# MULTIDIMENSIONAL DATA II

# RECOLLECTION

## SUBSETTING
Scatterplots, hyperslice,...

## EMBEDDING
Color, glyphs, worlds-within-worlds,...

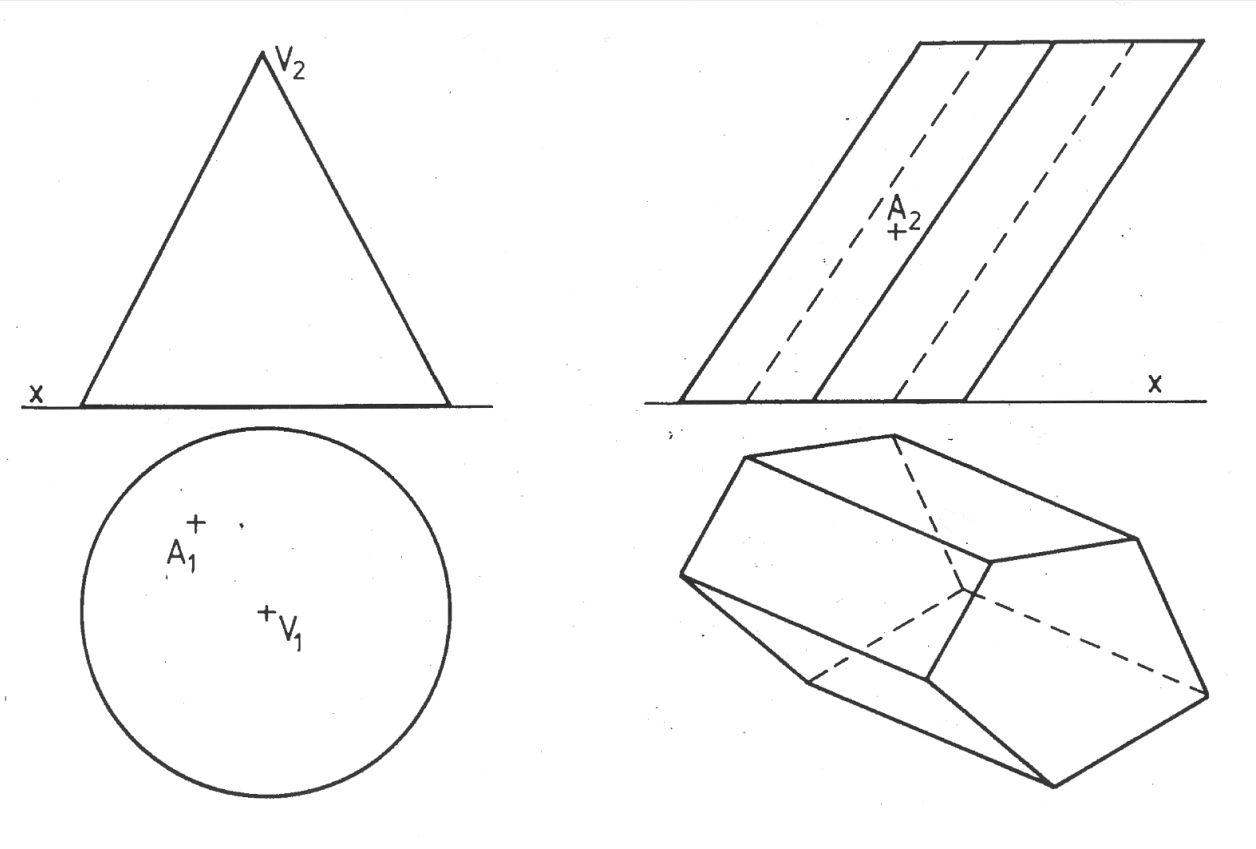
## REDUCTION
SOM, MDS, PCA, RadViz,...

## AXIS RECONFIGURATION

# AXIS RECONFIGURATION

## LEAVING CARTESIAN COORDINATES

## EXAMPLE: MONGE PROJECTION



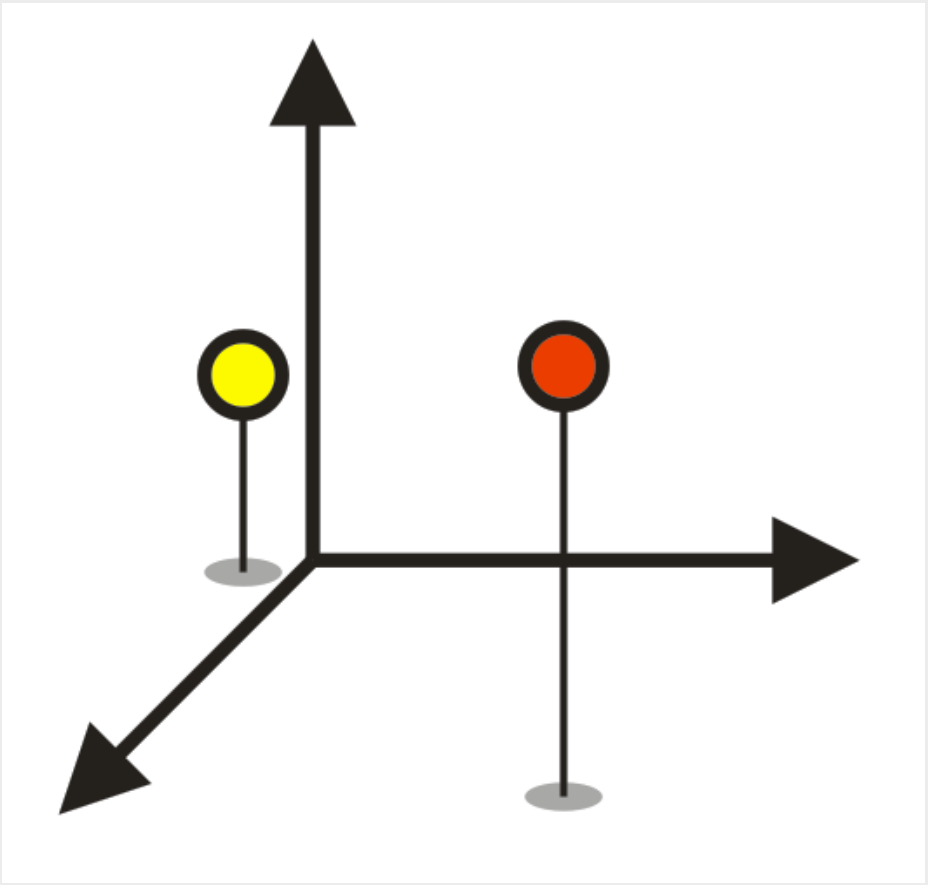
# MOTIVATION

## USUAL *ND* → 2D PROJECTION

Works only for small *n*

Ambiguous

Point ↔ point



# SIMPLE RECONFIGURATION

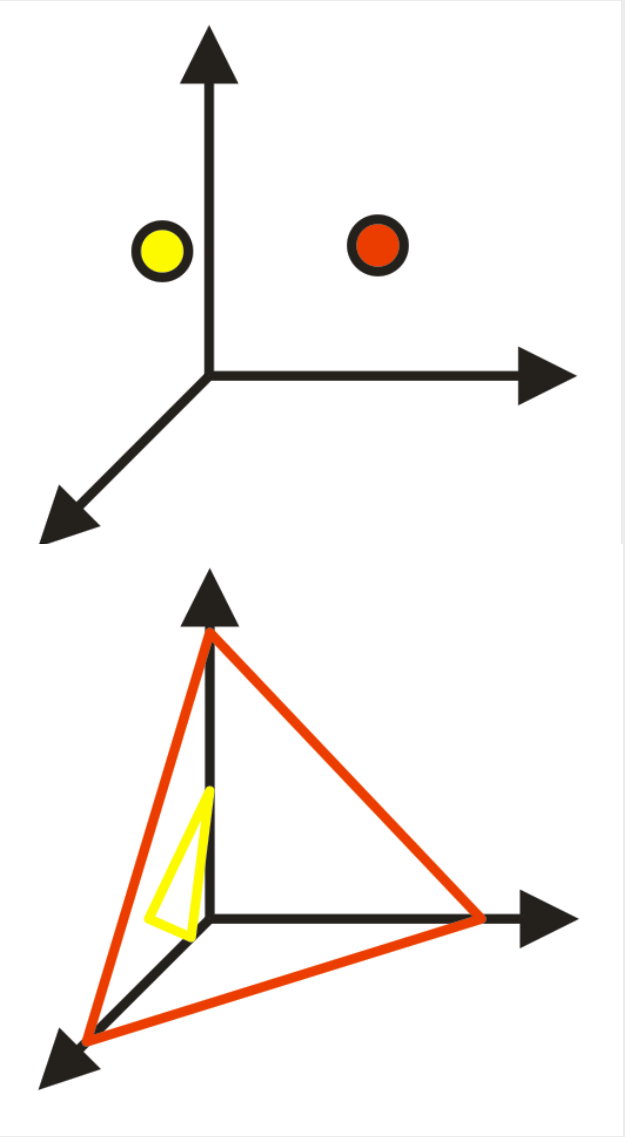
POINT ↔ LINE

SCALABLE TO LARGE *N*

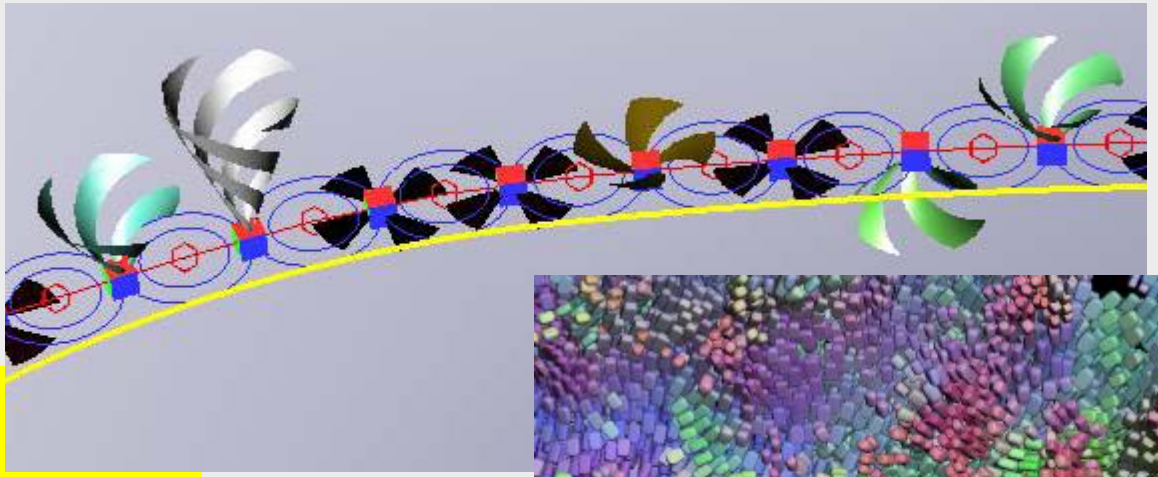
UNAMBIGUOUS

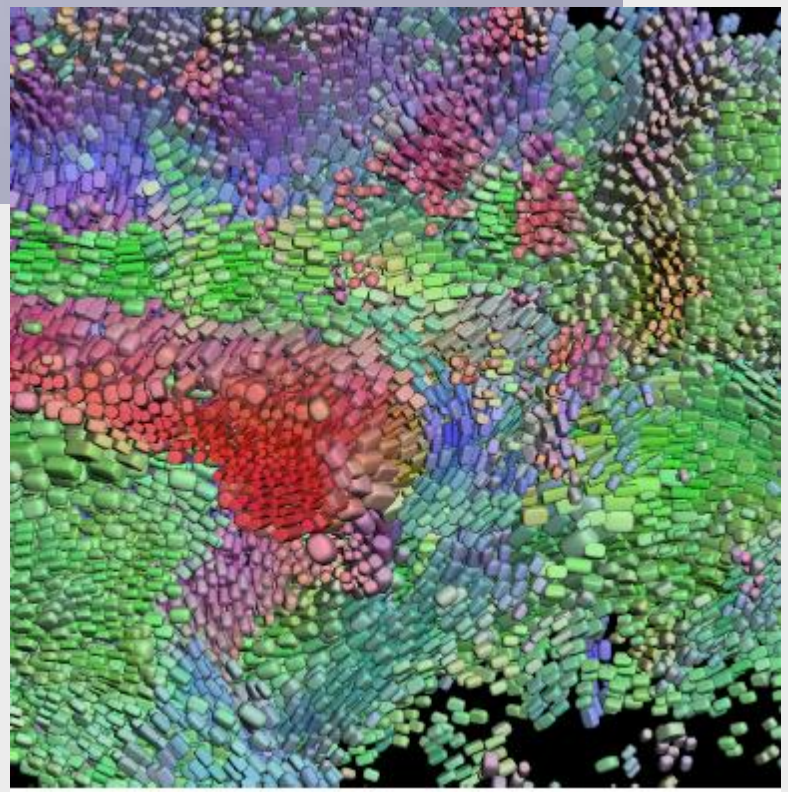
PRESERVES SIMILARITIES

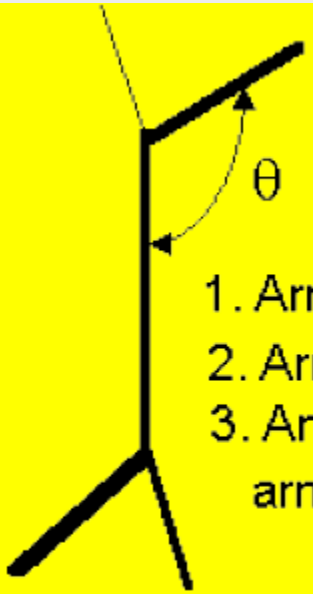
HARDER TO READ



# RECOLLECTION: GLYPHS



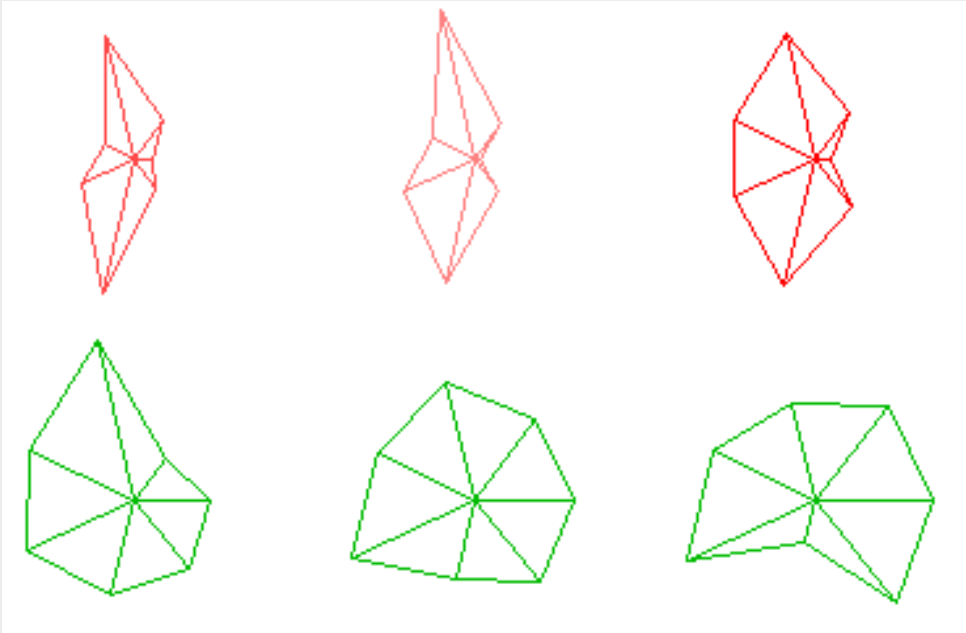


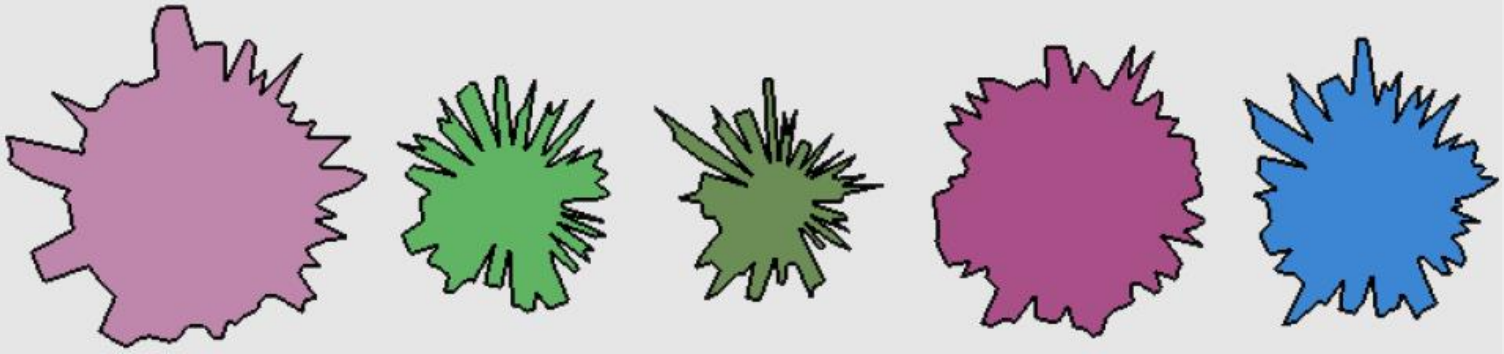



1. Arm Length
2. Arm Thickness
3. Angle between arm and stem

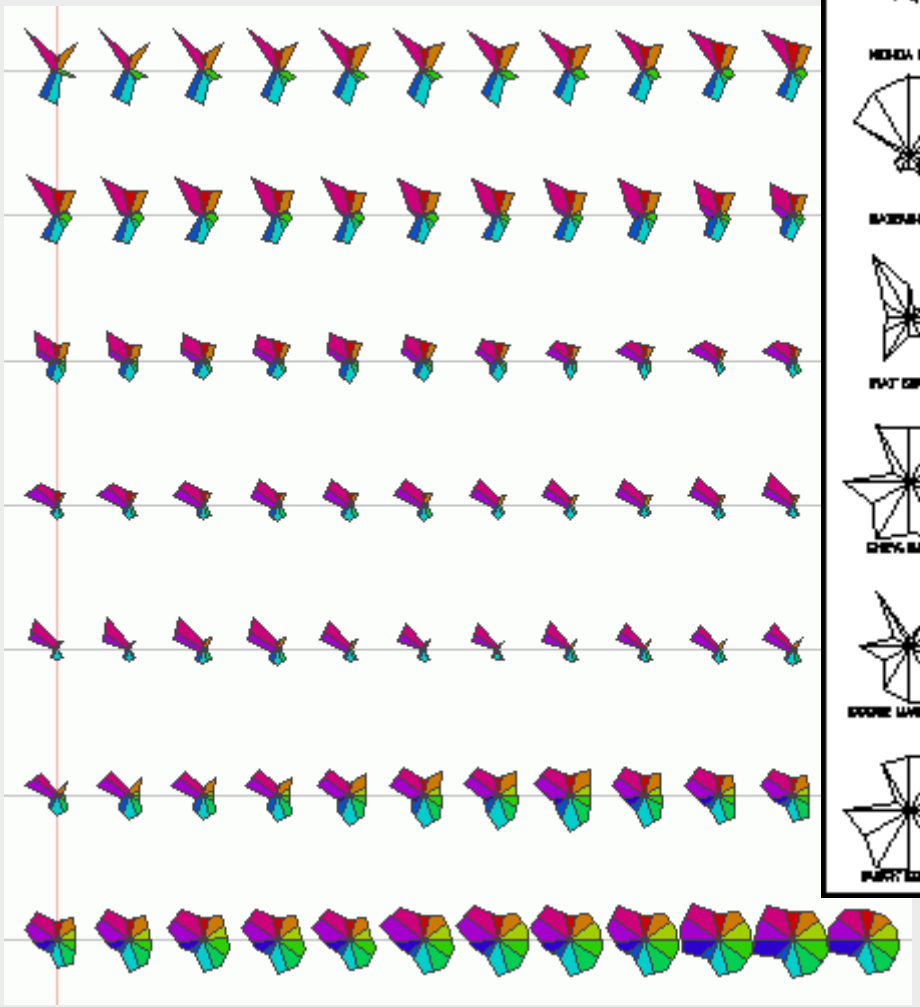
12 degrees of freedom

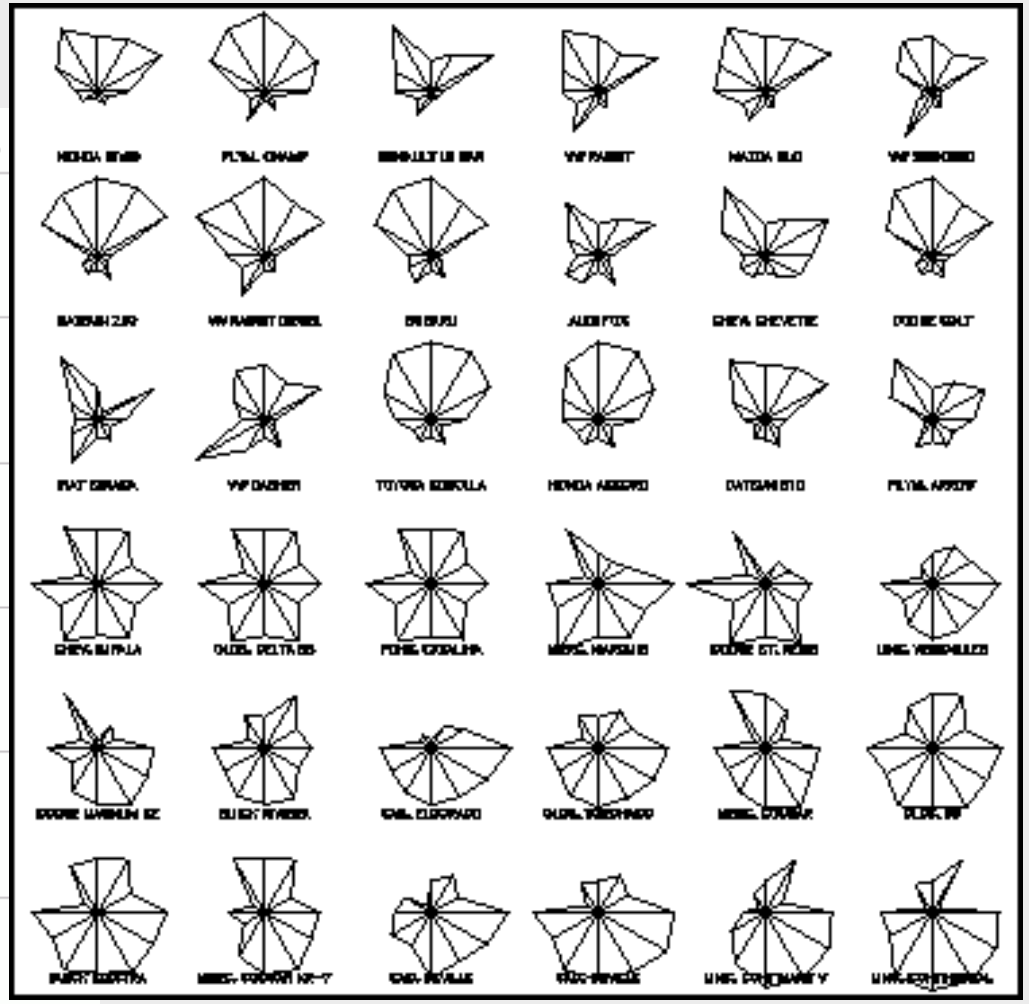
# STAR GLYPH / STAR PLOT



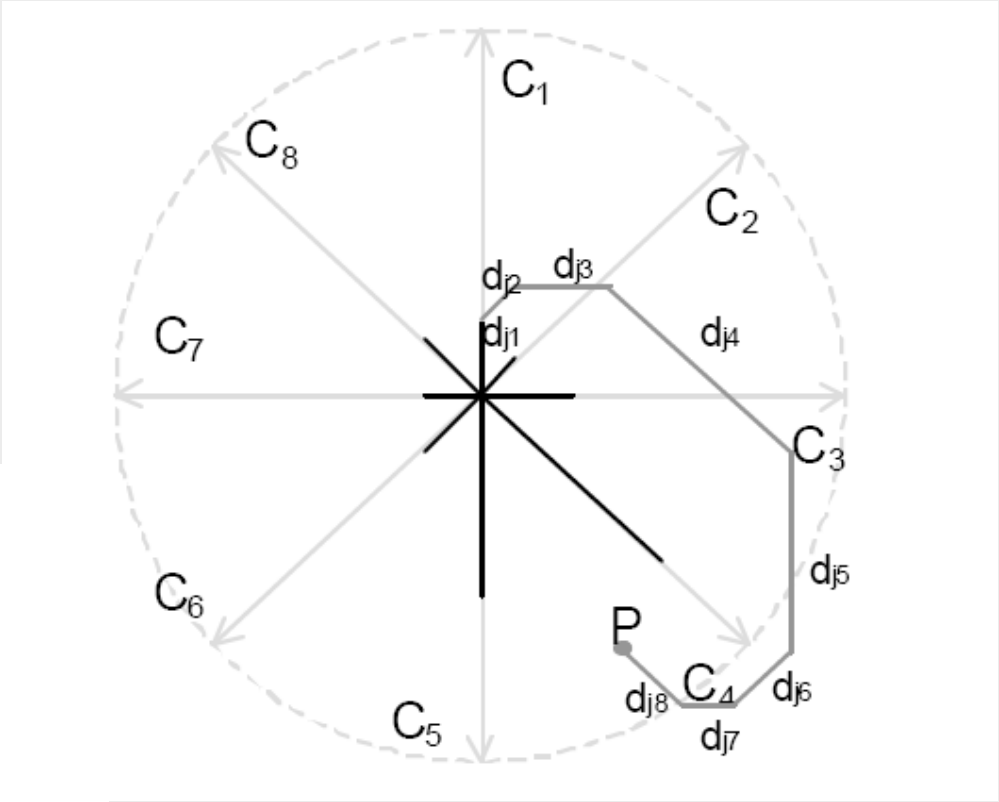


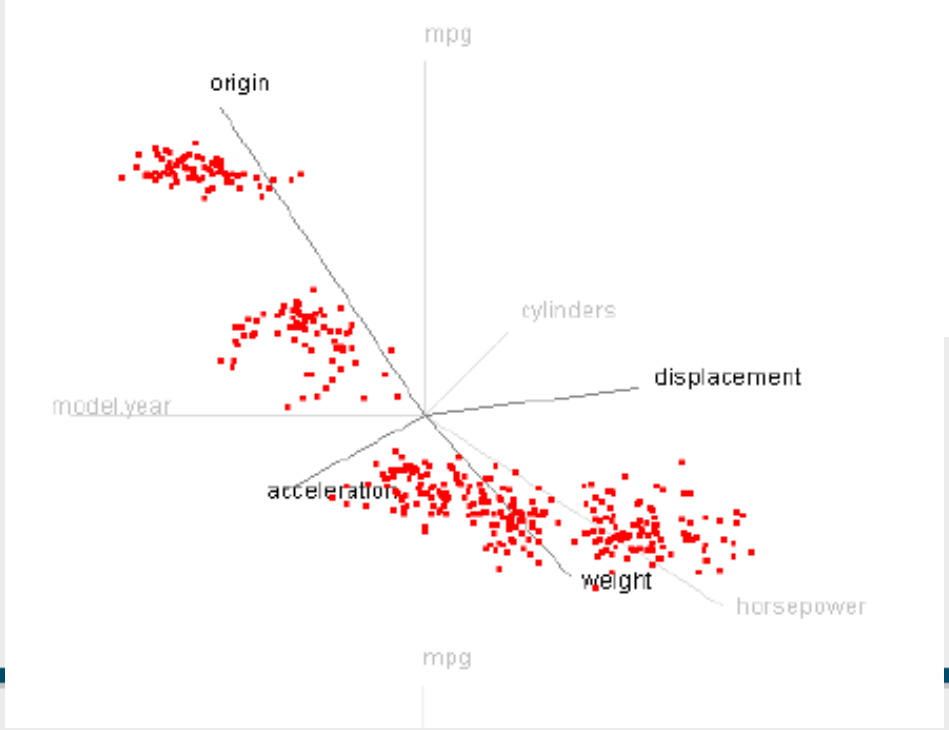
# STAR PLOT EXAMPLES





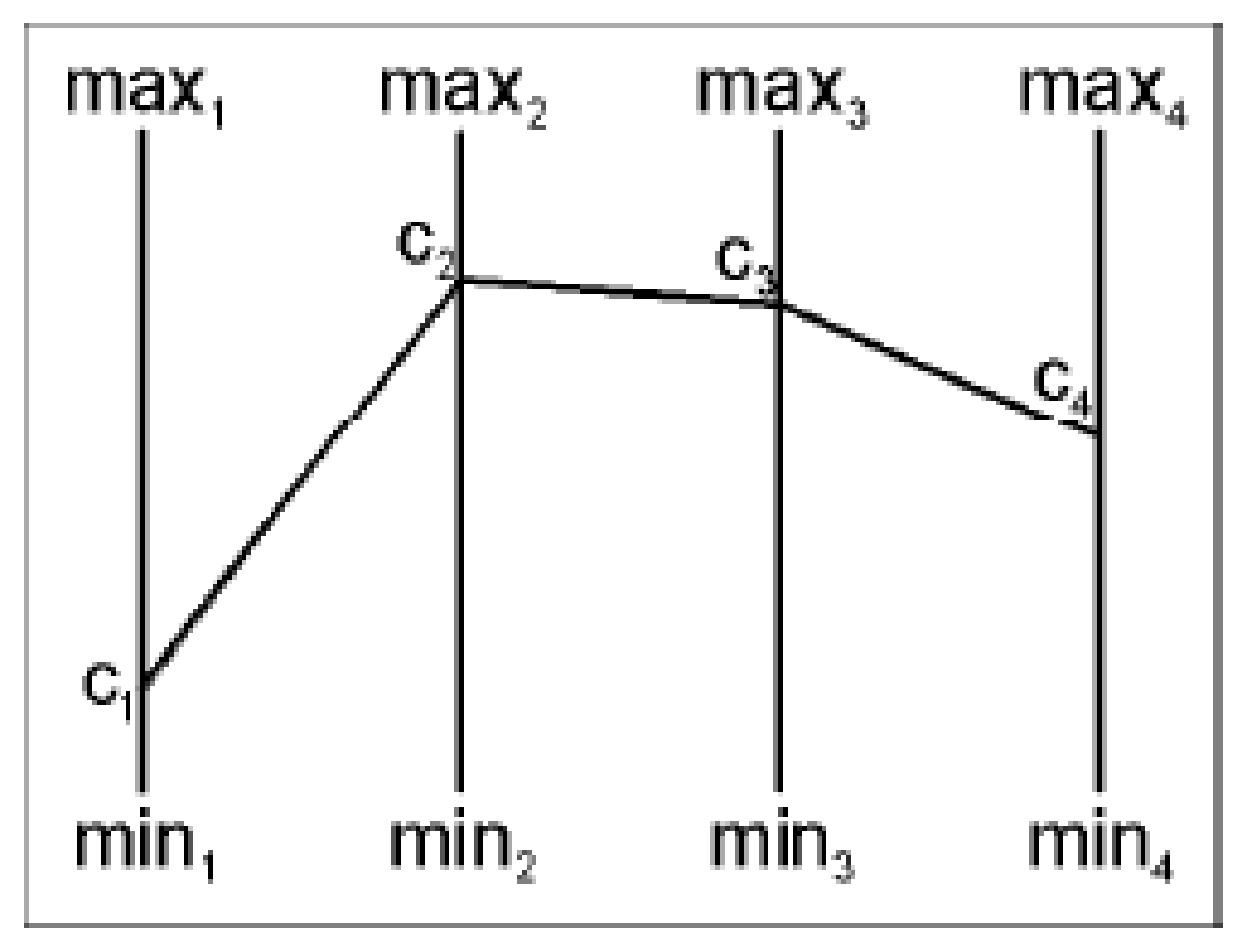
# STAR COORDINATES



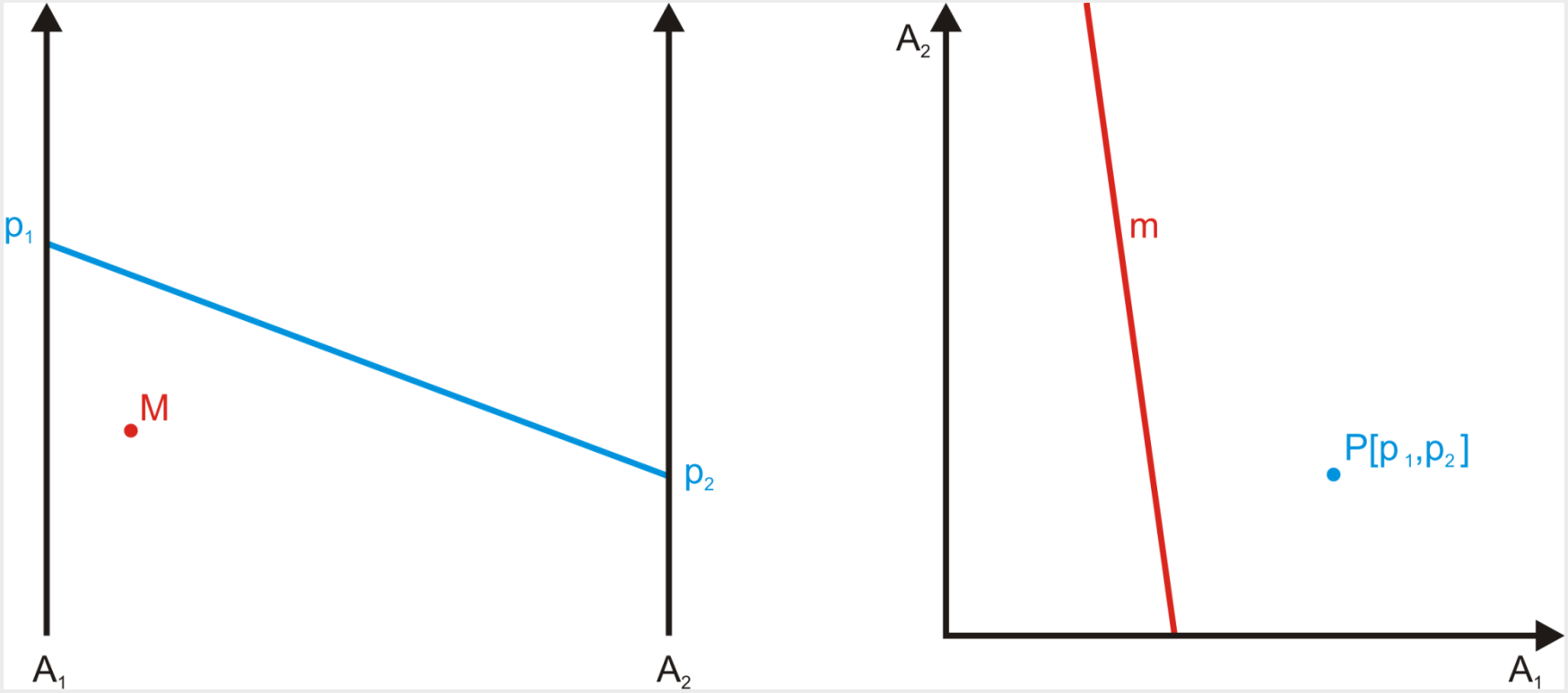
# PARALLEL COORDINATES

## ALFRED INSELBERG
## POINT ↔ LINE DUALITY



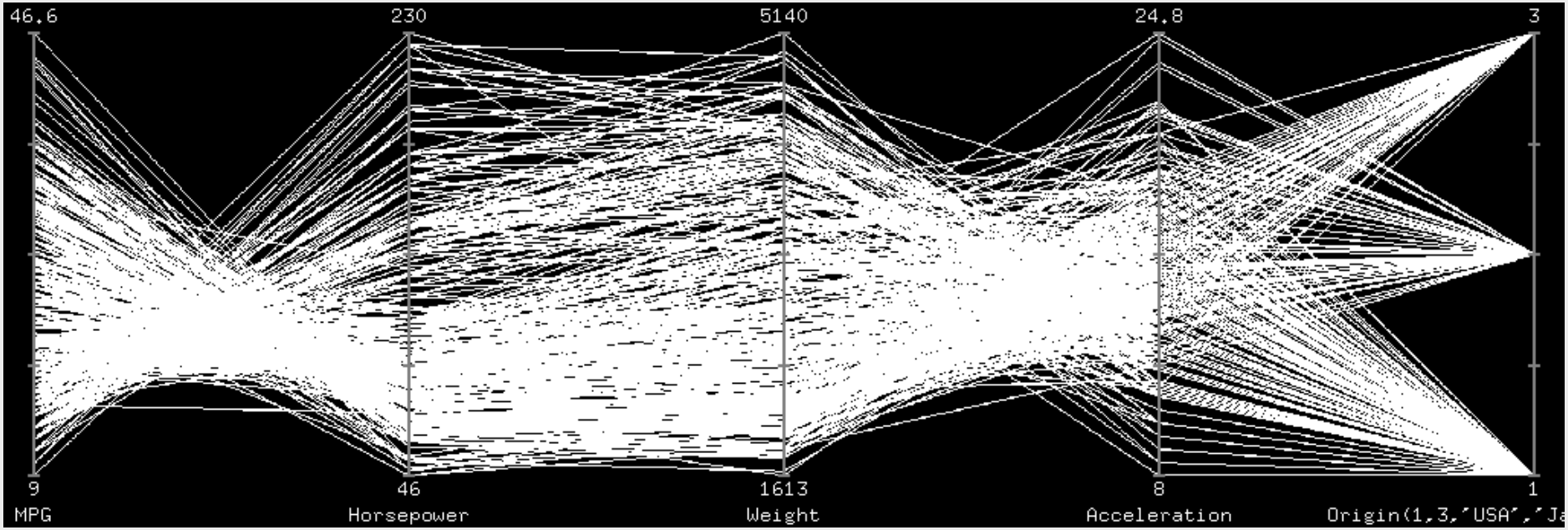
# POINT-LINE DUALITY IN PAR.COORDS.

| PARALLEL | | CARTESIAN |
|---|---|---|
| LINE p | ... | POINT P |
| POINT M | ... | LINE m |



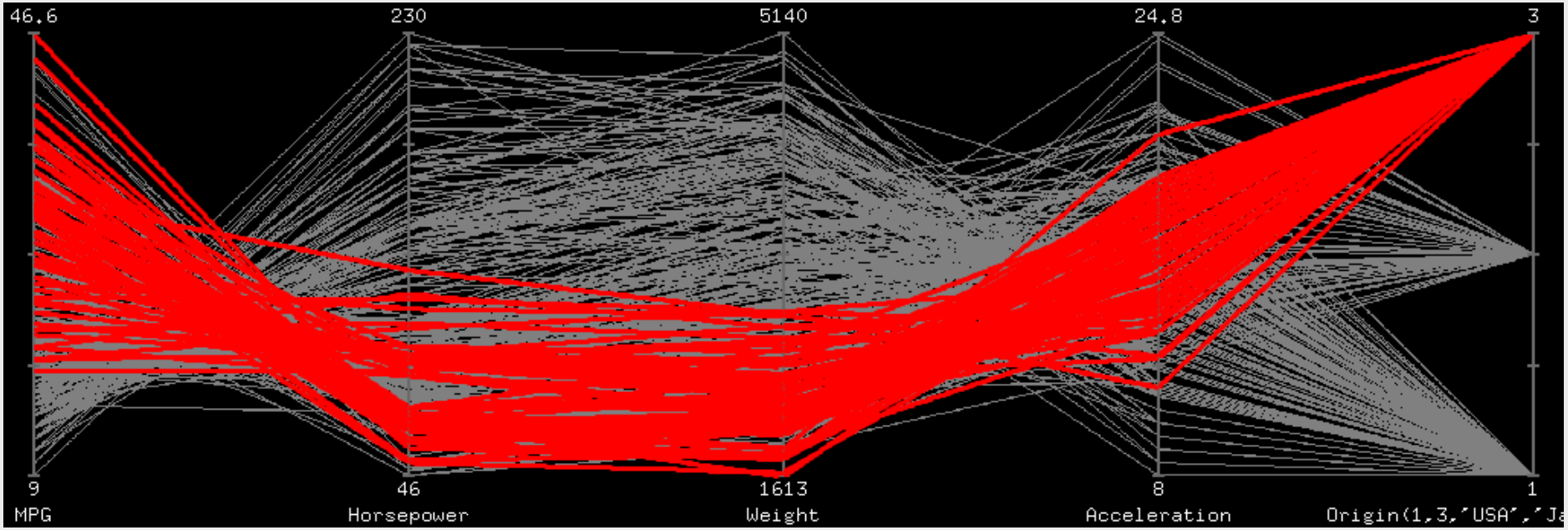
# VISUAL ANALYSIS IN PAR.COORDS.

## CORRELATIONS, PATTERNS



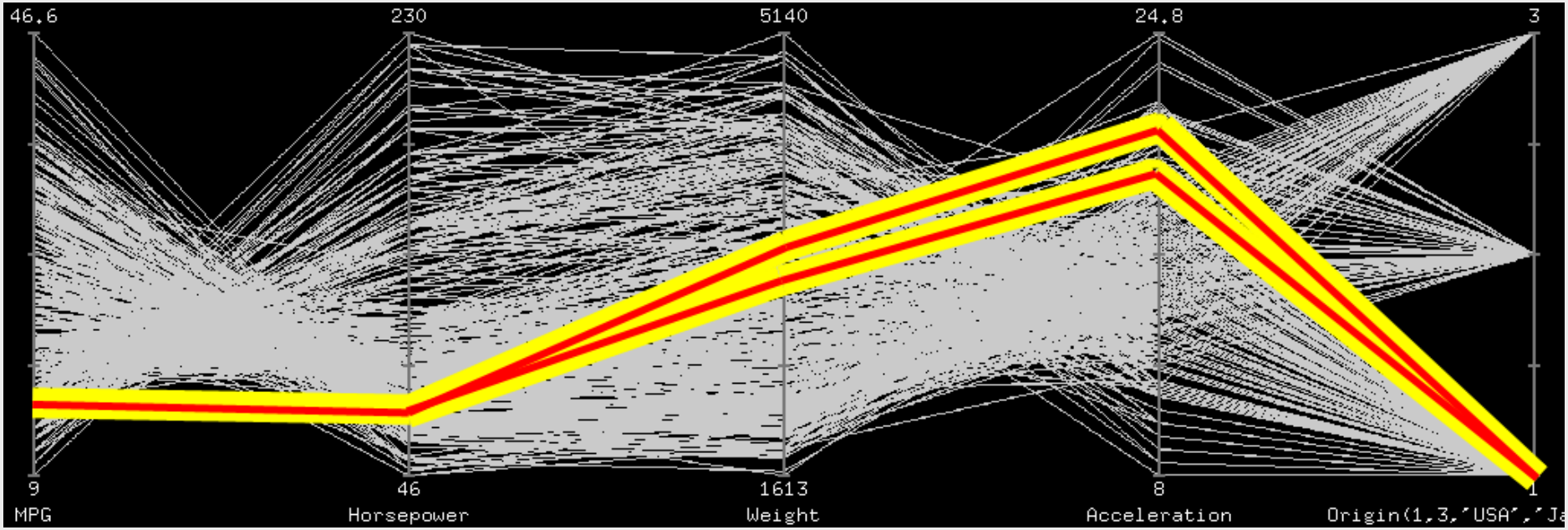
# VISUAL ANALYSIS IN PAR.COORDS.

## GROUPS



# VISUAL ANALYSIS IN PAR.COORDS.

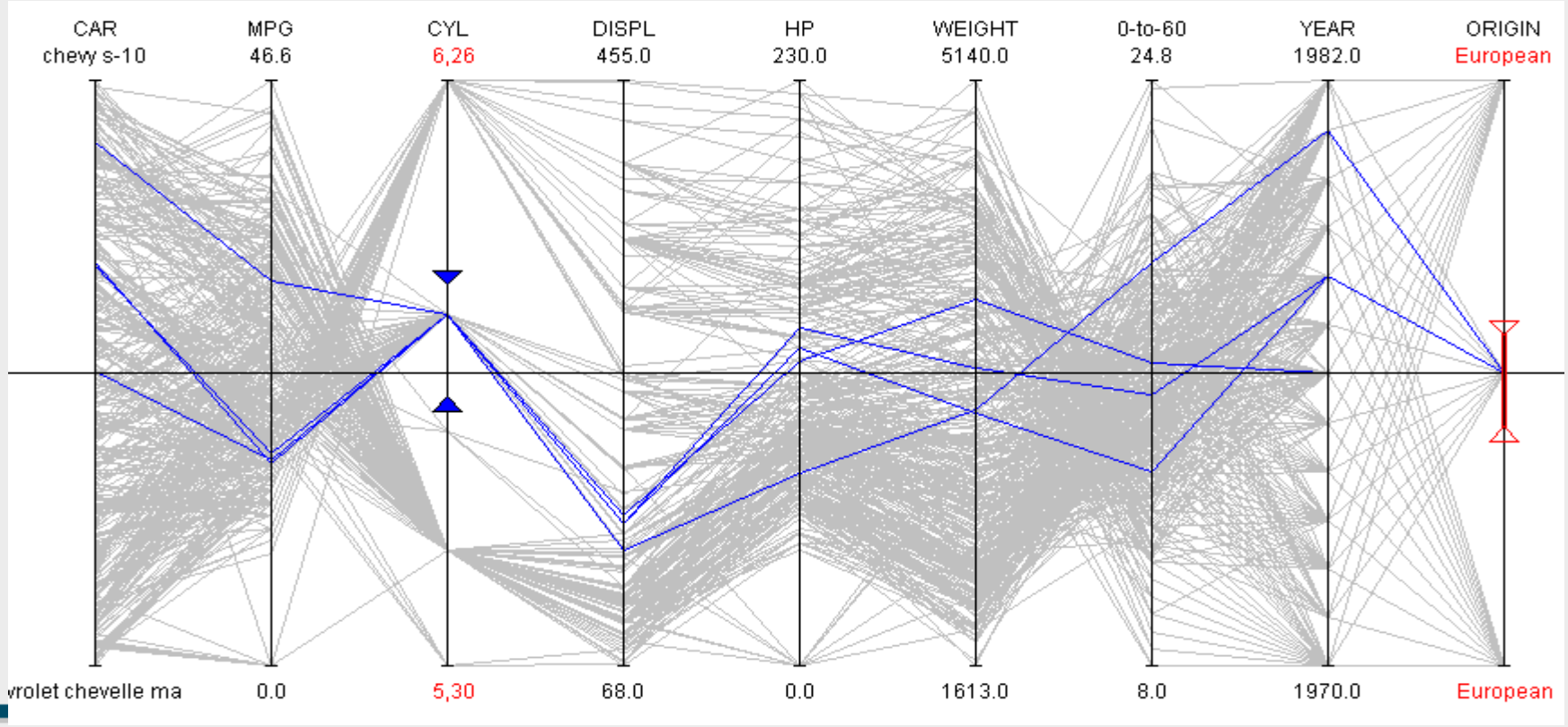
## OUTLIERS



# INTERACTION WITH PAR.COORDS.

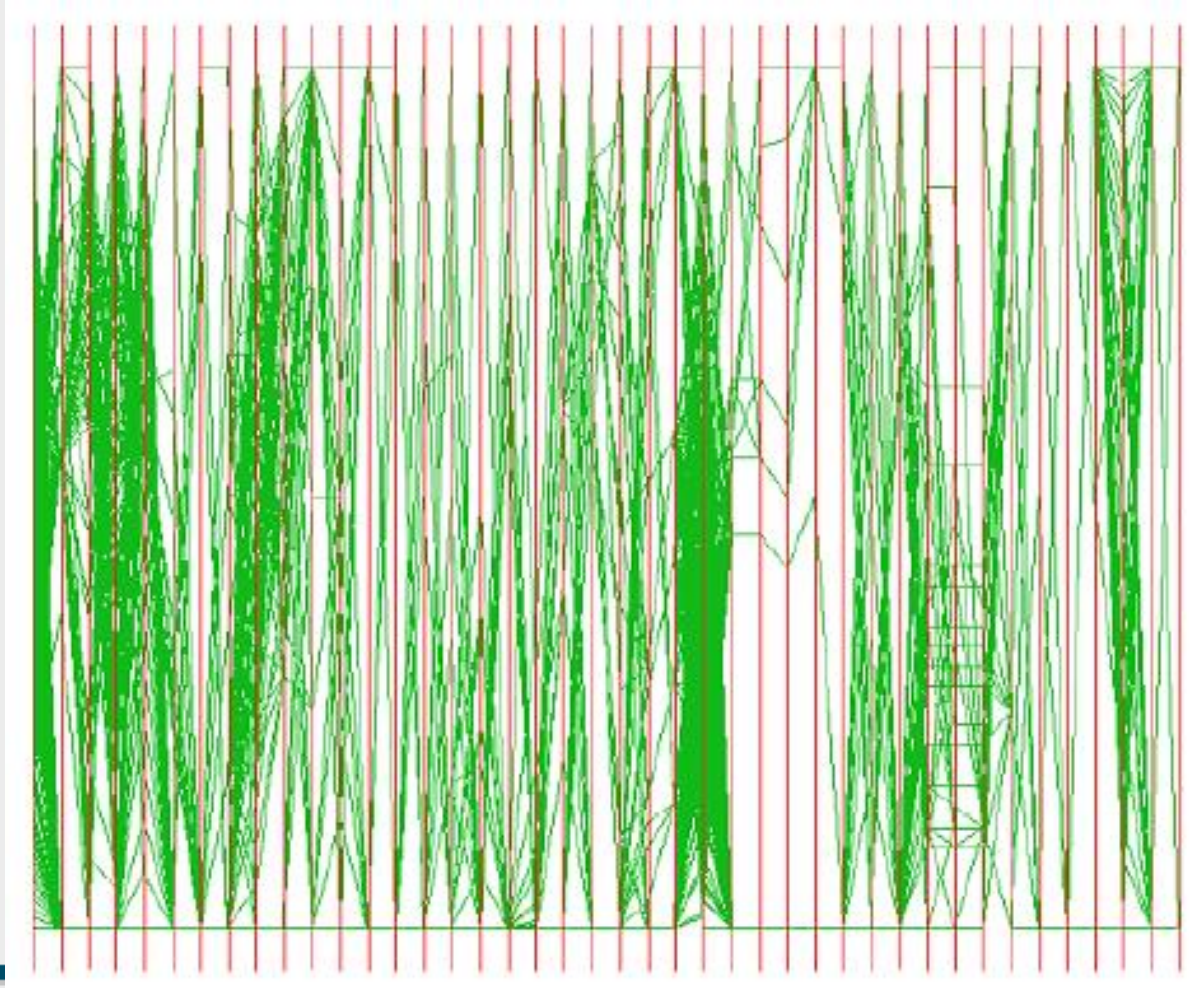
## AXIS ORDER, AXIS ORIENTATION
## BRUSHING

Combinations of per axis brushes



# PARALLEL COORDINATES PROPERTIES

## SCALES UP TO $N = 10 \ldots 20$

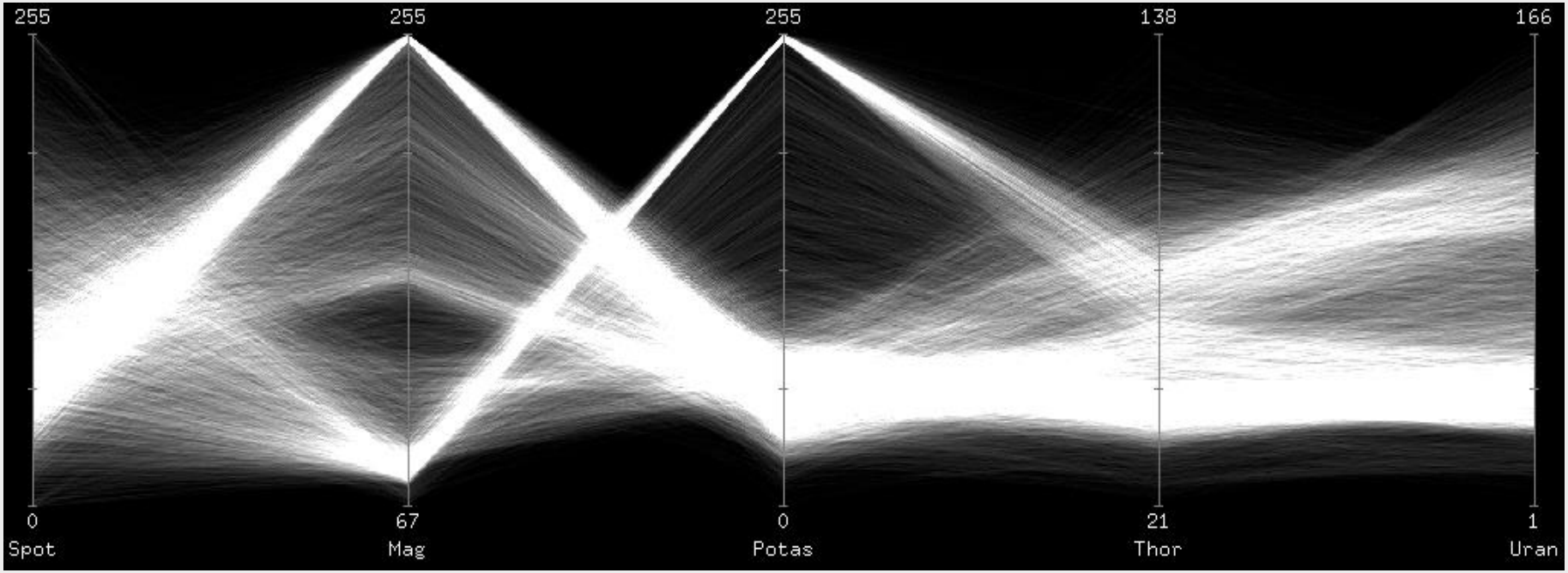


# PARALLEL COORDINATES PROPERTIES

## GRAPHICALLY INTENSE

One item → thousand pixels

Overplotting, low capacity



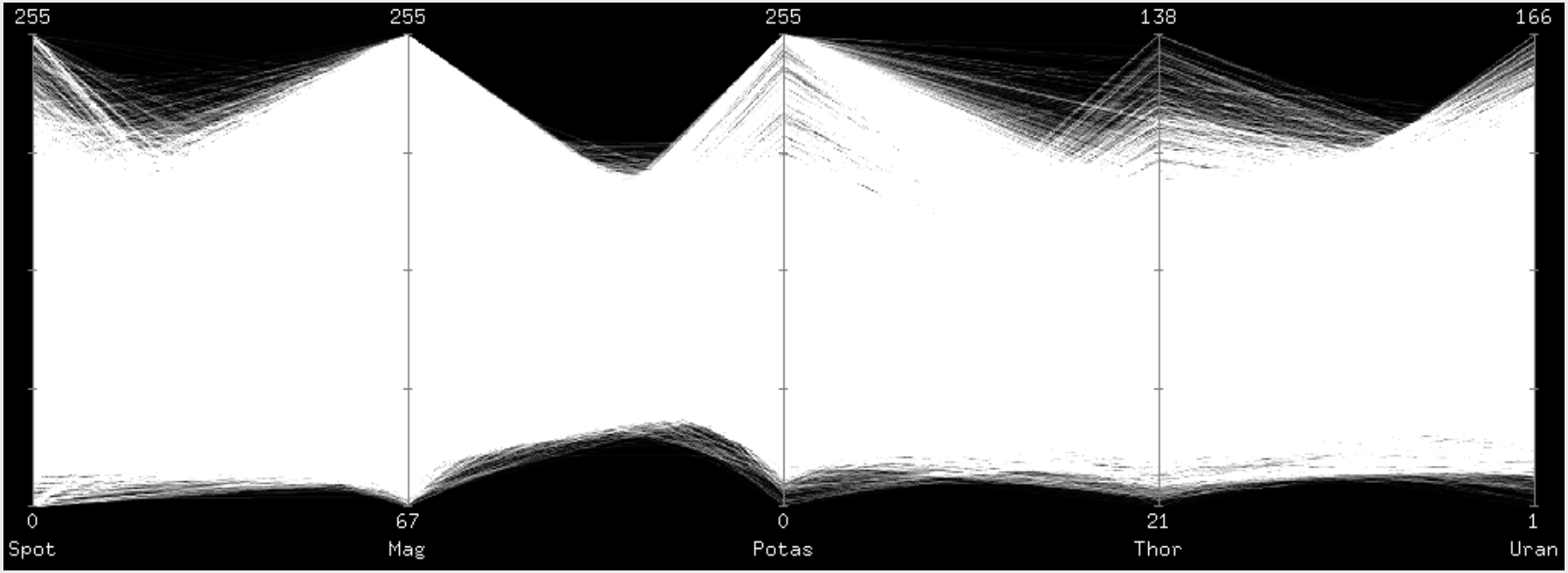

## 16.000 SAMPLES

# PARALLEL COORDINATES PROPERTIES

## GRAPHICALLY INTENSE

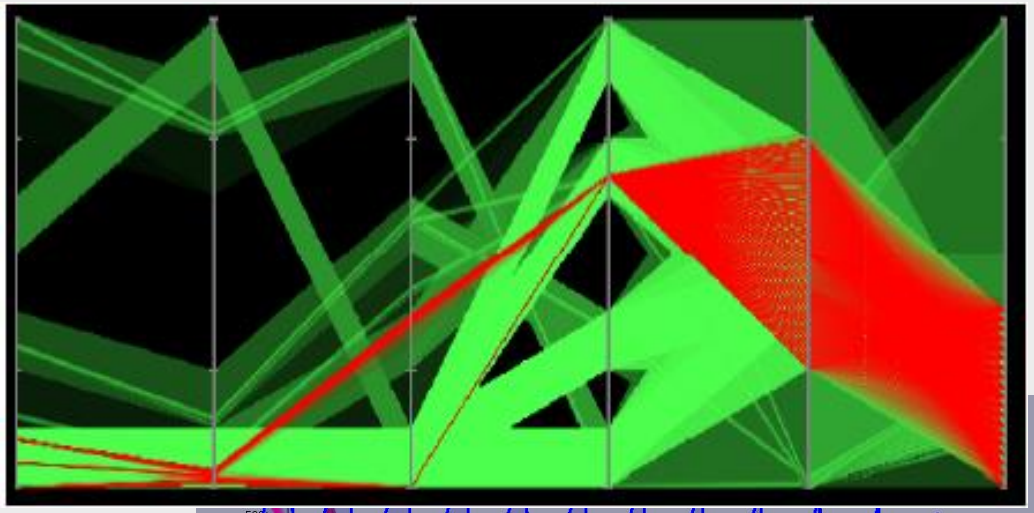
One item → thousand pixels

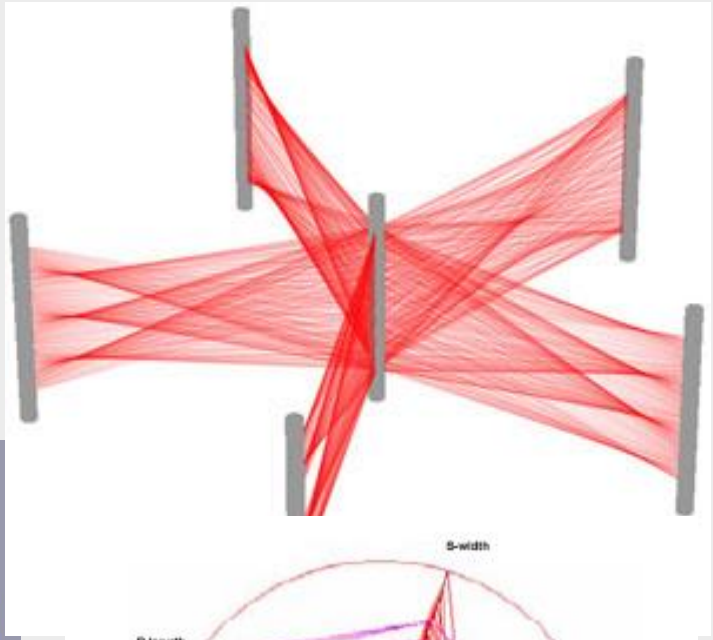
Overplotting, low capacity

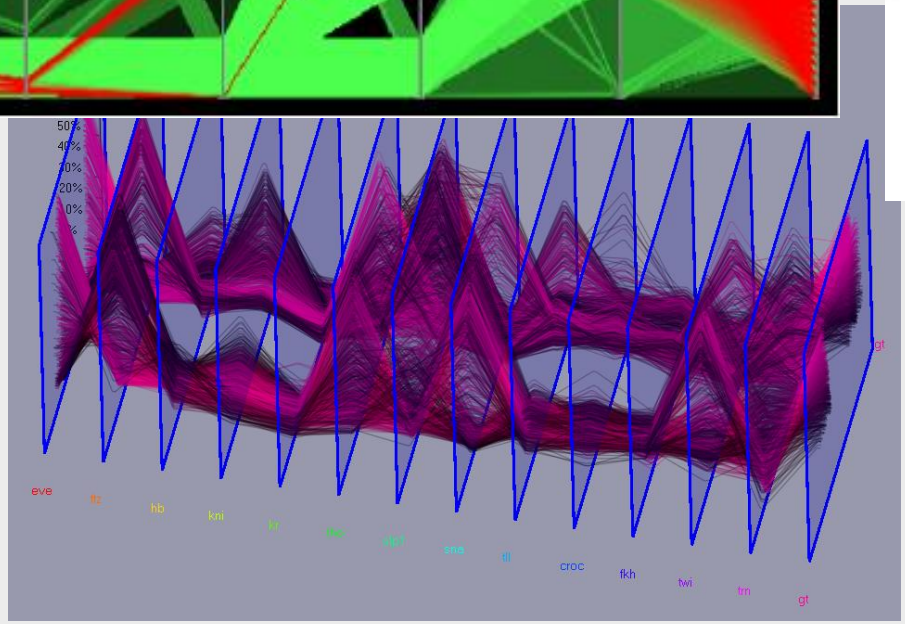


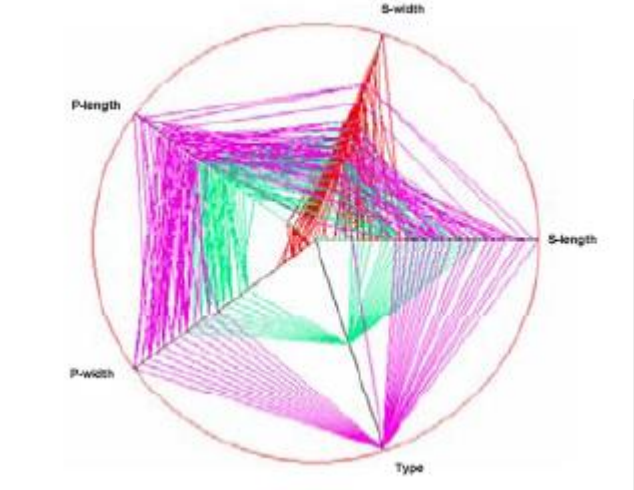

## 100.000 SAMPLES

# MODIFICATIONS







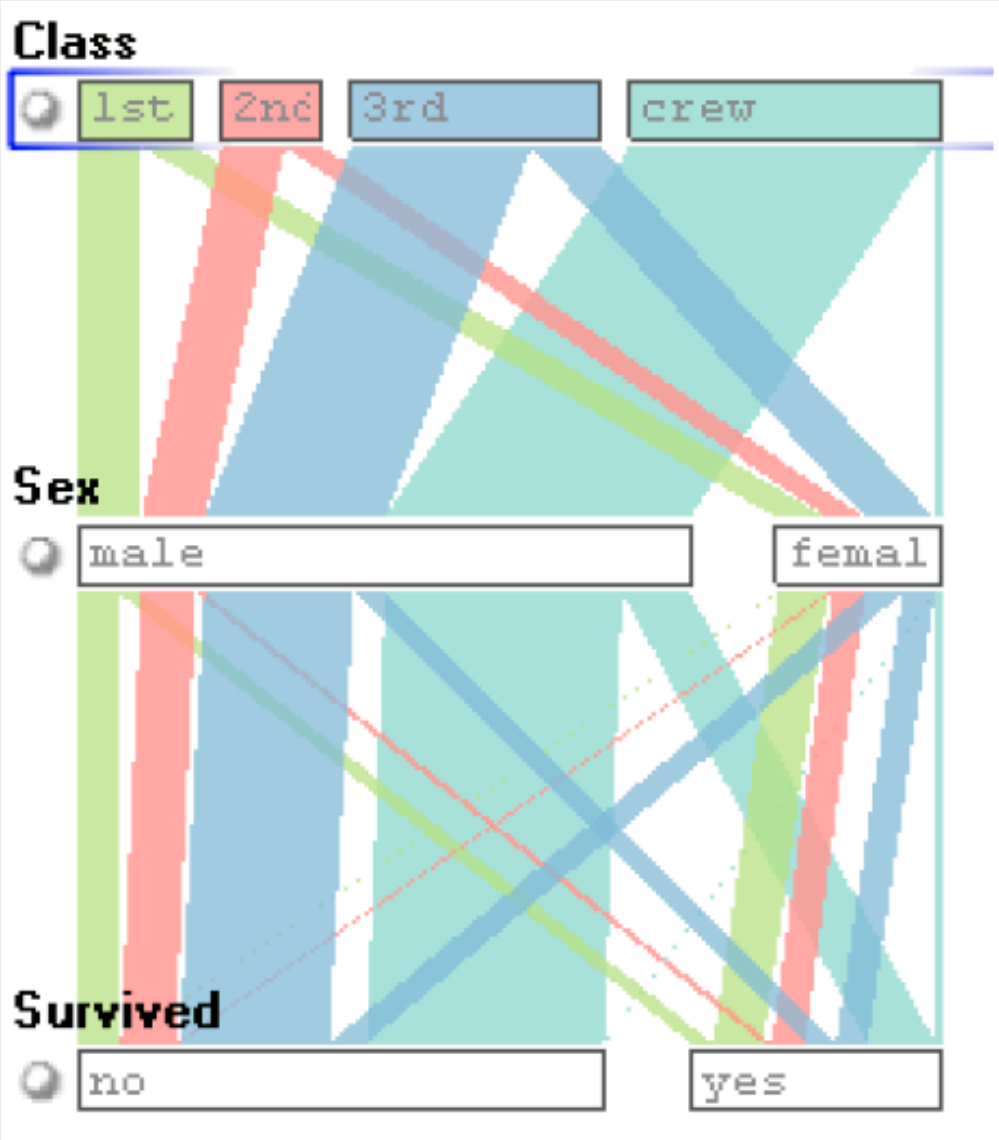
# PARALLEL SETS

CATEGORICAL DATA

PARALLEL AXES

COLORING BY ONE ATTRIBUTE

TITANIC DATA →



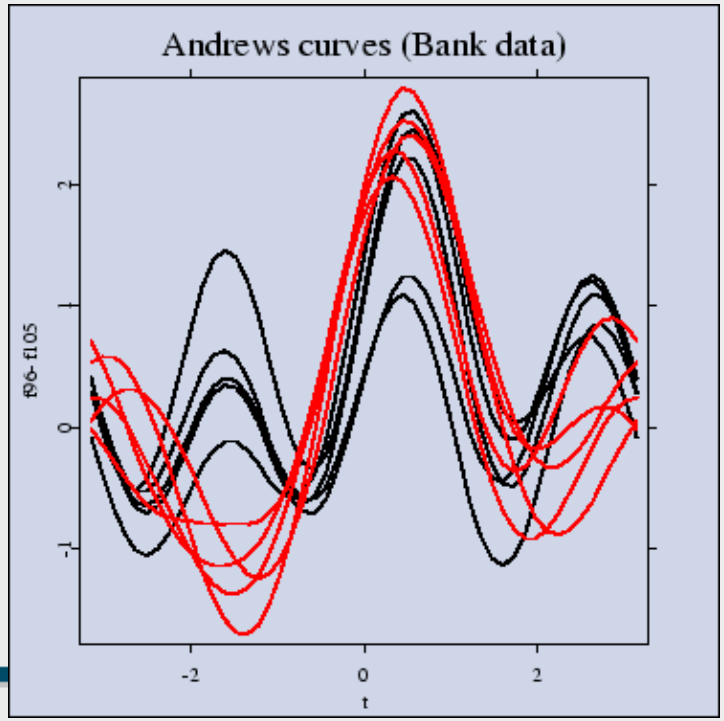
# ANDREWS PLOT

## COORDINATE SYSTEM BASED ON ORTHOGONAL TRIGONOMETRIC FUNCTIONS (LIKE FOURIER)

$$F_i(t) = X1_i/SQRT(2) + X2_i*SIN(t) + X3_i*COS(t) + X4_i*SIN(2t) + X5_i*COS(2t) + \ldots$$

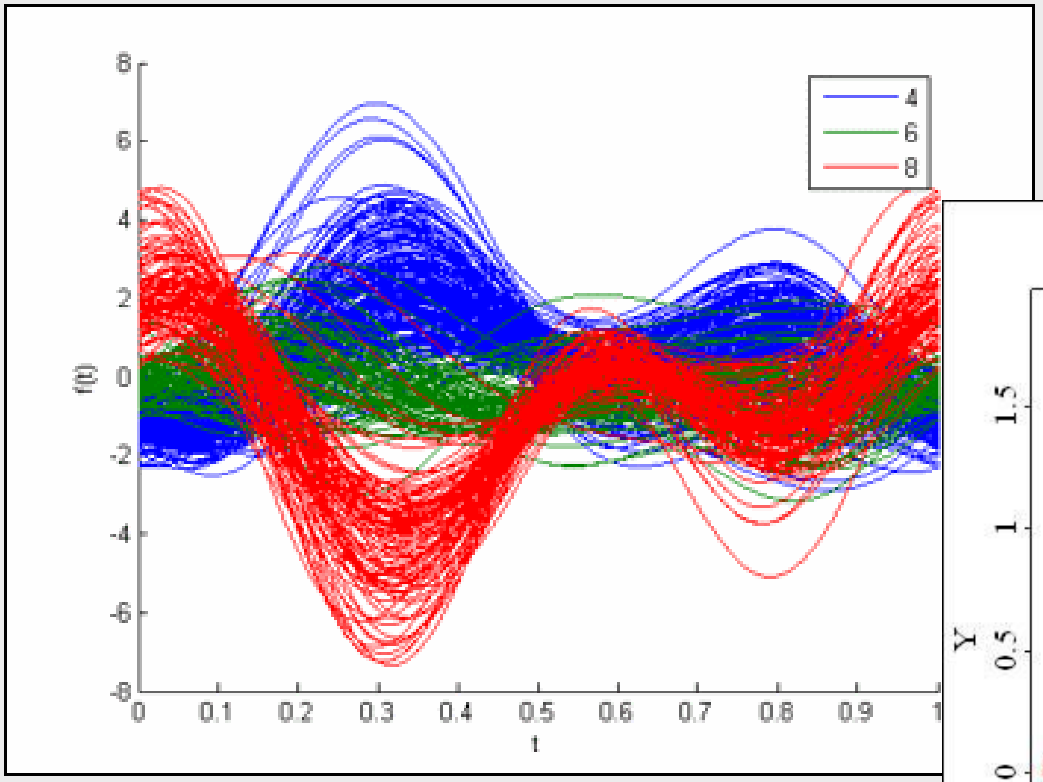
## NO SEMANTICS IN X,Y

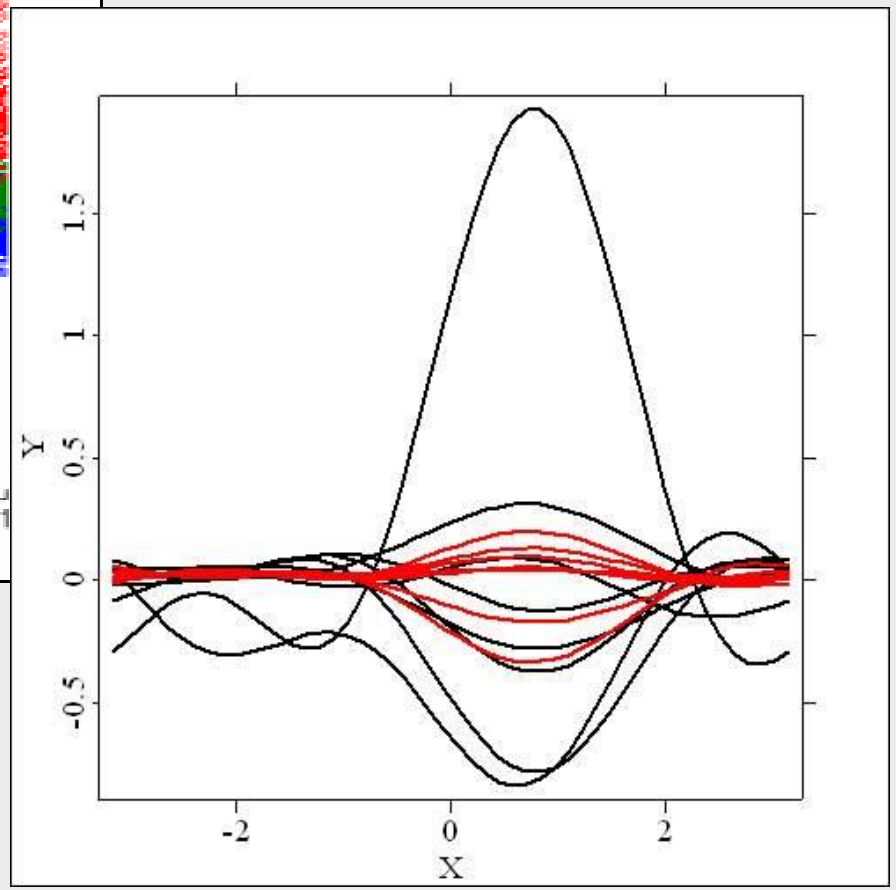
## ORDER OF DIMENSIONS SUPERIMPORTANT



# ANDREWS PLOT

← CARS




STOCKS →

# SUMMARY

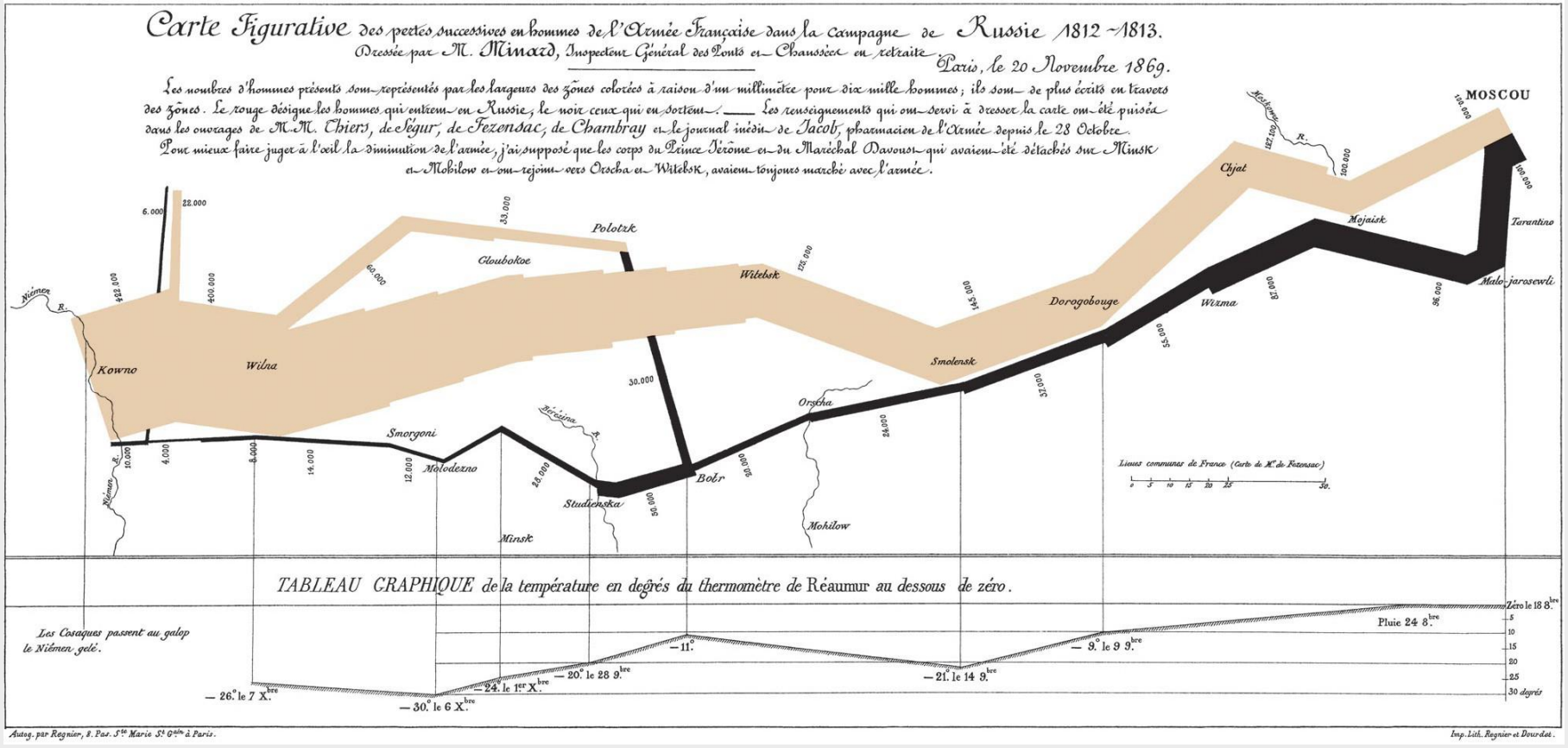
ORTHOGONAL COORDINATE SYSTEMS USE UP SPACE

RECONFIGURATION OF AXES
OFFERS MORE DIMENSIONS

RECONFIGURED COORDINATES SYSTEMS MAY
Be non-intuitive (e.g. par.coordinates, andrews plot)
Require learning
Be abstract (e.g. trigonometric functions)

# TIME-DEPENDENT DATA

# CHARLES MINARD, 1869
# NAPOLEON CAMPAIGN TO RUSSIA IN 1812



# MOTIVATION

*"PREDICTION IS VERY DIFFICULT, ESPECIALLY ABOUT THE FUTURE"*

UNDERSTANDING TEMPORAL RELATIONS HELPS PREDICT FUTURE

DETECTING EVENTS HELPS LEARN FROM THE PAST AND FIND RELATIONS

*References:* Aigner et al. :
Visualizing Time-Oriented Data - A Systematic View

# STRUCTURE OF TIME AXIS

## TIME POINTS VS. TIME INTERVALS

## GRANULARITY
seconds, weeks, ...

## LINEAR TIME
E.g. average income over last 50 years

## CYCLIC TIME
E.g. website visitors over a week

## BRANCHING TIME
E.g. project development

# DIMENSIONALITY

## SINGLE DIMENSION

E.g. ocean level over past 50 years

## MULTIPLE DIMENSIONS

Multiple dimensions in different time points
E.g. temperature, humidity, wind speed measured at different (not the same) time

## MULTIDIMENSIONAL

Complete multidimensional snapshots at different time points
E.g. credit card transactions

# ENTITIES

## SINGLE ENTITY

Various temporal aspects of 1 entity
E.g. health monitor of a patient

## MULTIPLE ENTITIES

Track development of each entity over time
e.g. GDP of European countries over years

## UNKNOWN ENTITIES

No entity match between timesteps
E.g. anonymous censuses from different years

# UNCERTAINTY

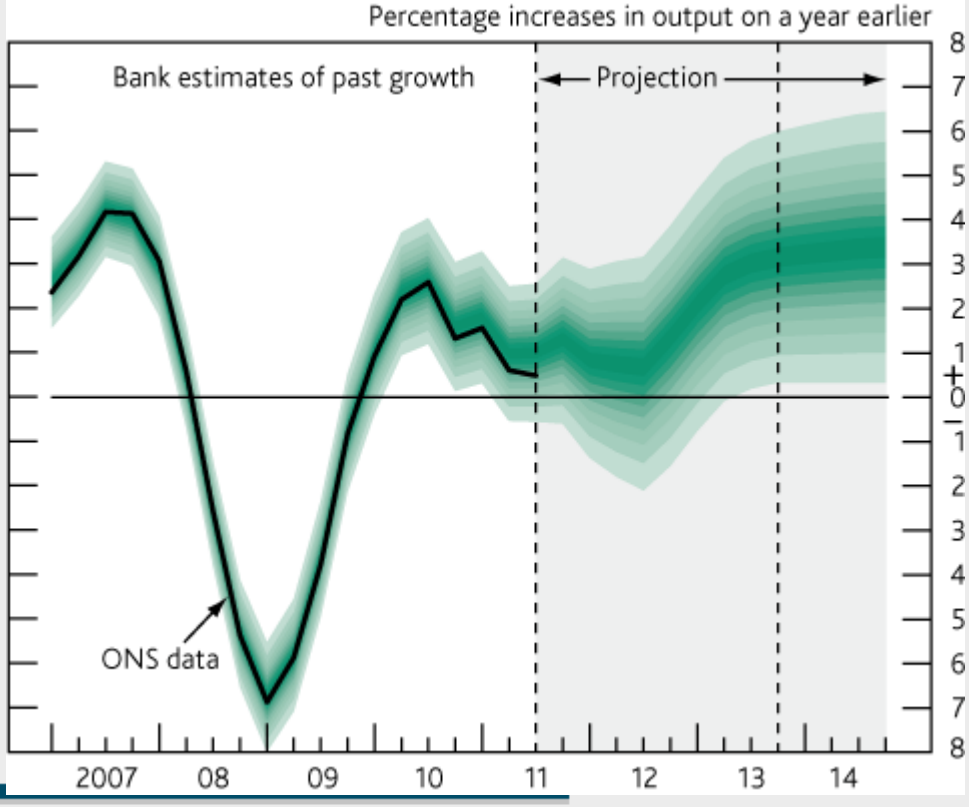
USUALLY ABOUT FUTURE DATA

LEVEL OF UNCERTAINTY

PROBABILITY (0..1)

VARIANCE

DENSITY DISTRIBUTION



# STREAMED DATA

FREQUENCY AND DYNAMICS

HOW OFTEN DATA CHANGES?

WHAT IS THE VARIATION OF DATA?

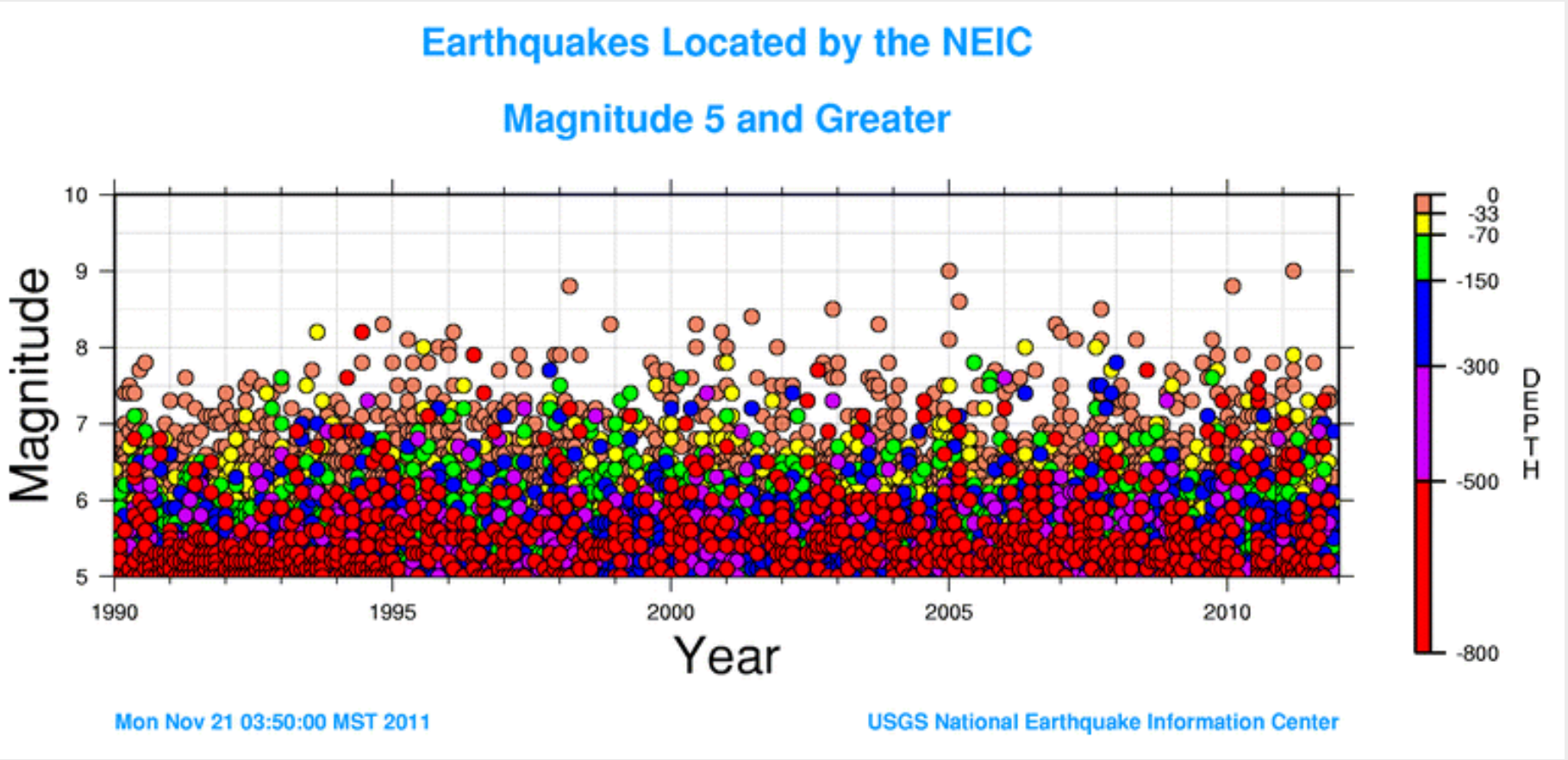
WHEN WAS THE LAST UPDATE

E.G. TRAFFIC INFORMATION, WEATHER INFORMATION

# GOALS OF TEMPORAL VISUALIZATION

# COMPARE DATA IN DIFFERENT TIMESTEPS

## DIFFERENCES BETWEEN SPECIFIC TIME STEPS

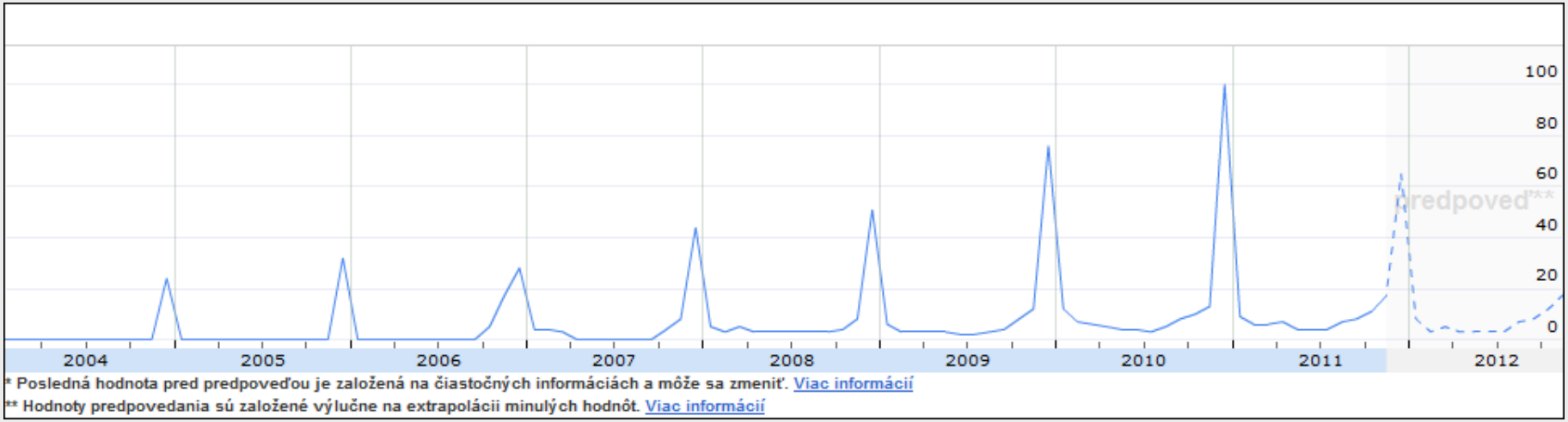


# DETECT EVENTS

## EVENT =
## WHEN A SIGNIFICANT CHANGE HAPPENS

# DETECT PATTERNS IN 1 ATTRIBUTE

## INCREASE, DECREASE, REPEAT, JUMP, DROP, ...

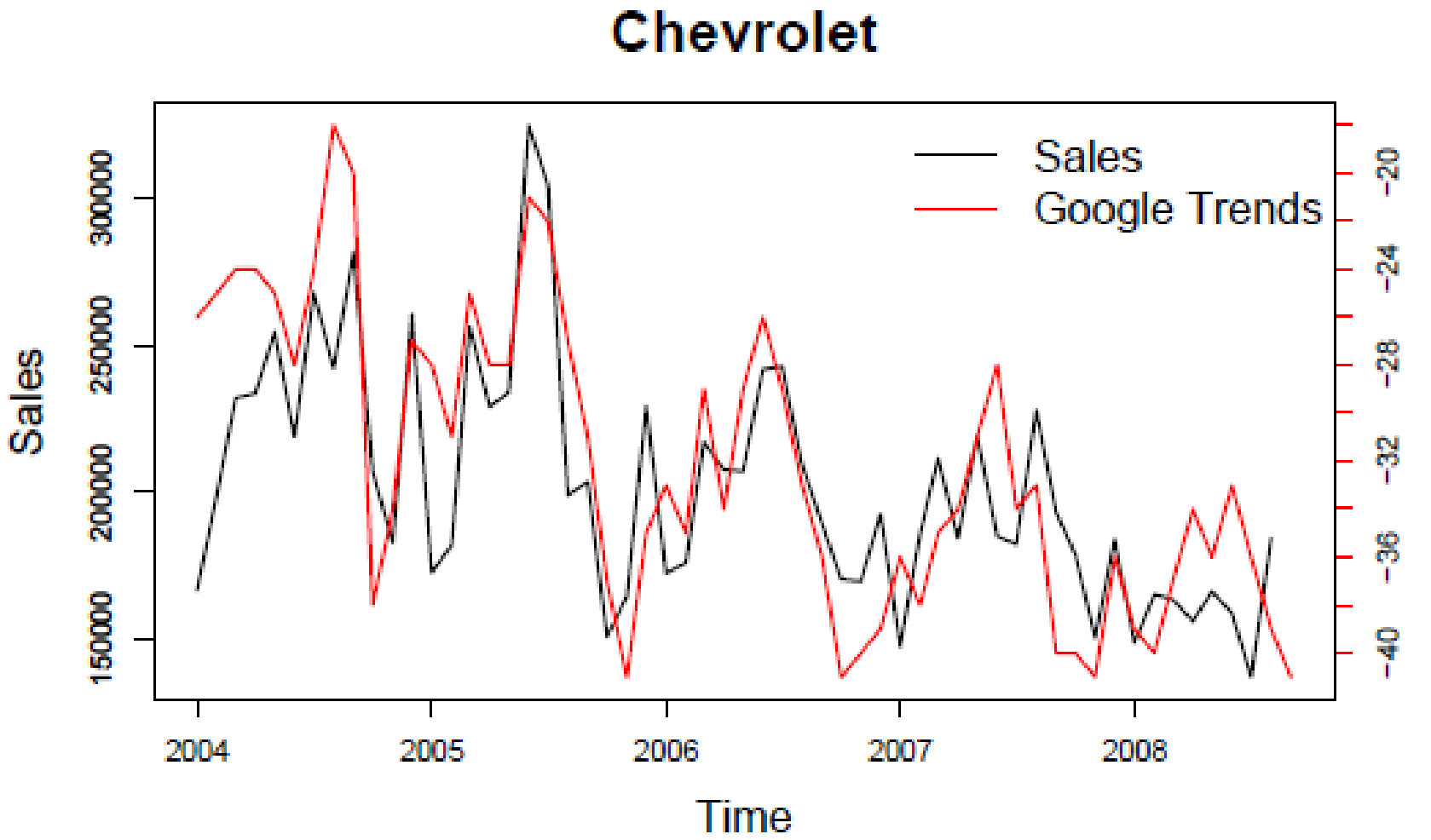



# DETECT LAYERED PATTERNS

## LOCAL + GLOBAL TRENDS


# DETECT ATTRIBUTE RELATIONS

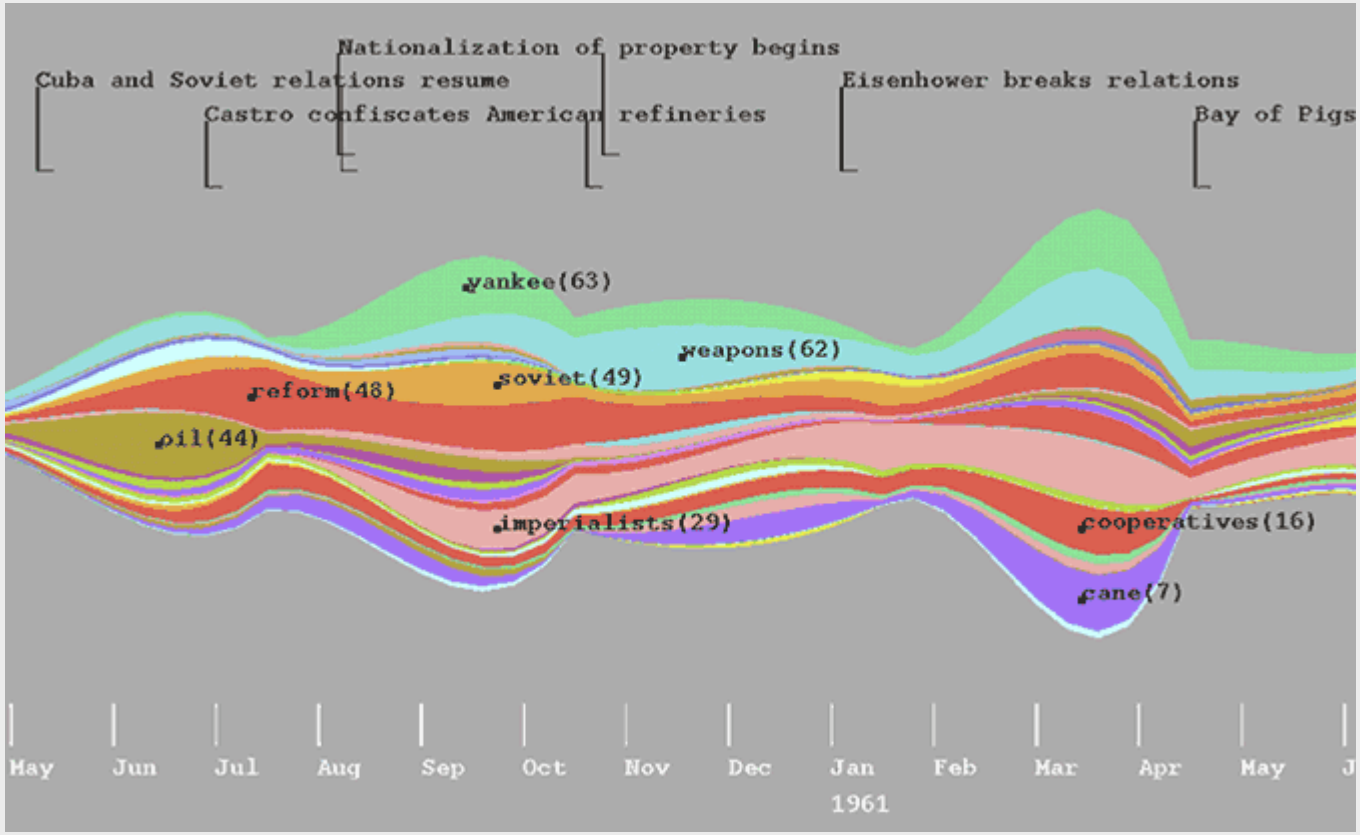
## ARE TWO VARIABLES RELATED IN TIME?



# EXAMPLE TECHNIQUES

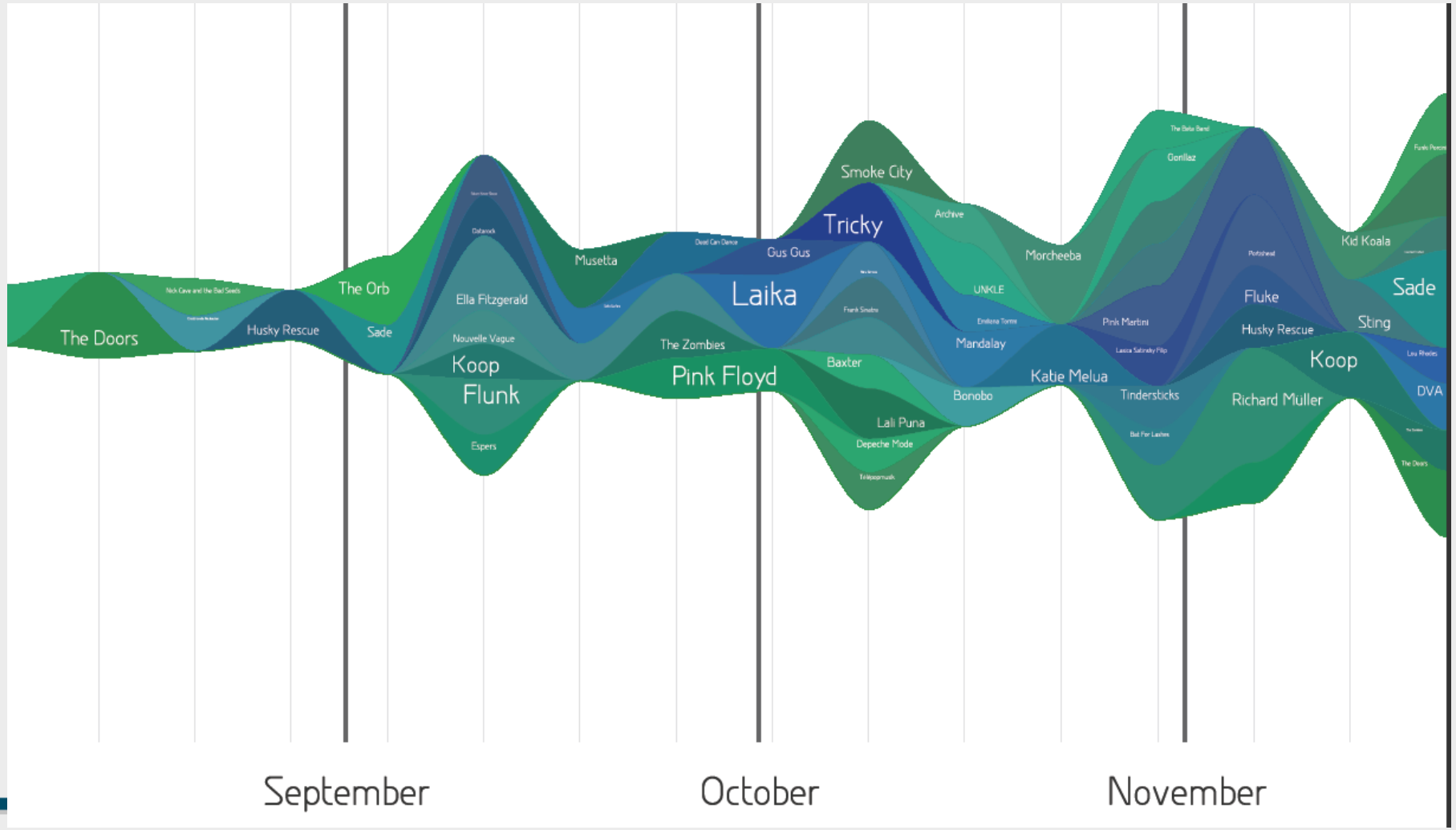
# THEME RIVER

## HISTOGRAM IN DIFFERENT TIME STEPS. SPLINE INTERPOLATION OF VALUES => AREAS



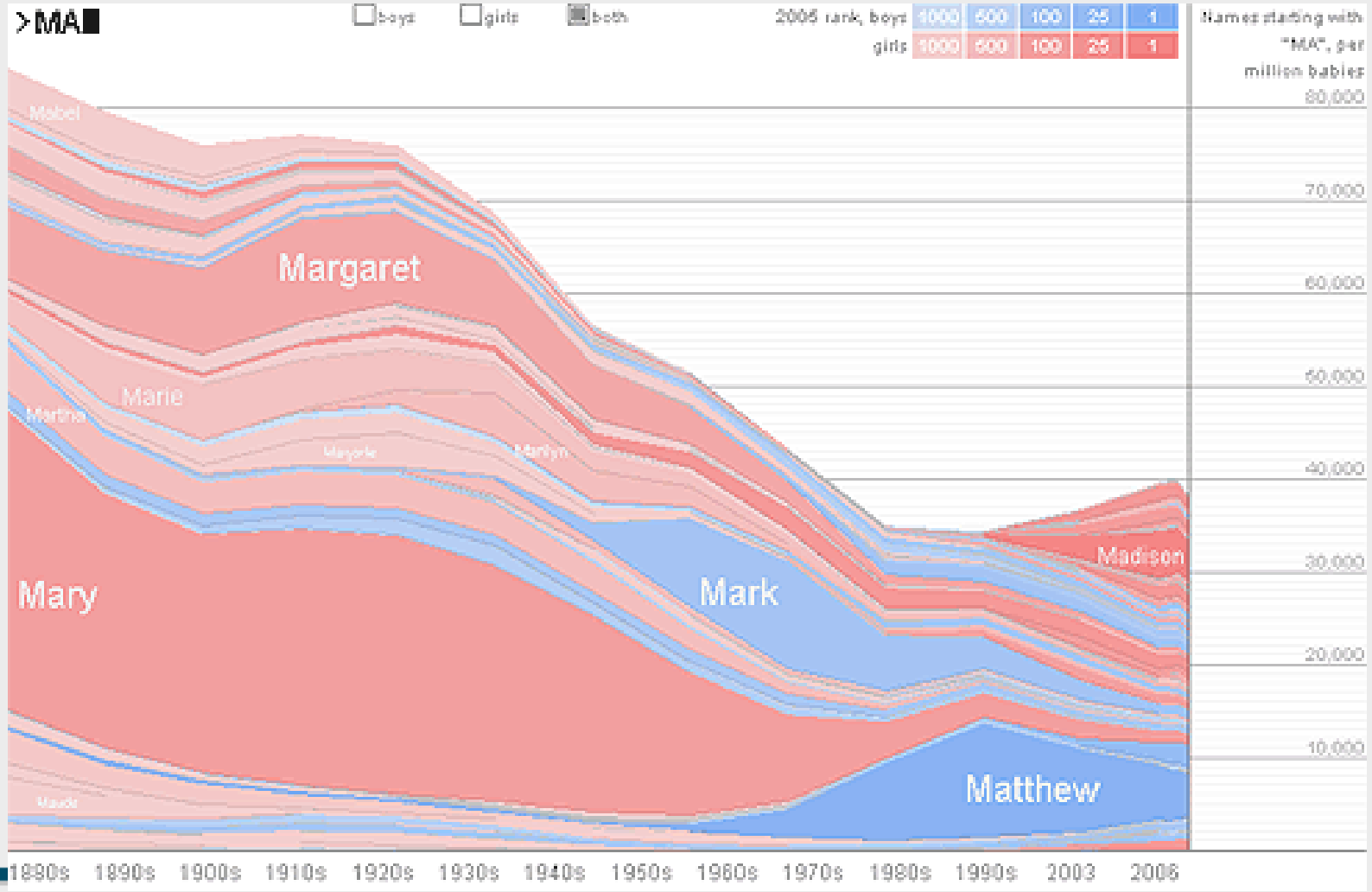
# THEME RIVER CLONES

http://lastgraph.aeracode.org/

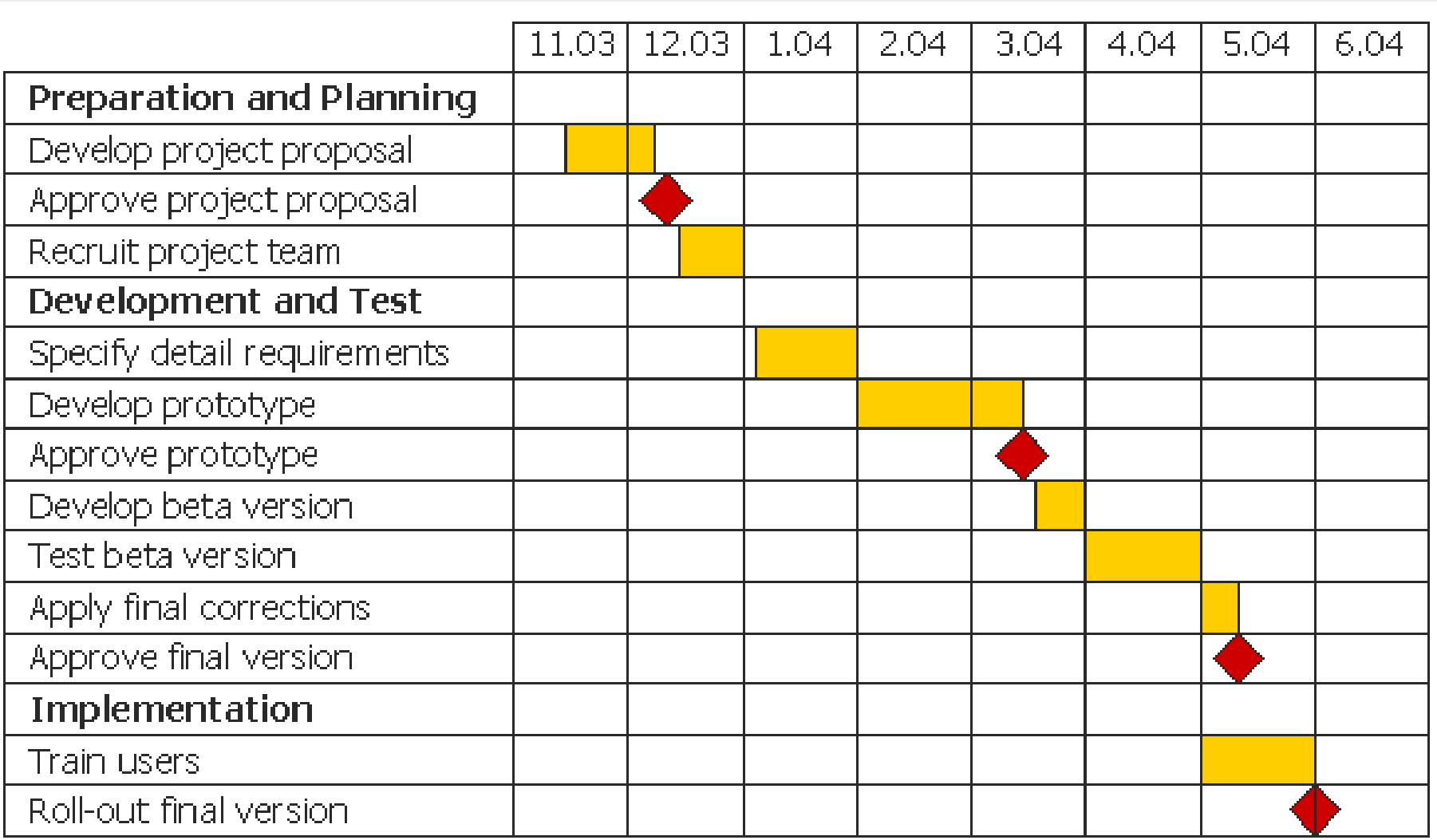


# THEME RIVER CLONES

http://babynamewizard.com/voyager

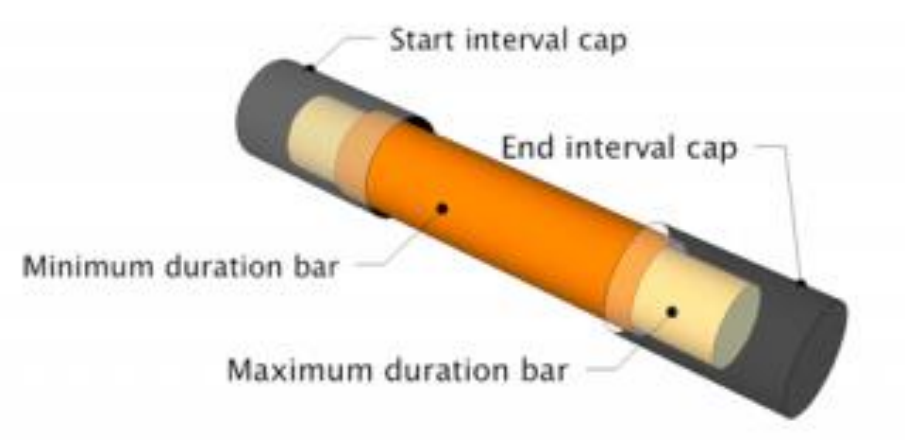


# GANTT CHART & MODIFICATIONS

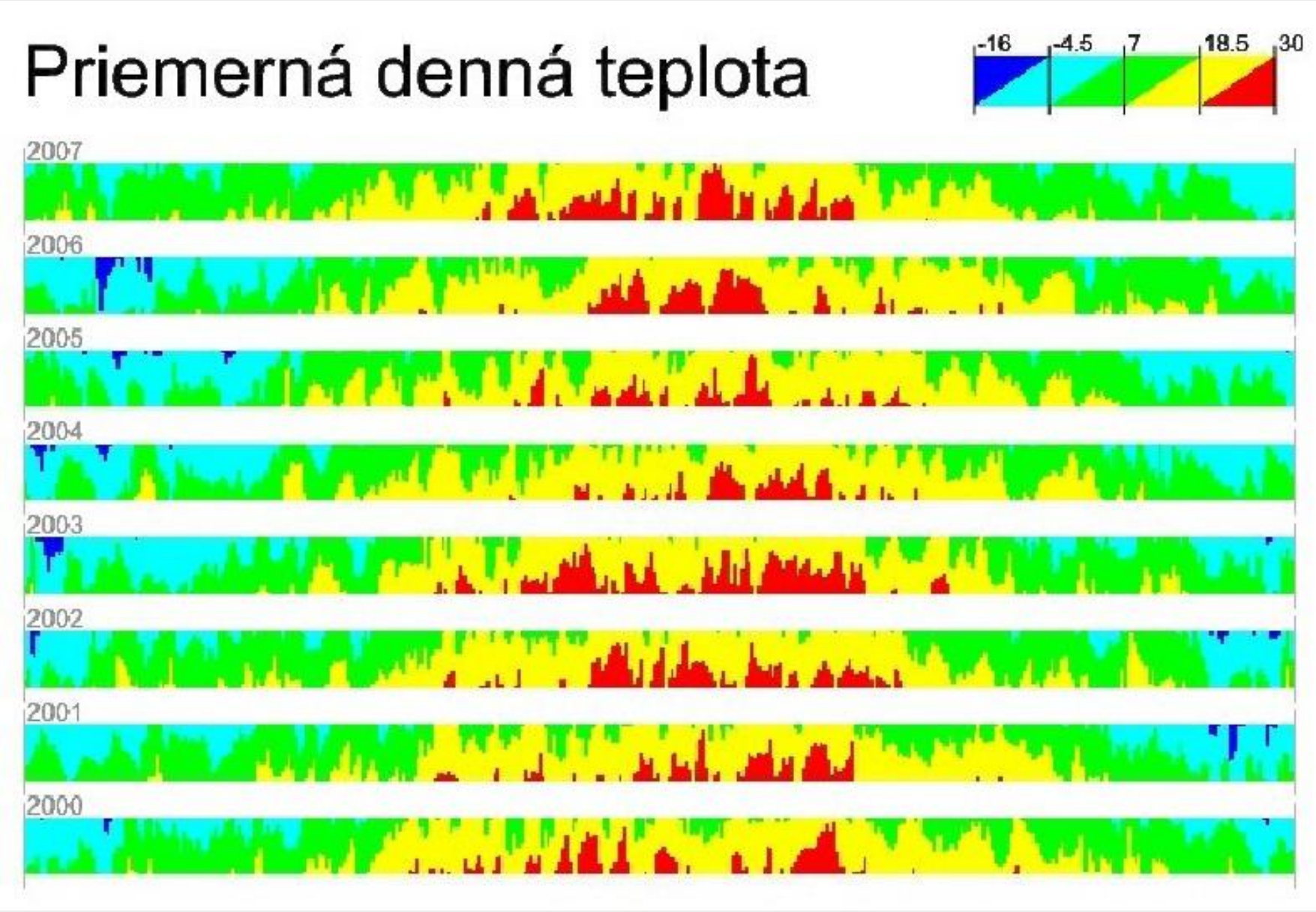


# GANTT CHART MODIFICATIONS

## PLANNINGLINES



# TWO-TONE PSEUDO COLORING



# SPIRAL GRAPH

## TIME AXIS AS A SPIRAL.
## CYCLE LENGTH IS A PARAMETER
## => PERIODICITY CAN BE REVEALED

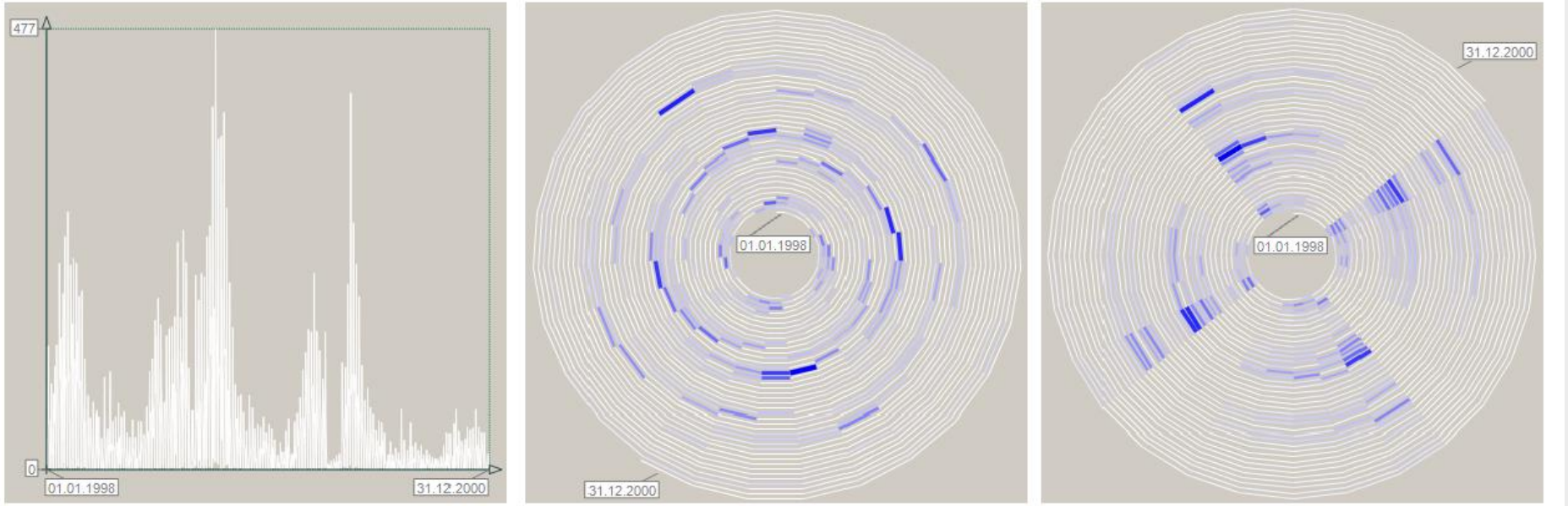
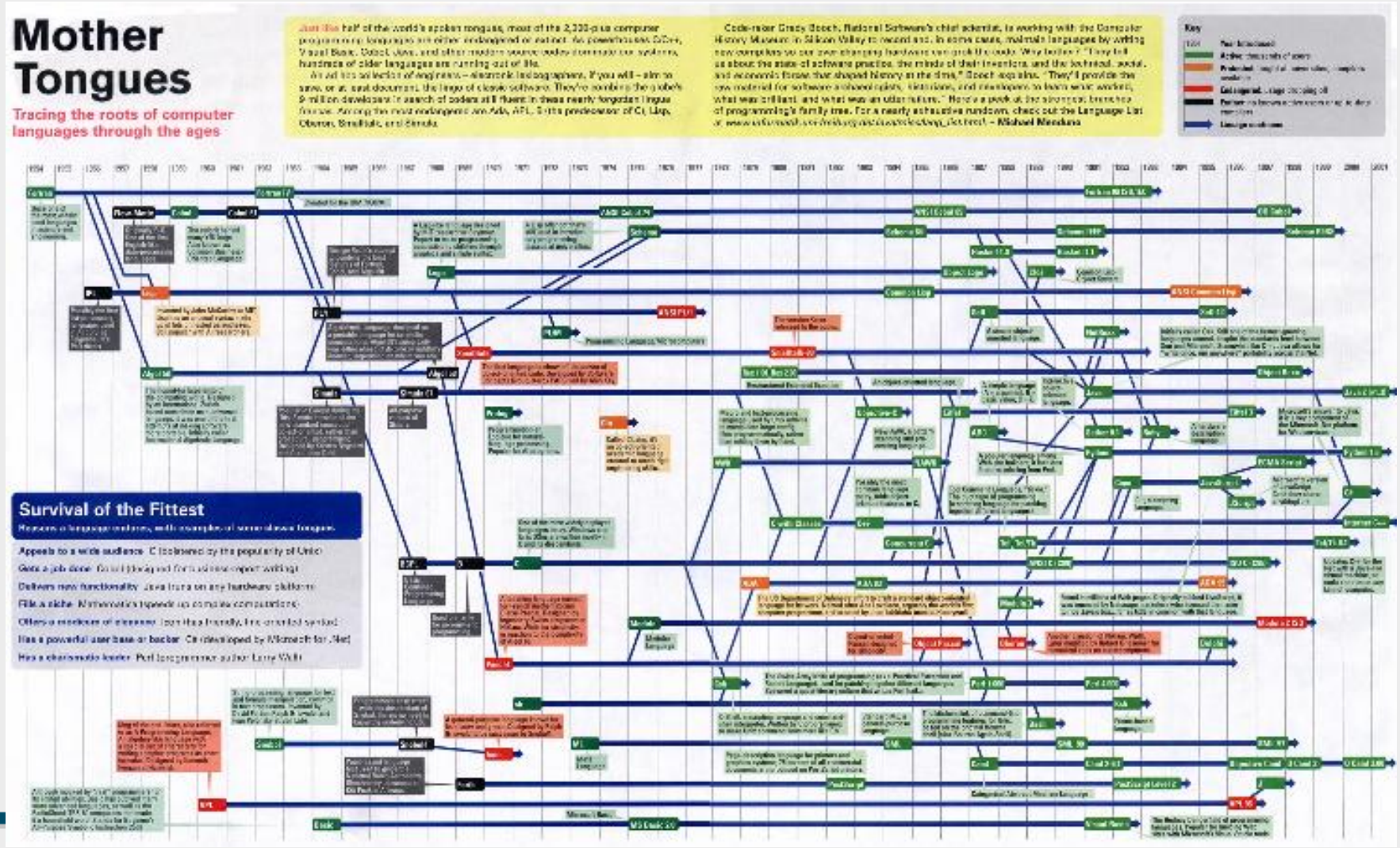



Fig. 1. Different visual representations of a time-oriented dataset describing the number of influenza cases over a period of three years – left: Time series plot (periodic pattern is difficult to discern), center: SpiralGraph encoding 27 days per cycle (improperly parameterized – periodic pattern is hard to see), right: SpiralGraph encoding 28 days per cycle (properly parameterized – periodic pattern stands out).

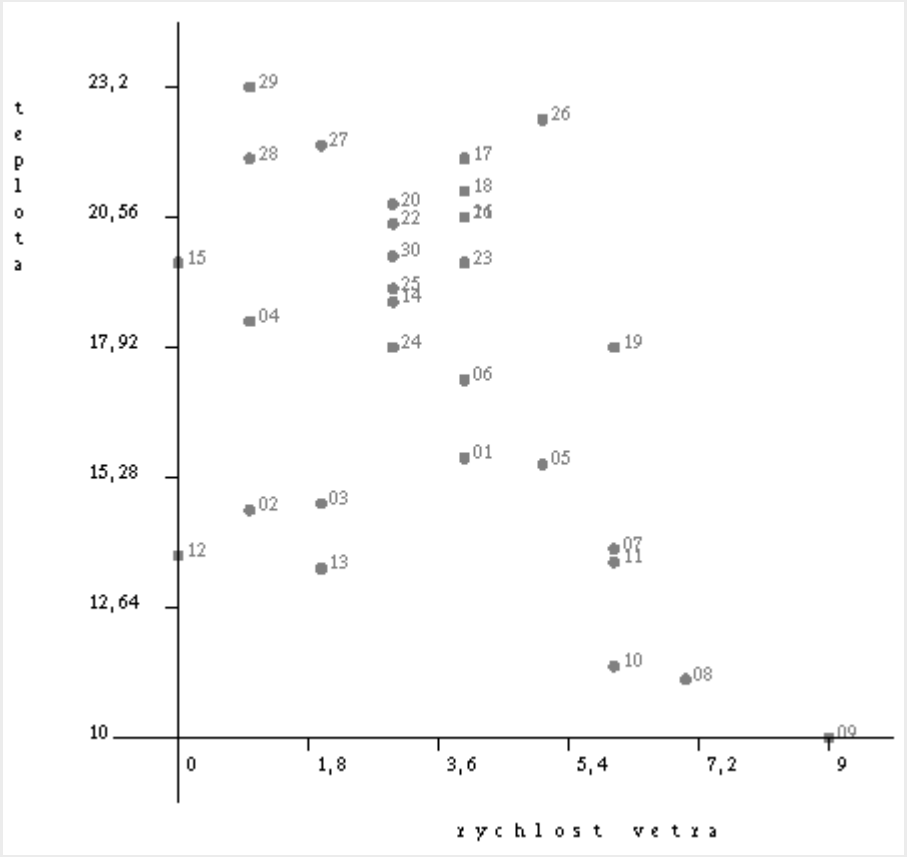
# BRANCHING TIME

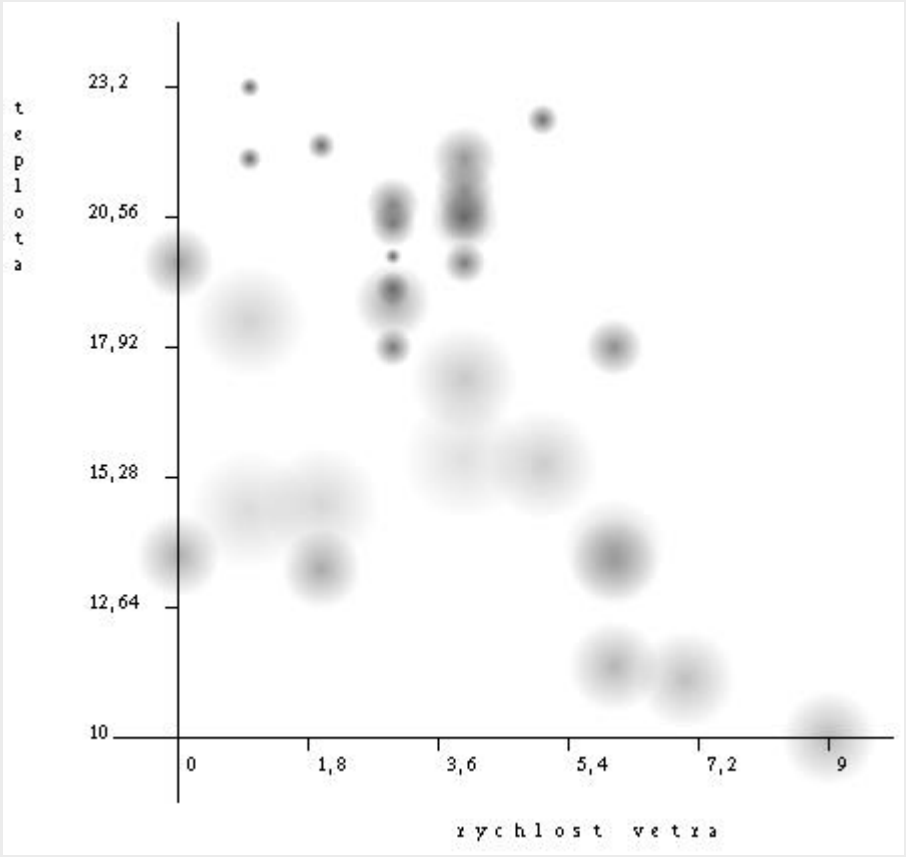
www.digibarn.com/collections/posters/tongues/



# TIME-DEPENDENT SCATTERPLOTS

## INK STAIN METAPHOR



# SUMMARY

## DATA TYPES

One or multiple attributes over time
One or multiple (or no known) entities over time

## VISUALIZATION OF TIME-DEPENDENT DATA

Temporal trends (rise, decline, periodicity)
Attribute correlation over time (helps prediction)
Event detection (outlier in temporal domain)