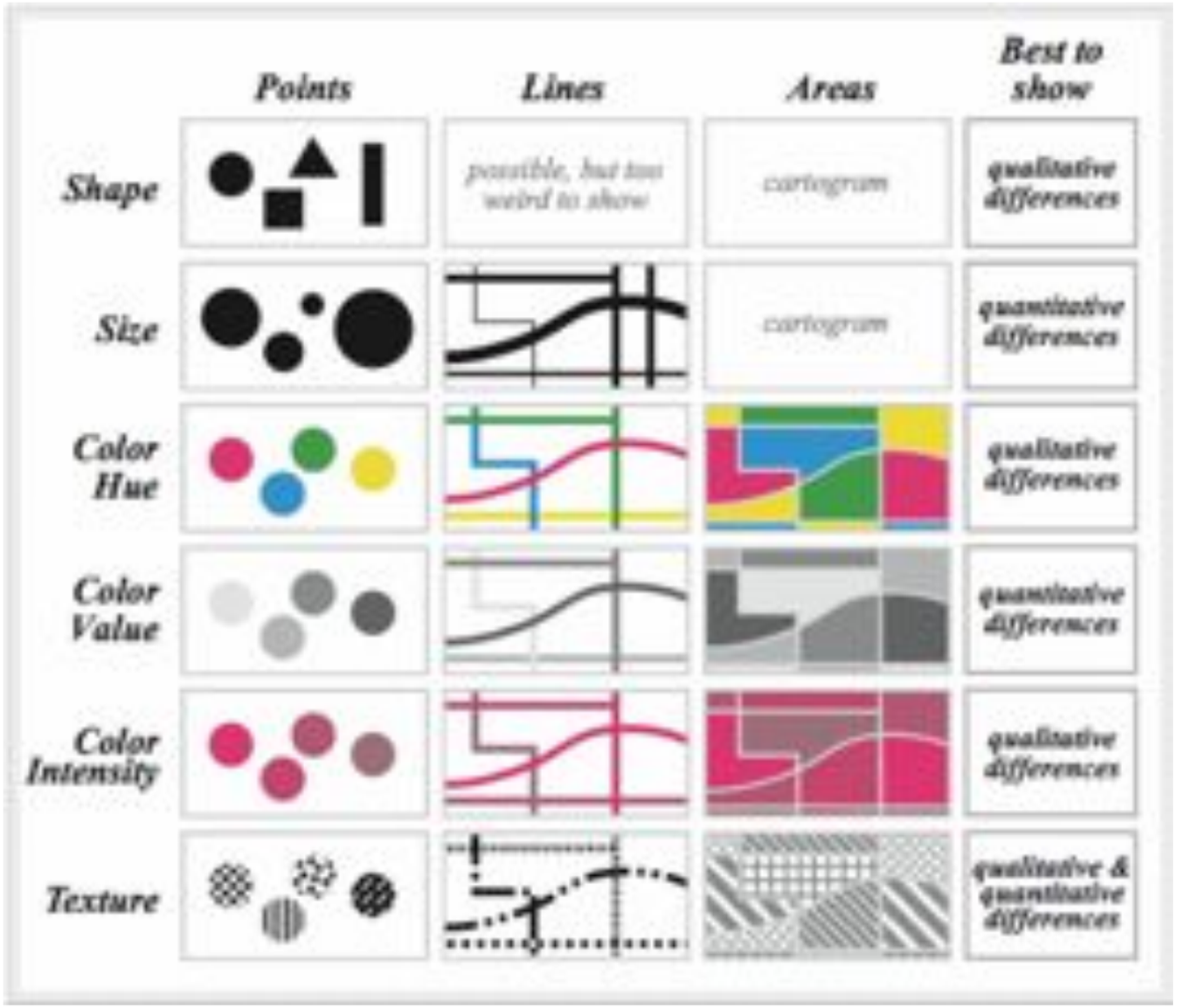
12 13 14

Gestalt - Principle of Symmetry

Symmetrical areas tend to be seen as figures against asymmetrical backgrounds.

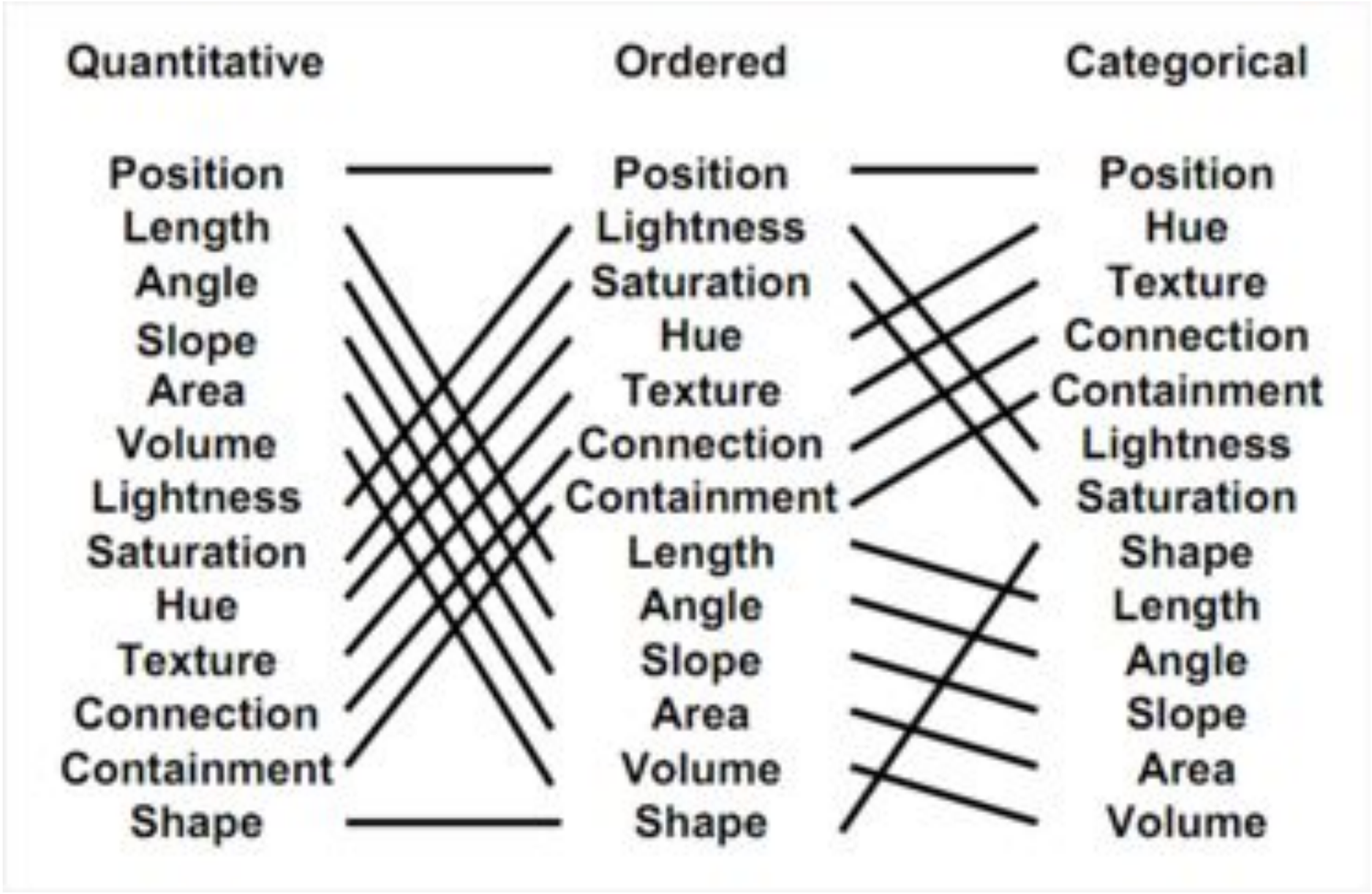


Semiology of graphics



Accuracy of quantitative perceptual tasks

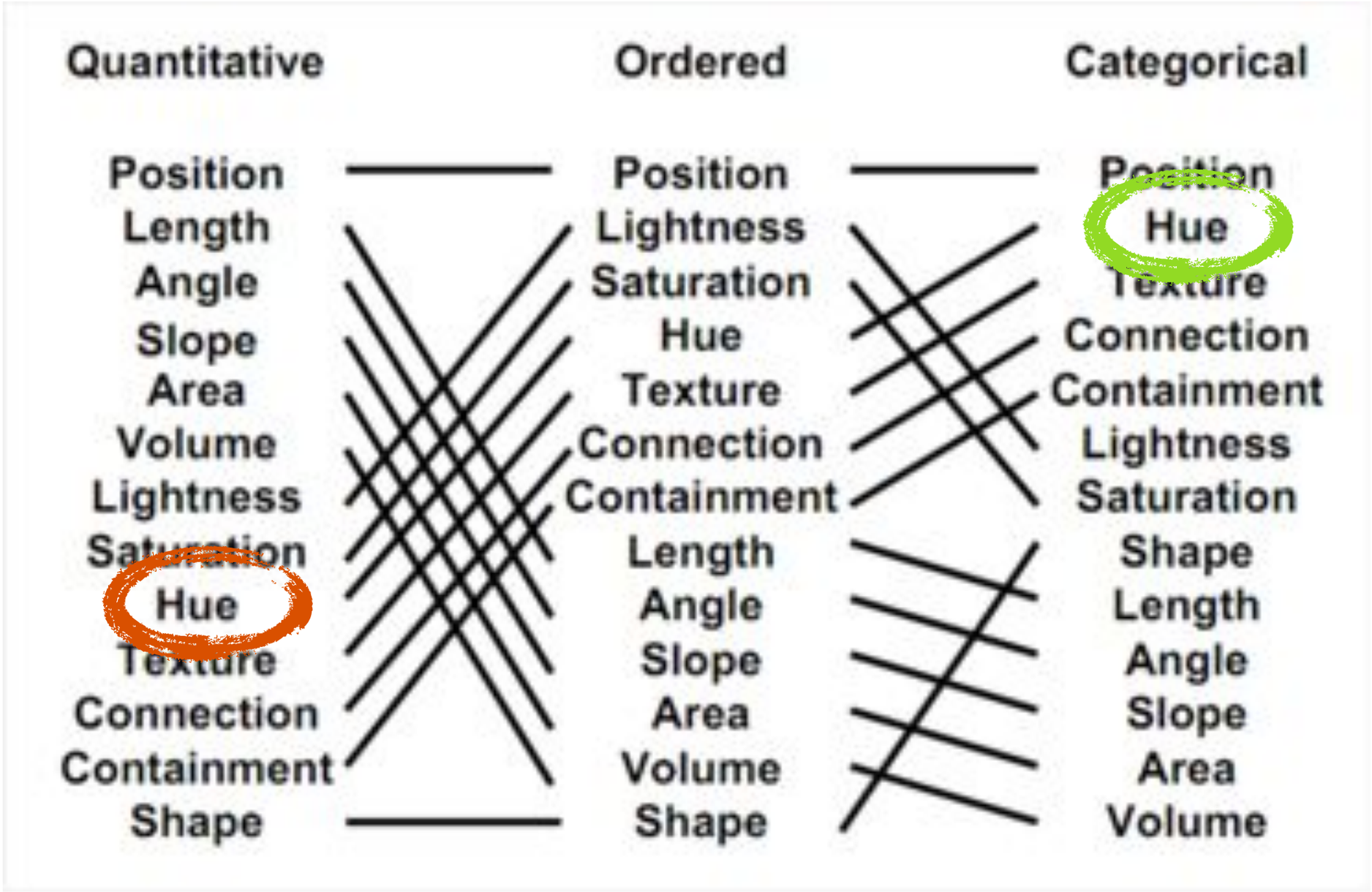
how much (quantitative) what/where (qualitative)



McKinlay

Accuracy of quantitative perceptual tasks

how much (quantitative) what/where (qualitative)



McKinlay

Accuracy of quantitative perceptual tasks

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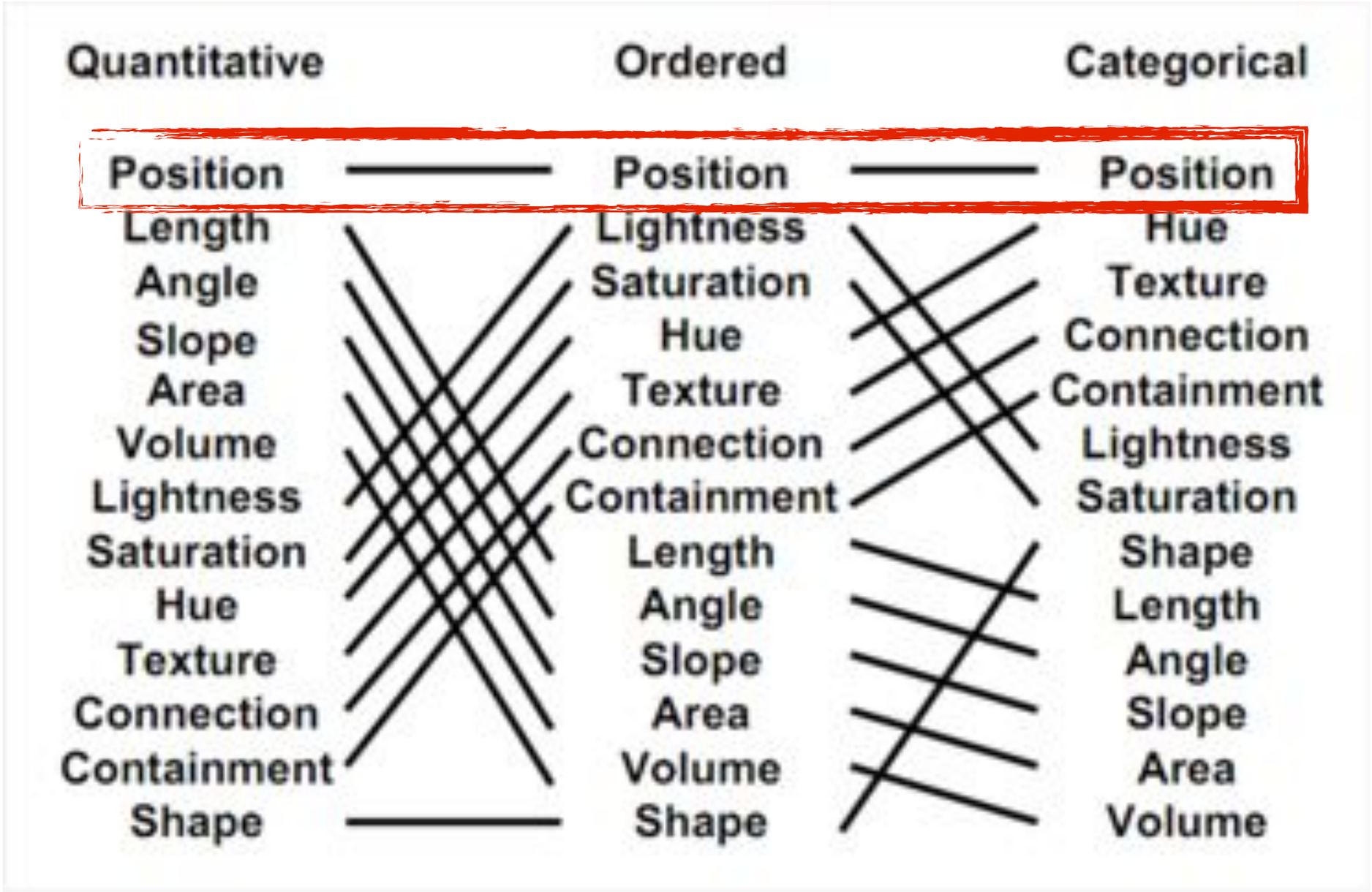


McKinlay

"power of the plane"

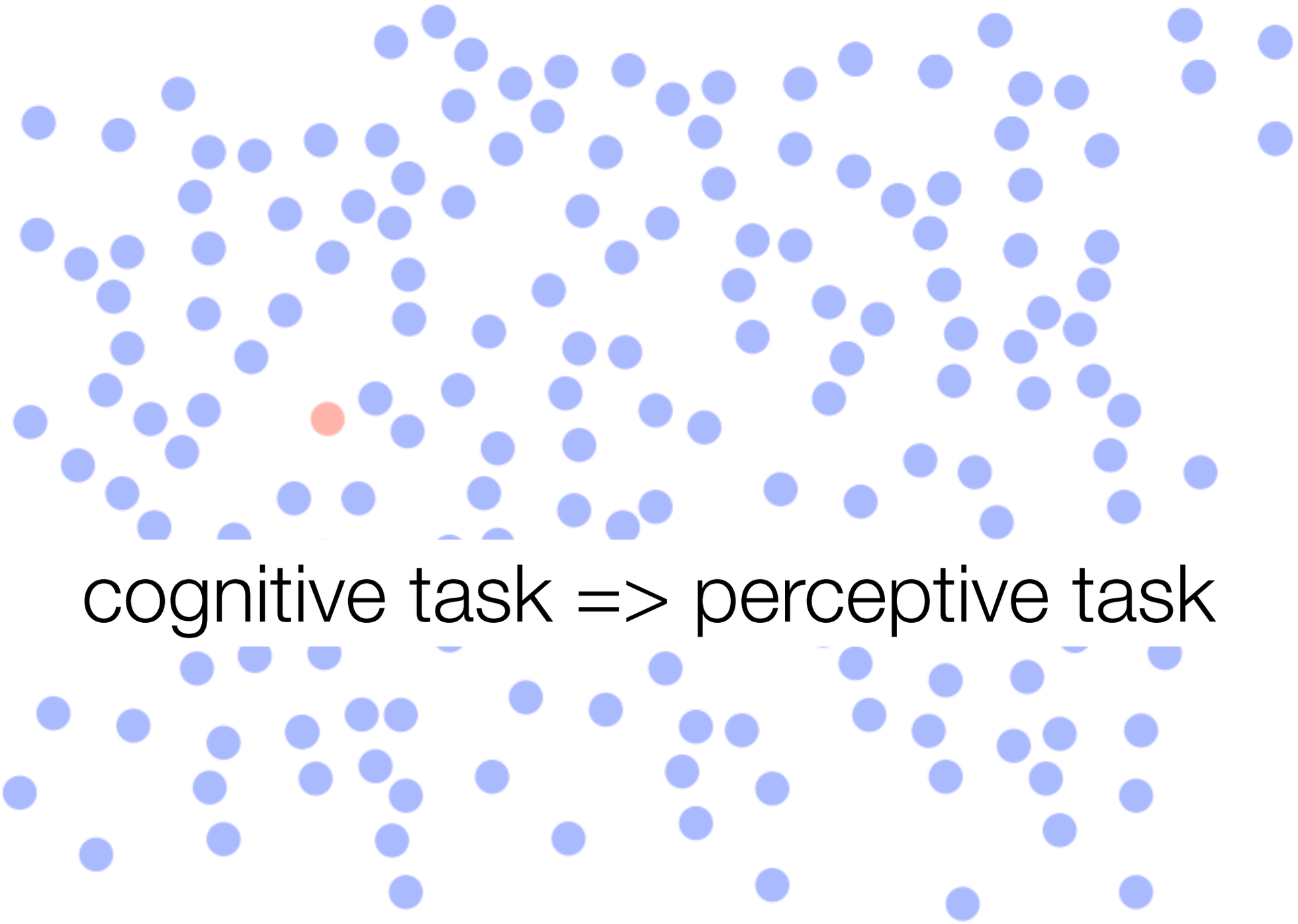
Pre-attentive vision

= ability of low-level human visual system to rapidly identify certain basic visual properties

- some features “pop out”
- used for:
  - target detection
  - boundary detection
  - counting/estimation
  - ...
- visual system takes over => all cognitive power available for interpreting the figure, rather than needing part of it for processing the figure

5

5



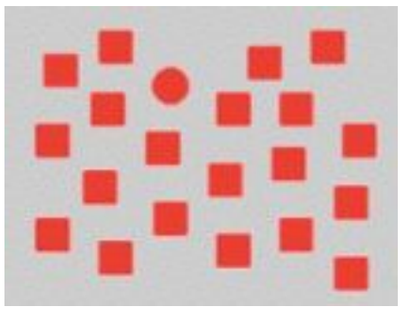
cognitive task => perceptive task

Limitations of preattentive vision

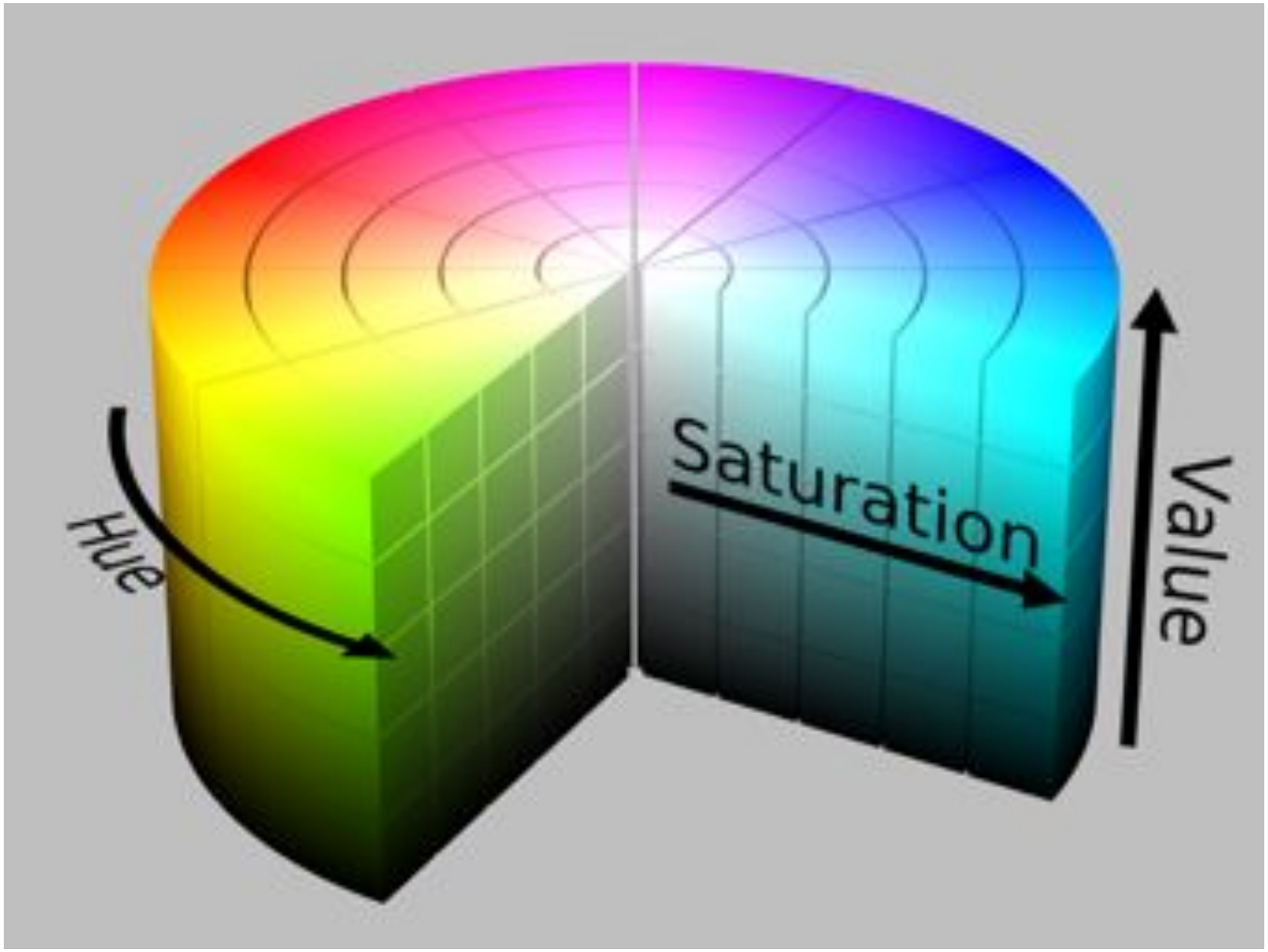
1. **Combining** pre-attentive features does *not* always work => would need to resort to "**serial search**" (most channel pairs; all channel triplets)

e.g. is there a red square in this picture

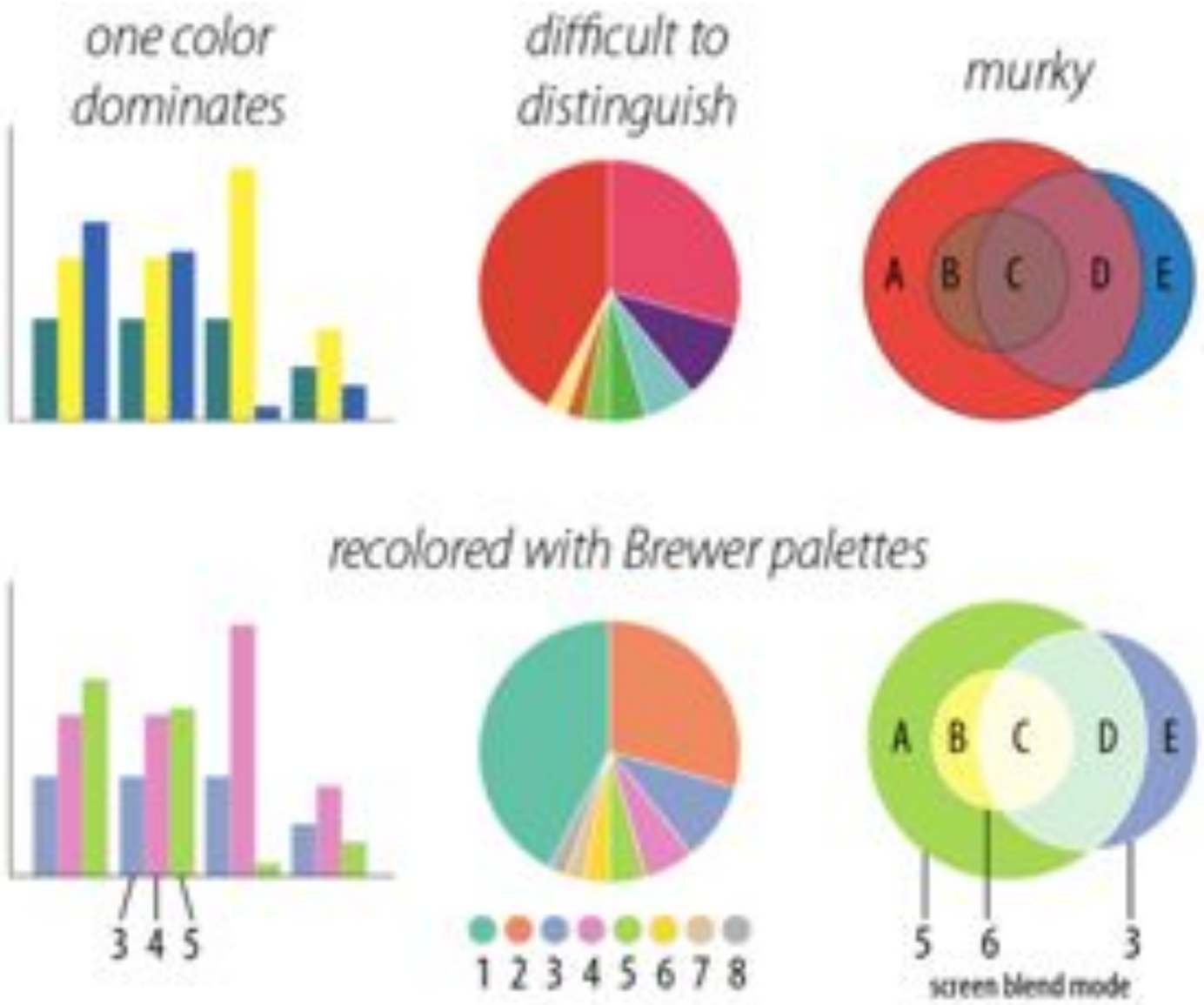
2. Speed depends on **which channel** (use one that is good for categorical)



About colour



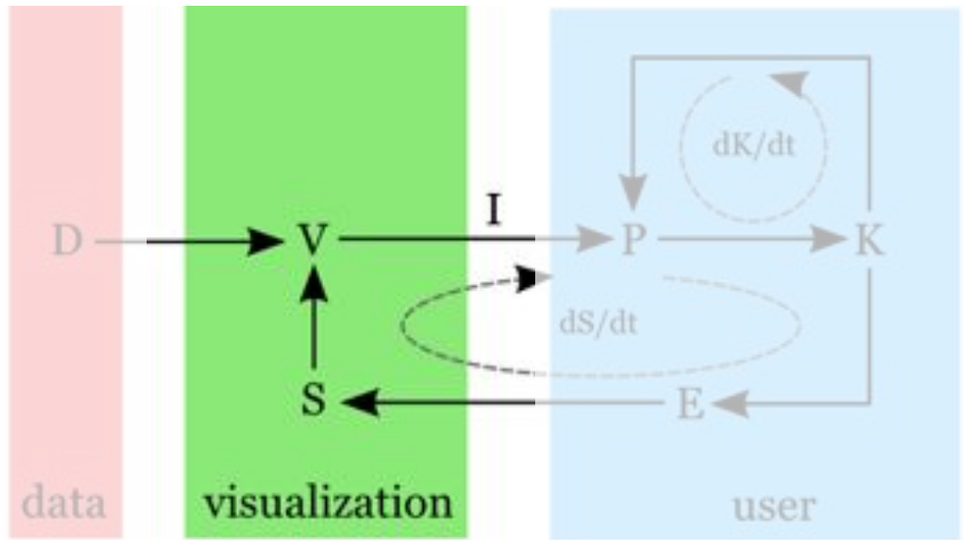
colorbrewer2.org



in R: please use RColorBrewer!

$$\textbf{“lie factor”} = \frac{\text{size of effect shown in graphic}}{\text{size of effect in data}}$$

Visualization foundations and techniques

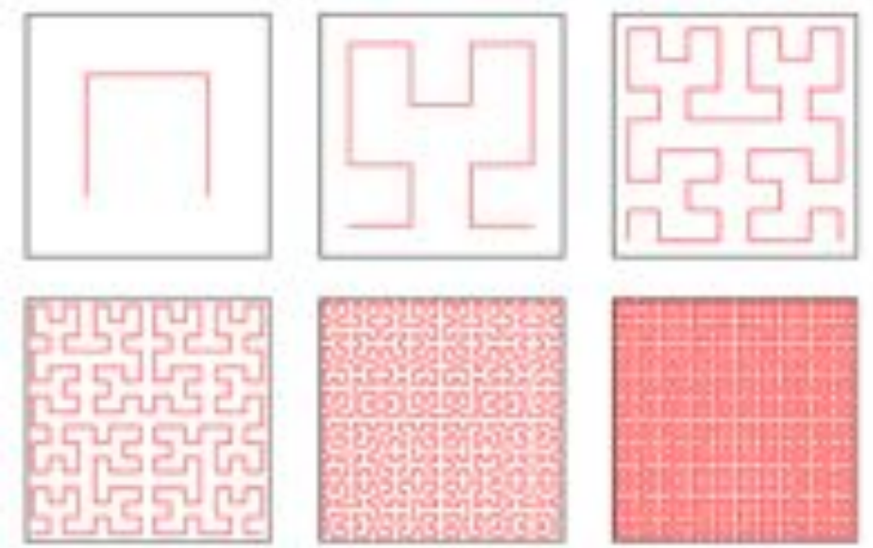


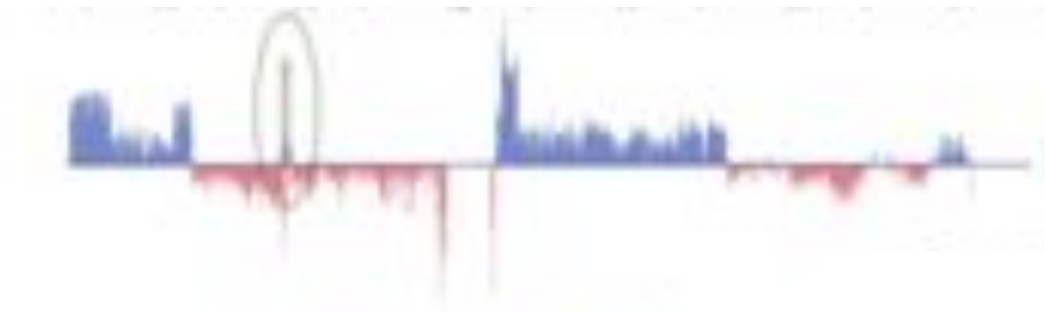
8 visual variables

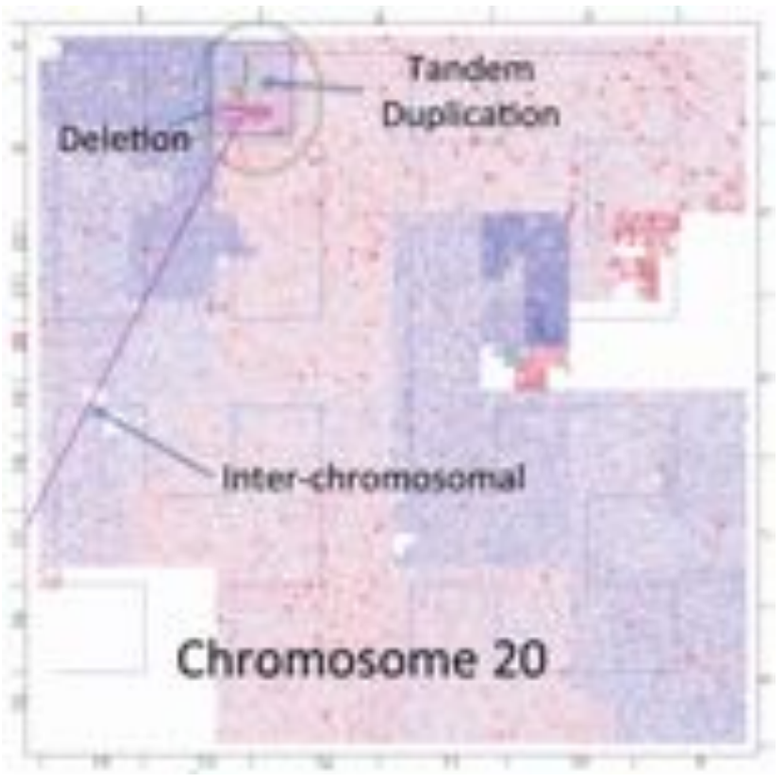
- See **semiology of graphics**
  - position
  - mark (circle, cross, rectangle, diamond, …)
  - size (length, area, volume)
  - brightness
  - colour (hue)
  - orientation
  - texture
  - motion

Visualization techniques for (geo)spatial data

- 1D, 2D
- space-filling curves: 1D -> 2D
  - *e.g.* Hilbert curve







Visualization techniques for multivariate data

- Really important in scientific research: often looking at **multiple dimensions** of the same data (*e.g.* gene expression values + SNPs + protein structures + phylogeny + geographical location of sample)

- **Point-based techniques**

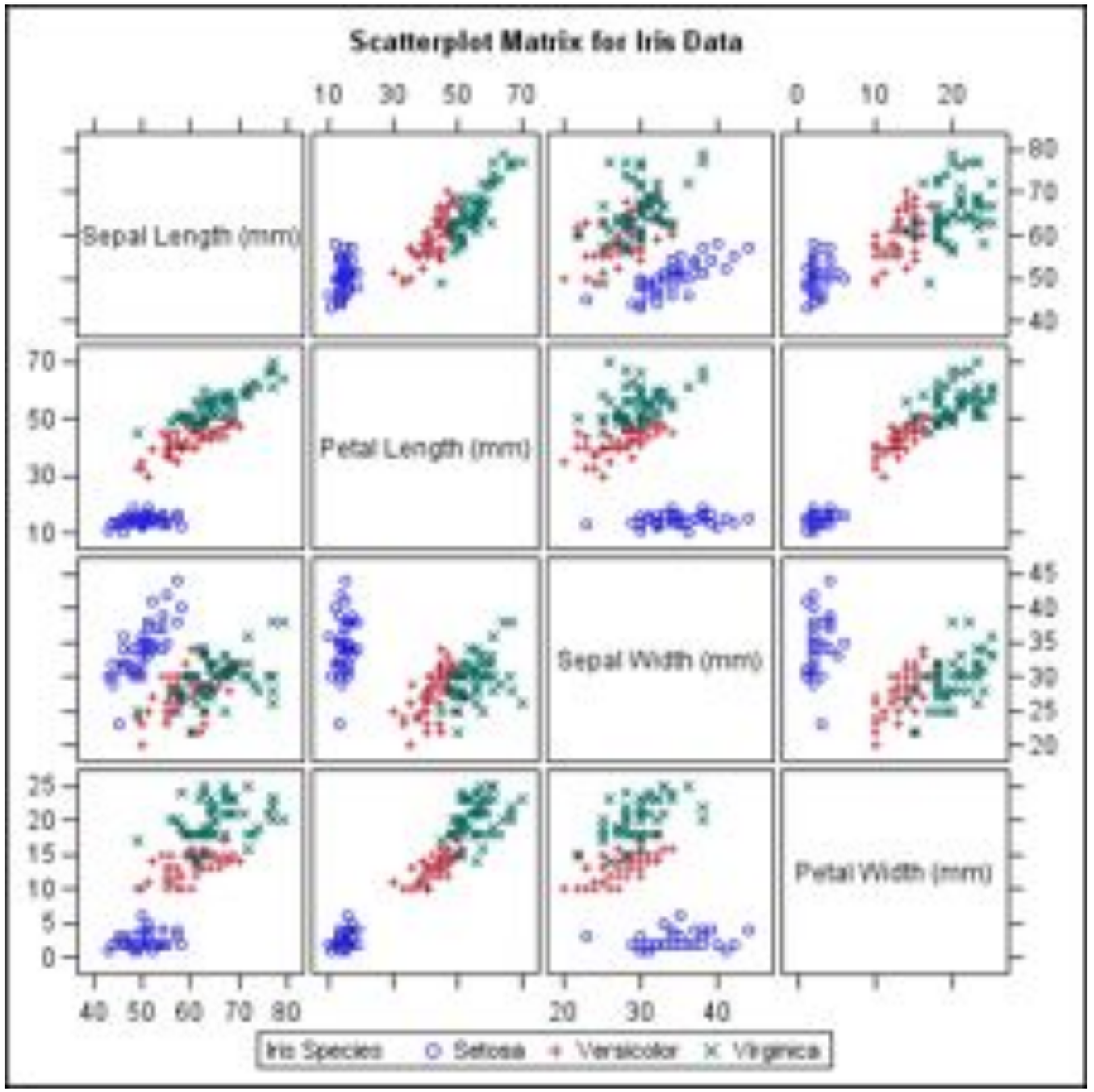
    - scatterplots and scatterplot matrices

    - radial axis plots (polar coordinates)

    - dimensionality reduction

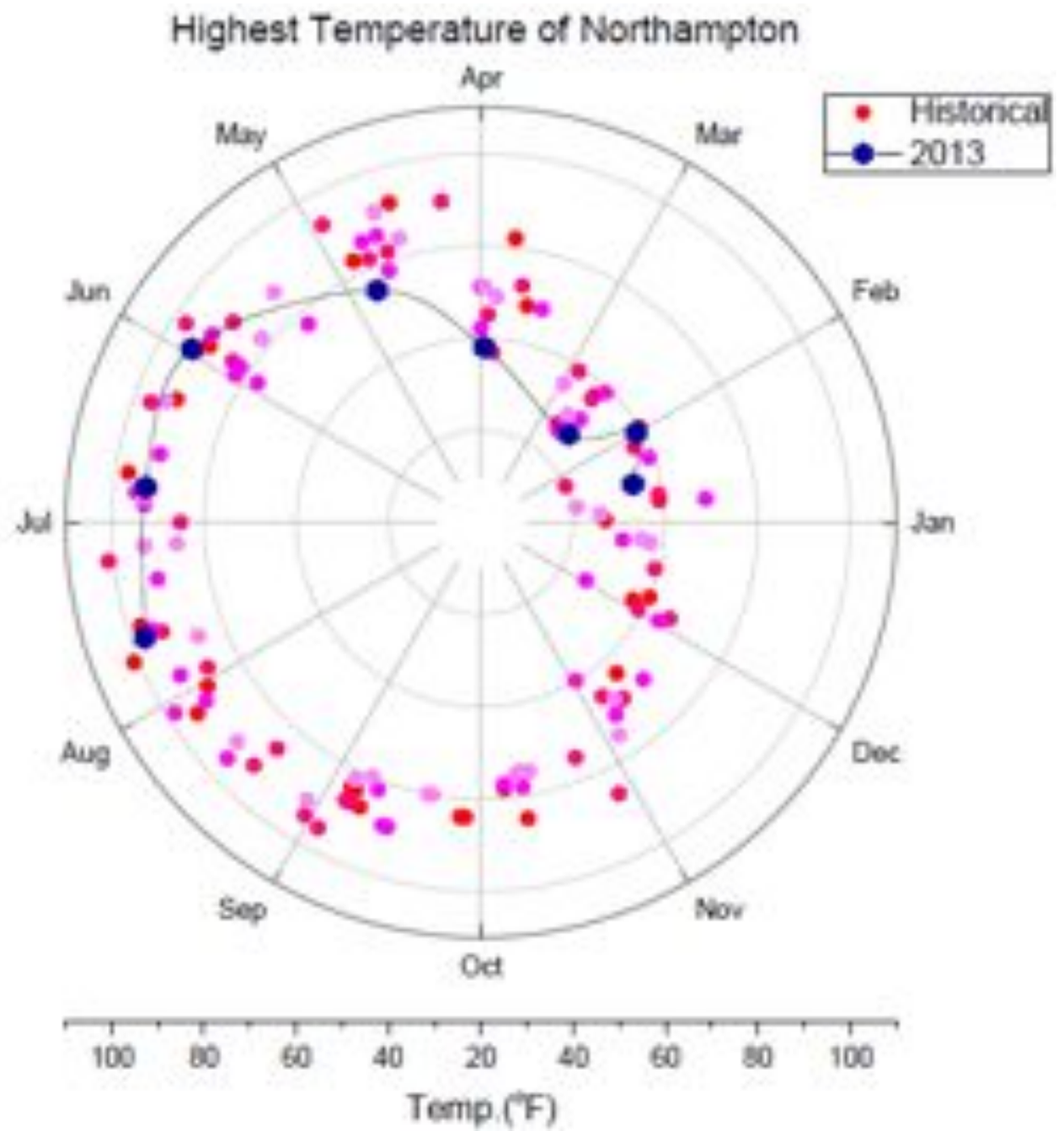
        - MDS, PCA: calculate most important combinations of dimensions

        - radviz: put all dimensions on circle and act as springs

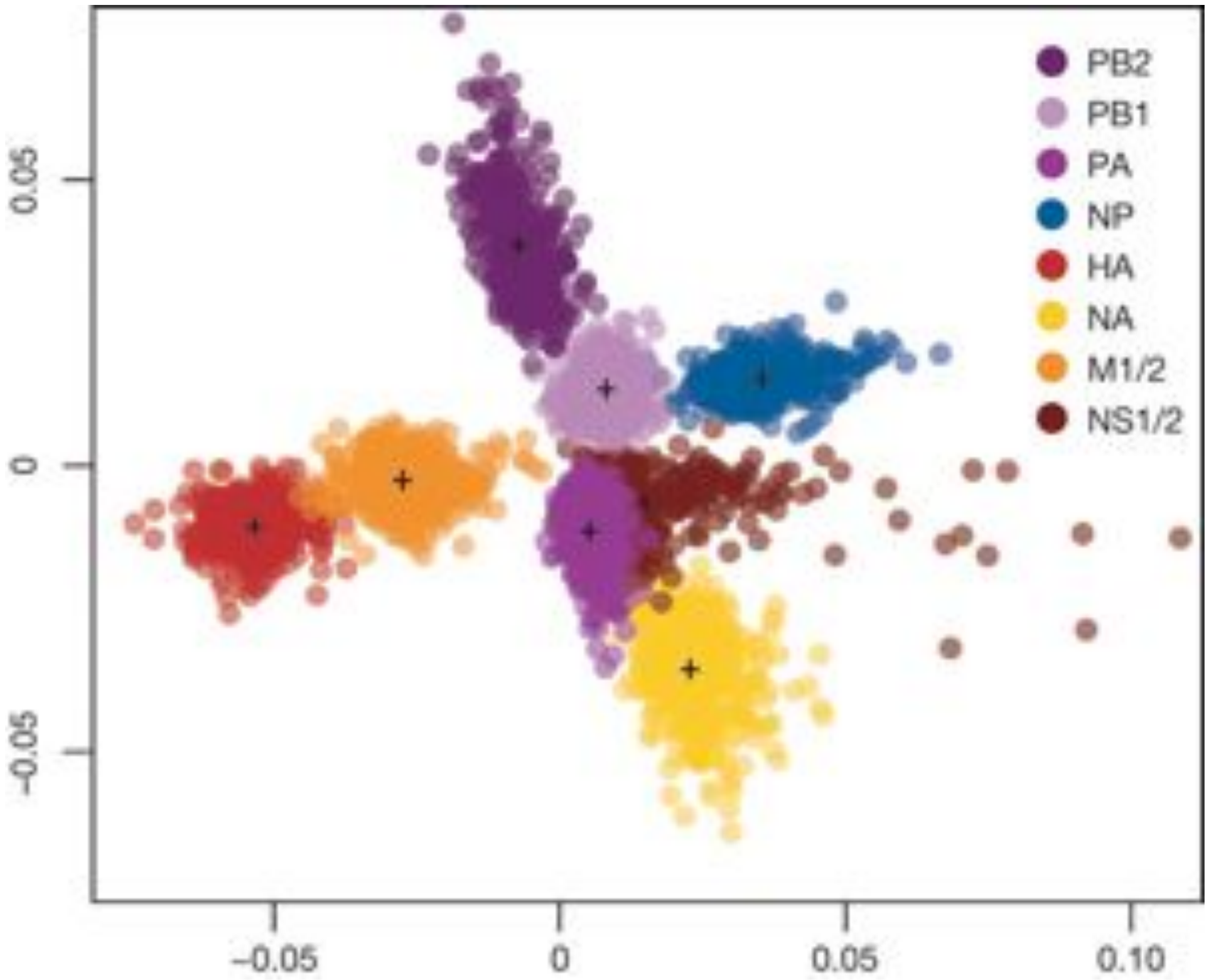


scatterplot matrix

(source: support.sas.com)

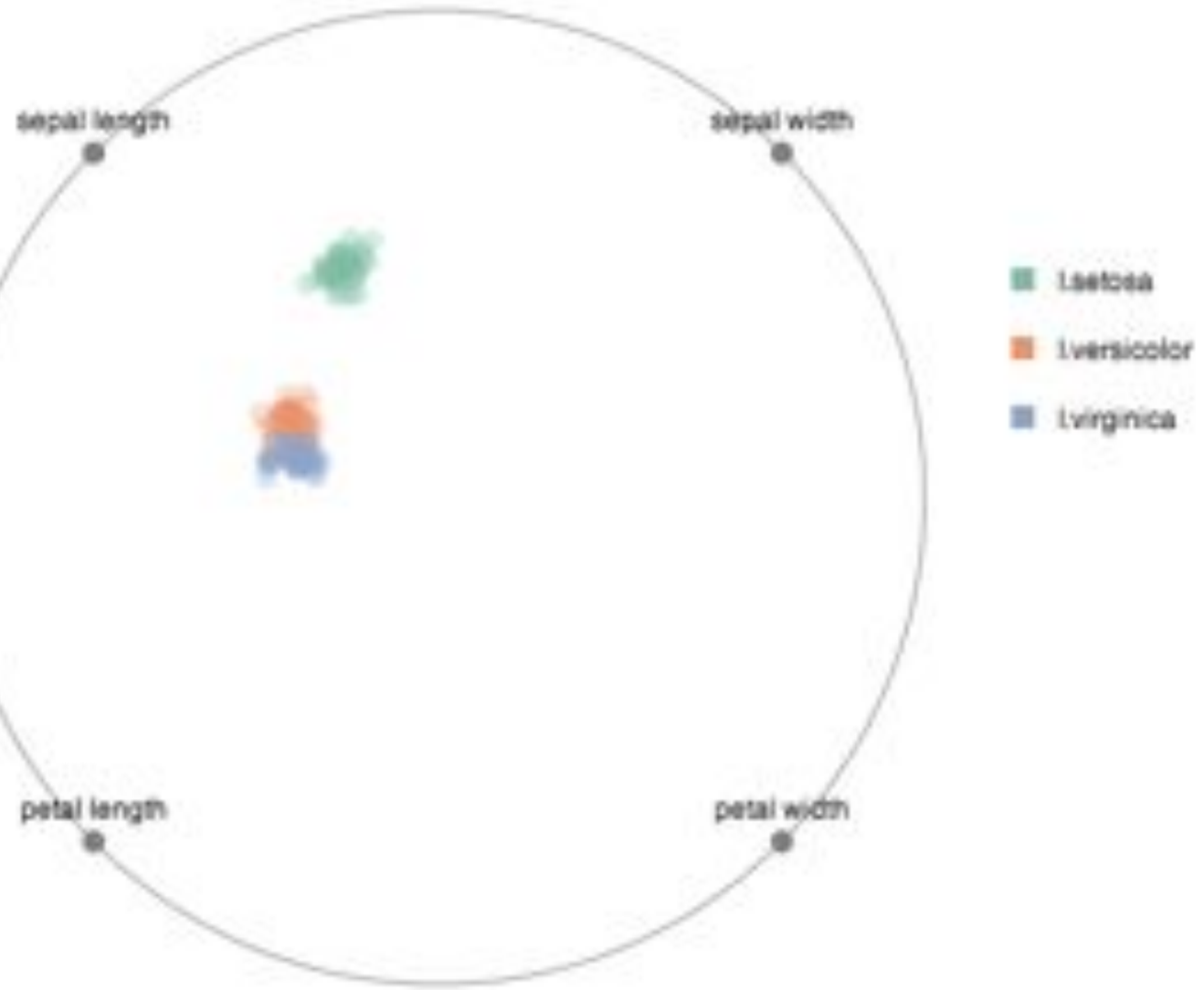


(source:originlab.com)



multi-dimensional scaling plot of distances between samples trees

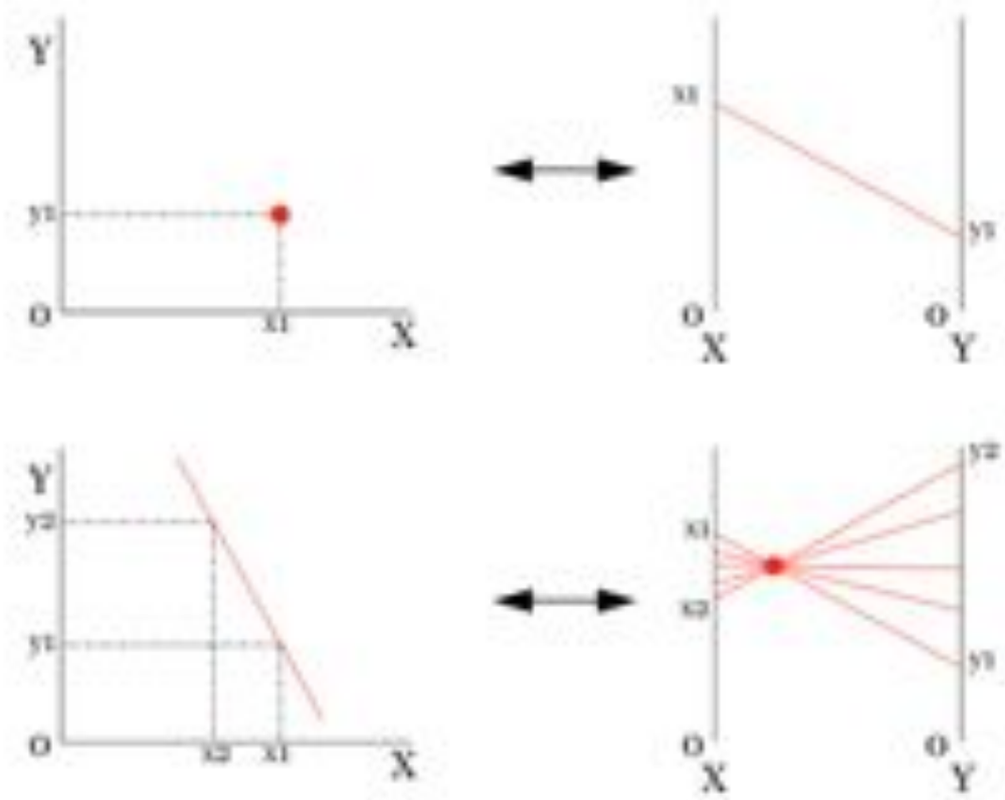
(source:doi:10.1038/nature06945)

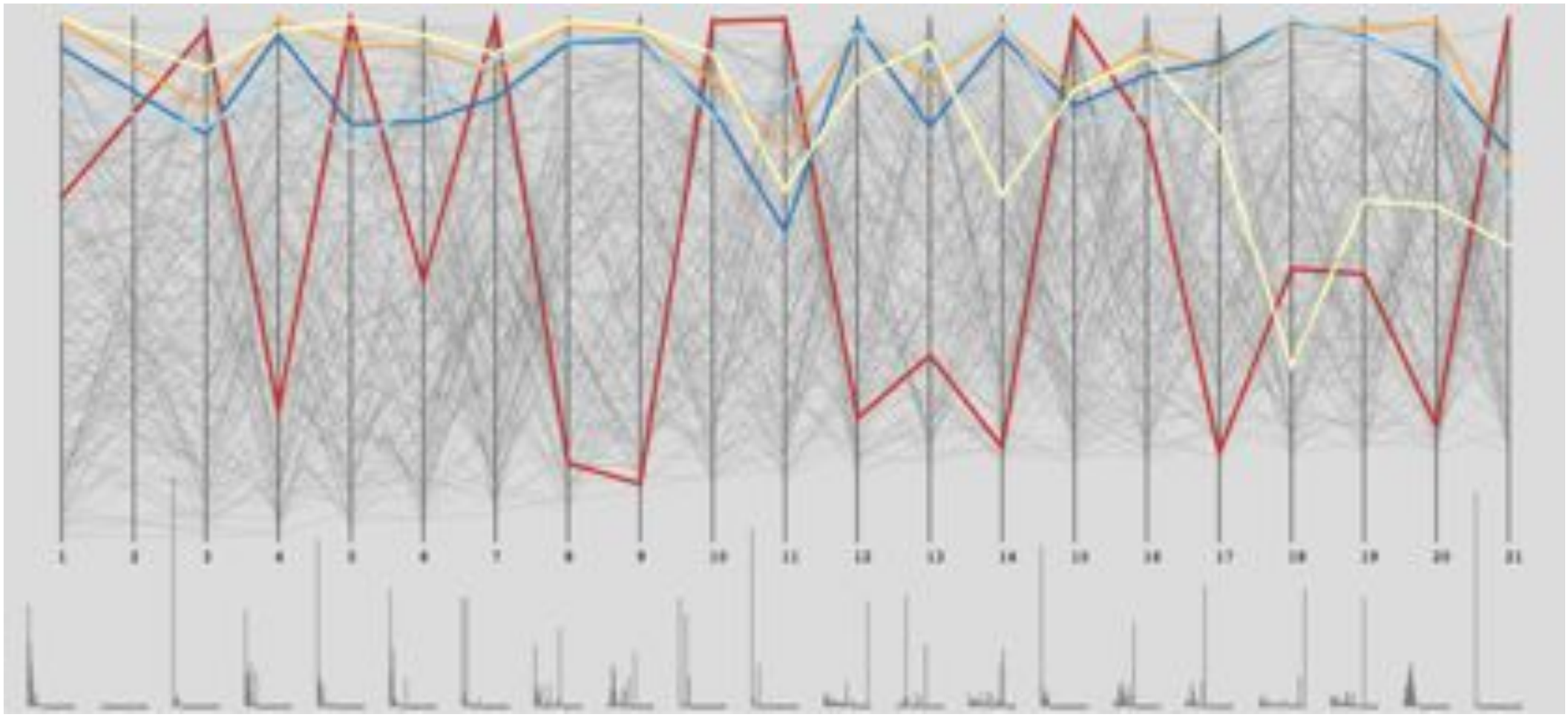

sepal length
sepal width
petal length
petal width
I.setosa
I.versicolor
I.virginica

radviz

- **Line-based techniques**
  - line graphs

- “parallel coordinates”: point in Euclidean space = line in parallel coordinate space and vice versa





parallel coordinates (Tour de France, 2005)

- **Region-based techniques**
  - barcharts & histograms
  - tabular displays (*e.g.* heatmap)
  - dimensional stacking

Scale-stack bar chart

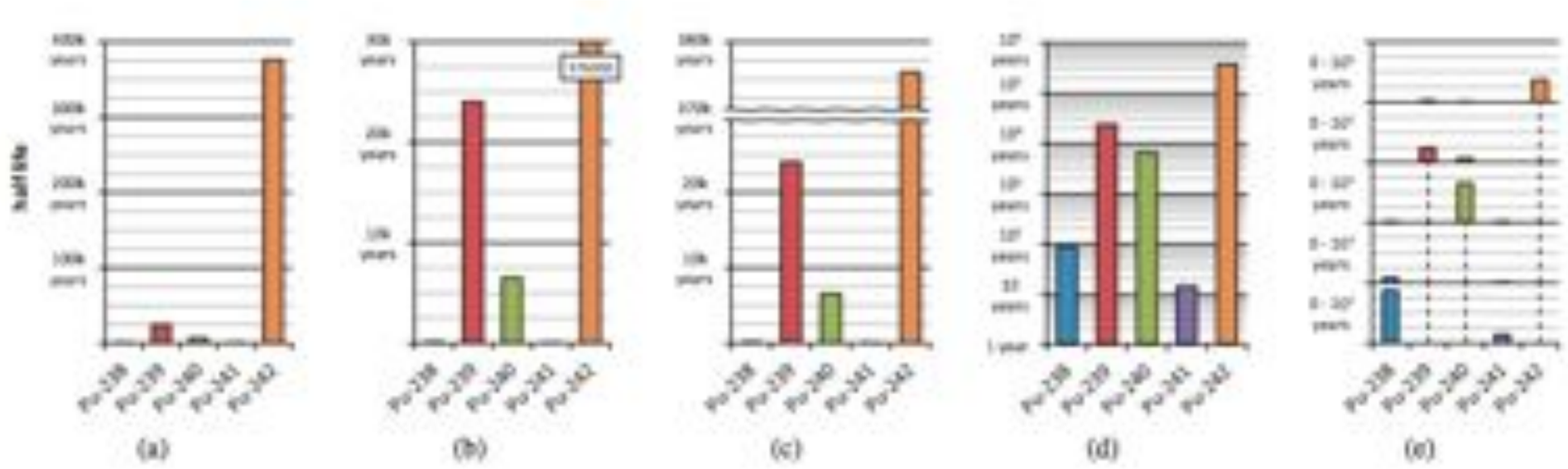
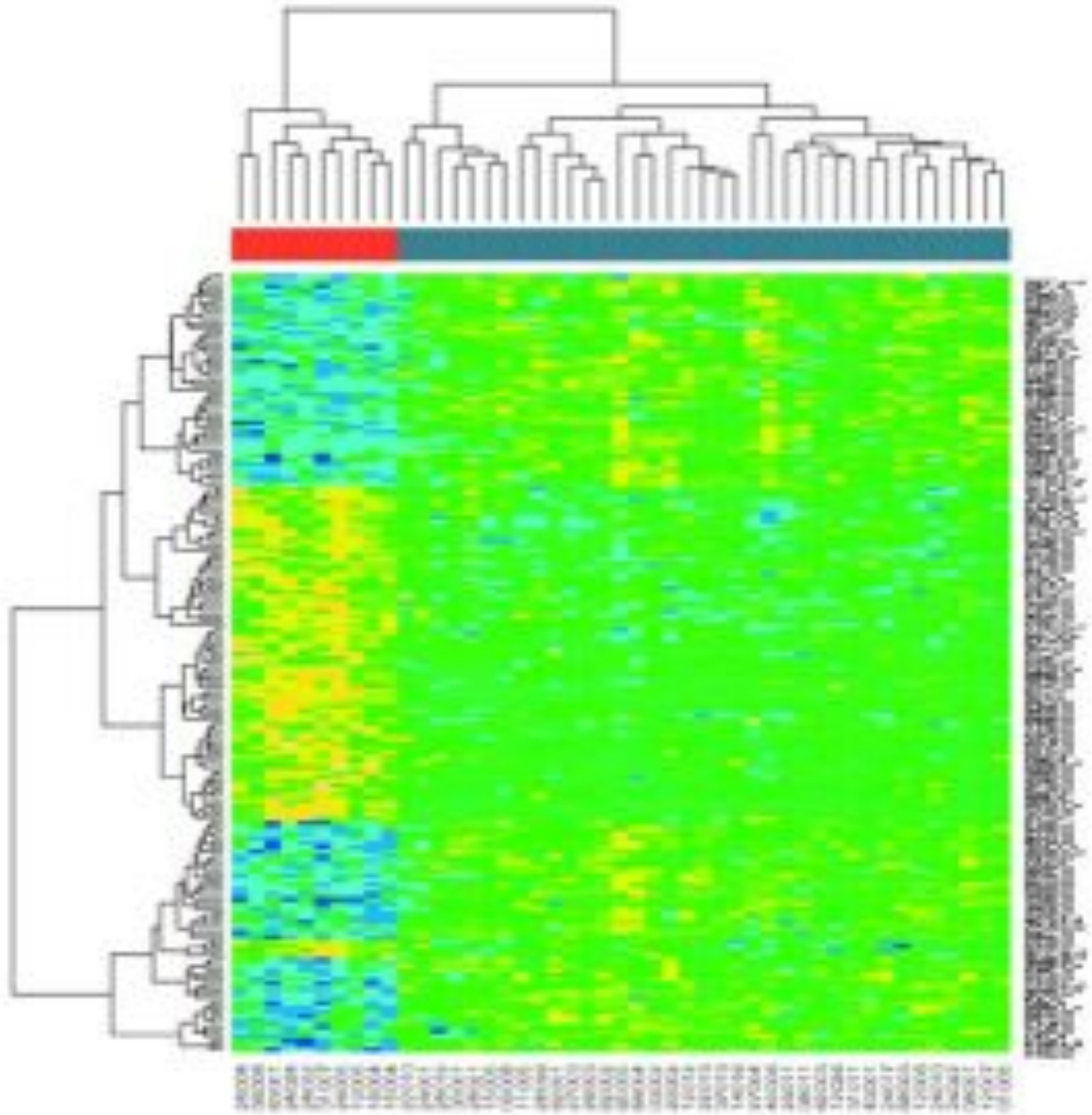


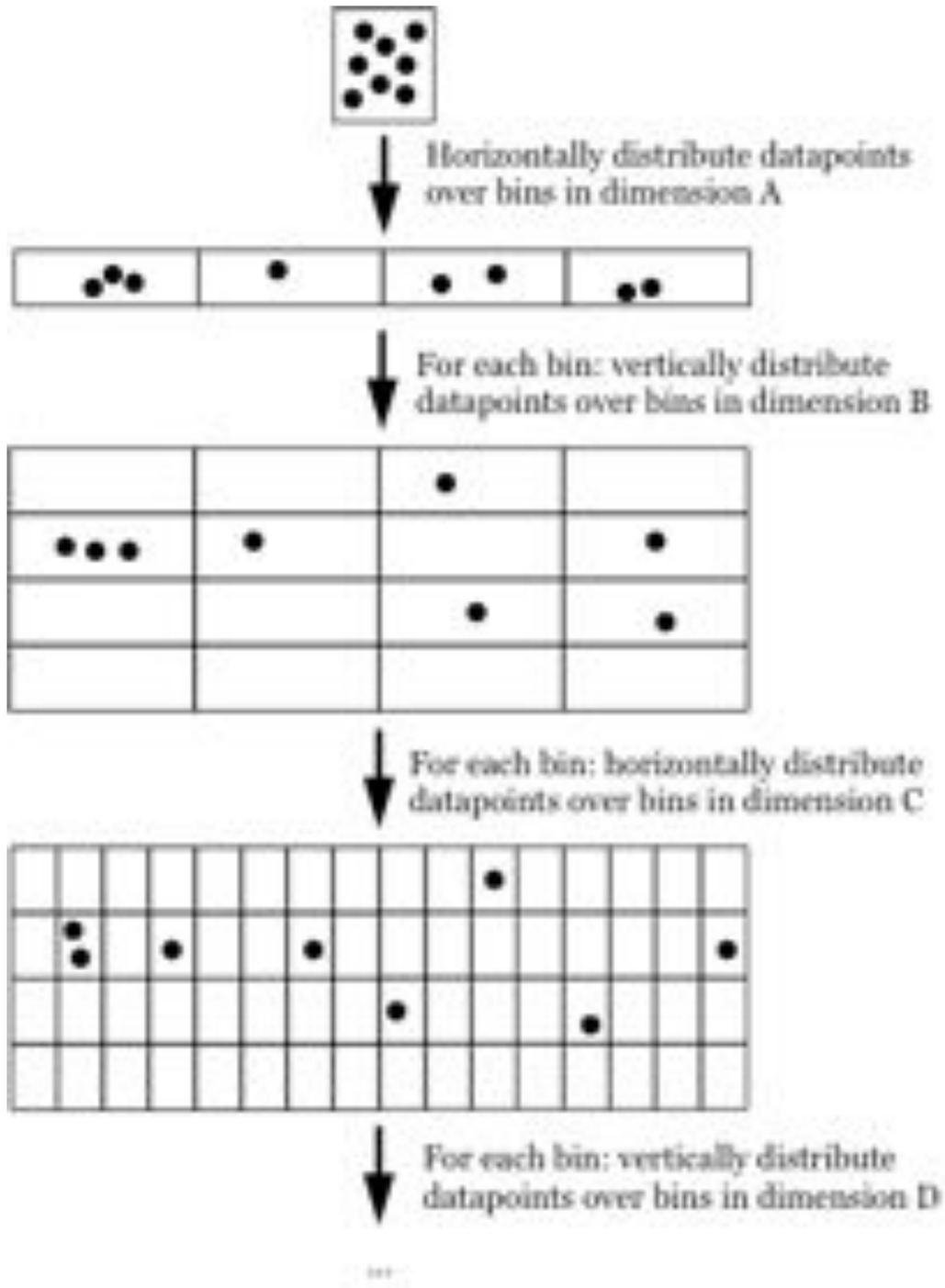
Figure 1: *Different bar charts for visualizing data with large value range. Half lives of different plutonium isotopes (see Sect. 6.1) are visualized with: (a) classic linear bar chart, (b) linear bar chart with cut-off bars, (c) linear bar chart with scale break, (d) logarithmic bar chart, and (e) our novel scale-stack bar chart.*

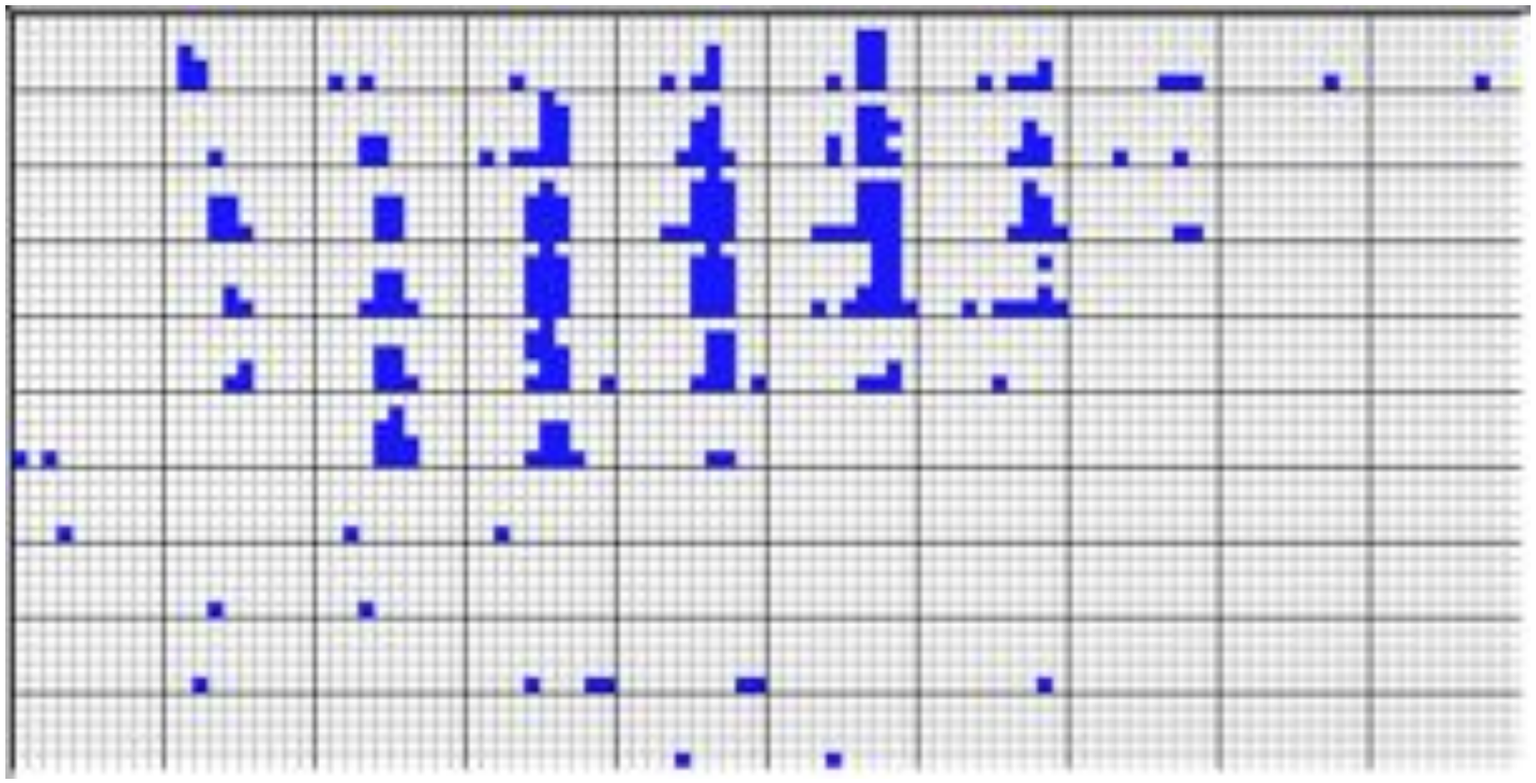
http://www.vis.uni-stuttgart.de/~sadlo/download/hlawatsch2013scaleStack.pdf



Heat map

(source:doi:10.1186/gb-2004-5-10-r80)


Horizontally distribute datapoints over bins in dimension A
For each bin: vertically distribute datapoints over bins in dimension B
For each bin: horizontally distribute datapoints over bins in dimension C
For each bin: vertically distribute datapoints over bins in dimension D
...

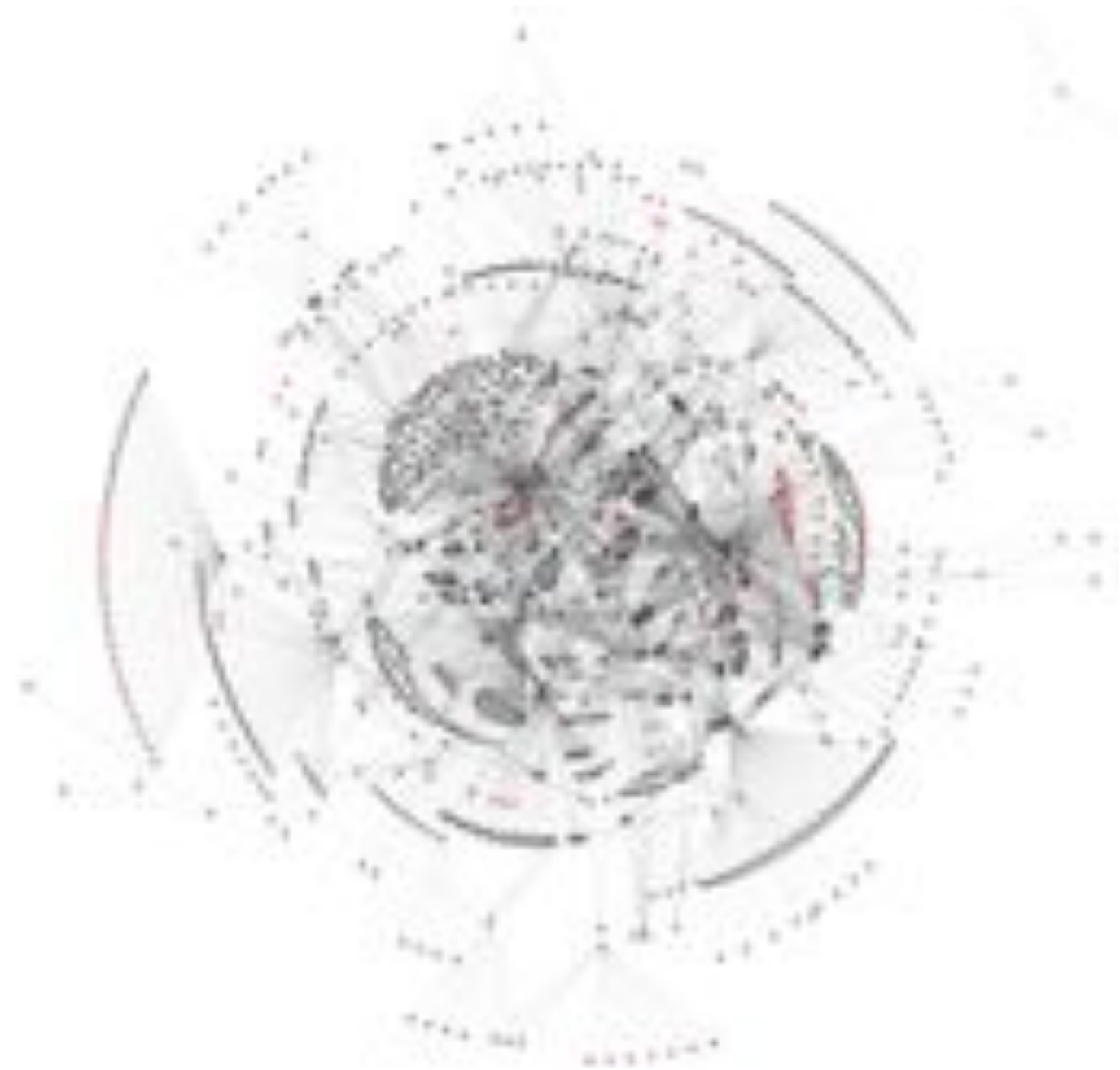


Dimensional stacking example of 4D drill-hole data: 3 spatial dimensions + ore grade as the fourth dimension

(source: http://web.cs.wpi.edu/)

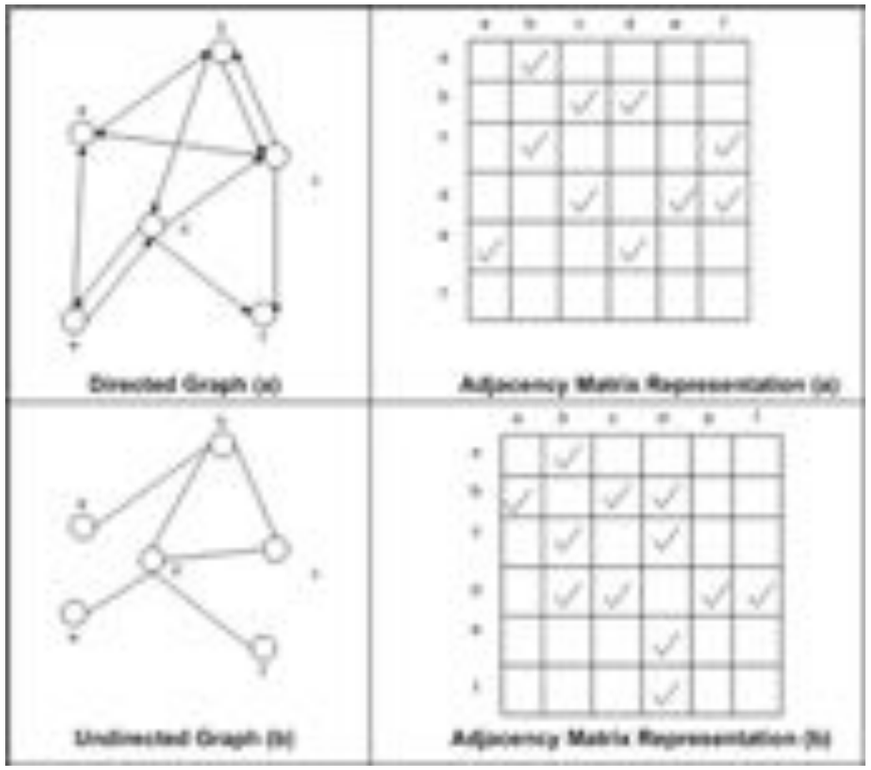
Visualization techniques for graphs/networks

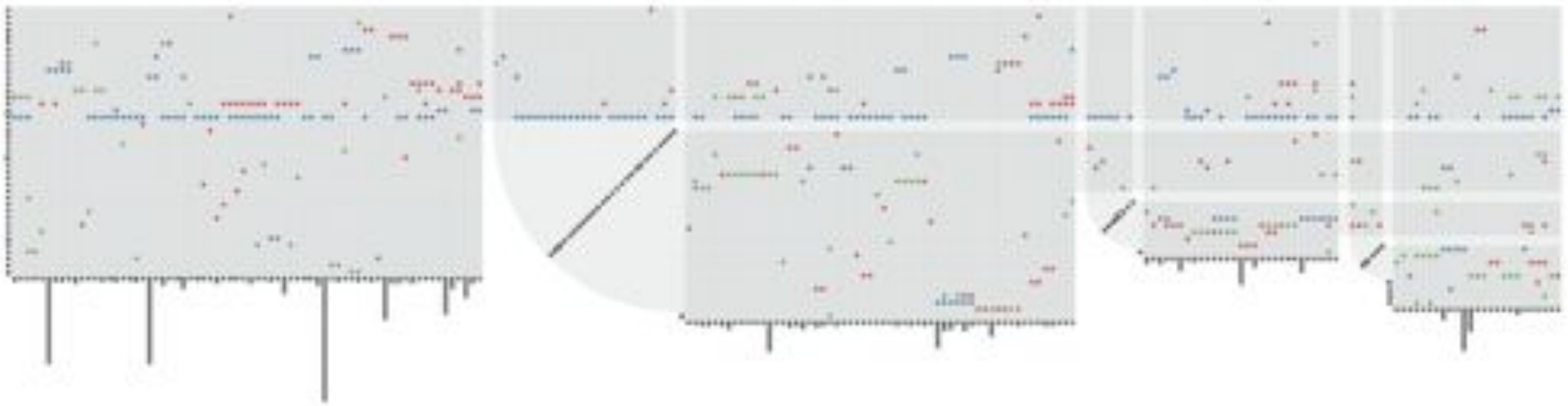
- node-link diagrams
  - max 20 nodes…



- adjacency matrix

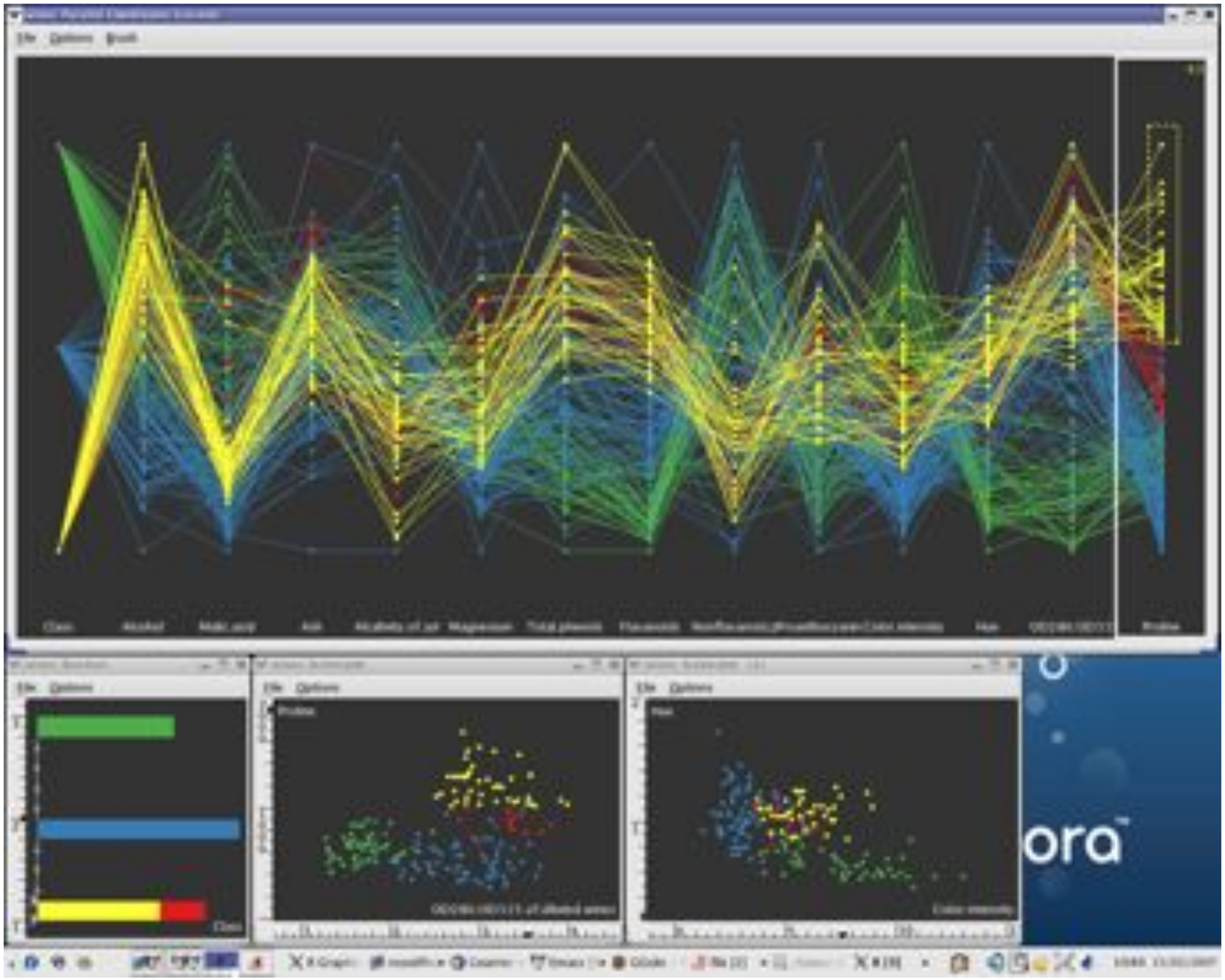
- compressed adjacency matrix (Dinkla *et al*, 2012)





Interaction concepts

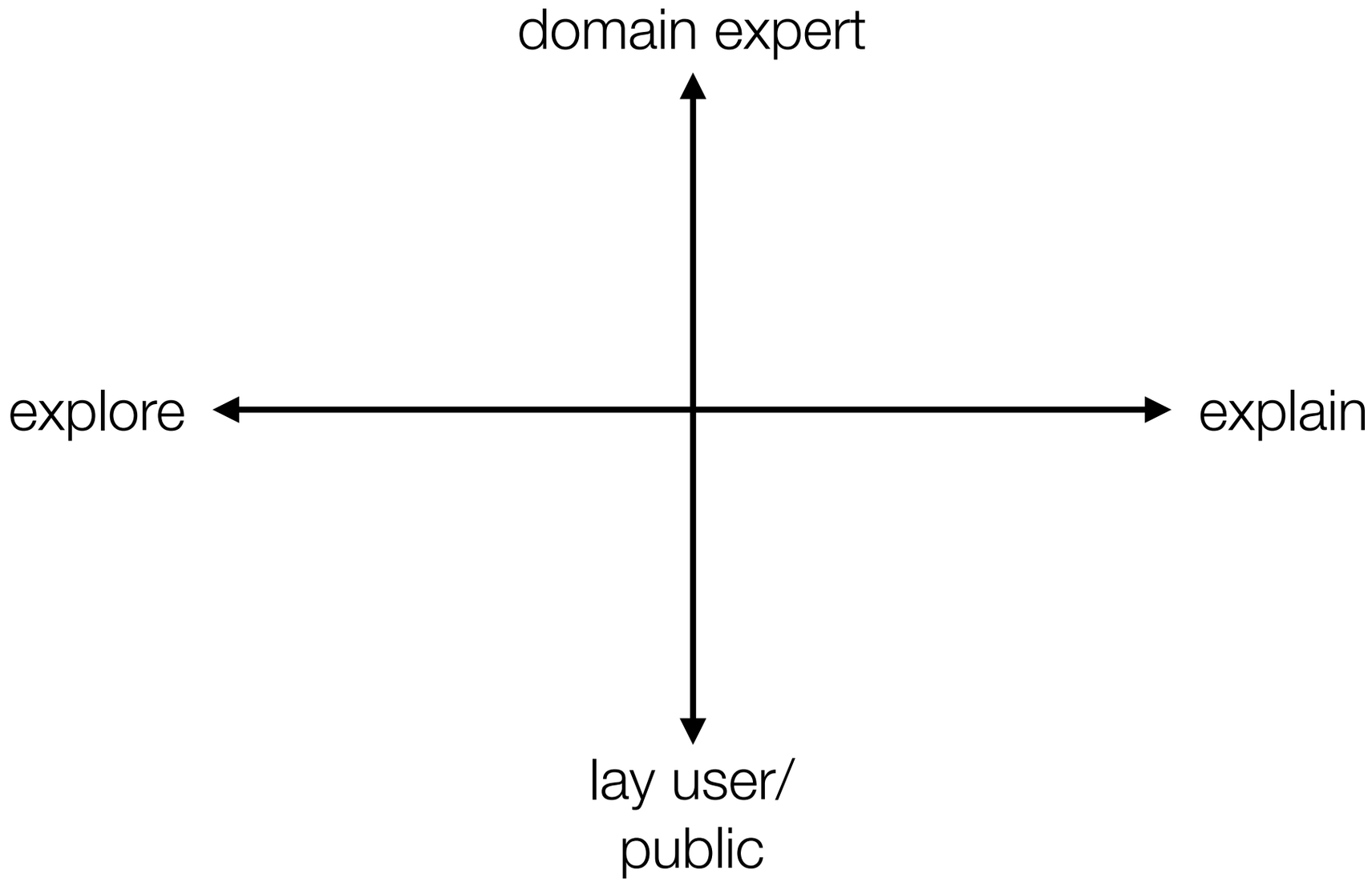
- operators:
  - navigation
  - selection
  - filtering
  - connecting (“brushing and linking”)



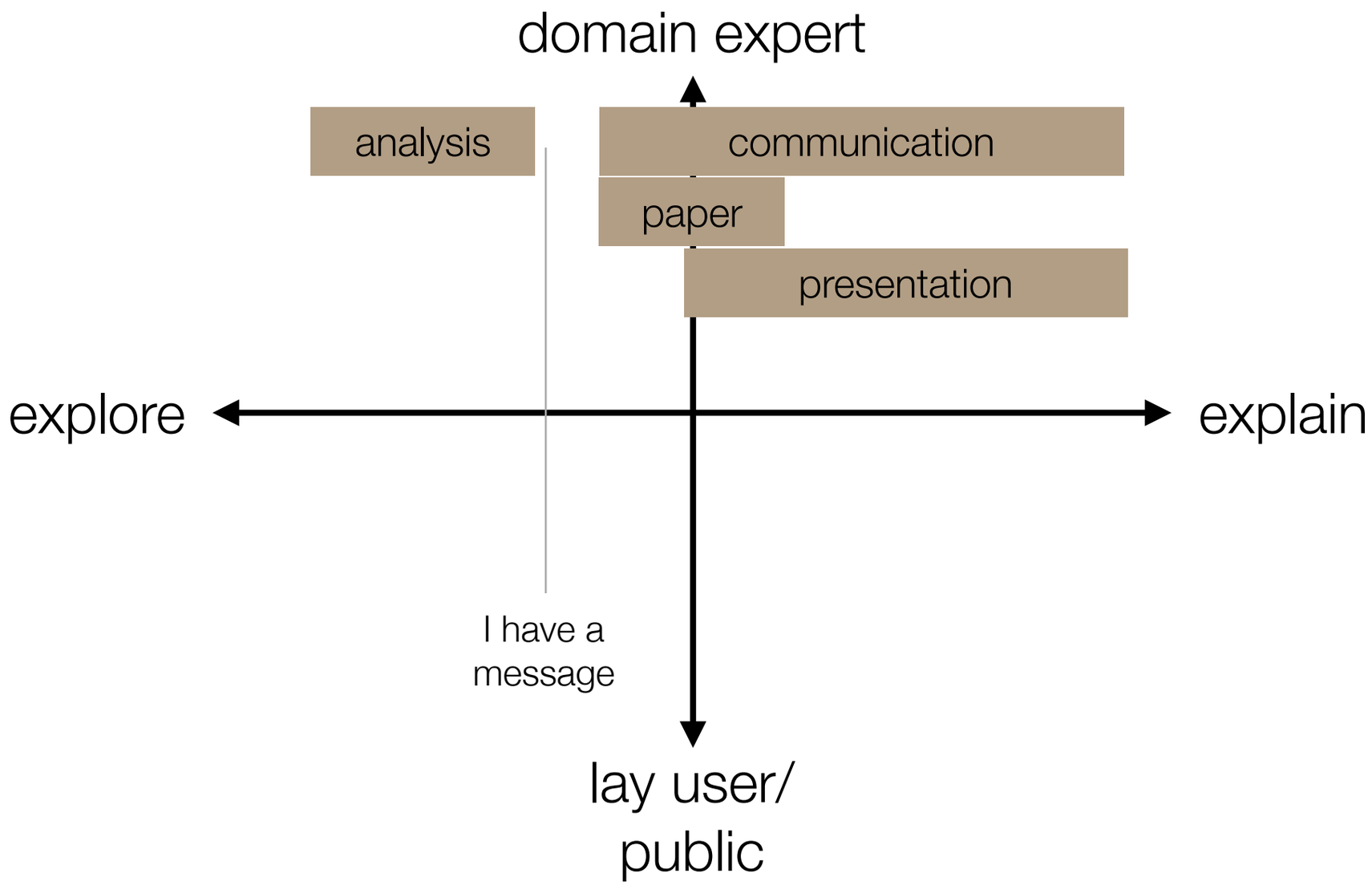
brushing and linking

(source: apiacoa.org)

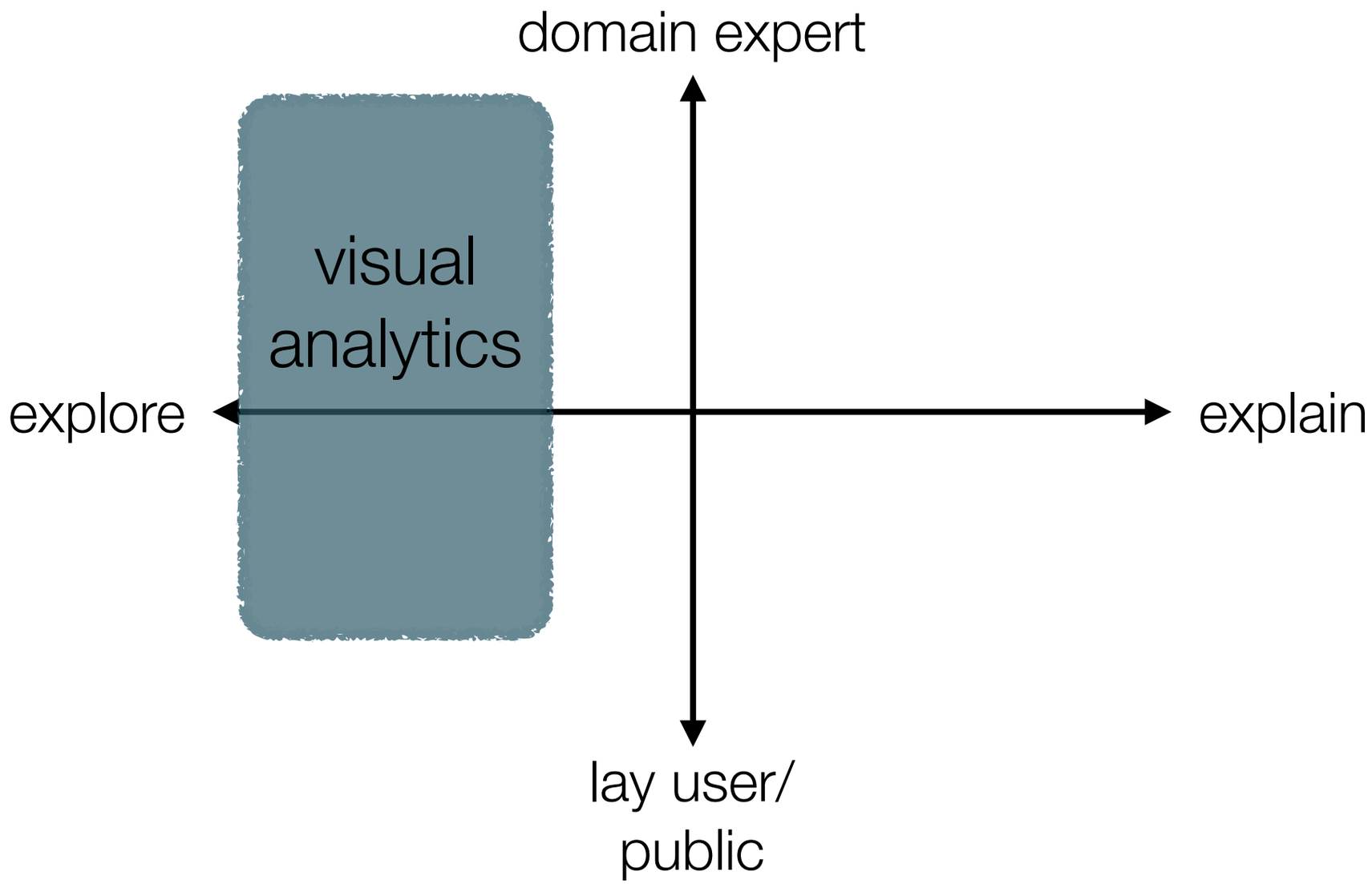
Data visualization framework



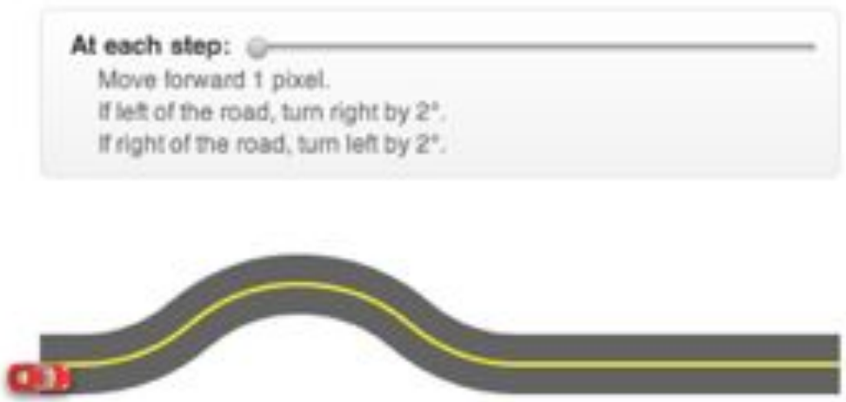
Data visualization framework

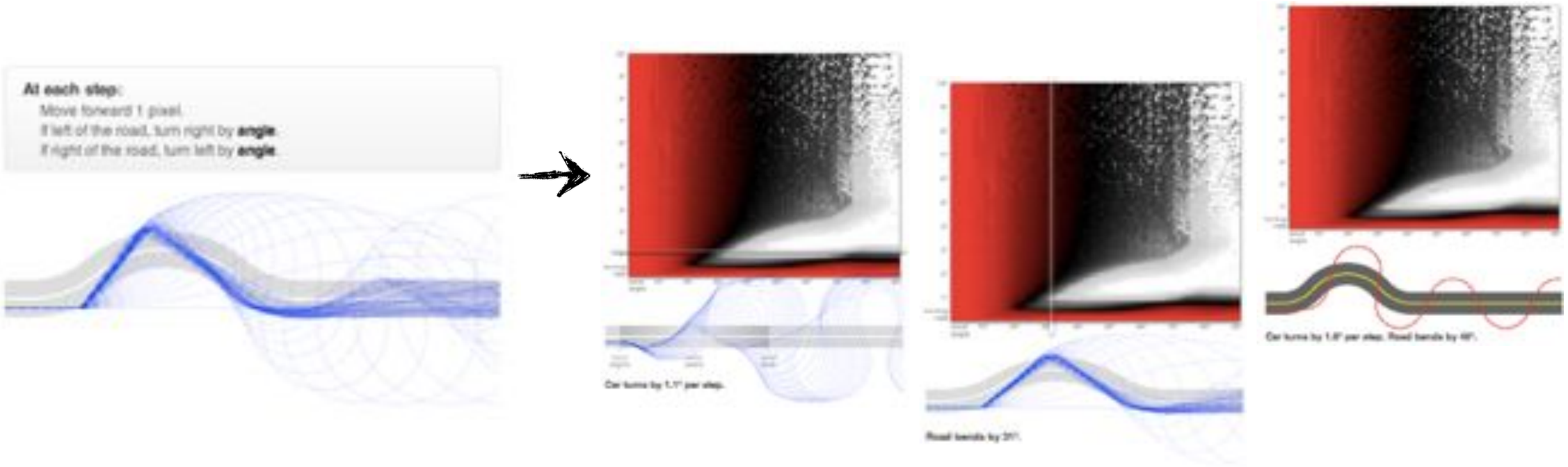


Data visualization framework



Bret Victor - Ladder of abstraction





Bret Victor - Ladder of abstraction

literal
lay user/public

abstract
domain expert

Design decision styles

1. **Unintended design** - Design decisions based on what's easiest to implement. Developer focuses on development and deployment without any consideration of what will happen when people use the tool.

2. **Self design** - Design decisions based on by developer's own use.

3. **Genius design** - Developer still does not look beyond own experience, but that experience is extensive.

4. **Task-focused design** - Developer investigates which actions the user wants/needs to perform.

5. **Goal-focused design** - Developer goes further than activities and investigates goals, needs and contexts of the user.

Design decision styles

1. **Unintended design** - Design decisions based on what's easiest to implement. Developer focuses on development and deployment without any consideration of what will happen when people use the tool.

2. **Self design** - Design decisions based on by developer's own use.

combine

3. **Genius design** - Developer still does not look beyond own experience, but that experience is extensive.

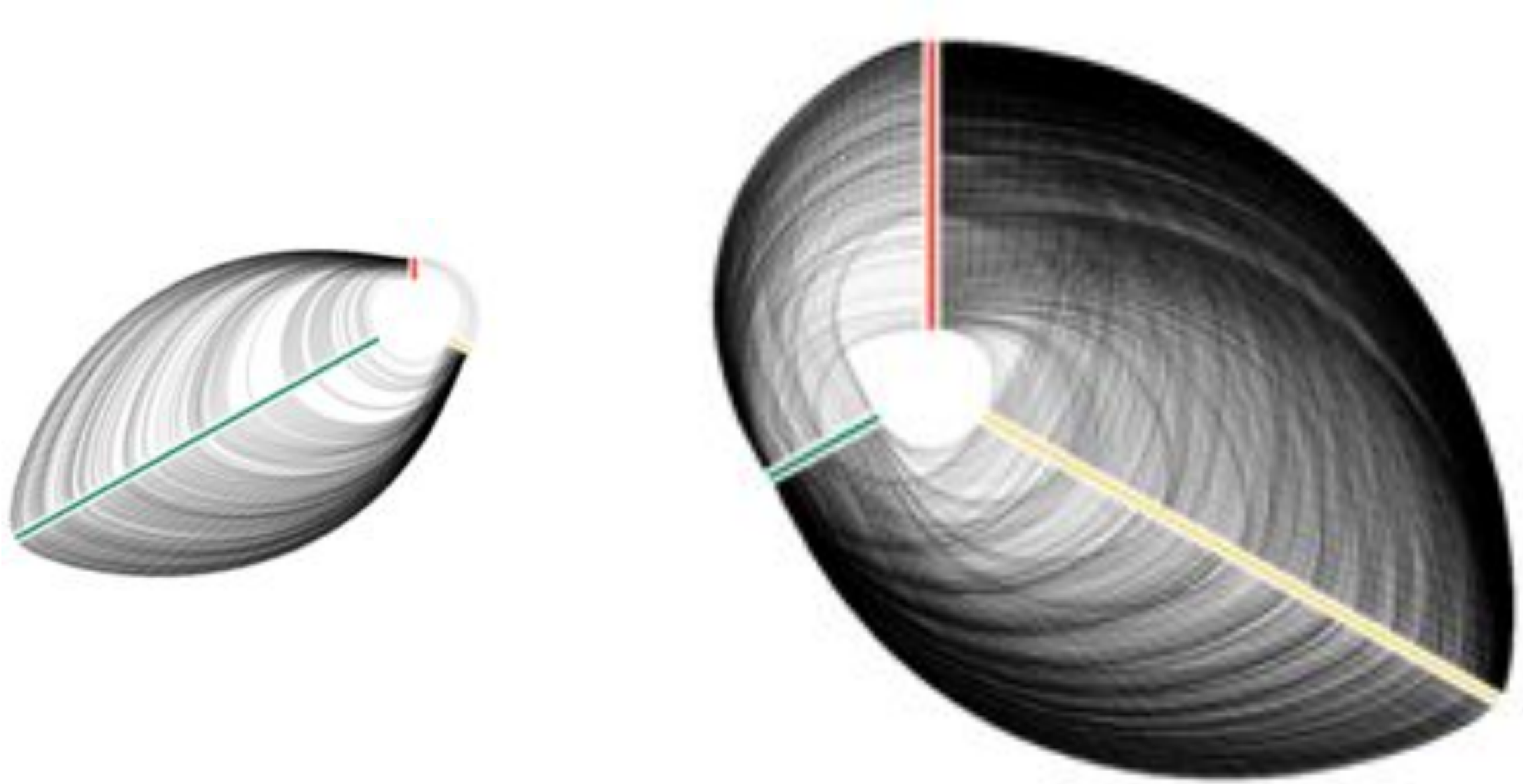
4. **Activity-focused design** - Developer investigates which actions the user wants/needs to perform.

5. **User-focused design** - Developer goes further than activities and investigates goals, needs and contexts of the user.

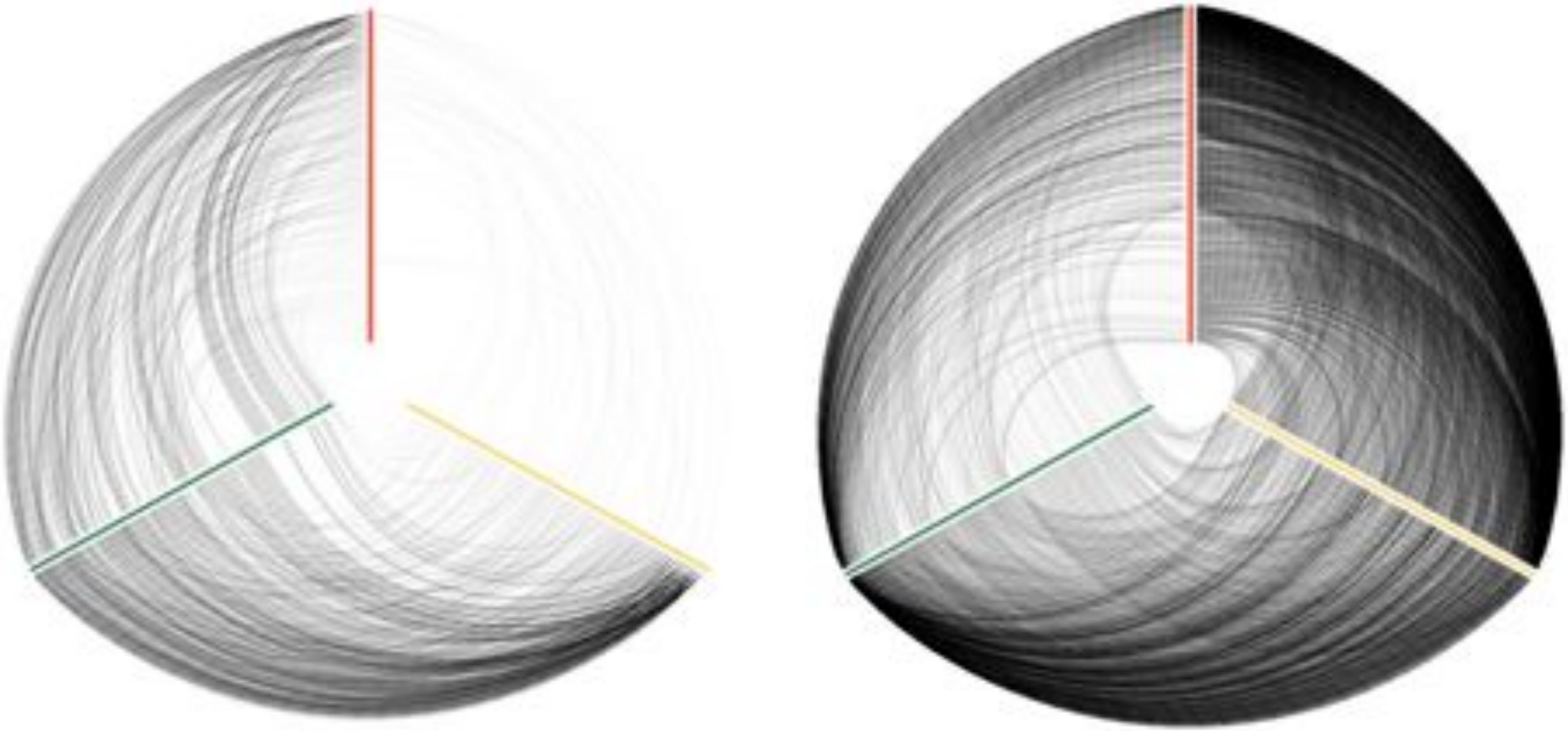
Examples hypothesis generation

For domain expert: what's my hypothesis?

Martin Krzywinski

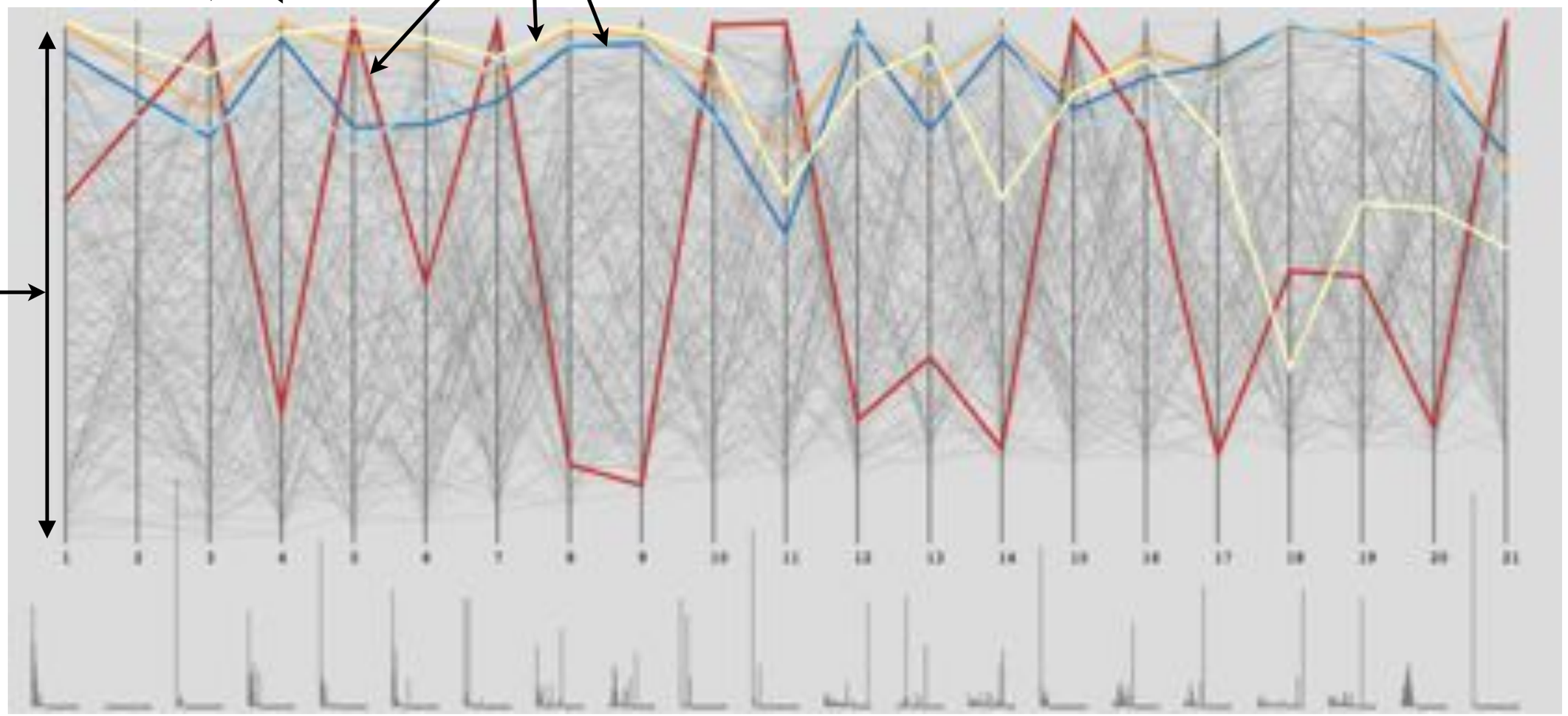


Martin Krzywinski



Martin Krzywinski

Tour de France, 2011



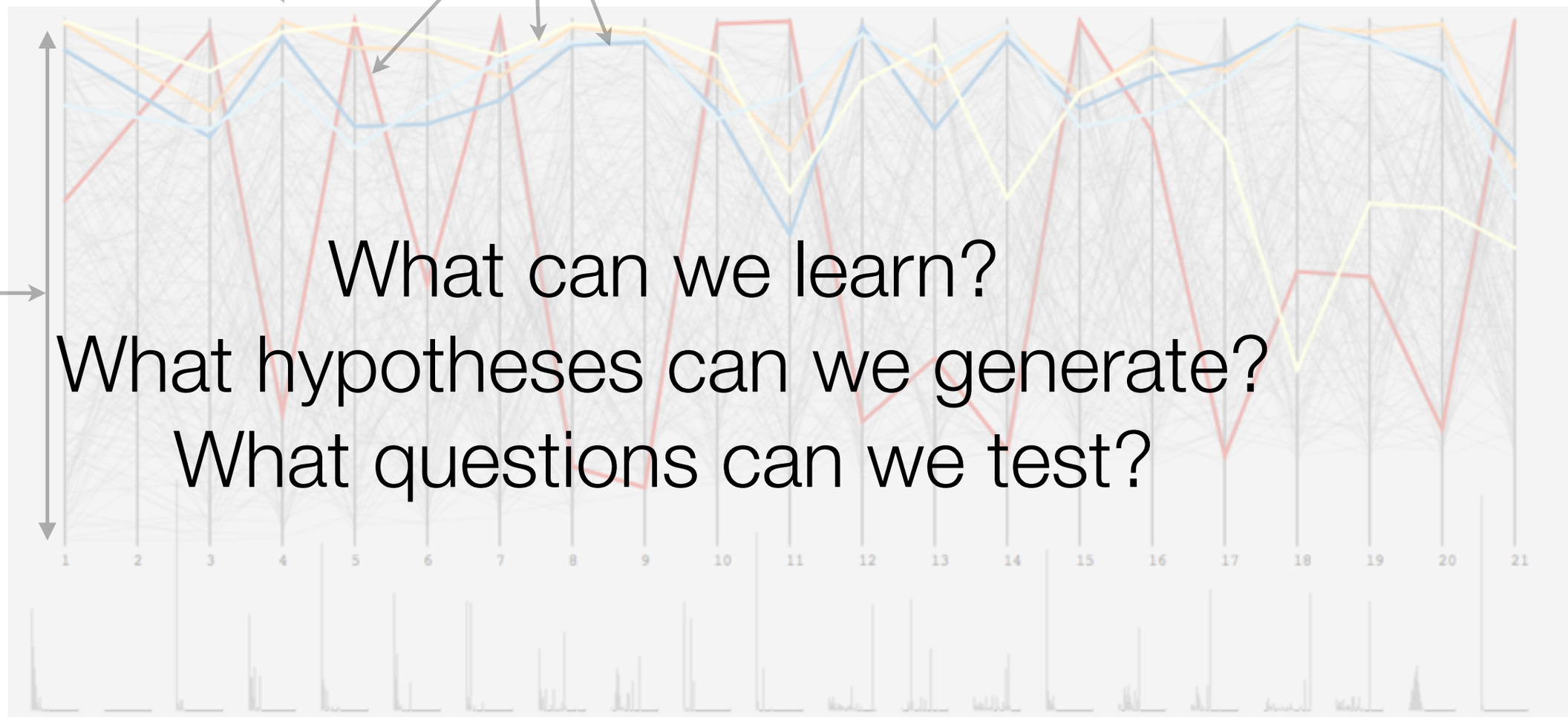
Cavendish: red
Evans: orange
Gilbert: yellow
Andy Schleck: light blue
Frank Schleck: dark blue

stages

riders

Tour de France, 2011

rank (who came first, second, ...)

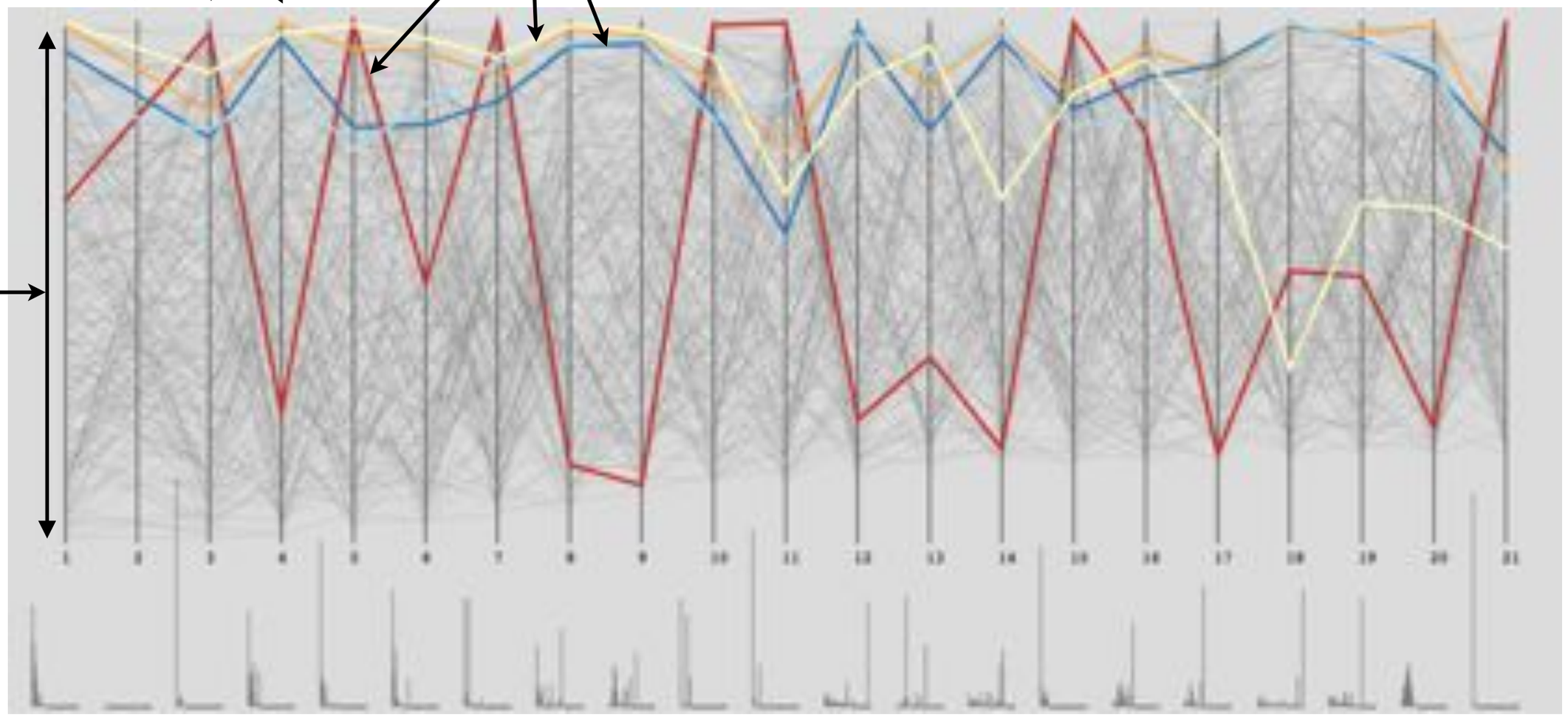


What can we learn?
What hypotheses can we generate?
What questions can we test?

distribution of arrival times

Cavendish: red
Evans: orange
Gilbert: yellow
Andy Schleck: light blue
Frank Schleck: dark blue

Tour de France, 2011



Cavendish: red
Evans: orange
Gilbert: yellow
Andy Schleck: light blue
Frank Schleck: dark blue

- Which trips are in mountains?
- When do riders start giving up and leaving the Tour?
- Is Cavendish an expert for the mountains or for flats?
- How does Philippe Gilbert perform across the Tour?
- What's with the group of riders performing bad in stages 18 and 20, but good in stage 19?

Overview of lecture

A. Why visual analytics?

B. Data visualization

- Data foundations
- Human perception foundations
- Visualization foundations and techniques

C. Visualization evaluation

D. Tools of the trade

E. Examples

F. Exercises

C. Visualization evaluation

Quantitative evaluation

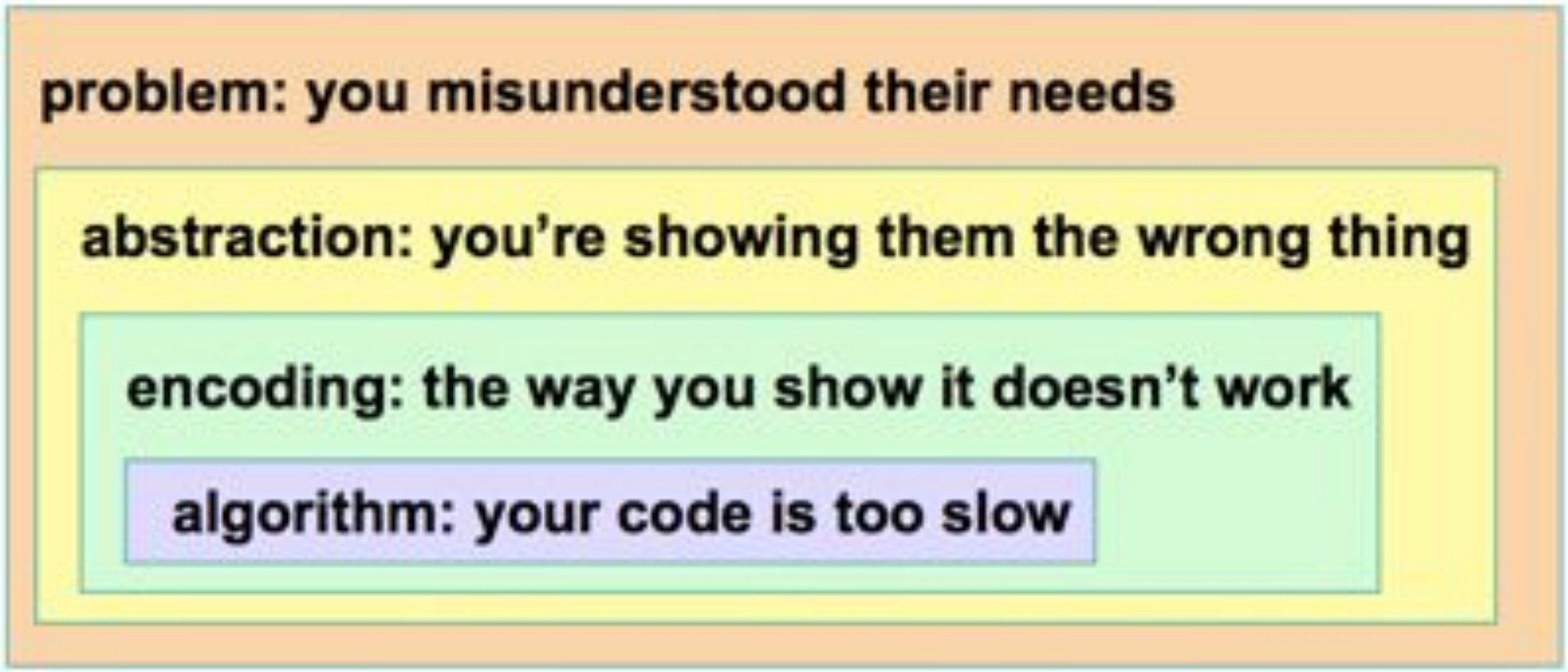
- spike data with known signal, and record time that it takes for user to find that signal => measure => run statistics “this visualization is better than that one”

- user tasks:
  - identify
  - locate
  - distinguish
  - categorize
  - cluster
  - rank
  - compare
  - associate
  - correlate

Qualitative evaluation

- very close interaction with domain expert
- let expert use the interactive visualization and try to find out what insights he/she gained from the visualization
  - experimenter observation
  - think-aloud protocol
  - collecting participant opinions

Make sure you measure the right thing



Overview of lecture

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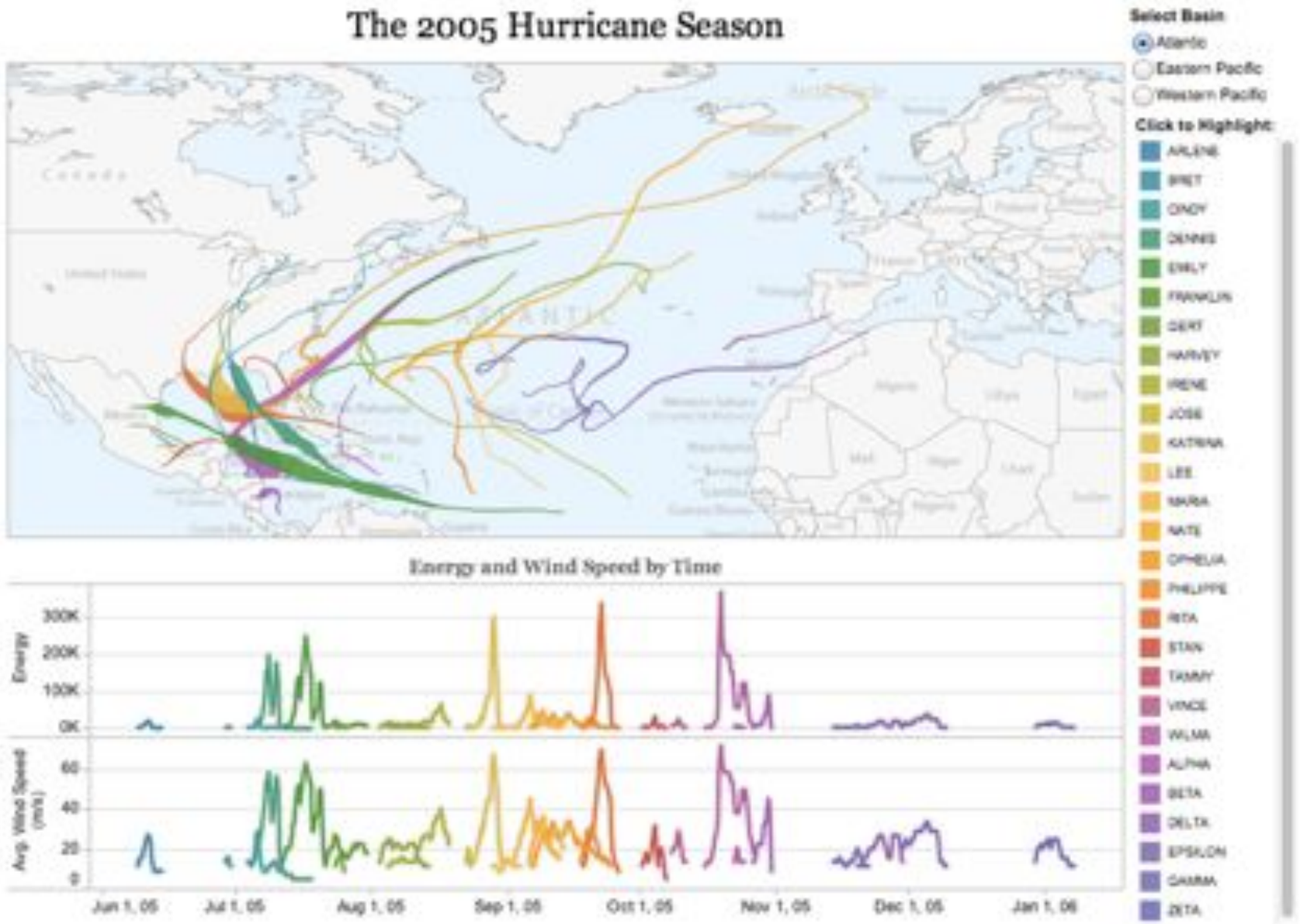
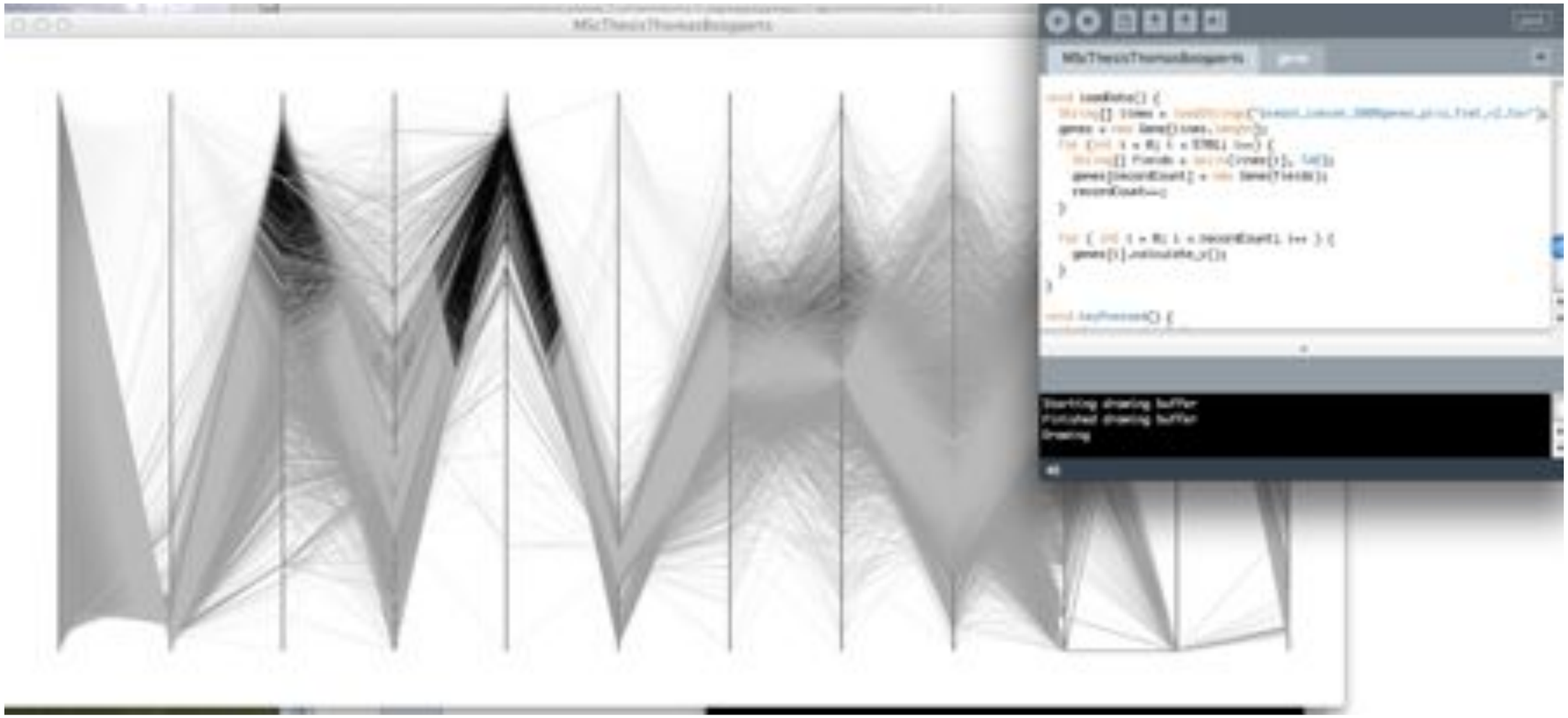
Tableau


The 2005 Hurricane Season
Select Basin
Atlantic
Eastern Pacific
Western Pacific
Click to Highlight:
ARLENE
BRET
CINDY
DENNIS
EMILY
FRANKLIN
GERT
HARVEY
IRENE
JOSE
KATRINA
LEE
MARIA
NATE
OPHELIA
PHILIPPE
RITA
STAN
TAMMY
VINCE
WILMA
ALPHA
BETA
DELTA
EPSILON
GAMMA
ZETA
Energy and Wind Speed by Time
Energy
300K
200K
100K
0K
Avg Wind Speed (m/s)
60
40
20
0
Jun 1, 05
Jul 1, 05
Aug 1, 05
Sep 1, 05
Oct 1, 05
Nov 1, 05
Dec 1, 05
Jan 1, 06

Processing - http://processing.org

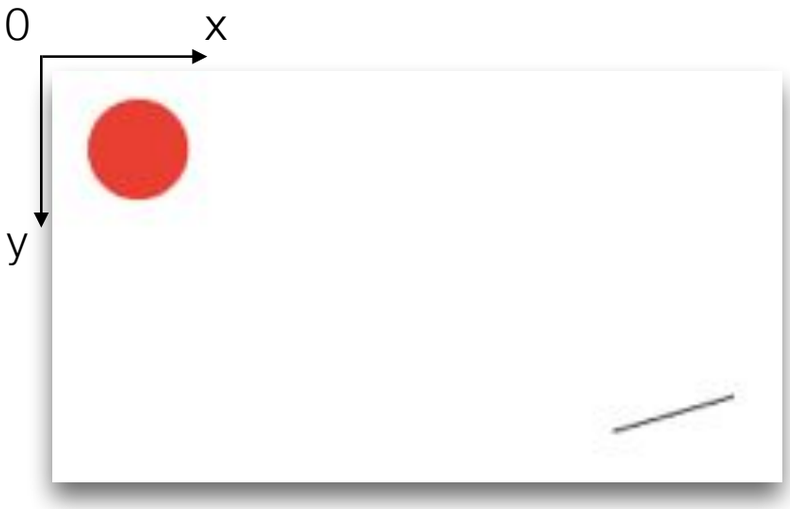
- java



SVG

my_first_graphic.html

```
1  <html>
2  <body>
3    <svg xmlns="http://www.w3.org/2000/svg" xmlns:xlink="http://www.w3.org/1999/xlink">
4      <line x1="239" y1="212" x2="287" y2="198" stroke="black"></line>
5      <circle cx="50" cy="100" r="20" fill="red"></circle>
6    </svg>
7  </body>
8  </html>
```

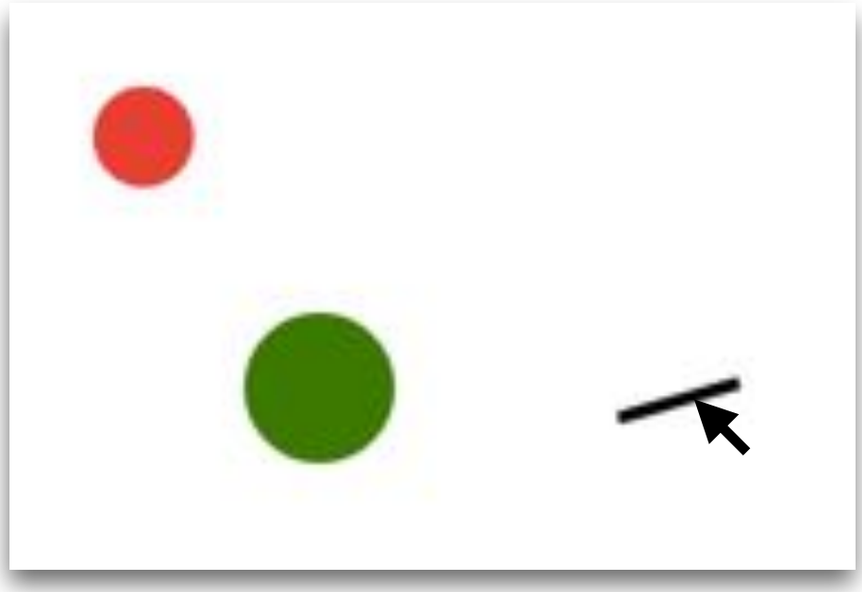


http://www.w3.org/TR/SVG/

http://www.w3schools.com/SVG/default.asp

https://developer.mozilla.org/en-US/docs/Web/SVG/Element

Adding some interactivity



```
<!DOCTYPE html>
<html>
    <head>
        <style>
            circle:hover {
                opacity: 0.5;
            }
            line:hover {
                stroke-width: 5;
            }
        </style>
    </head>
    <body>
        <svg xmlns="http://www.w3.org/2000/svg" xmlns:xlink="http://www.w3.org/1999/xlink">
            <line x1="233" y1="212" x2="287" y2="198" stroke="black"></line>
            <circle cx="80" cy="100" r="30" fill="red"></circle>
            <a xlink:href="http://www.standaard.be">
                <circle cx="120" cy="200" r="30" fill="green" />
            </a>
        </svg>
    </body>
</html>
```

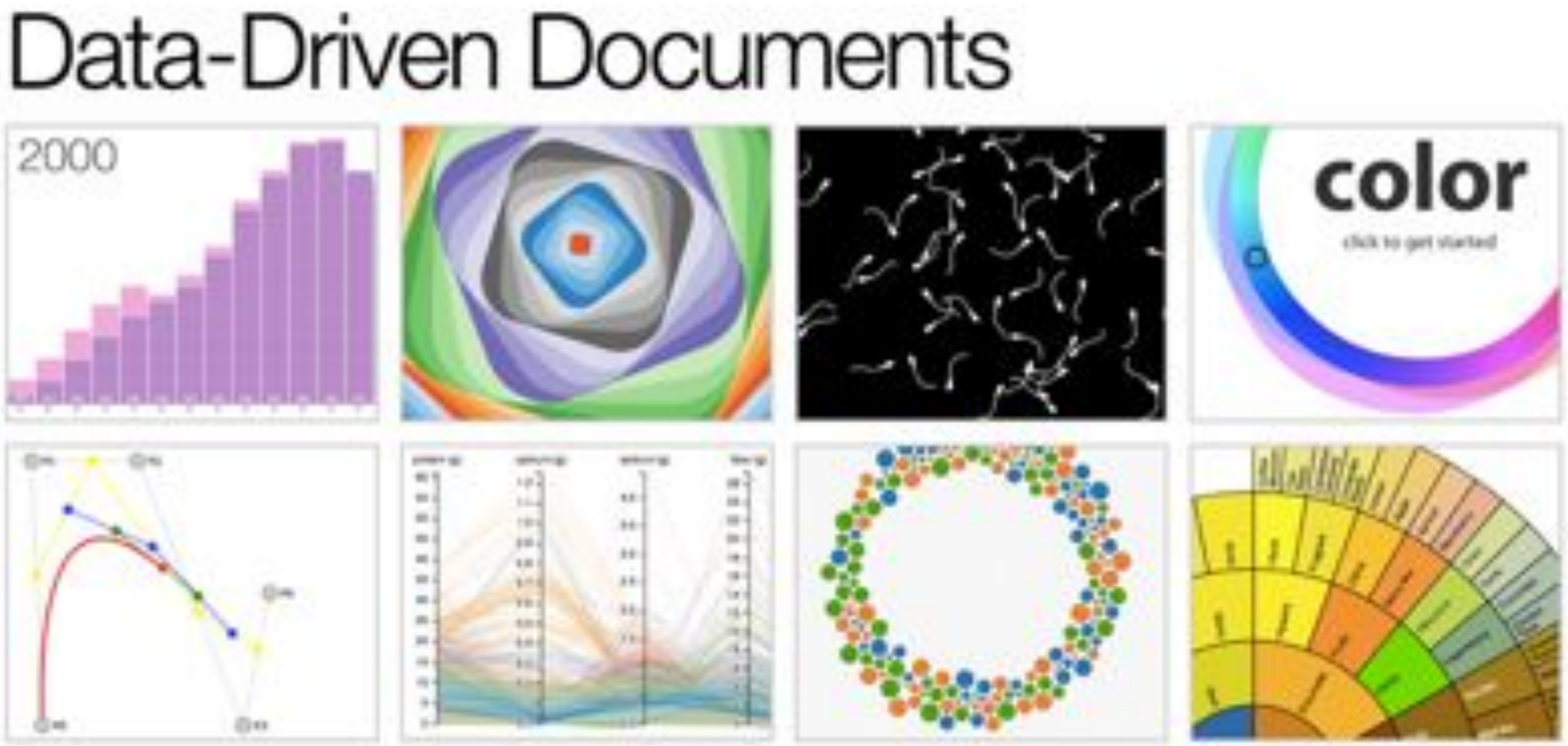
Perl::SVG

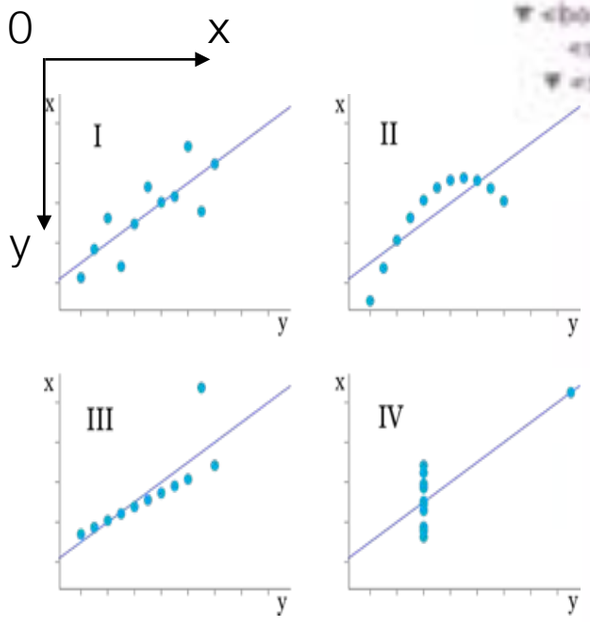
```perl
#!/usr/bin/perl
use strict;
use warnings;

use SVG;

# create an SVG object with a size of 40x40 pixels
my $svg = SVG->new(
   width  => 40,
   height => 40,
);

# add a circle
$svg->circle(
   cx => 20,
   cy => 20,
   r  => 18,
);


# now render the SVG object, implicitly use svg namespace
print $svg->xmlify;
```

http://www.w3schools.com/SVG/default.asp

D3 - http://d3js.org/

- javascript





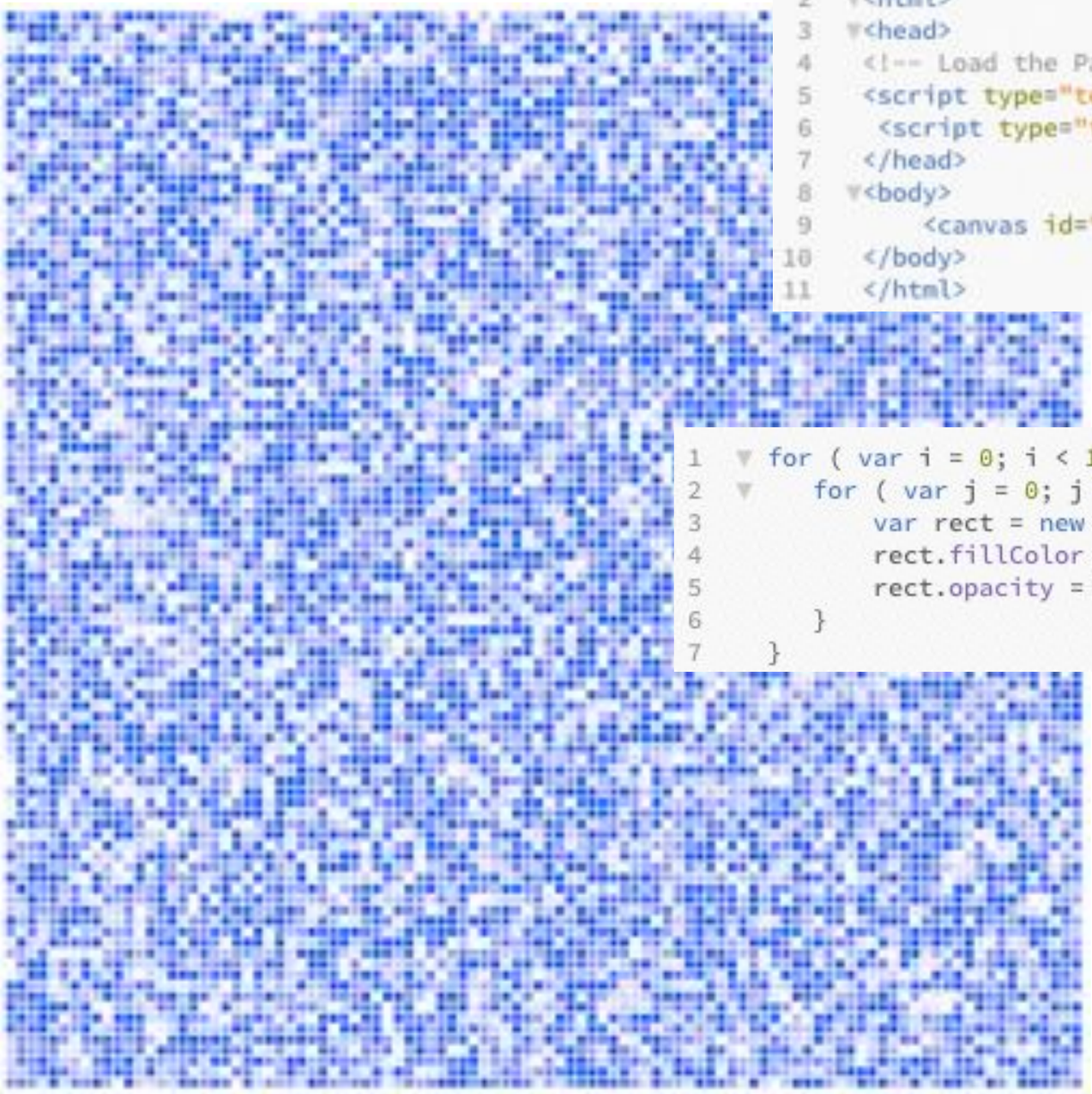

```
<!DOCTYPE html>
<html data-brackets-id="1" lang="en">
  <head data-brackets-id="2">
    <meta data-brackets-id="3" charset="utf-8">
    <title data-brackets-id="4">Playing with D3</title>
    <script data-brackets-id="5" type="text/javascript" src="http://mbostock.github.com/d3/d3.js"></script>
    <script src="http://d3js.org/d3.v2.js"></script>
  </head>
  <body data-brackets-id="6">
    <script data-brackets-id="7" type="text/javascript" src="graph.js"></script>
    <svg>
      <line x1="283" y1="216" x2="322" y2="248" style="stroke: #cccccc; stroke-width: 0.5px;"></line>
      <line x1="283" y1="216" x2="243" y2="248" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="283" y1="216" x2="272" y2="168" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="283" y1="216" x2="233" y2="199" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="322" y1="248" x2="283" y2="279" style="stroke: #cccccc; stroke-width: 0.5px;"></line>
      <line x1="243" y1="248" x2="283" y2="279" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="243" y1="248" x2="283" y2="279" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="272" y1="168" x2="233" y2="199" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="283" y1="279" x2="235" y2="300" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="283" y1="279" x2="276" y2="329" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="180" y1="234" x2="187" y2="285" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="187" y1="285" x2="235" y2="300" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <line x1="235" y1="300" x2="276" y2="329" style="stroke: #cccccc; stroke-width: 5px;"></line>
      <circle r="10" cx="283" cy="216" style="fill: #800000;"></circle>
      <circle r="10" cx="322" cy="248" style="fill: #800000;"></circle>
      <circle r="10" cx="243" cy="248" style="fill: #800000;"></circle>
      <circle r="10" cx="272" cy="168" style="fill: #800000;"></circle>
      <circle r="10" cx="233" cy="199" style="fill: #800000;"></circle>
      <circle r="10" cx="283" cy="279" style="fill: #800000;"></circle>
      <circle r="10" cx="180" cy="234" style="fill: #800000;"></circle>
      <circle r="10" cx="187" cy="285" style="fill: #800000;"></circle>
      <circle r="10" cx="235" cy="300" style="fill: #800000;"></circle>
      <circle r="10" cx="276" cy="329" style="fill: #800000;"></circle>
    </svg>
  </body>
</html>
```

paper.js - http://paperjs.org

- javascript

index.html

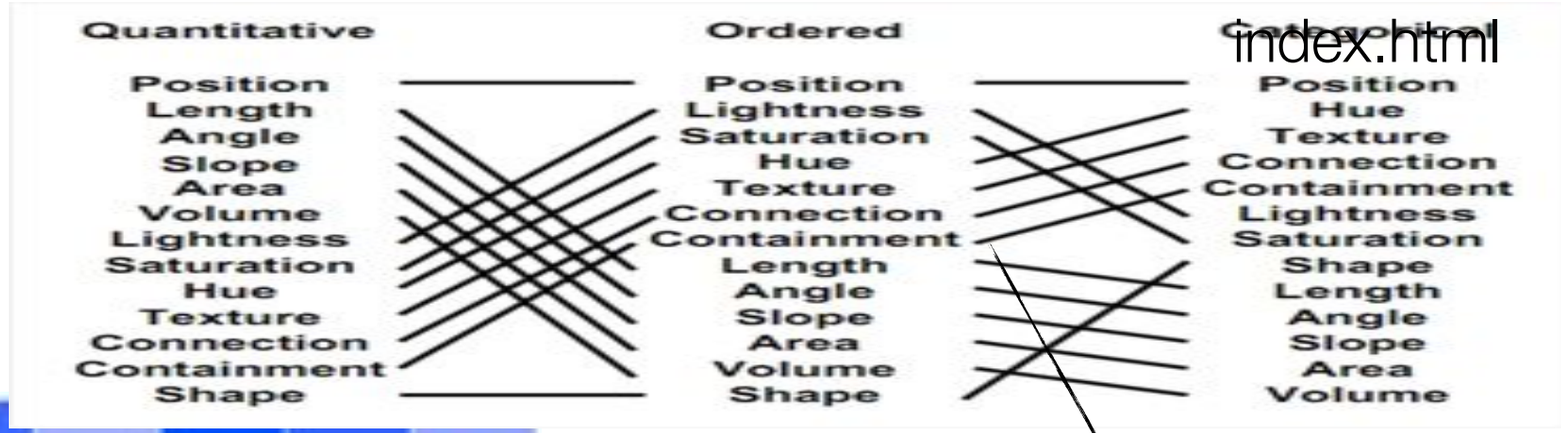
```
<!DOCTYPE html>
<html>
<head>
<!-- Load the Paper.js library -->
<script type="text/javascript" src="paperjs/dist/paper.js"></script>
 <script type="text/paperscript" src="heatmap.js" canvas="myCanvas"></script>
</head>
<body>
    <canvas id="myCanvas" resize></canvas>
</body>
</html>
```



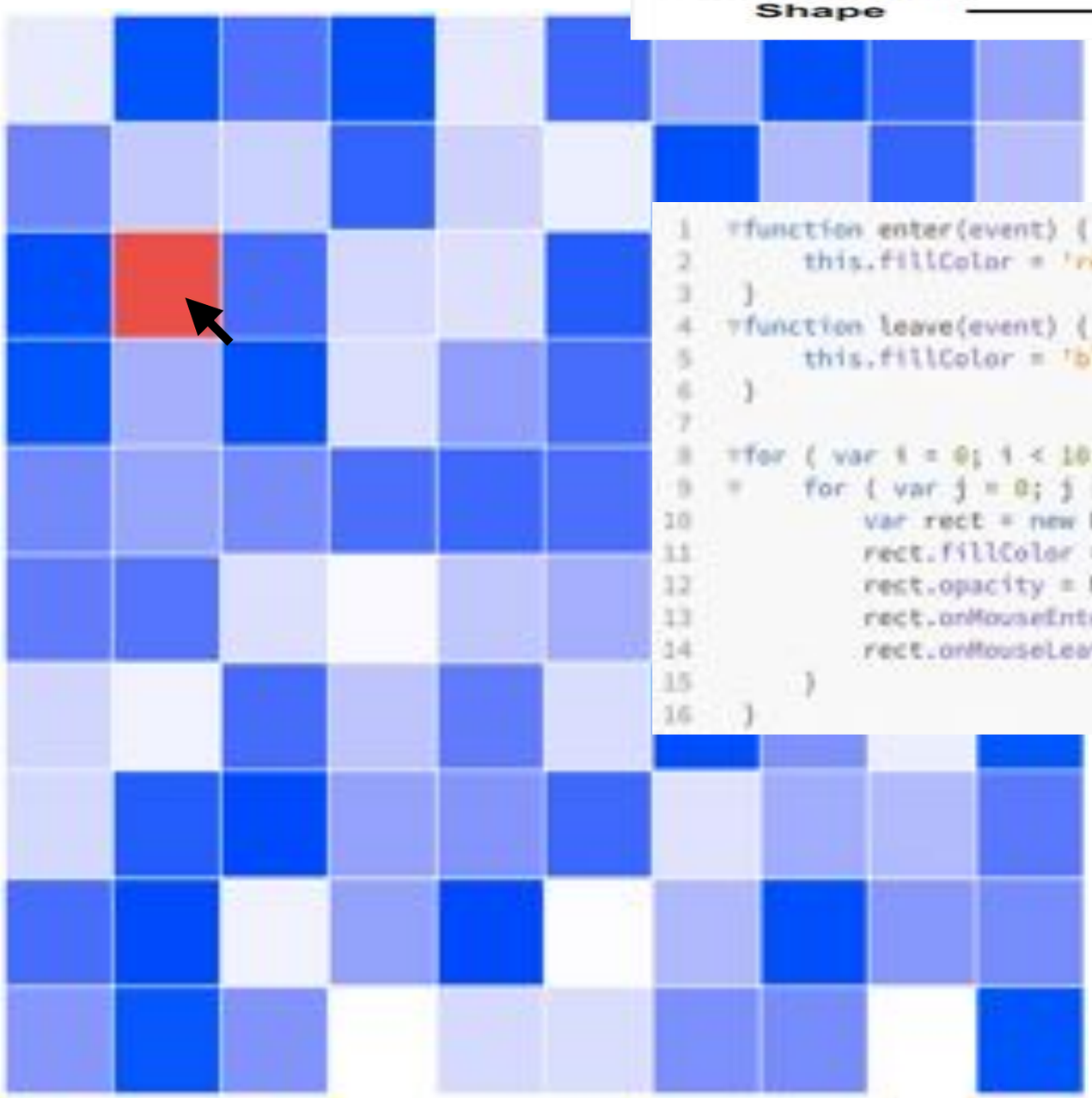
heatmap.js

```
for ( var i = 0; i < 100; i++ ) {
    for ( var j = 0; j < 100; j++ ) {
        var rect = new Path.Rectangle(new Point(i*5,j*5), new Point(i*5+4,j*5+4))
        rect.fillColor = 'blue'
        rect.opacity = Math.random()
    }
}
```

index.html

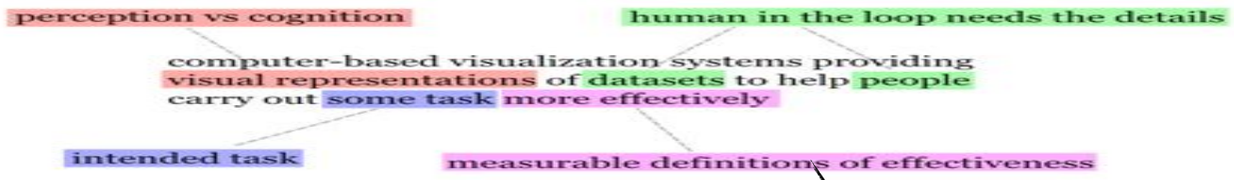


heatmap.js

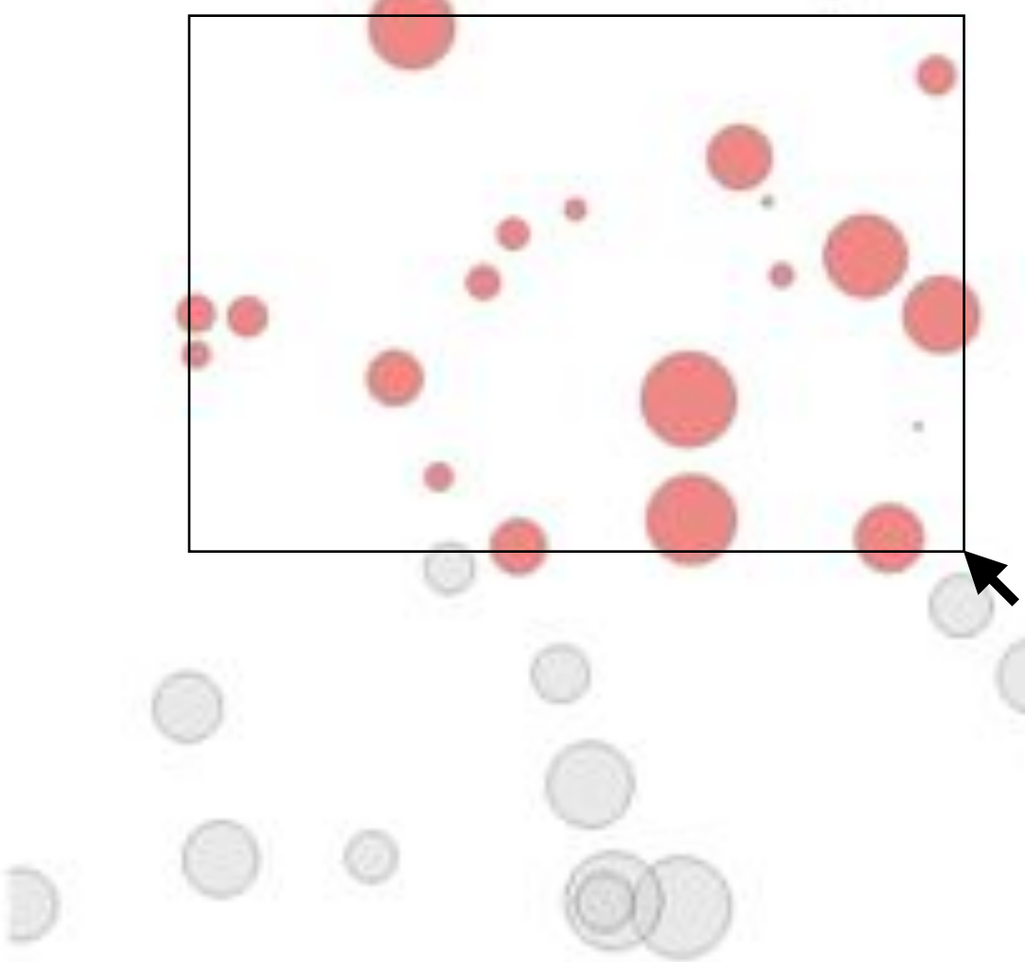


```
function enter(event) {
    this.fillColor = 'red'
}
function leave(event) {
    this.fillColor = 'blue'
}

for ( var i = 0; i < 10; i++ ) {
    for ( var j = 0; j < 10; j++ ) {
        var rect = new Path.Rectangle(new Point(i*50,j*50), new Point(i*50+49,j*50+49))
        rect.fillColor = 'blue'
        rect.opacity = Math.random()
        rect.onMouseEnter = enter
        rect.onMouseLeave = leave
    }
}
```

index.html



drag_select.js



```
var objects = new Array;
for (i = 0; i < 50; i++) {
    var circle = new Path.Circle(new Point(Math.random()*500, Math.random()*500), Math.random()*20)
    circle.fillColor = 'lightgrey';
    circle.strokeColor = 'black';
    circle.opacity = 0.5;
    objects.push(circle);
}

var mouseDownPosition;
var mouseDragPosition;
var selectionRectangle;
function onMouseDown(event) {
    mouseDownPosition = event.point;
}
function onMouseDrag(event) {
    mouseDragPosition = event.point;
    if (selectionRectangle) { selectionRectangle.remove(); }
    selectionRectangle = new Path.Rectangle(mouseDownPosition, mouseDragPosition);
    selectionRectangle.strokeColor = 'grey';

    // This is slow because has to go over all objects with every pixel dragged
    for (var i = 0; i < objects.length; i++ ) {
        if ( selectionRectangle.bounds.intersects(objects[i].bounds) ) {
            objects[i].FillColor = 'red';
        } else {
            objects[i].FillColor = 'lightgrey'
        }
    }
}
function onMouseUp(event) {
    selectionRectangle.remove();
}
```

Overview of lecture

A. Why visual analytics?

B. Data visualization

- Data foundations
- Human perception foundations
- Visualization foundations and techniques

C. Visualization evaluation

D. Tools of the trade

E. Examples

F. Exercises

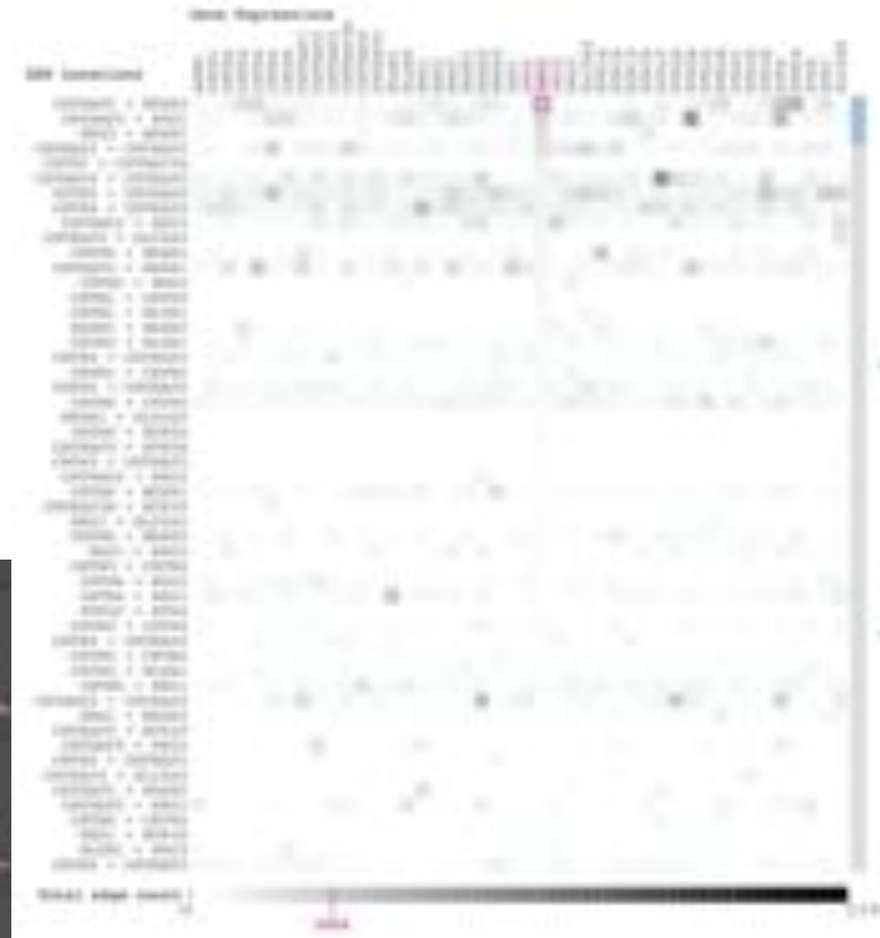
E. Examples

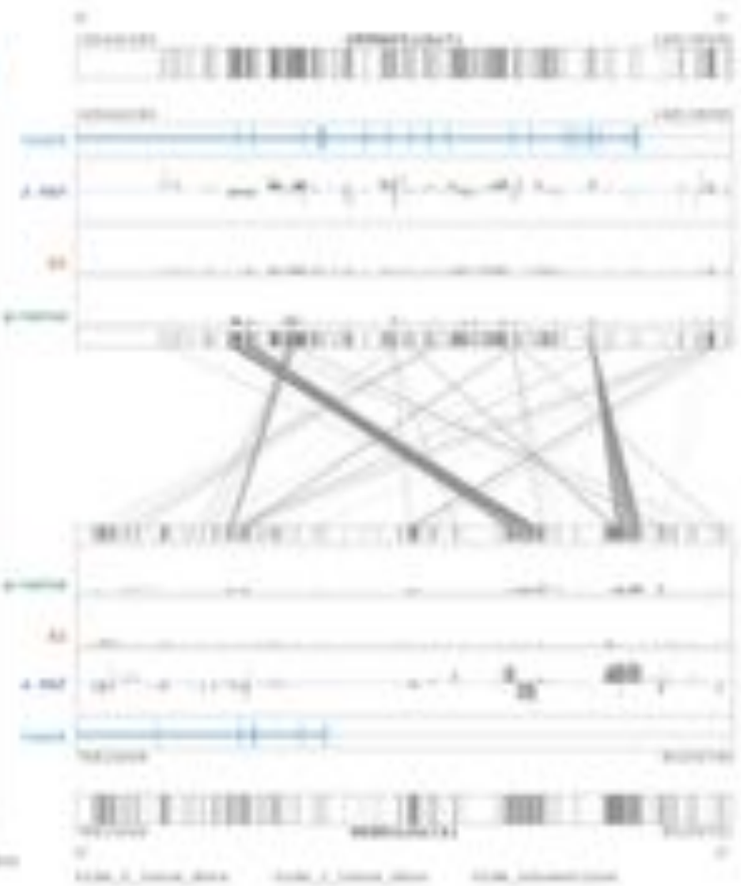
Data exploration
Data filtering
User-guided analysis

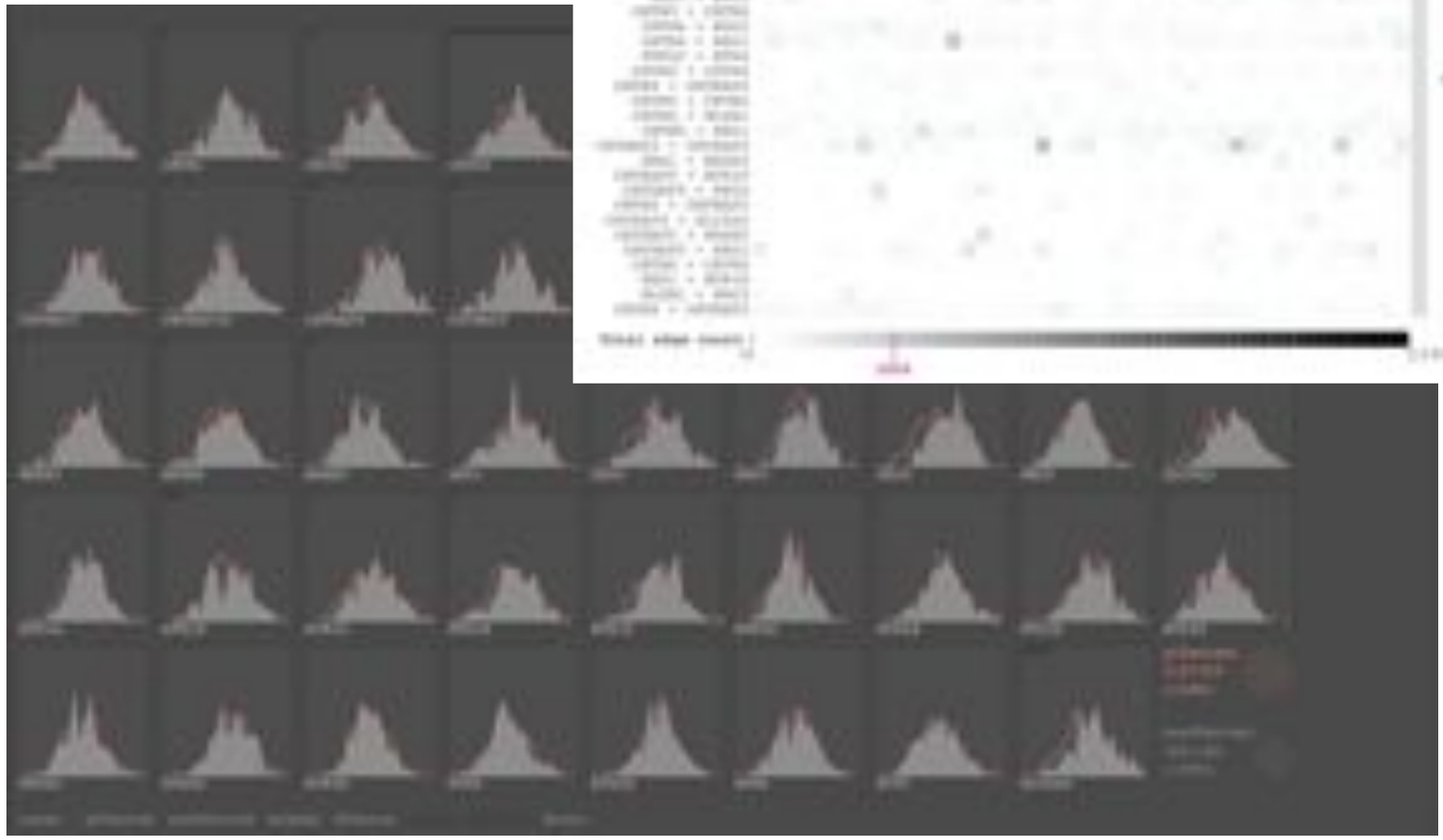
Data exploration

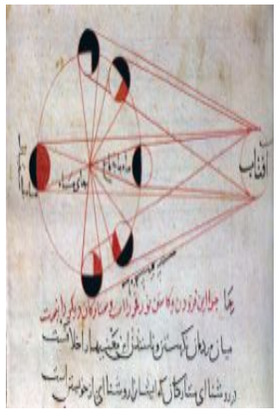
Aracari

Bartlett C et al. BMC Bioinformatics (2012)







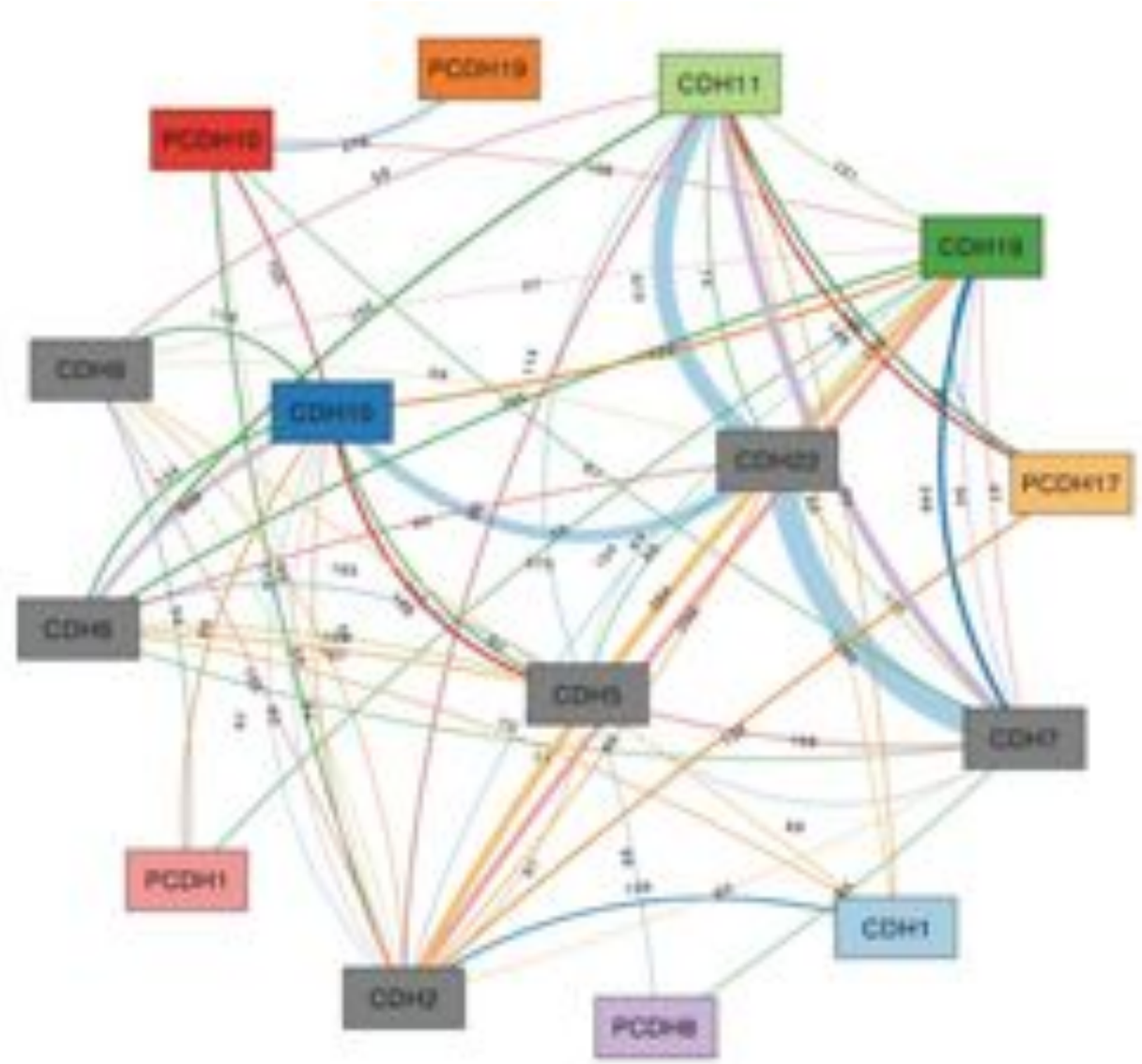


Ryo Sakai

5

Reveal

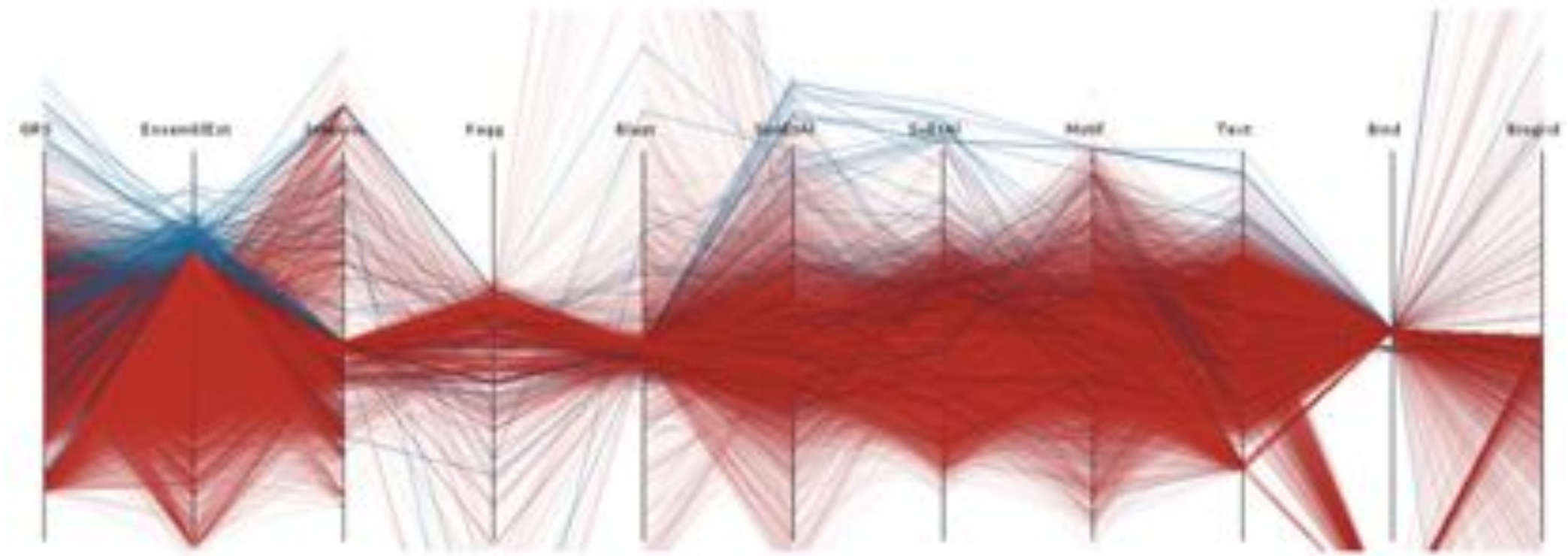
Jäger, G et al. Bioinformatics (2012)



ParCoord

Boogaerts T et al. IEEE International Conference on Bioinformatics & Bioengineering (2012)

Endeavour gene prioritization



Thomas Boogaerts

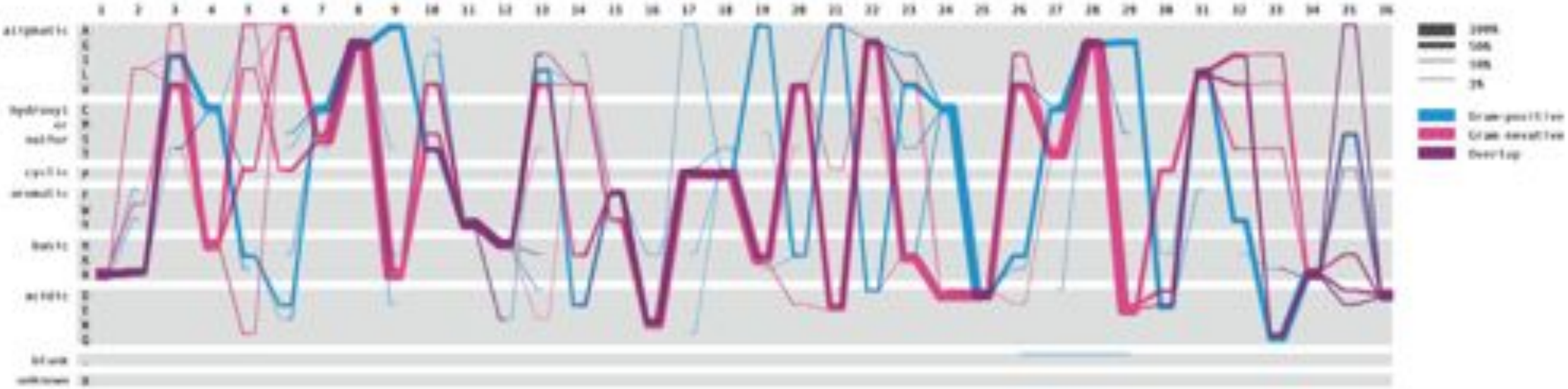
total

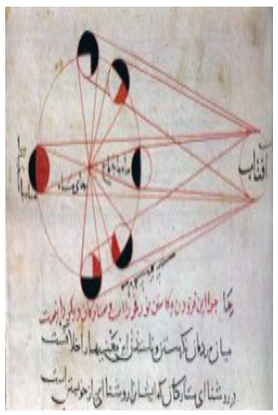
gram-positive

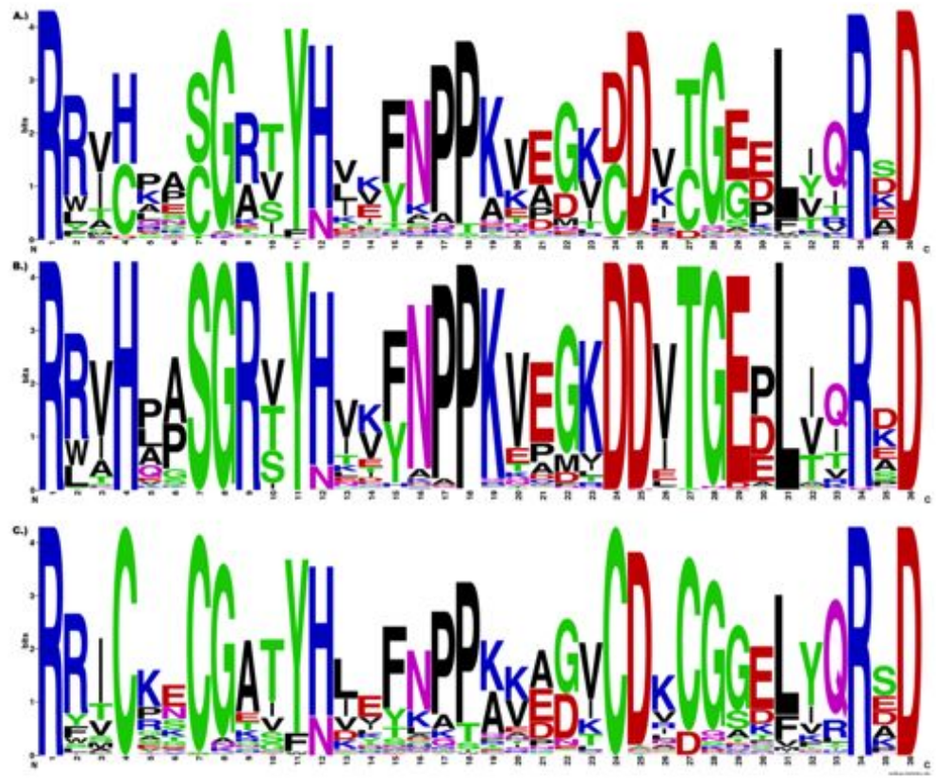
gram-negative

Sequence logo

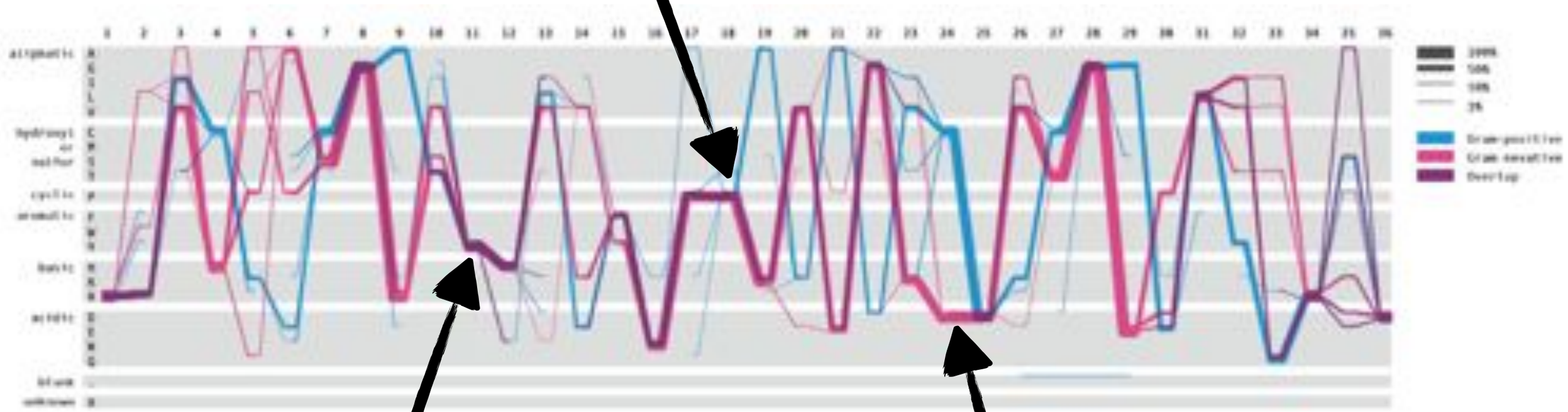
Sequence Diversity Diagram







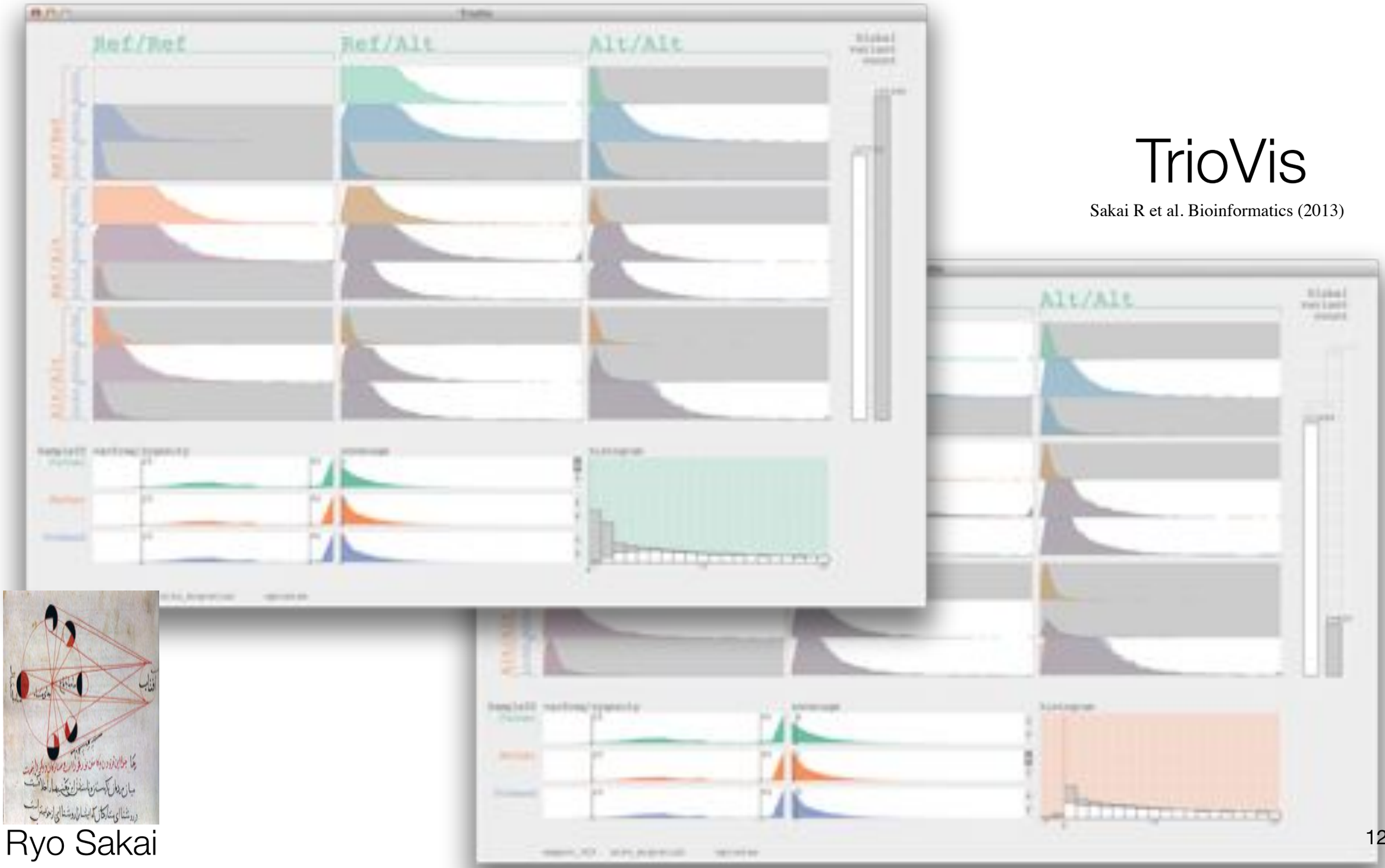
subgroup



similarity

difference

Data filtering (visual parameter setting)



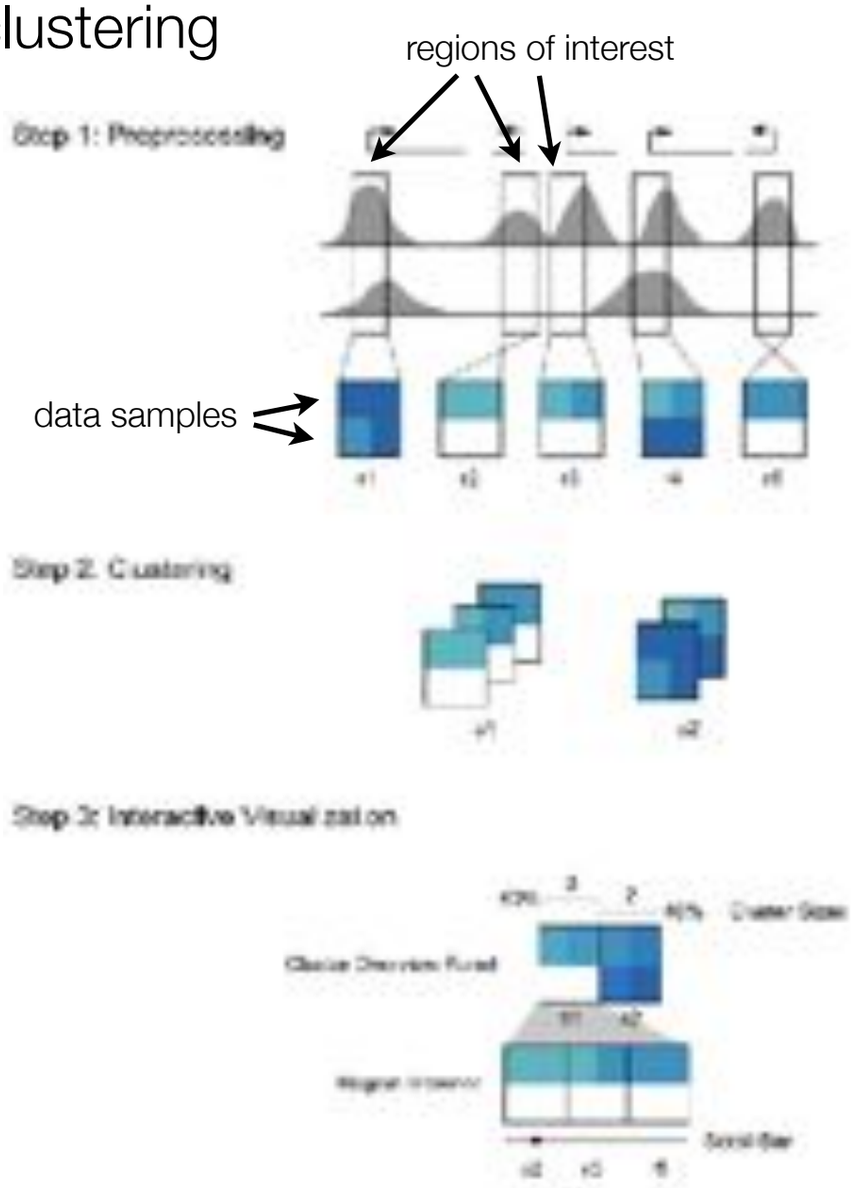
TrioVis

Sakai R et al. Bioinformatics (2013)

Ryo Sakai

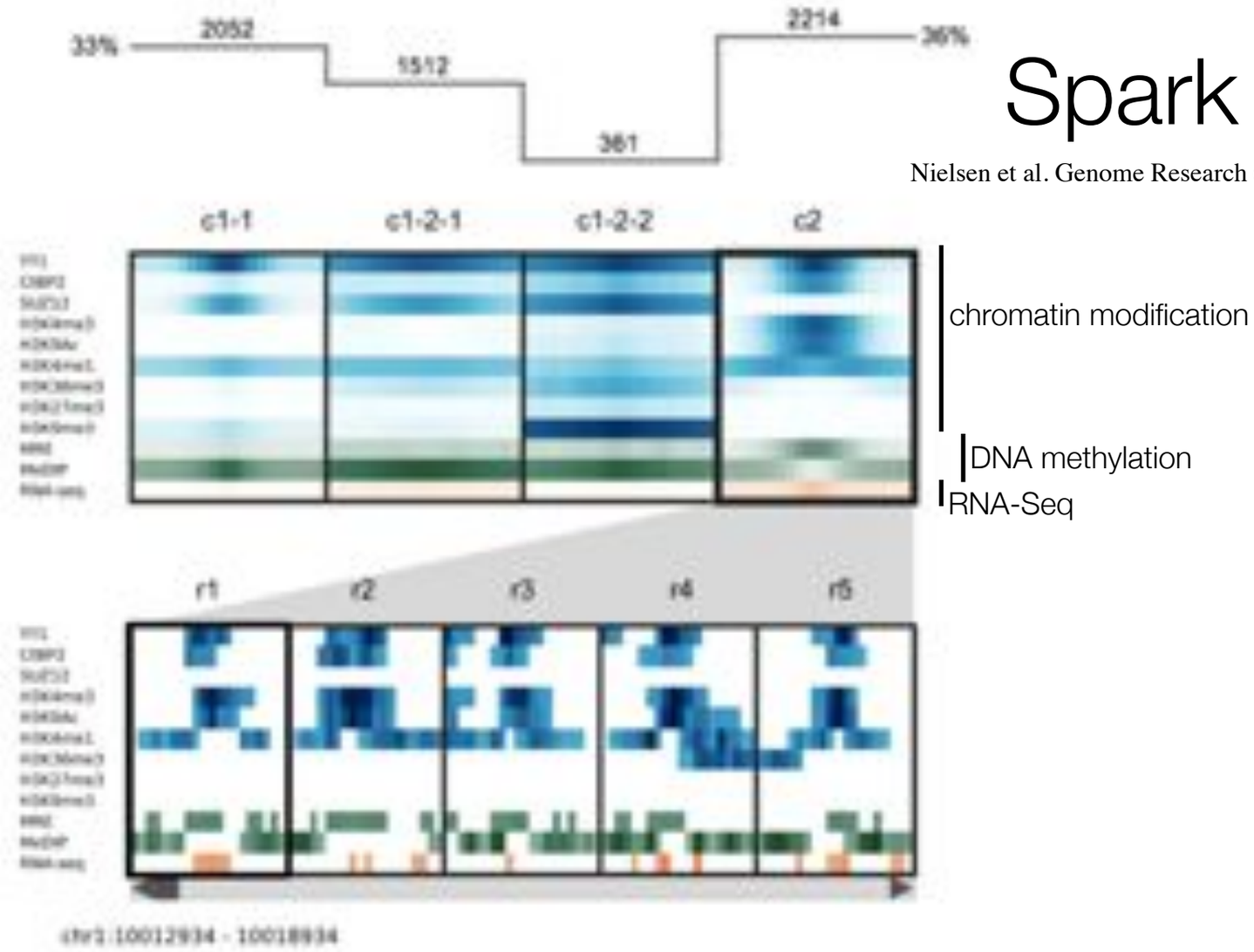
User-guided analysis

clustering



Spark

Nielsen et al. Genome Research (2012)



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Redesign exercise

(Thanks Martin! Vizbi 2012 practical session - http://bit.ly/10GOTt2)

- Every row will be given a different re-design exercise.
- Sit together as a group and discuss what's wrong with the picture.
- Present this to the rest of the class, covering:
  - A brief description of the figure
  - What are its strong and weak points
  - What requires improvement?
  - *Why* does it require improvement?
  - Do you have an idea on how to make it better? (maybe make sketch)

Programming SVG

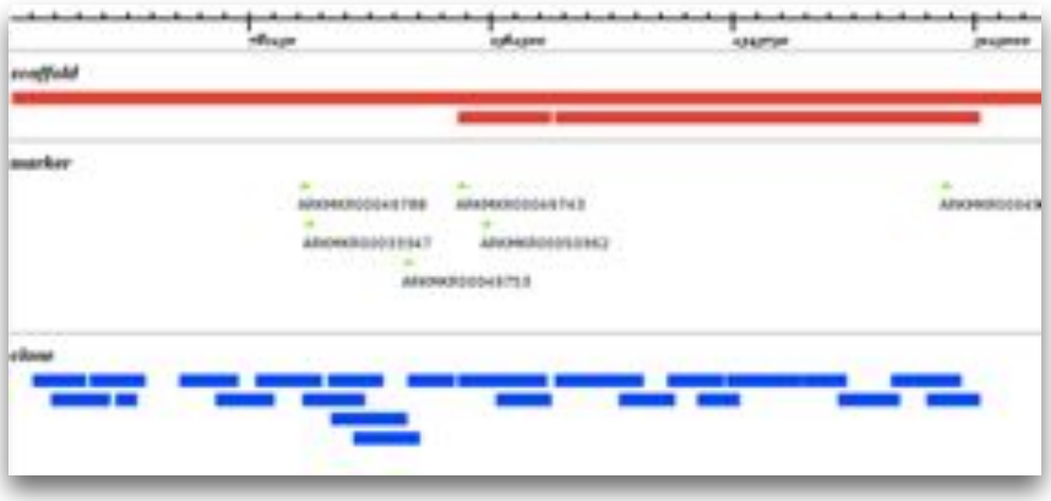
- Preamble: to use perl and SVG for visualization:
  - Write a perl script that spits out a text file, *e.g.* named `something.svg`
  - That file should look like this:

```
<html>
<body>
  <svg xmlns="http://www.w3.org/2000/svg" xmlns:xlink="http://www.w3.org/1999/xlink">
    <line x1="239" y1="212" x2="287" y2="198" stroke="black"></line>
    <circle cx="50" cy="100" r="20" fill="red"></circle>
  </svg>
</body>
</html>
```

change these bits…

  - For help, see
    - https://developer.mozilla.org/en-US/docs/Web/SVG
    - https://developer.mozilla.org/en-US/docs/Web/SVG/Element
    - https://developer.mozilla.org/en-US/docs/Web/SVG/Attribute
- Open the SVG file in your favourite web-browser (except IE…)

- Given the GFF file `/homes/evopserver/lectures/Visualization/structural_variation.gvf`:
  - Create a graphic like this one
  - Or can you think of an alternative (or even better) visual encoding for this data?



- How would you visualize the data from /homes/evopserver/`lectures/R-Intro/Features.txt`?
  - Sketch, then implement