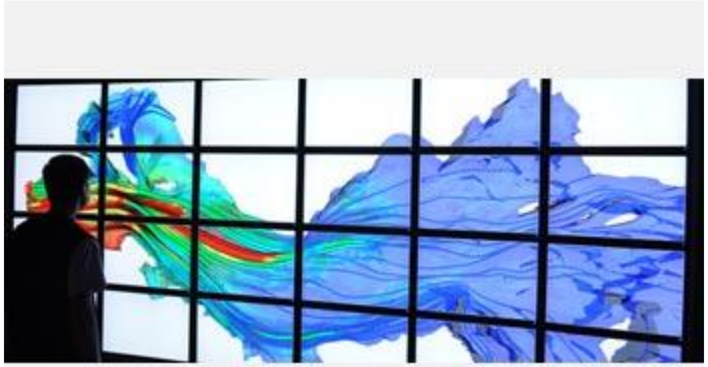
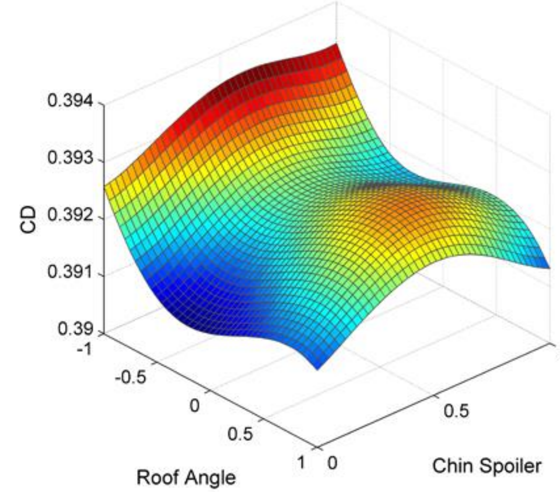


www.nsf.gov

www.estatevaults.com



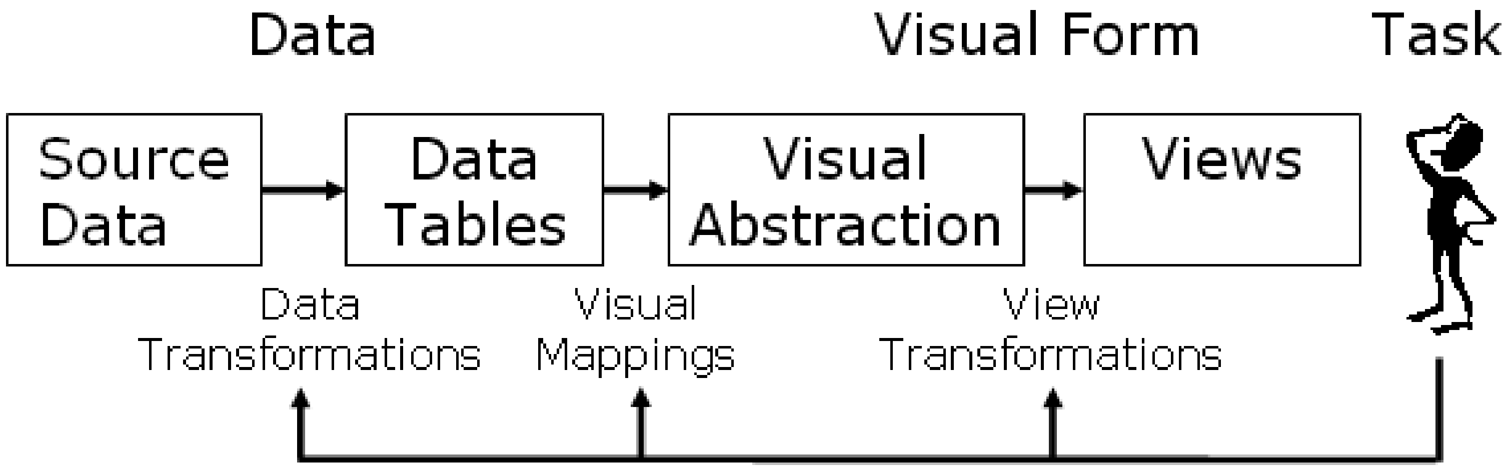
exa.com

4. Basic principles of visualization

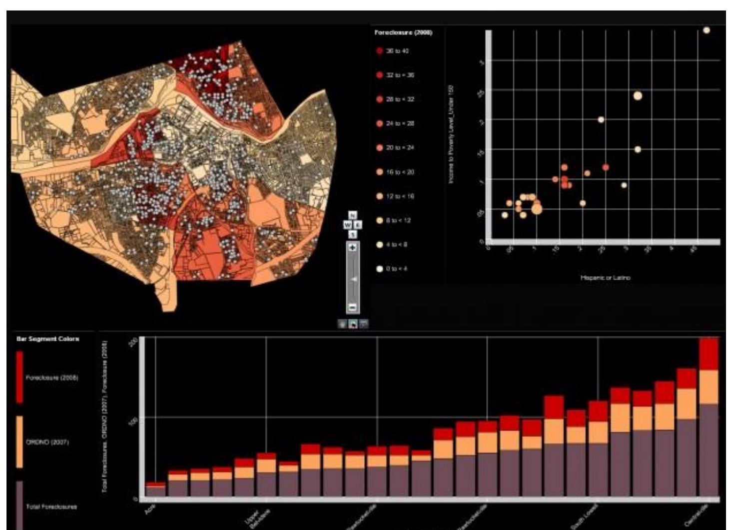
www.usingmindmaps.com

www.cg.tuwien.ac.at

Visualization pipeline



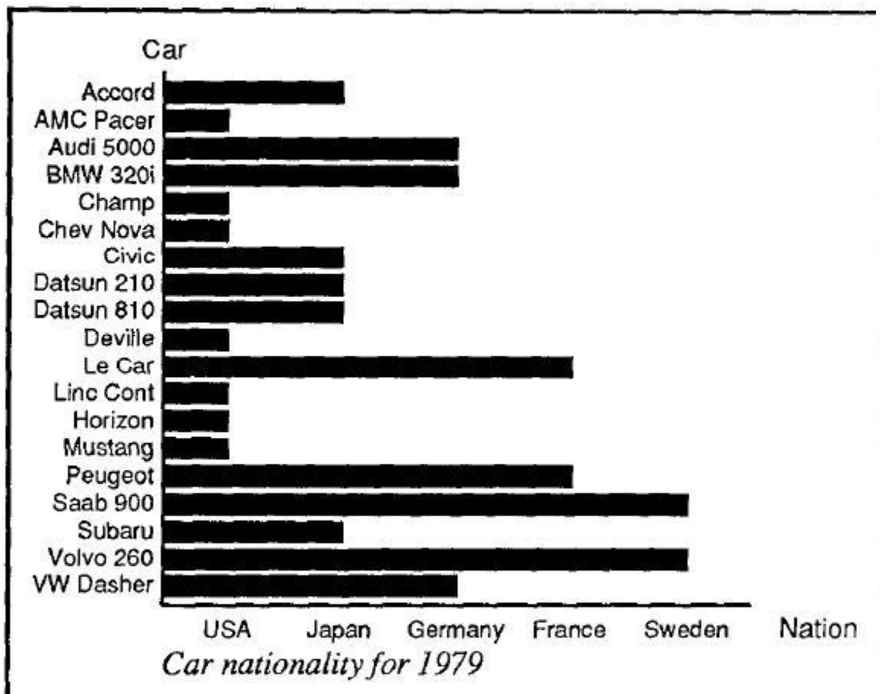
prefuse.org



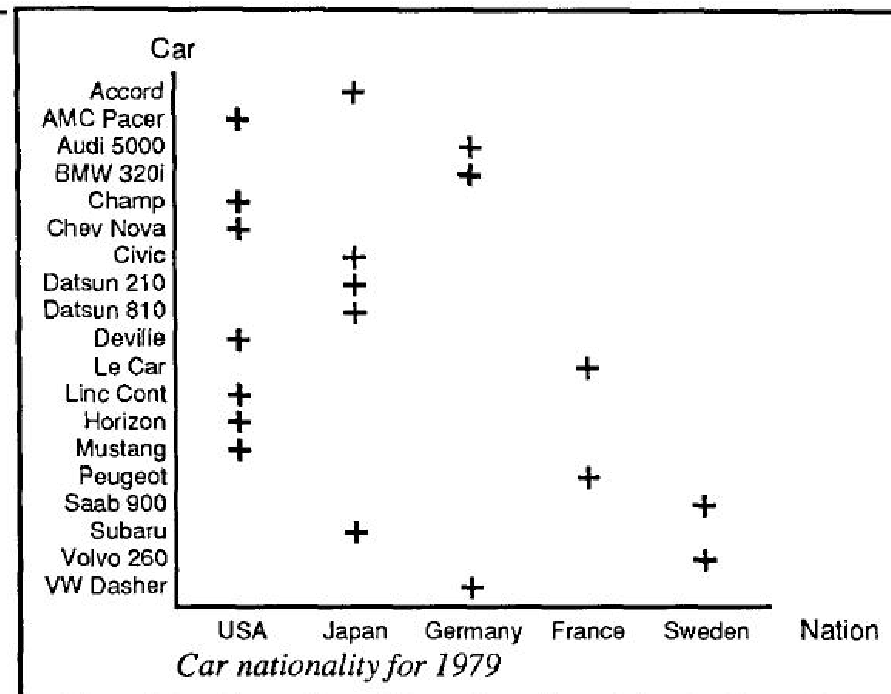
flowingdata.com

Working with data

- Data preprocessing
  - last lecture
- Data mapping to visualization



Car nationality for 1979



Car nationality for 1979

apt

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Working with data

- Transformation and rendering

opengl.org

myego.cz

https://d3js.org/

en.wikipedia.org

Visualization metrics

- Metrics for measuring the success of information transfer using the proposed visualization
    - **Expressiveness**
    - **Effectiveness**

Expressiveness

- **M_{exp} = displayed information/information to be expressed**

  $0 \le M_{exp} \le 1$

- If $M_{exp} = 1$, expressiveness is ideal
- If $M_{exp} < 1$, we display less information than we want to
- If $M_{exp} > 1$, we present more information than we should

Effectiveness

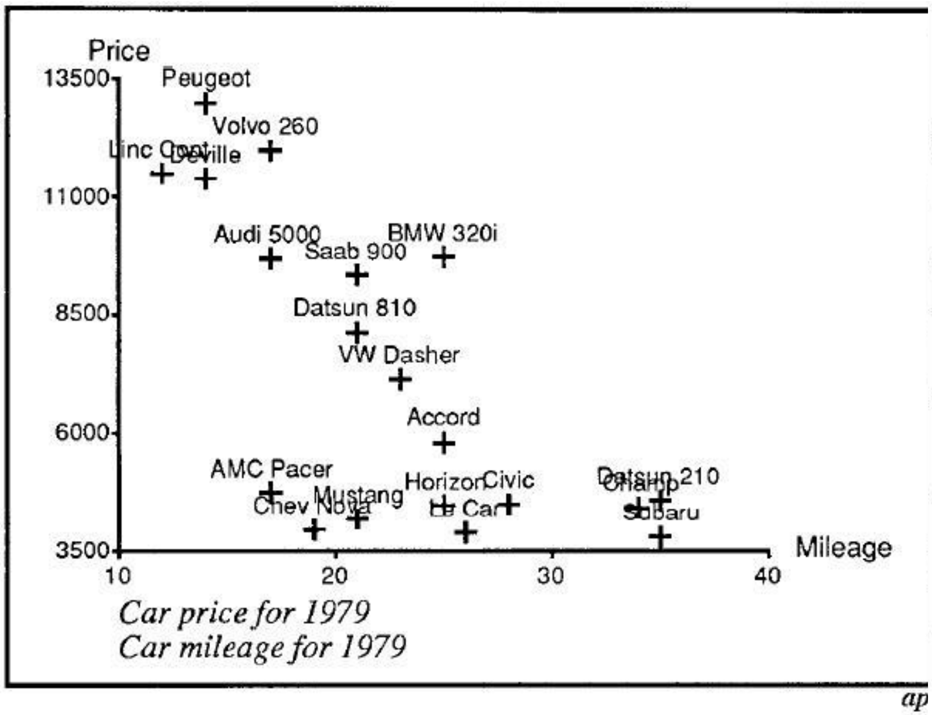
- Visualization is effective:
  - Correct and fast interpretation
  - Fast rendering

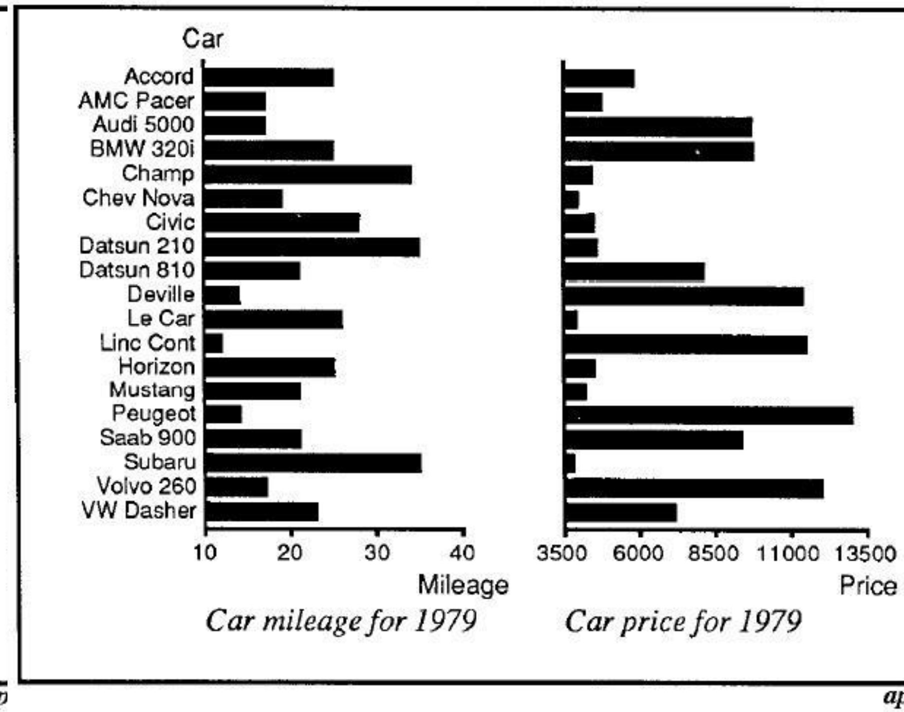
$$\mathbf{M_{eff} = 1/(1 + interpret + render)}$$

$0 \leq M_{eff} \leq 1$

- If M_{eff} is close to 1, time for interpretation and rendering is short

Example





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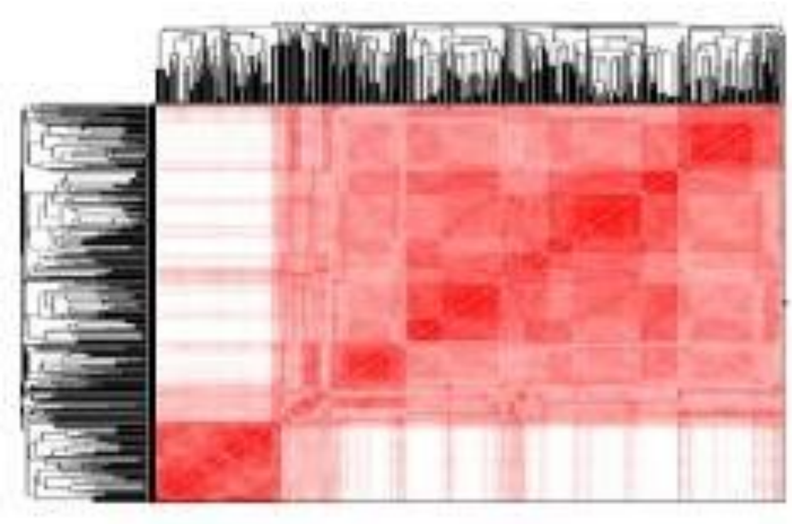
Graphical symbols

- Easily recognizable graphical symbols

Clear meaning

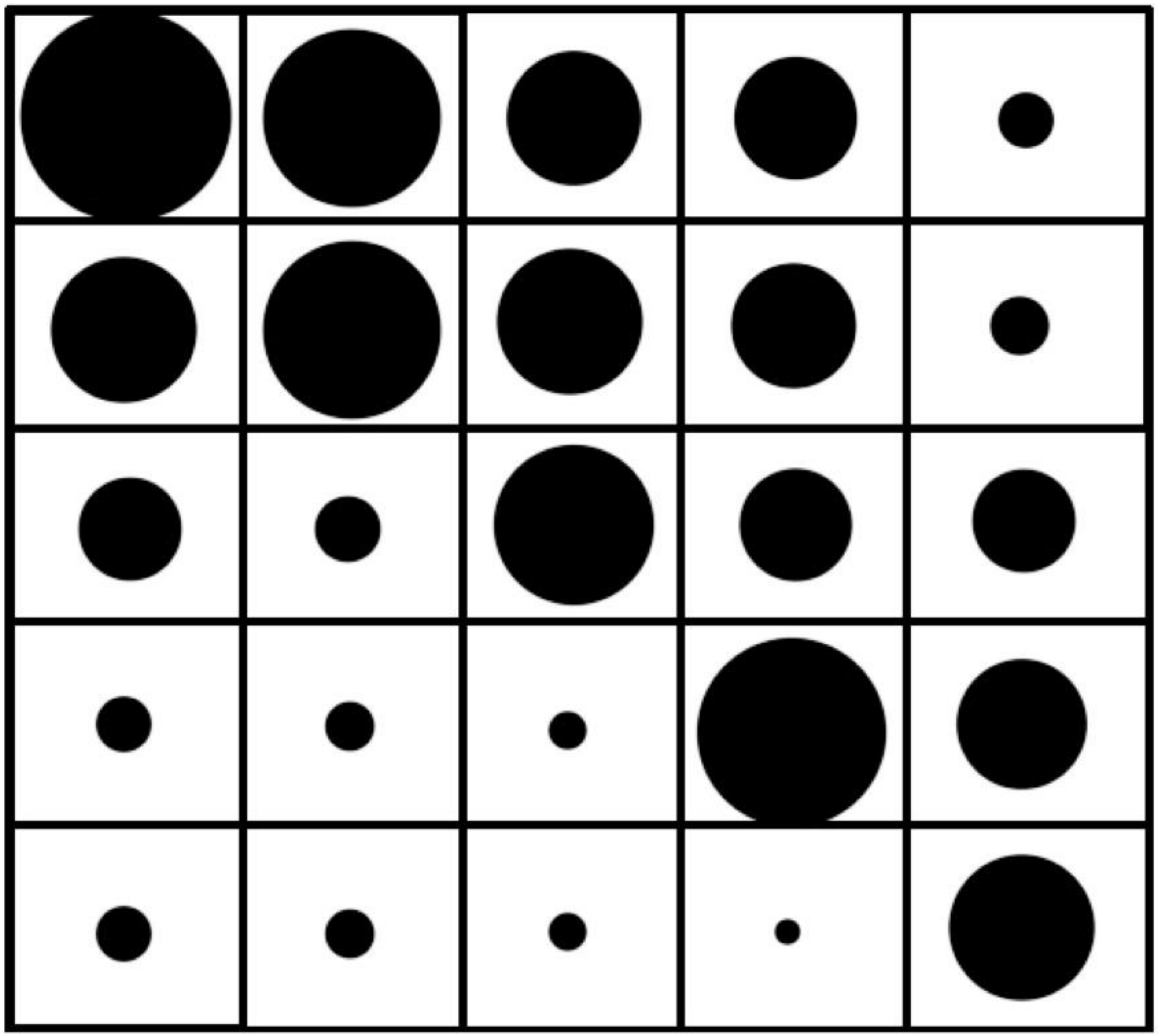


Complex meaning

Graphical symbols

- Without outer, cognitive identification any graphical representation makes sense. External identification has to be easily readable and understandable.
- **Similarity in data ↔ visual similarity of corresponding graphical symbols**
- **Ordering in data ↔ visual ordering in corresponding graphical symbols**

Dimensionality of 2D graphics



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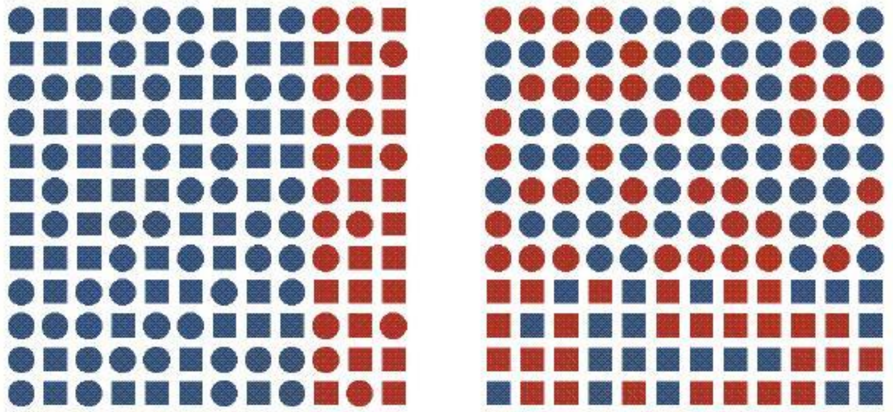
Analysis of graphics

1) Subconsciously we perceive grouping of objects

Feature	Author
line (blob) orientation	Julész & Bergen [1983]; Wolfe [1992]
length	Triesman & Gormican [1988]
width	Julész [1985]
size	Triesman & Gelade [1980]
curvature	Triesman & Gormican [1988]
number	Julész [1985]; Trick & Pylyshyn [1994]
terminators	Julész & Bergen [1983]
intersection	Julész & Bergen [1983]
closure	Enns [1986]; Triesman & Souther [1985]
colour [hue]	Triesman & Gormican [1988]; Nagy & Sanchez [1990]; D'Zmura [1991]
intensity	Beck et al. [1983]; Triesman & Gormican [1988]
flicker	Julész [1971]
direction of motion	Nakayama & Silverman [1986]; Driver & McLeod [1992]
binocular lustre	Wolfe & Franzel [1988]
stereoscopic depth	Nakayama & Silverman [1986]
3-D depth cues	Enns [1990]
lighting direction	Enns [1990]

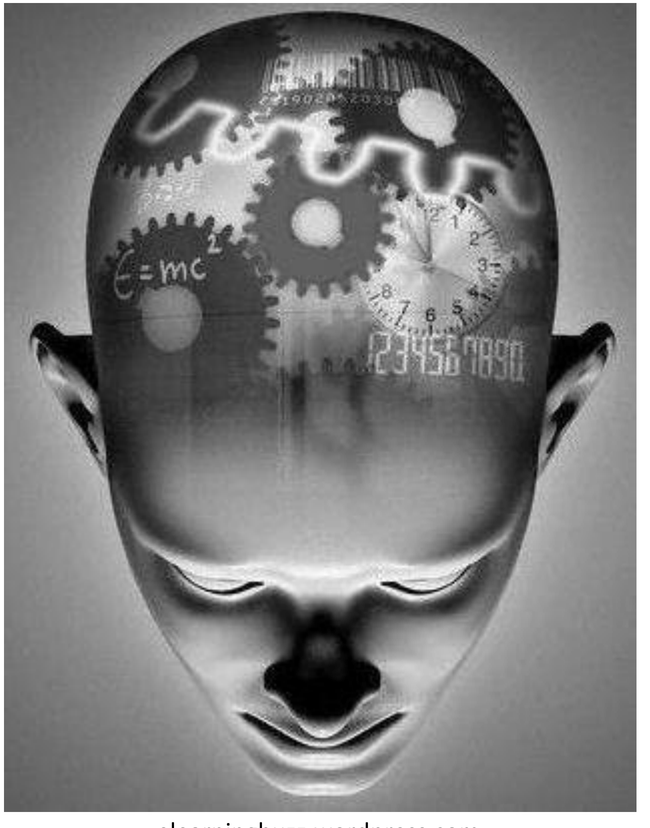


(a) (b)

http://www.infovis-wiki.net/index.php/Preattentive_processing

Analysis of graphics

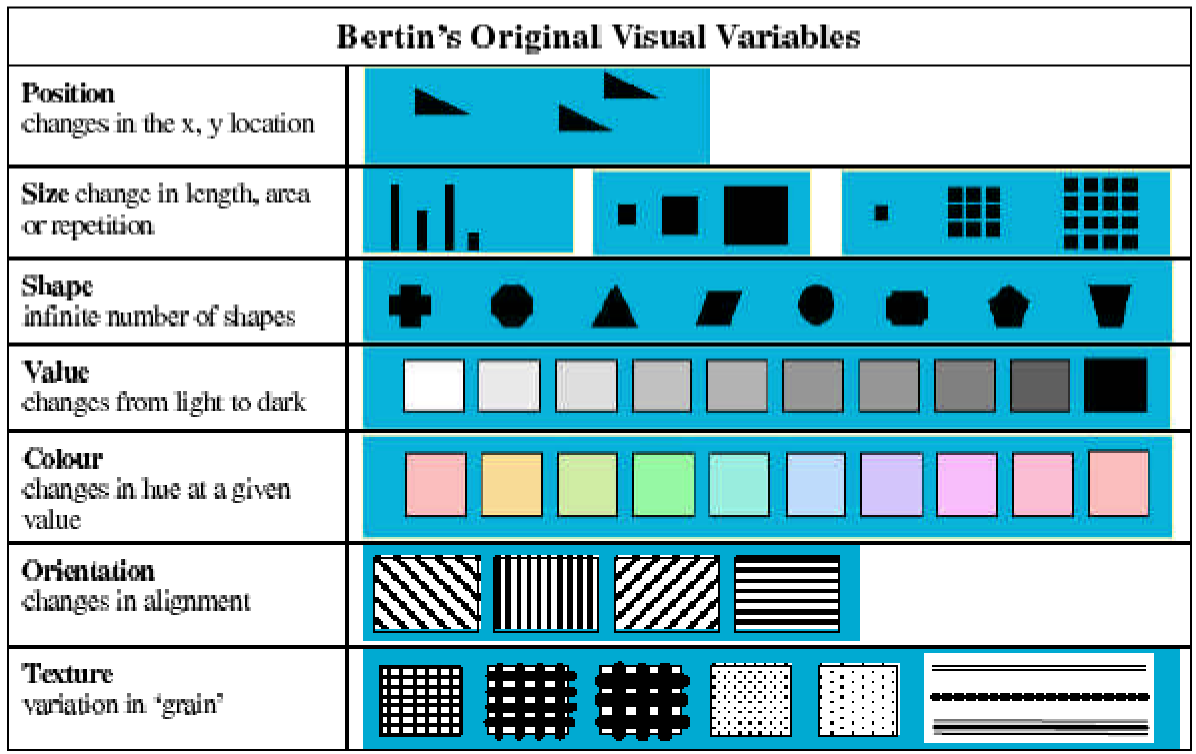
2) Cognitively we characterize these groups



elearningbuzz.wordpress.com

Eight visual variables

- Variables maximizing the effectiveness of a given visualization:
  - Position
  - Shape
  - Size
  - Brightness
  - Color
  - Orientation
  - Texture
  - Motion



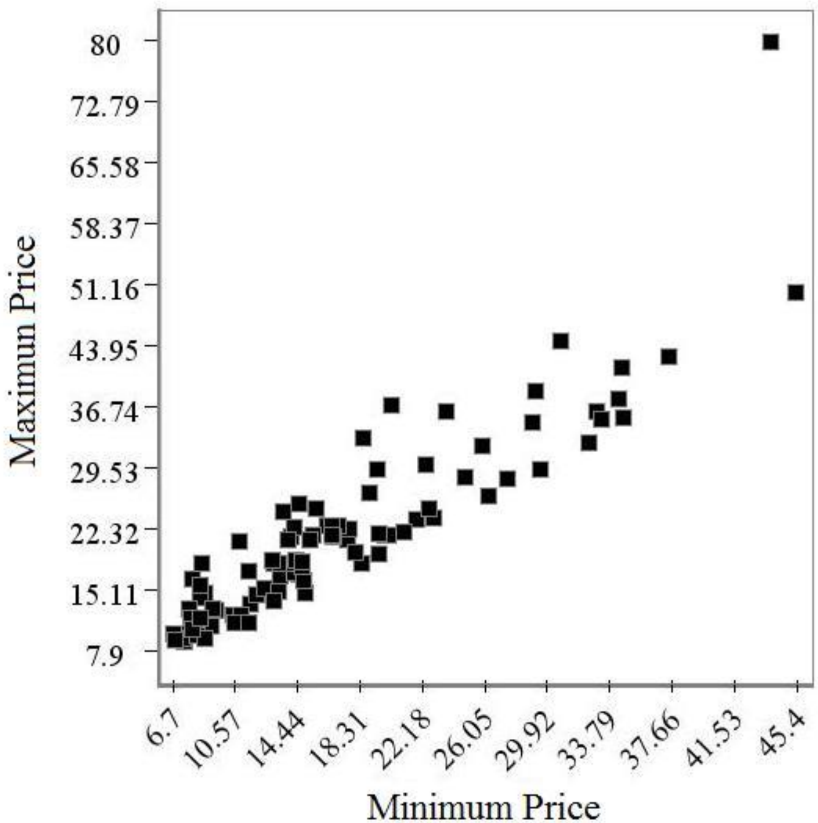
www.infovis-wiki.net

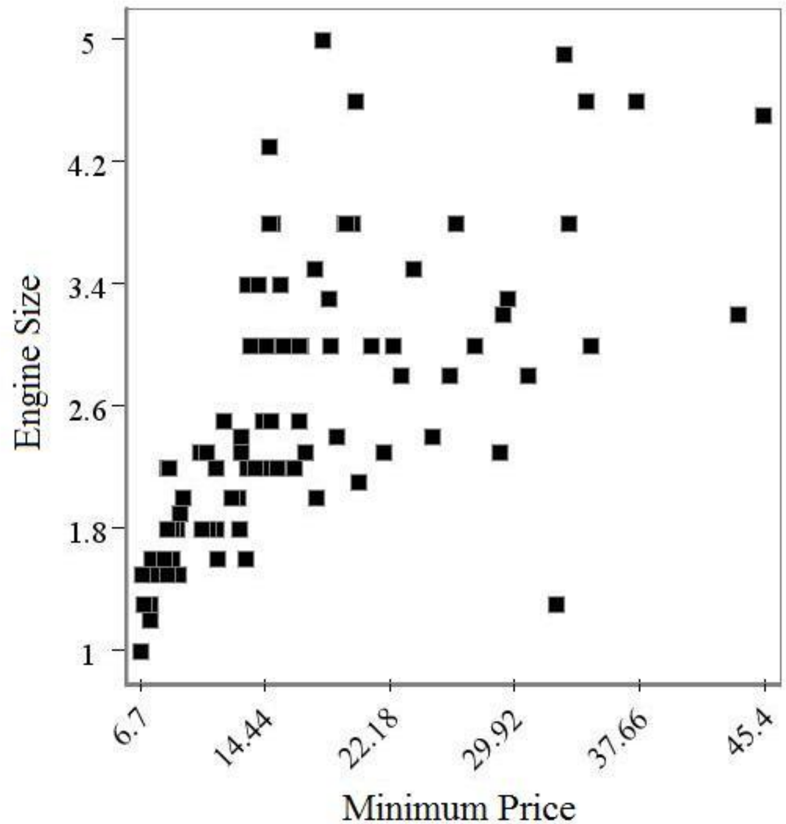
Position

- The most important variable
- Positioning of graphical elements on screen

- Best case – each graphical symbol has its unique position, symbols do not overlap
- Worst case – all graphical symbols are positioned to a single spot

Position





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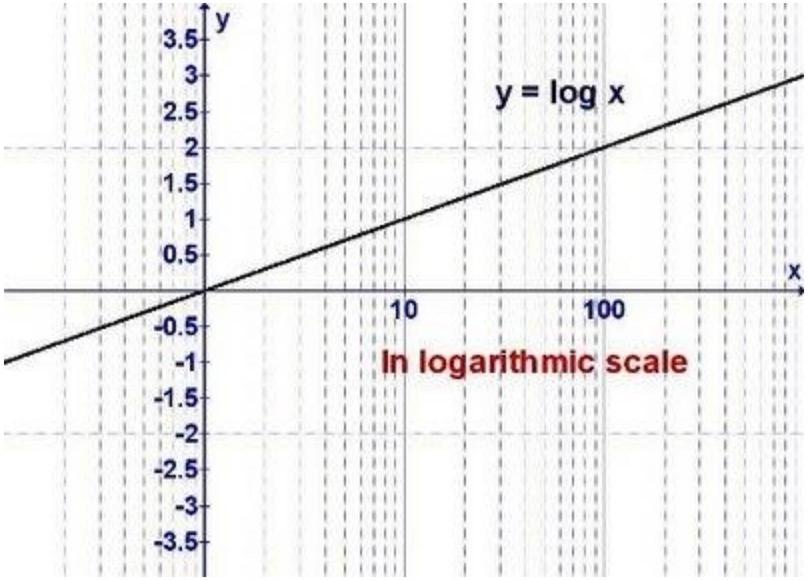
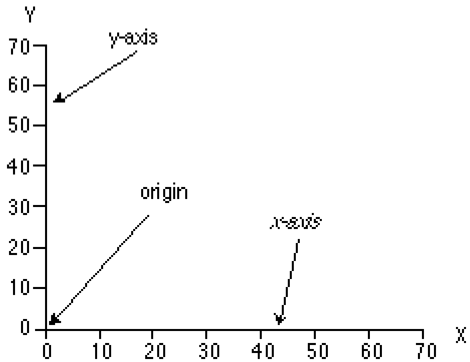
Position

- Linear scale
- Logarithmic scale



mathsisinteresting.blogspot.com

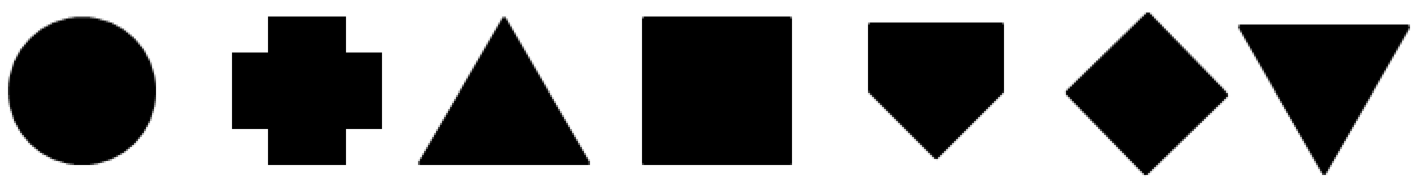
- Additional graphics - axes



cstl.syr.edu

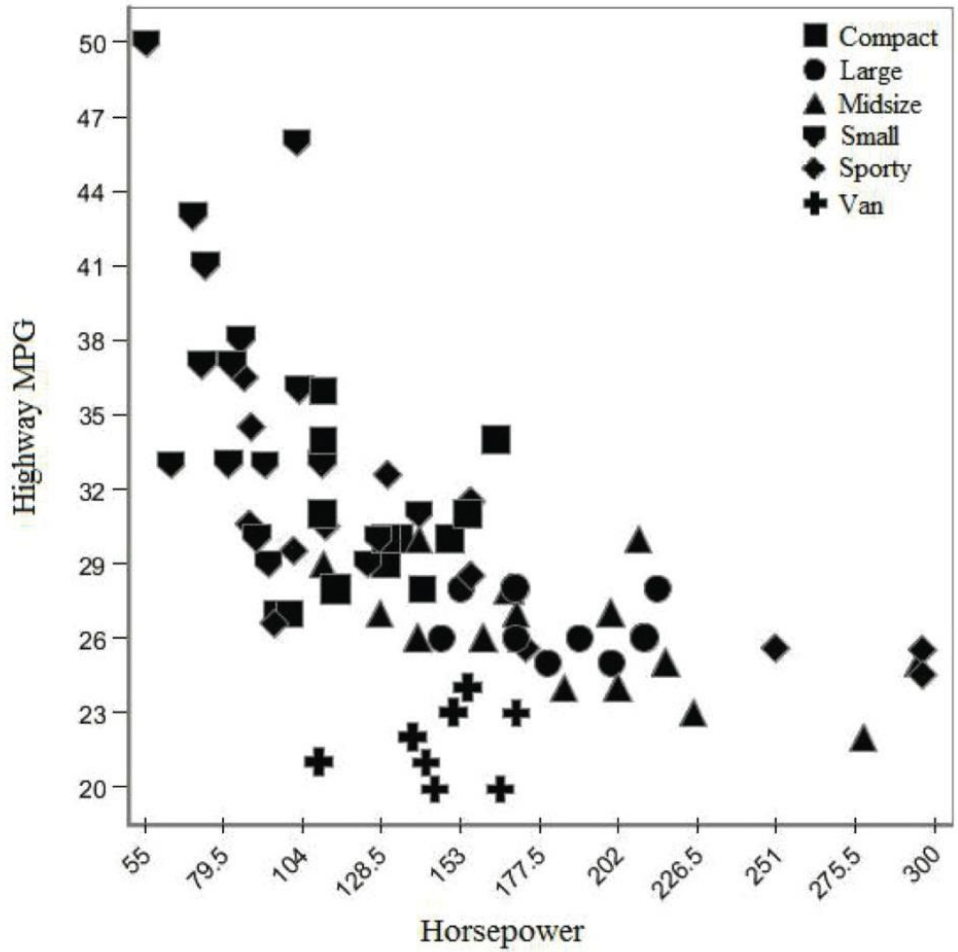
Shape

- Points, lines, regions, volumes, and their combination
- Symbols, letters, words, …



- Except for size, orientation, etc. – these are other visual variables

Shape



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Size

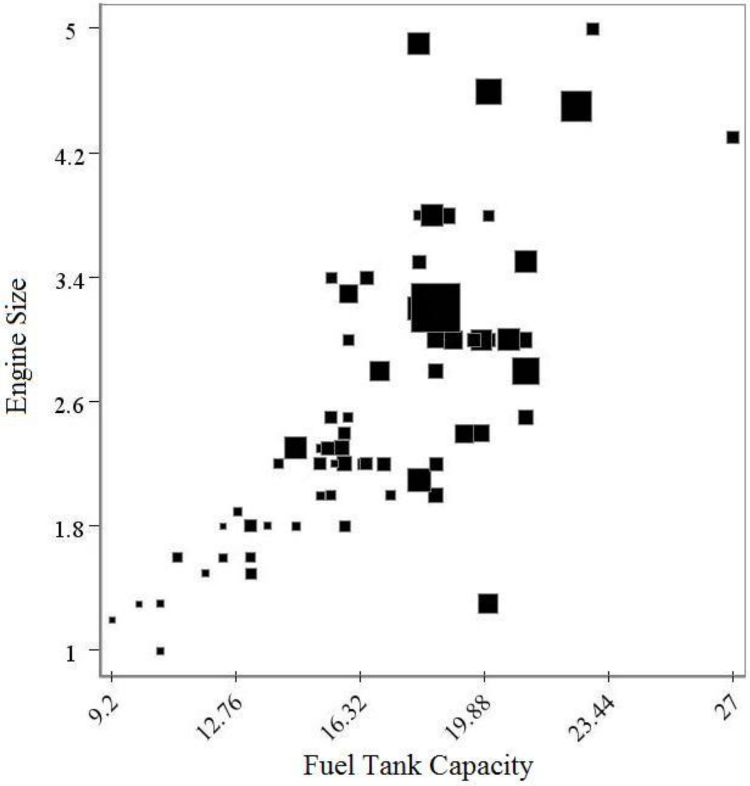
- Usable for datasets of small cardinality (it is hard to distinguish between symbols with small difference in size)

Size

- Depends on the symbol type selection

- Points, lines, curves are appropriate in combination with size

- Inappropriate for regions



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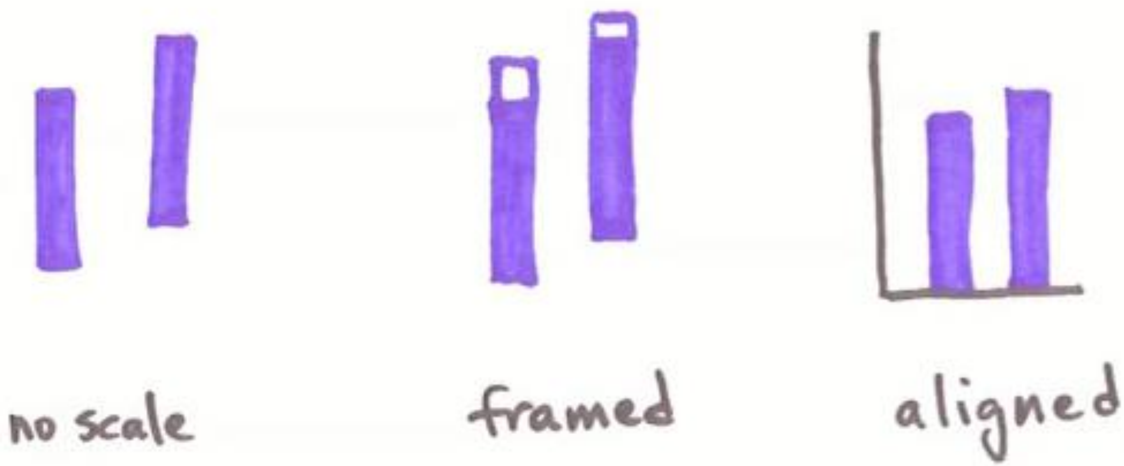
Accuracy in perception

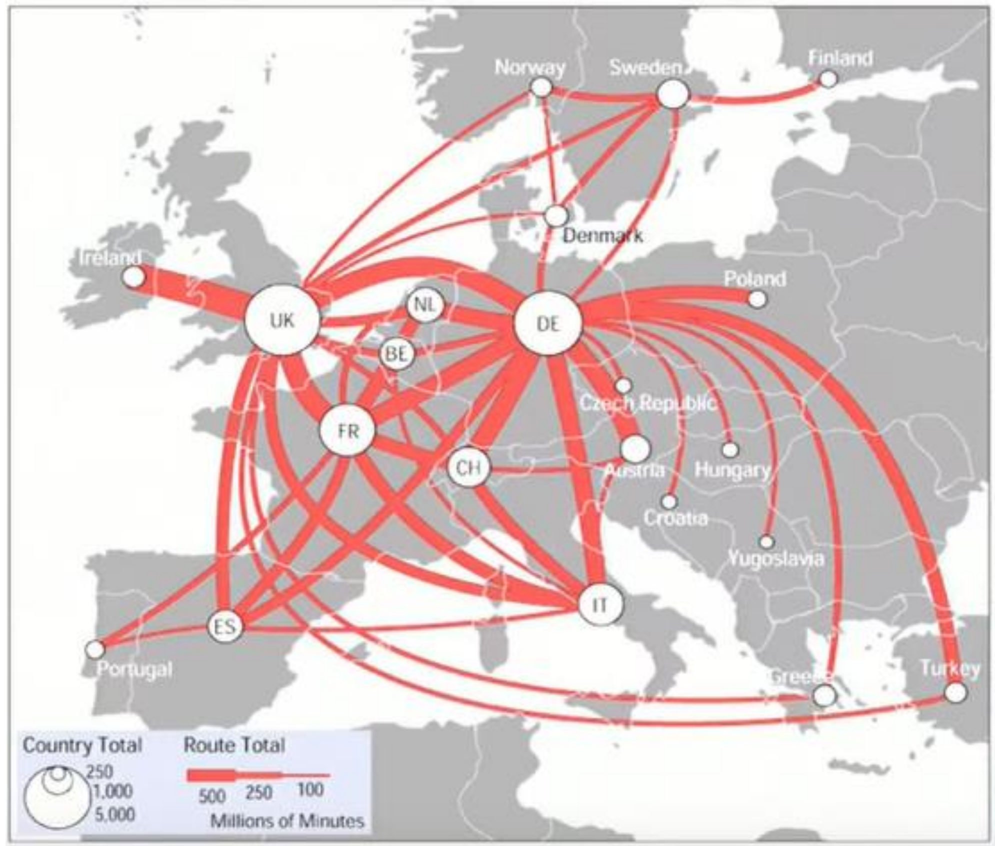
- position along common scale



  - frame increases accuracy [Cleveland 84]

Linewidth

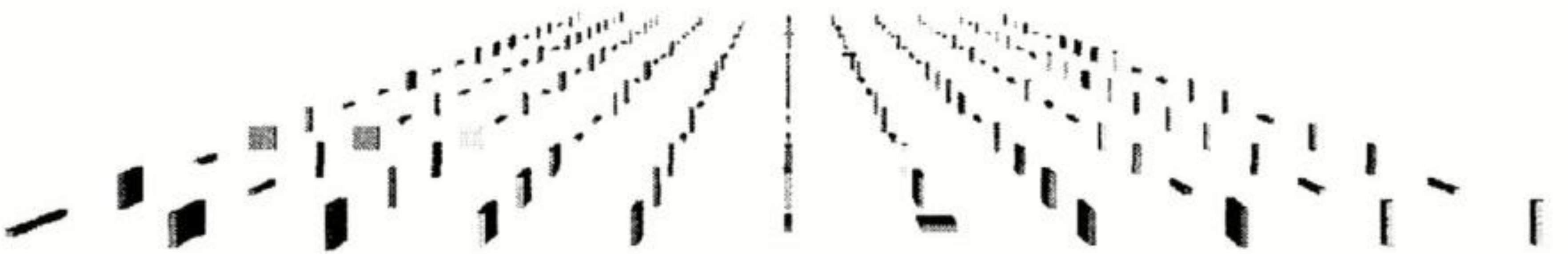
- How many usable steps to distinguish between values?
  - Only a few …



[mappa.mundi.net/maps/maps 014/telegeography.html]

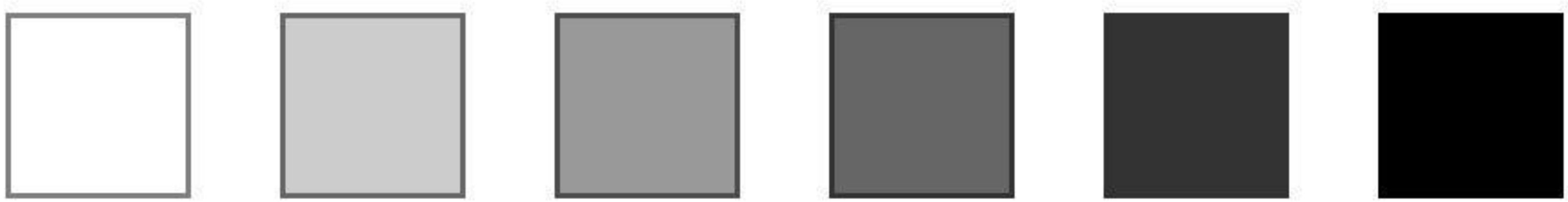
Perspective projection kills size

- perspective distortion
  - interferes with all size channel encodings
  - power of the plane is lost!



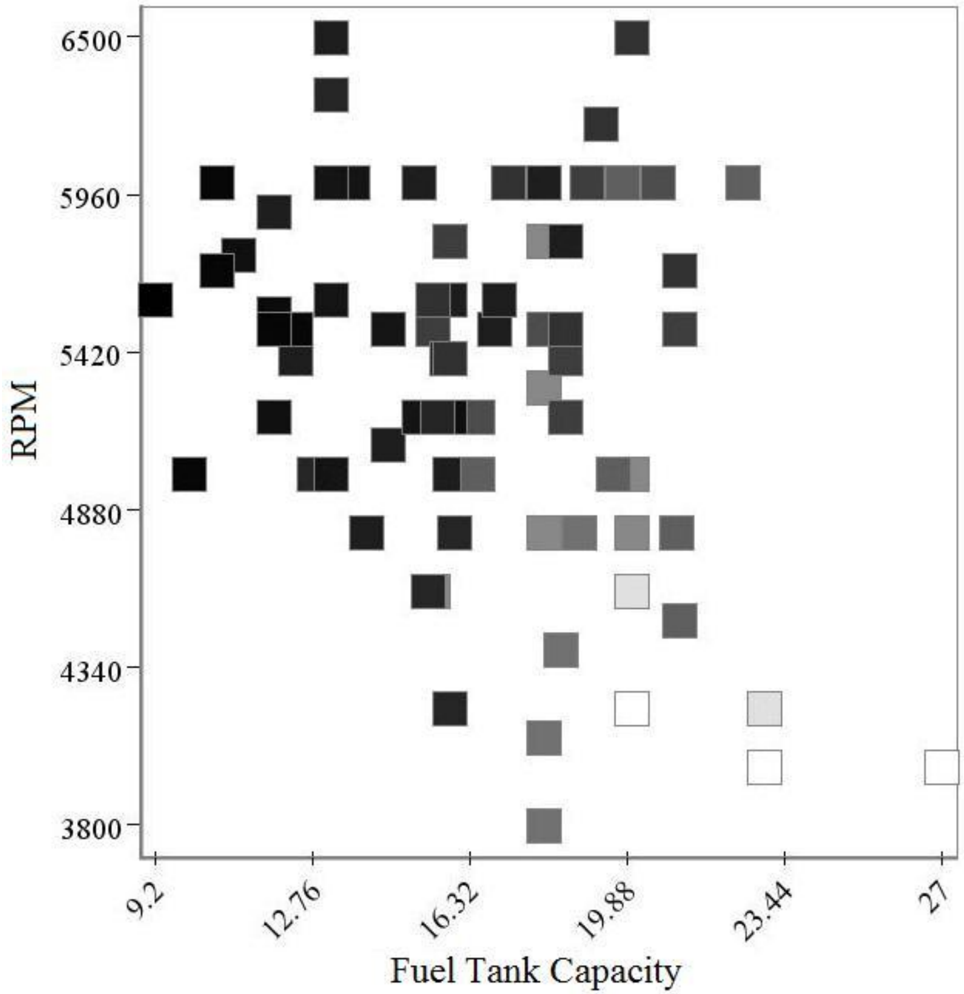
Brightness

- Brightness scale for mapping values :



- Linear brightness scale

Brightness



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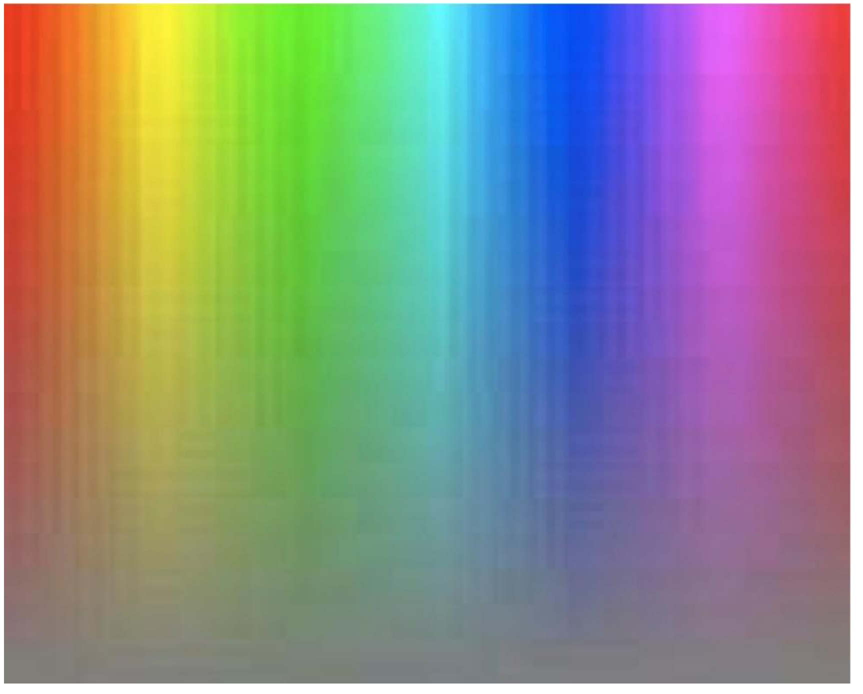
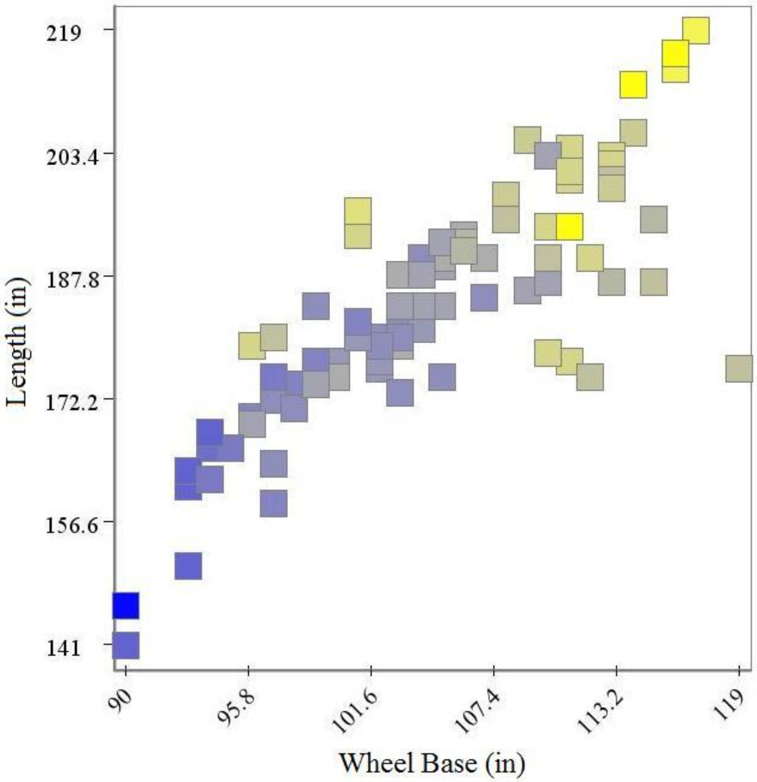
Color

- Hue, saturation



Color



- http://colorbrewer2.org/

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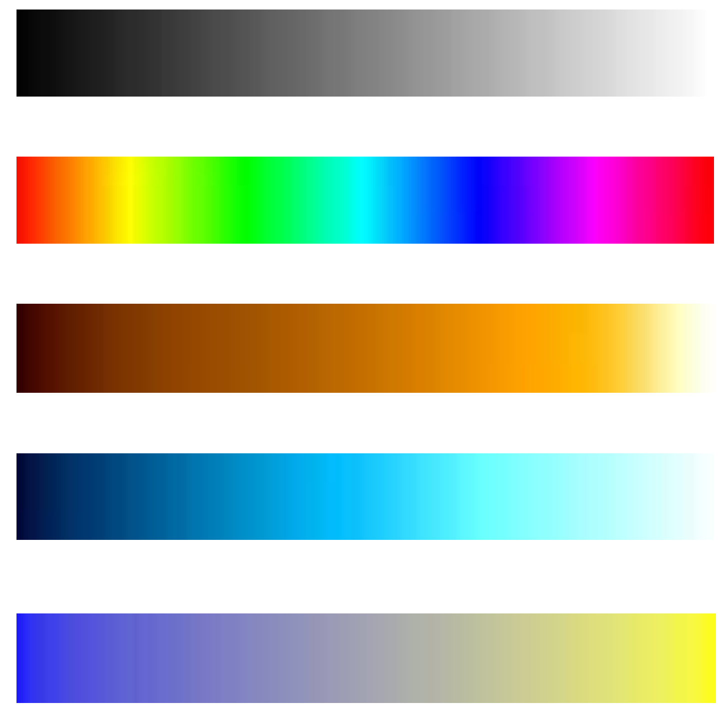
Color

- Standard linear grayscale
- Rainbow
- „Heated“
- Blue to cyan
- Blue to yellow



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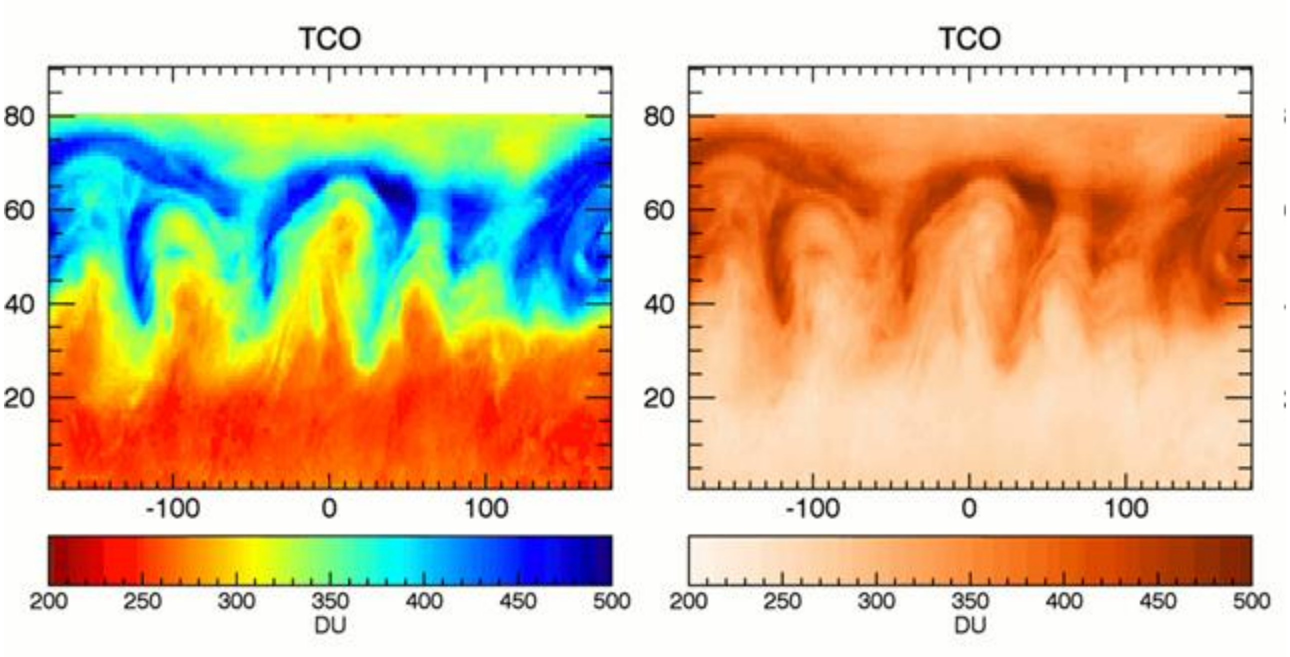
Problem with rainbow scale

- Can distort perceptions of data and alter meaning by creating false boundaries between values



Problem with rainbow scale

- Why?
  - Rainbow scales are not ‘perceptually uniform’ – they create sharp artificial boundaries between colors (particularly involving yellow) that are not necessarily present in the underlying data.

Problem with rainbow scale

SANFORD AND SELNICK

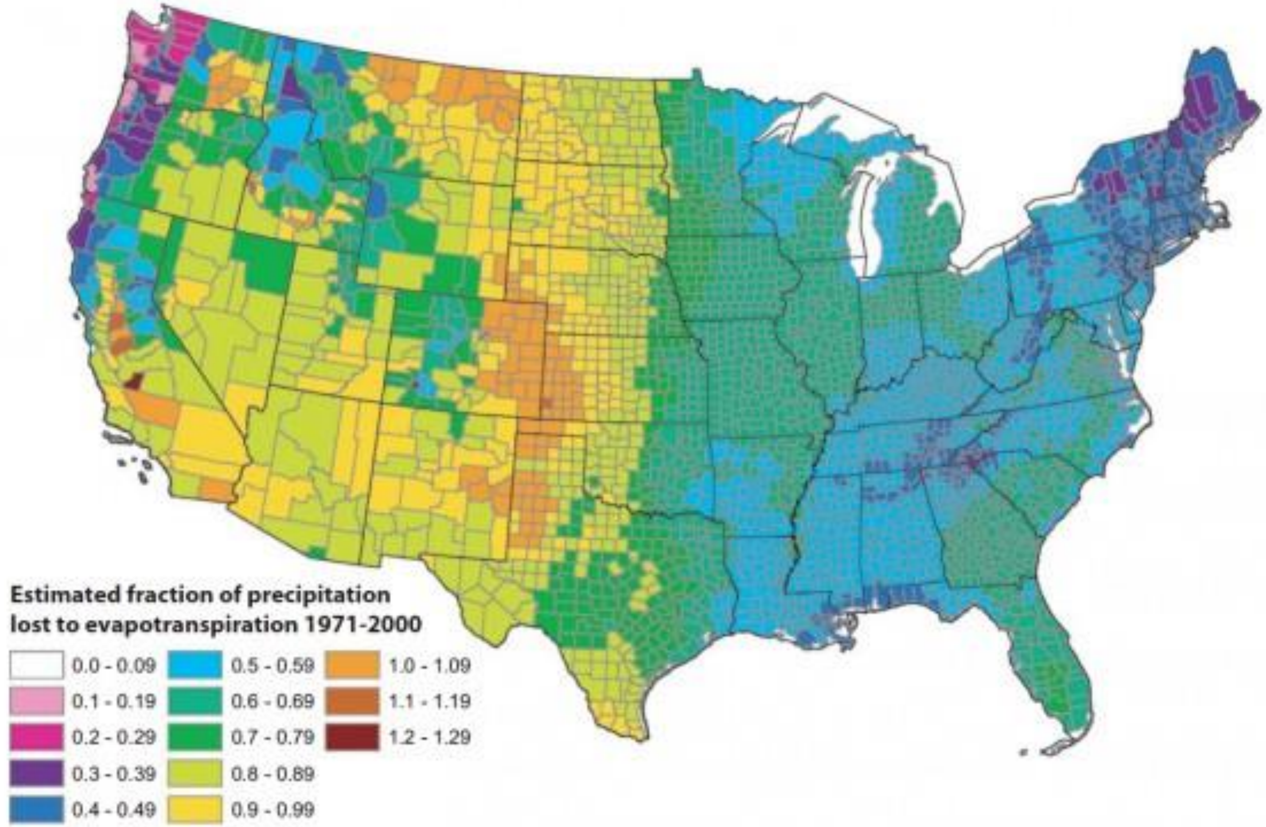
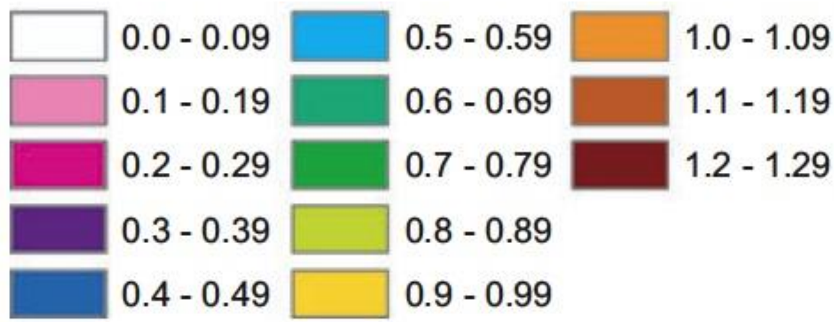
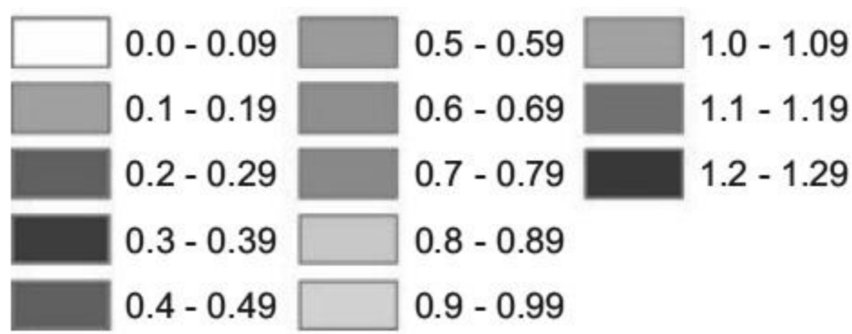


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.

Problem with rainbow scale

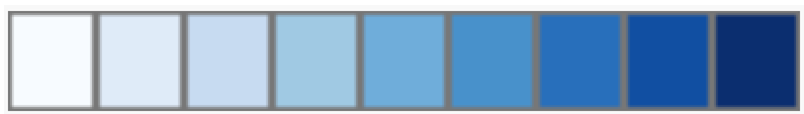


Luminance



Why rainbow?

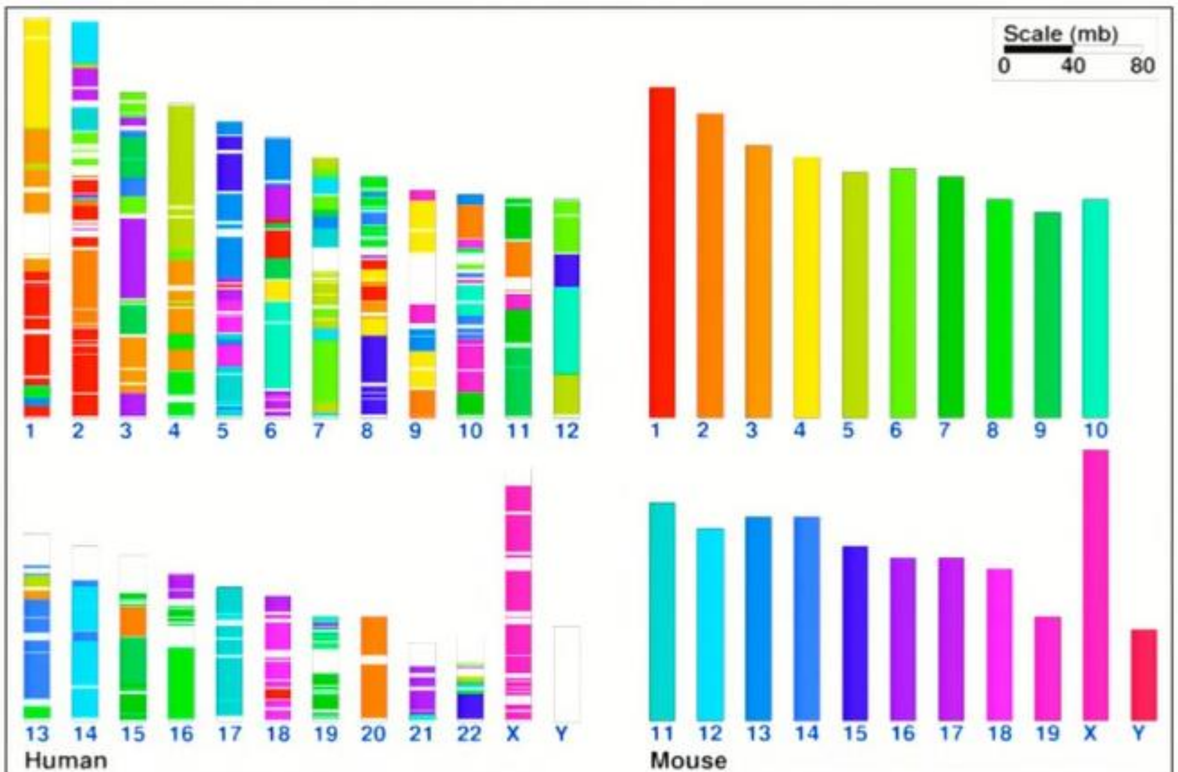
- It’s attractive
- Using single hue is less interesting to look at



- Rainbow can introduce a lot of artifacts
- Use ColorBrewer!

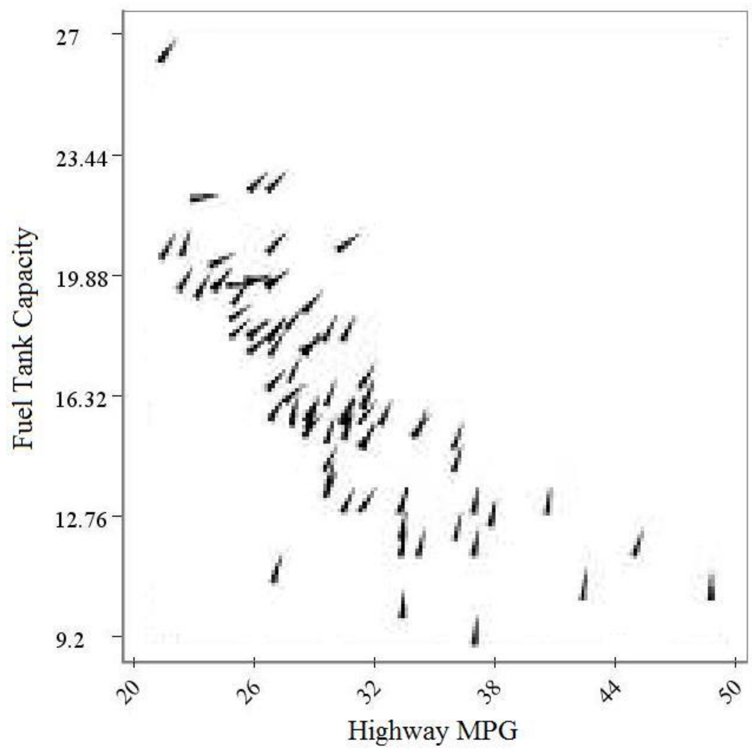
Categorical color constraints

- Noncontiguous small regions of color: only 6-12 bins



Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Sinha and Meller. Bioinformatics 2007

Orientation



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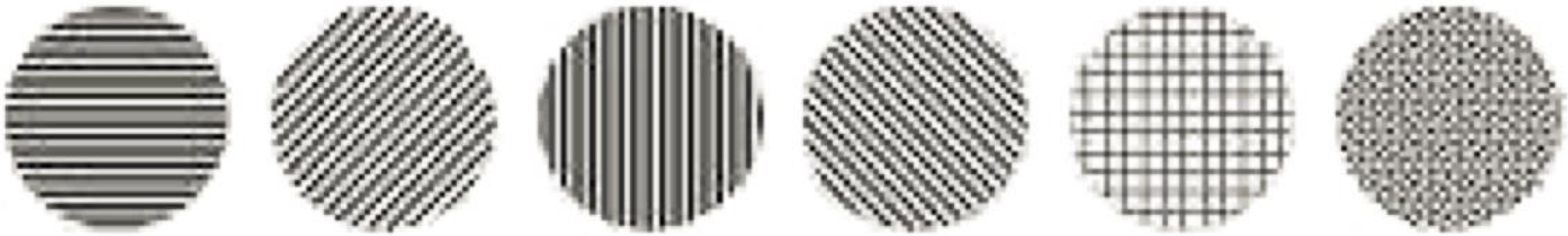
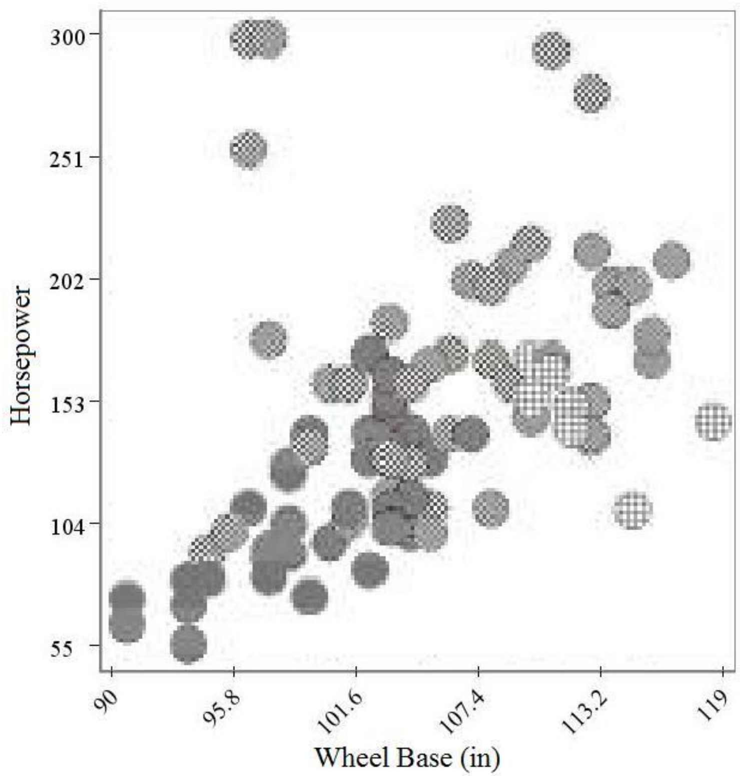
Texture





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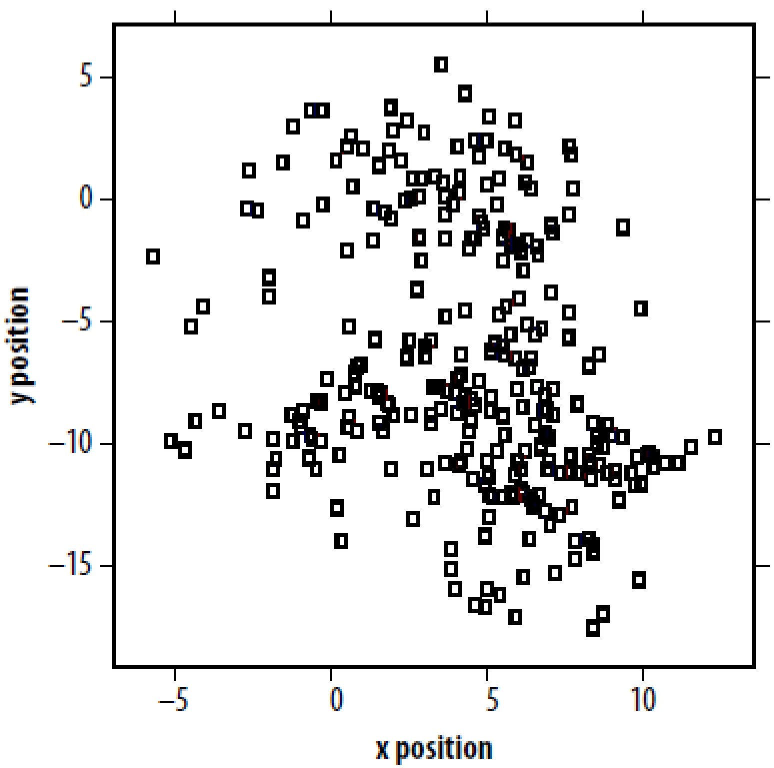
Motion

- Can be associated with any other visual variable

- Position – direction of movement
- Size – increase/decrease
- Brightness – lighter/darker
- Orientation – bigger/smaller angle

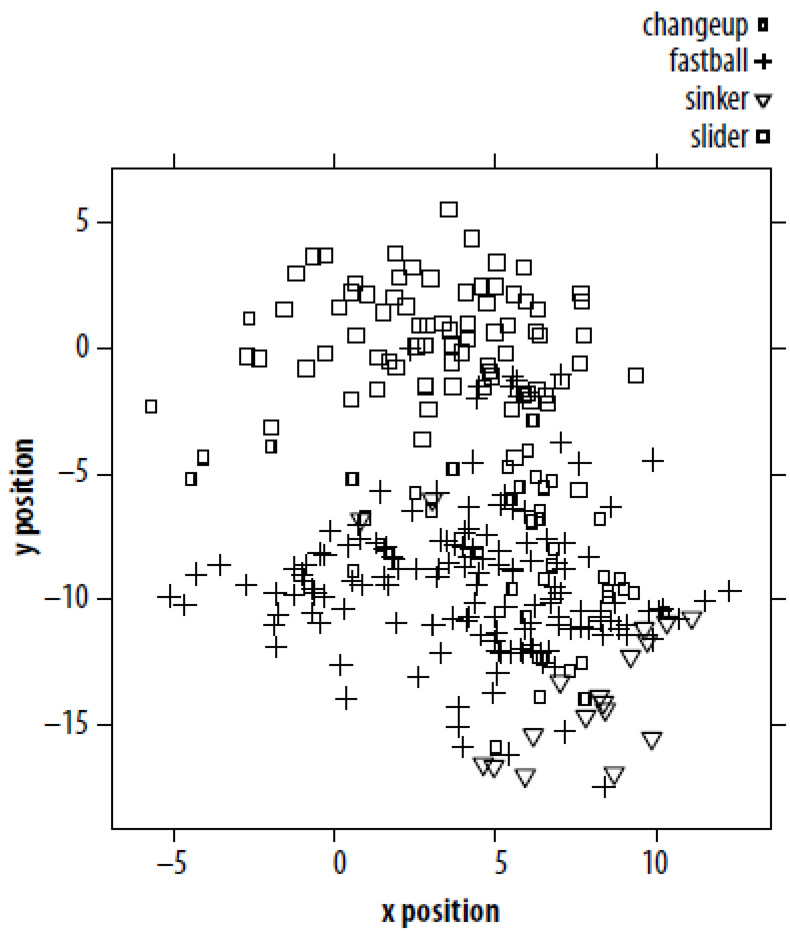
Example – baseball

- Mapping of ball hits to space defined by x, y position



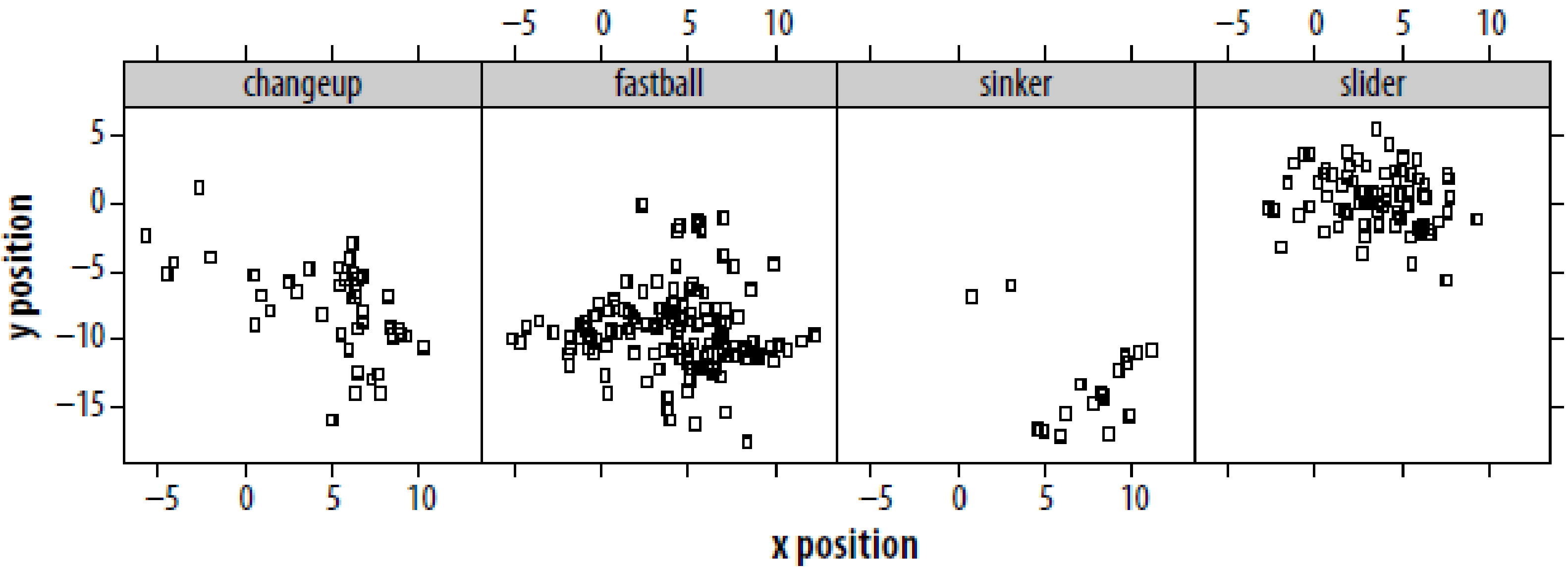
Example – baseball

- Type of hit mapped to different types of glyphs



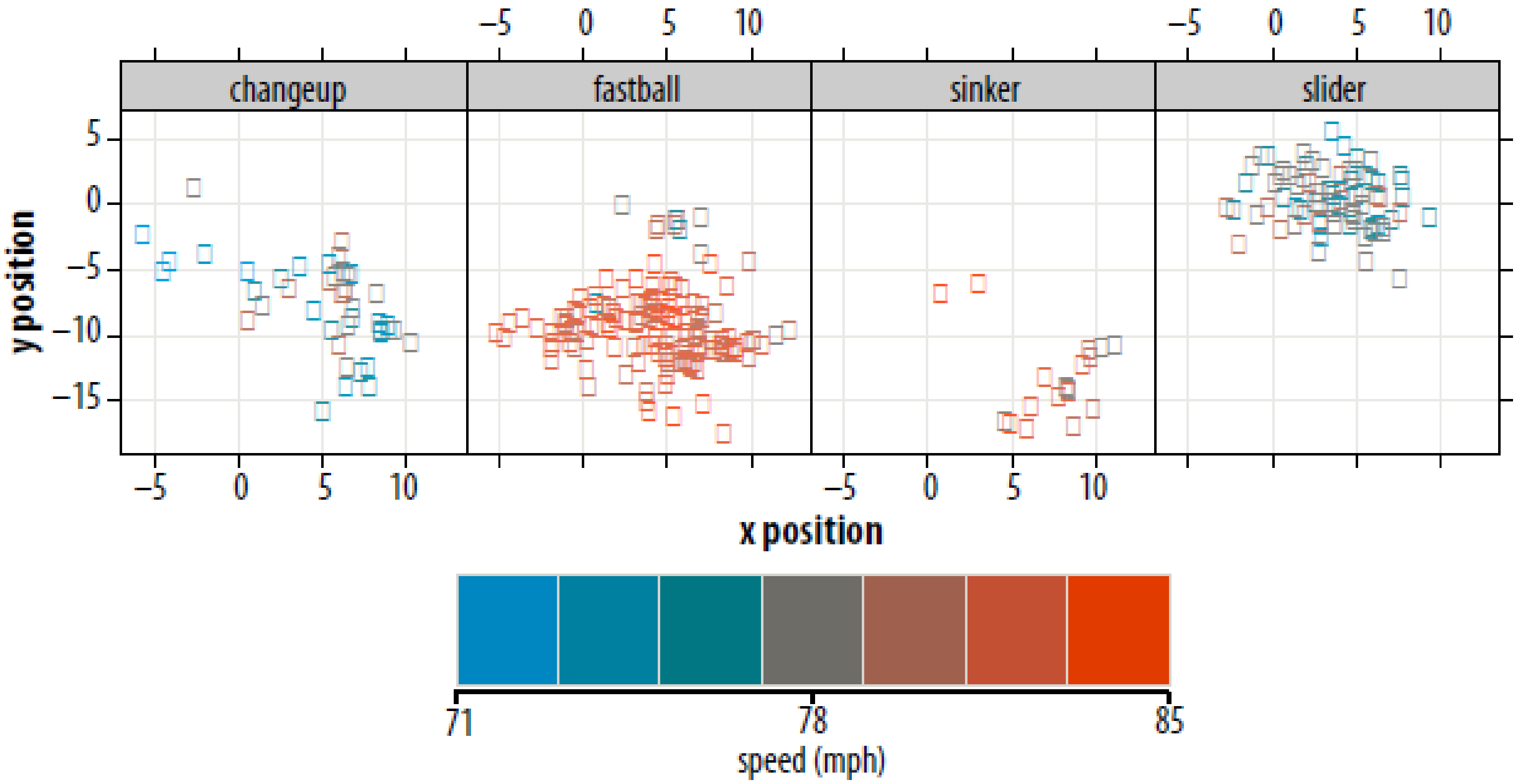
Example – baseball

- Reducing the graph size by spreading the hits to more graphs



Example – baseball

- Adding color to express the hit speed

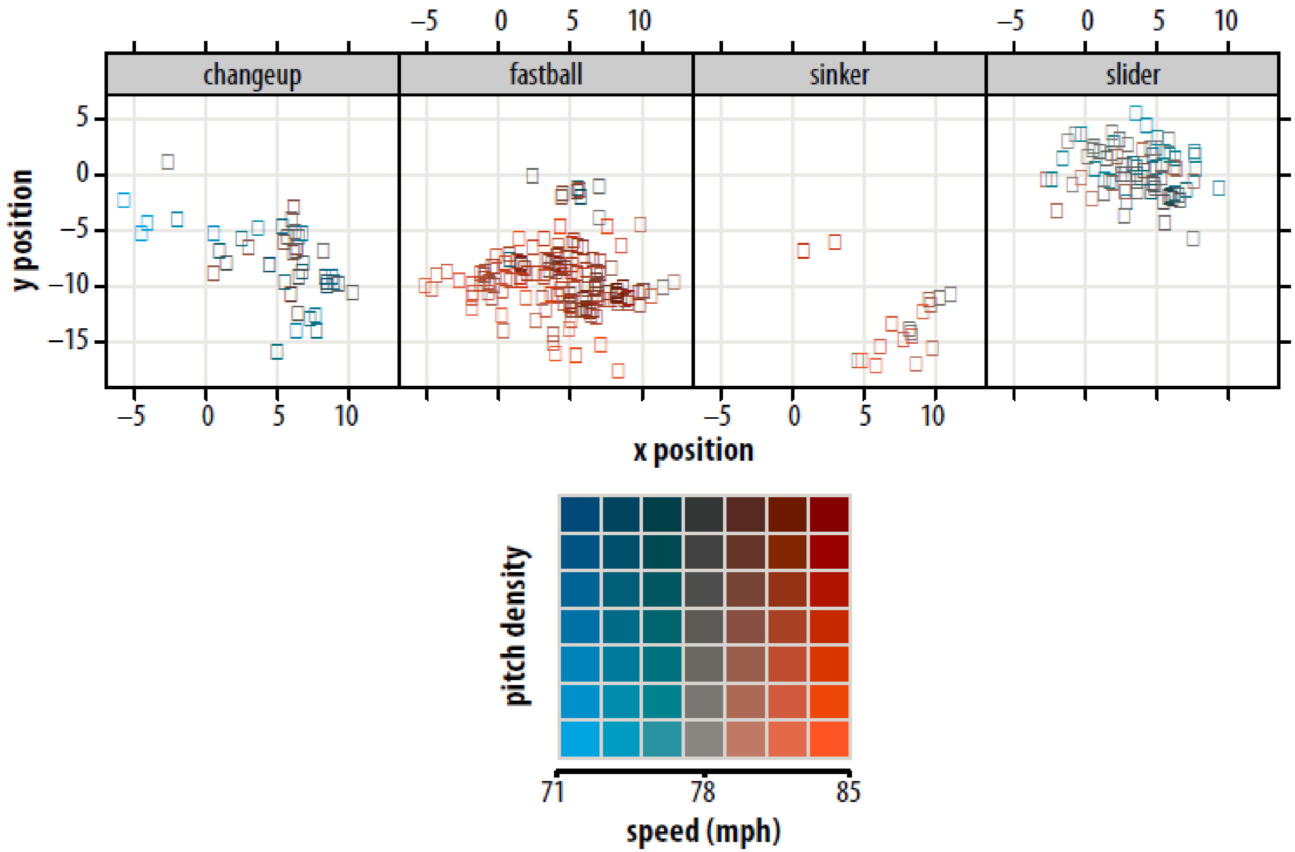


Color perception

- Differences in color can be detected already in 200 millisecs – even earlier than we realize that we focus on visualization (so called preattentive concept)
- Color can be three-dimensional (e.g., RGB)
  - In practice we use only 2D color coding
    - Thanks to high number of color blind persons
    - Different scales in perceivable hues for different colors (yellow vs. blue)

Example – baseball

- Using 2D color field adding the information about the density of hits on given spot



Formalization of visualization

- Jacques Bertin (1918 - 2010)

Bertin (1967) Semiology of Graphics

- First attempt to define graphics
- Creating so called marking system
- Graphical lexicon:

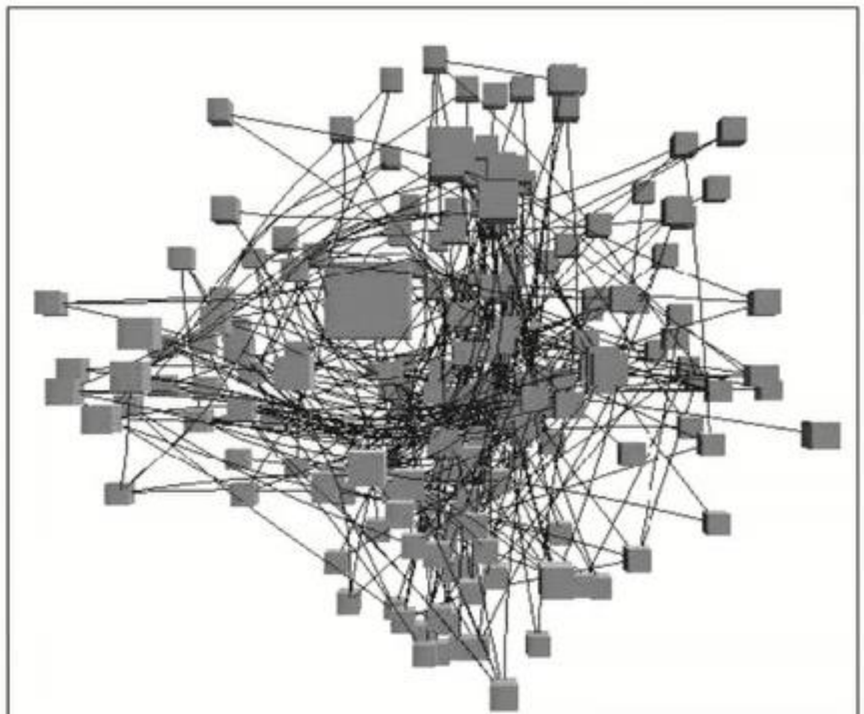
Marks	Points, lines, and areas
Positional	Two planar dimensions
Retinal	Size, value, texture, color, orientation, and shape

Back to depth perception in 3D …

http://www.perceptionsense.com/2013/10/forced-perspective-photography-cameras.html

Dangers of depth: difficulties in 3D

- occlusion
- interaction complexity

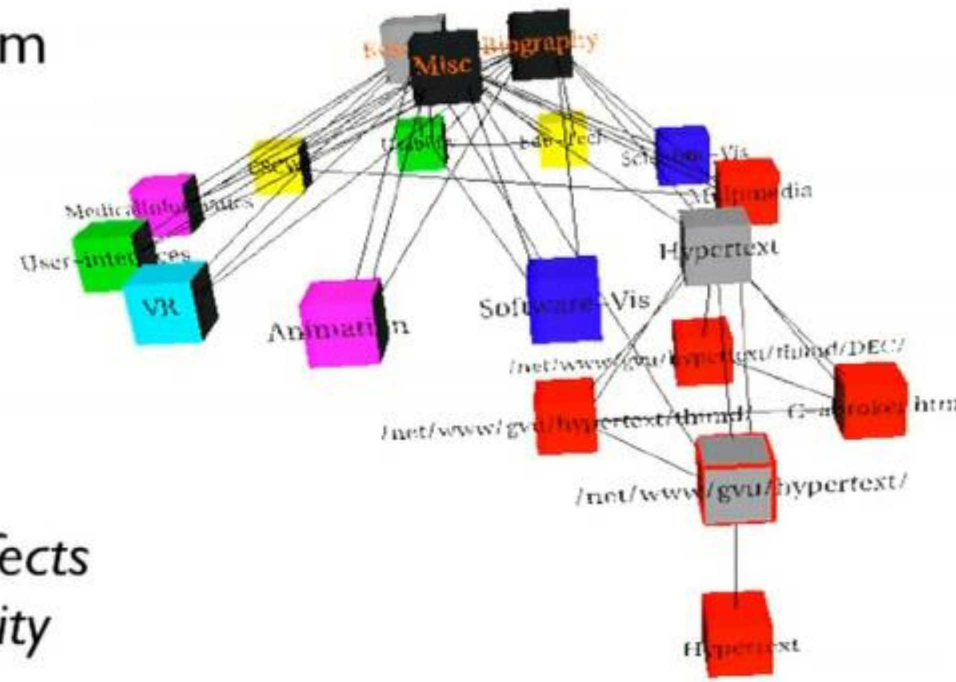


Distortion Viewing Techniques for 3D Data. Carpendale et al. InfoVis1996.

Dangers of depth: difficulties in 3D

- text legibility
  - far worse when tilted from image plane
- further reading

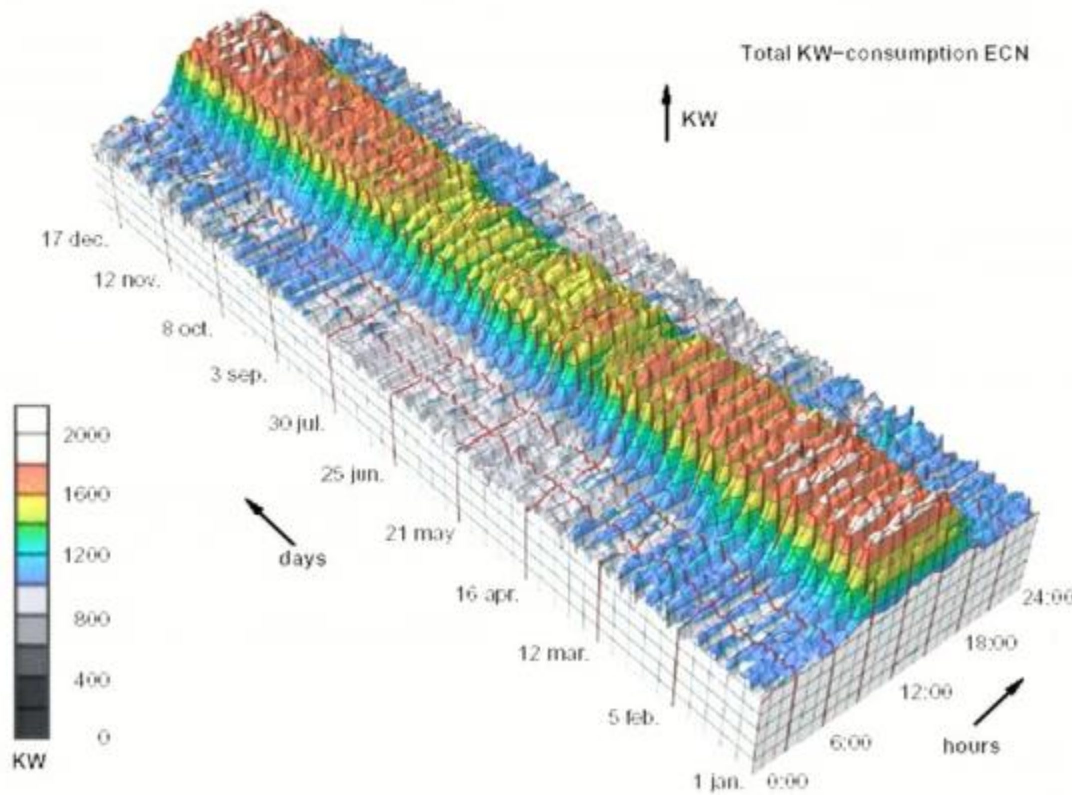
Exploring and Reducing the Effects of Orientation on Text Readability in Volumetric Displays.
Grossman et al. CHI 2007



Visualizing the World-Wide Web with the Navigational View Builder. Mukherjea and Foley. Computer Networks and ISDN Systems, 1995.

Example

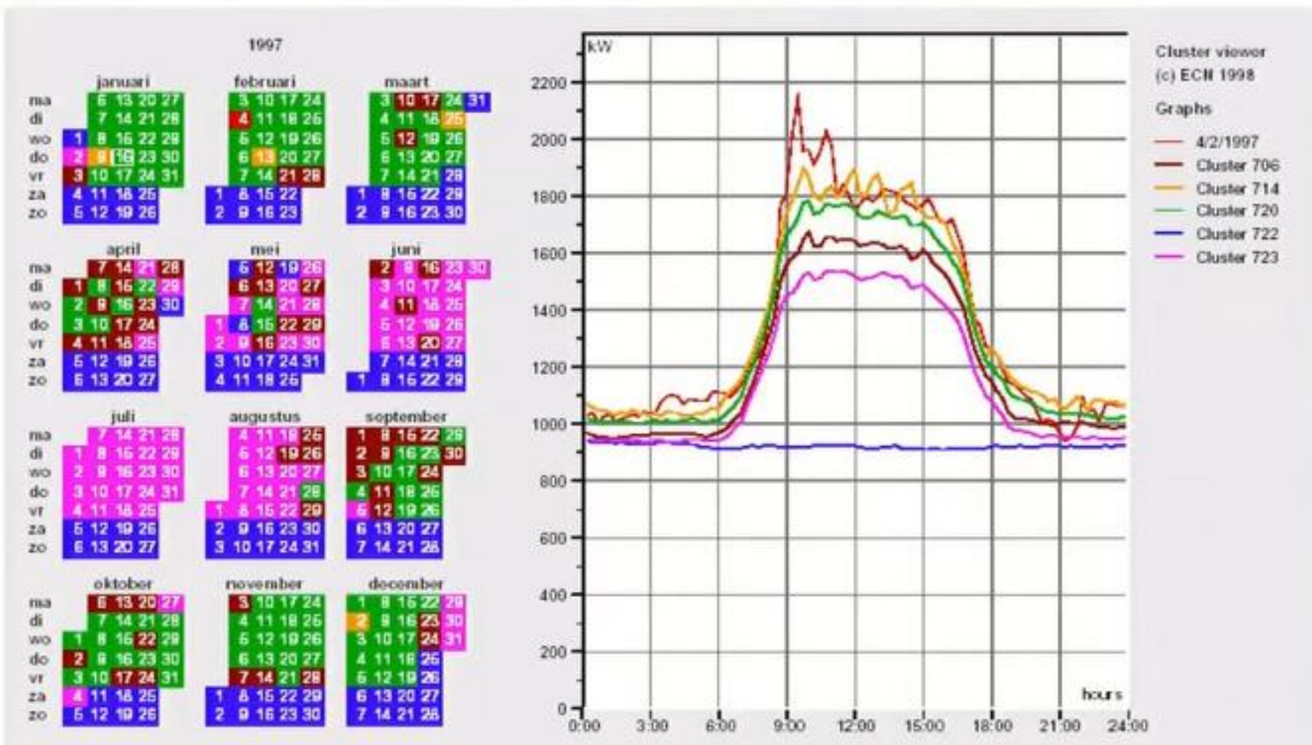
- extruded curves: detailed comparisons impossible



Cluster and Calendar based Visualization of Time Series Data. van Wijk and van Selow, Proc InfoVis 99.

Possible solution

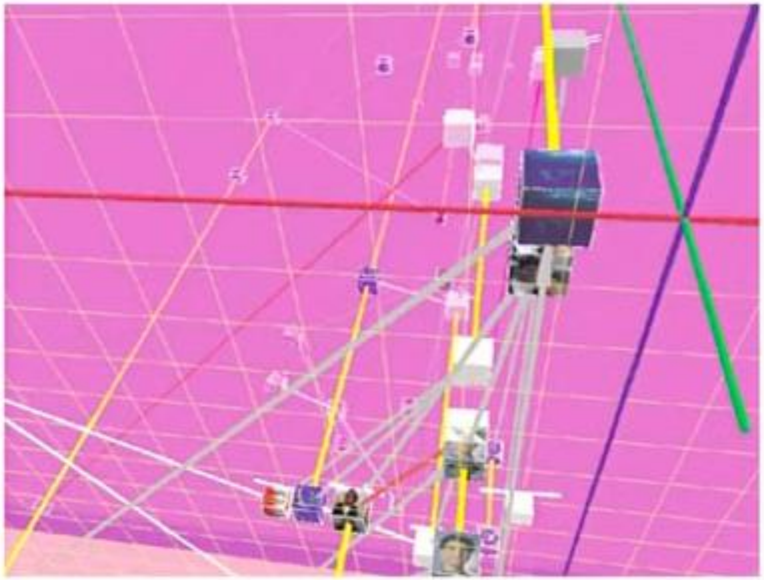
- derived data: clusters
- multiple views: calendar, superimposed 2D curves



Cluster and Calendar based Visualization of Time Series Data.
van Wijk and van Selow, Proc InfoVis 99.

When to use depth?

- 3D legitimate for true 3D spatial data
- 3D needs very careful justification for abstract data
  - enthusiasm in 1990s, but now skepticism
  - be especially careful with 3D for point clouds or networks



WEBPATH-a three dimensional Web history. Frecon and Smith. InfoVis 1999