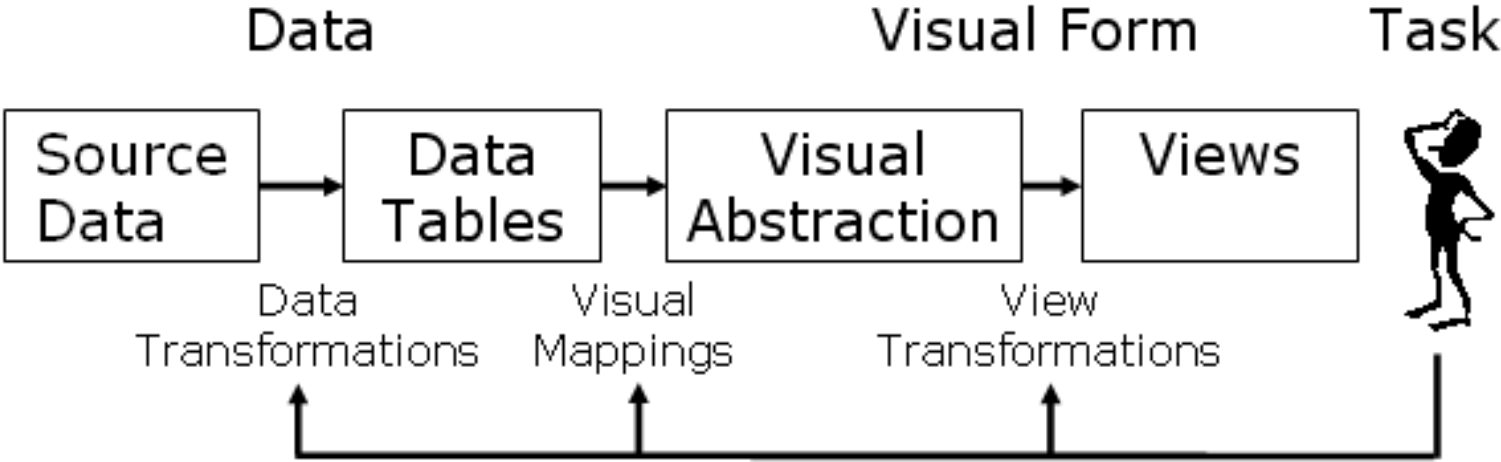


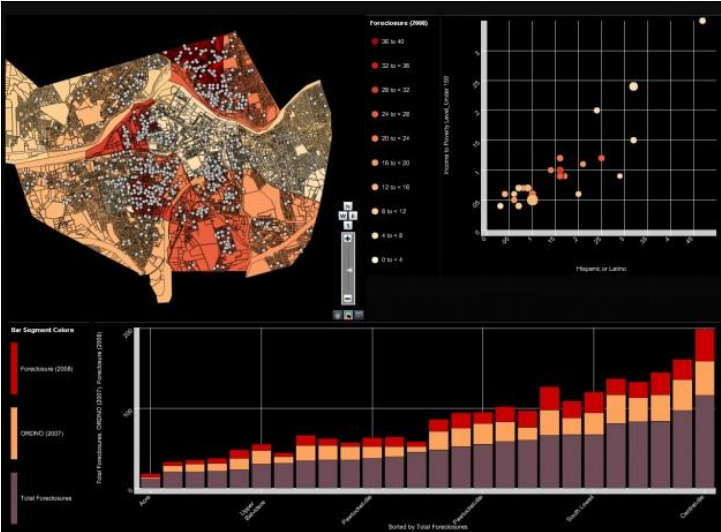
3. Basic principles of visualization



Visualization pipeline



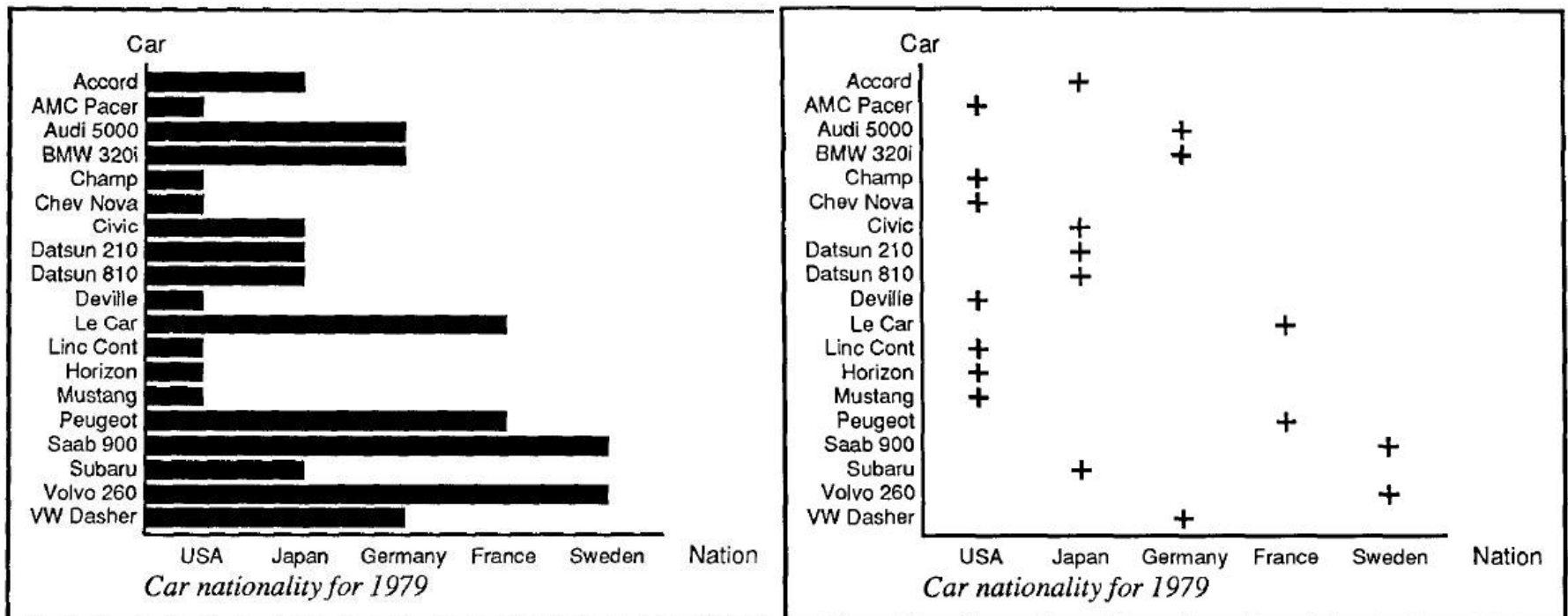
prefuse.org



flowingdata.com

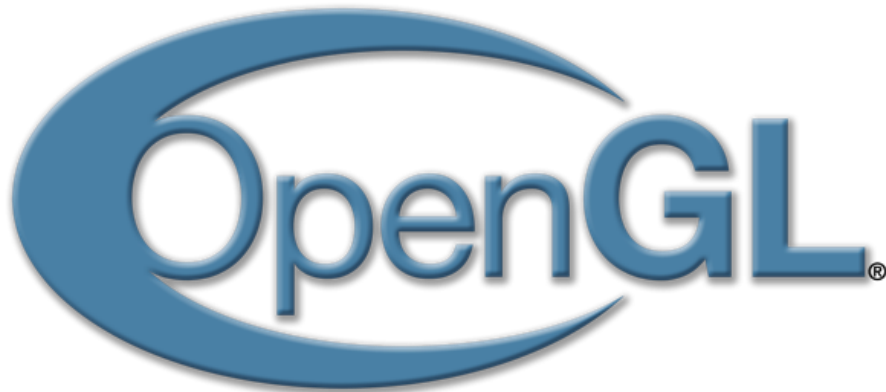
Working with data

- Data preprocessing
 - last lecture
- Data mapping to visualization



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**

$$0 \leq M_{\text{exp}} \leq 1$$

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

Effectiveness

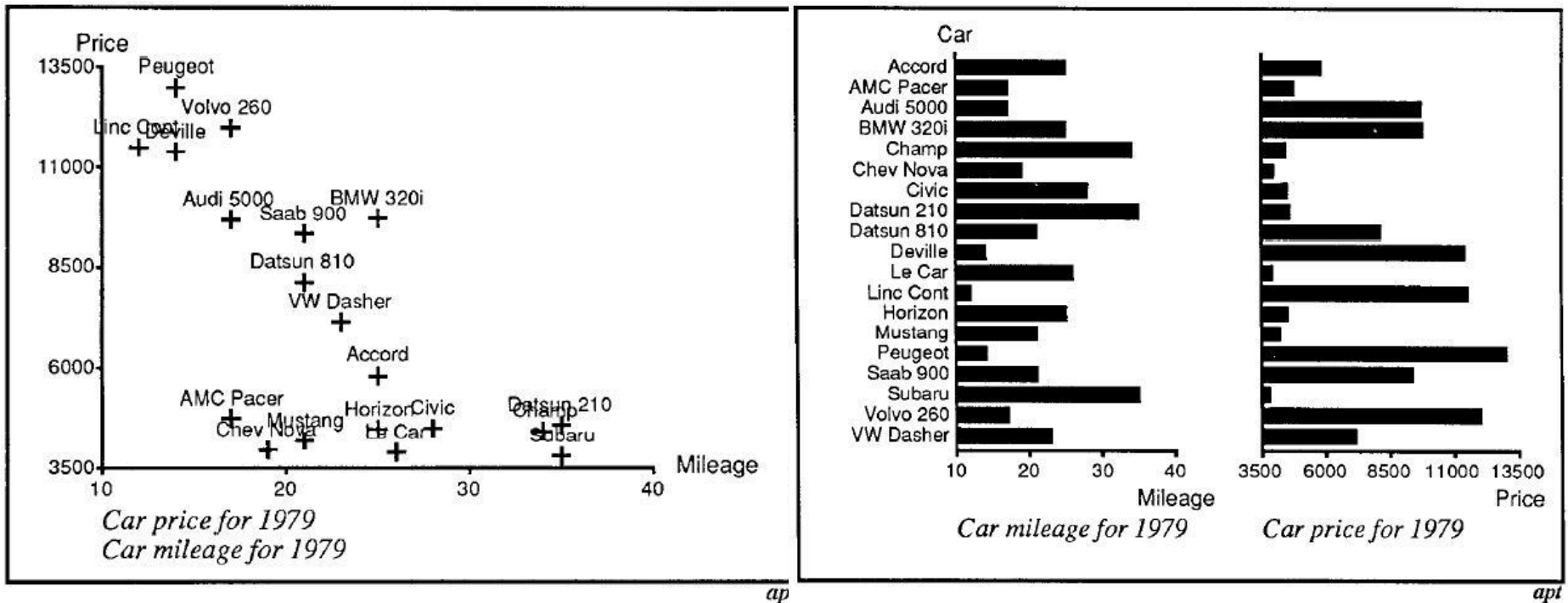
- Visualization is effective:
 - Correct and fast interpretation
 - Fast rendering

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

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

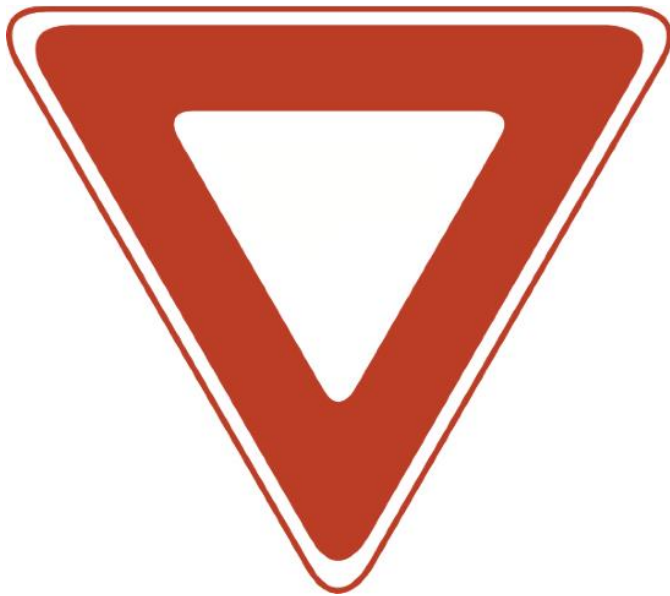
- If M_{eff} is close to zero, time for interpretation and rendering is short

Example

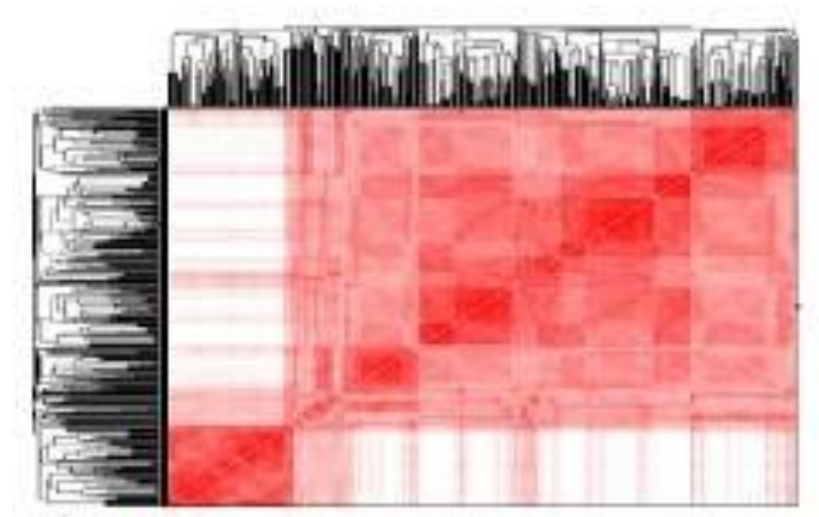


Graphical symbols

- Easily recognizable graphical symbols



Clear meaning

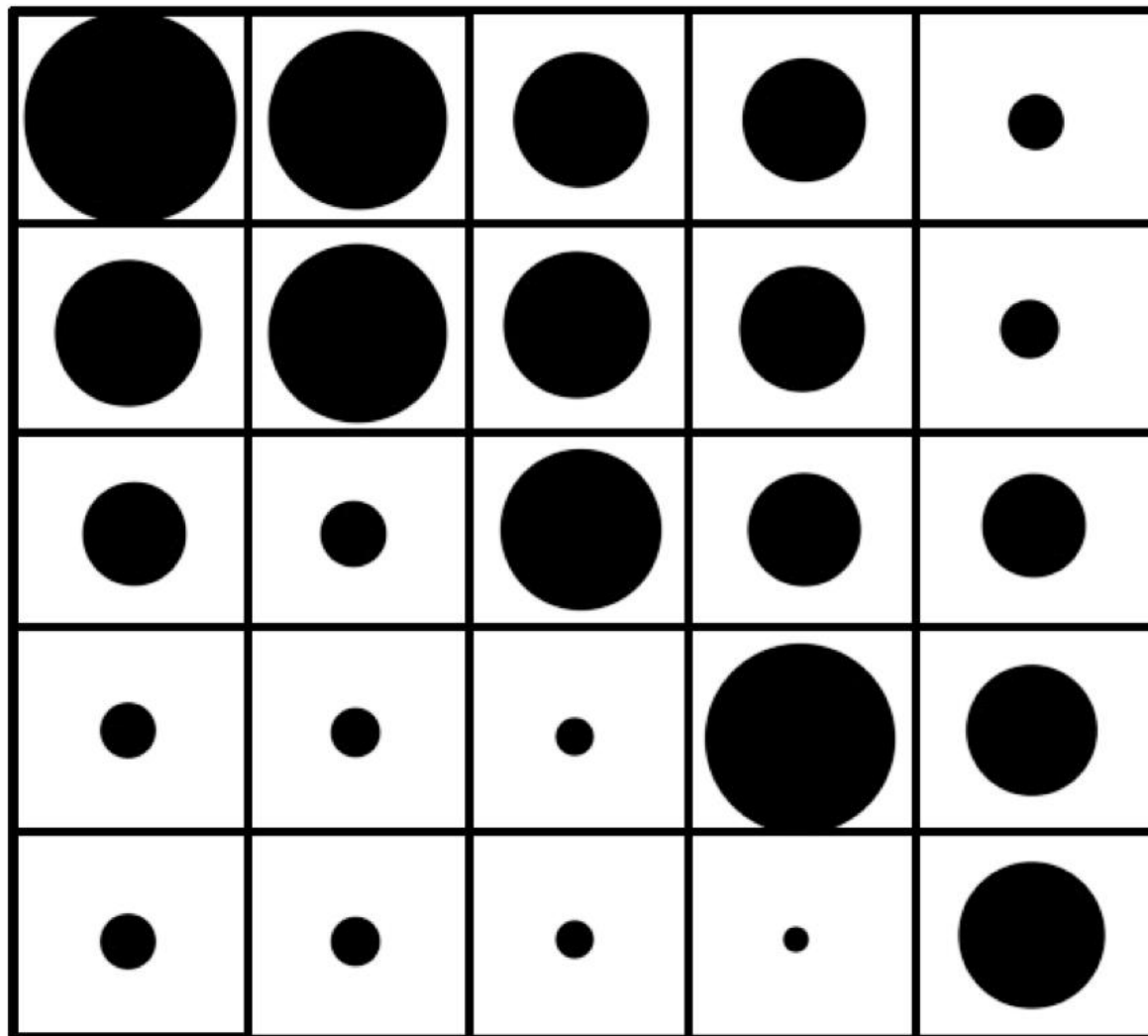


Complex meaning

Graphical symbols

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

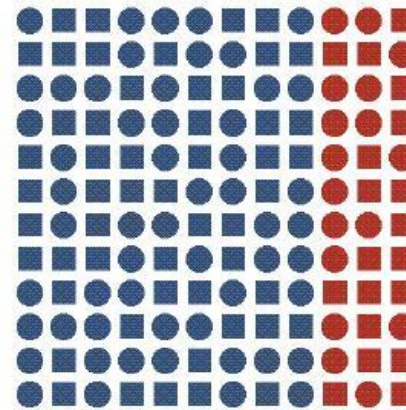
Dimensionality of 2D graphics



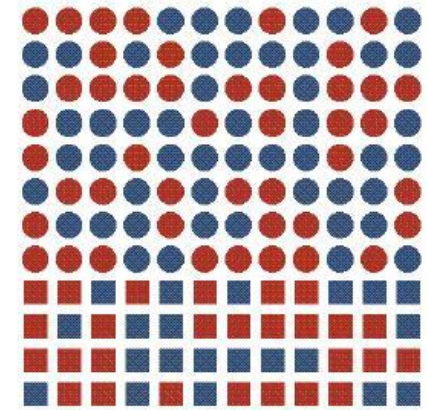
Analysis of graphics

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]



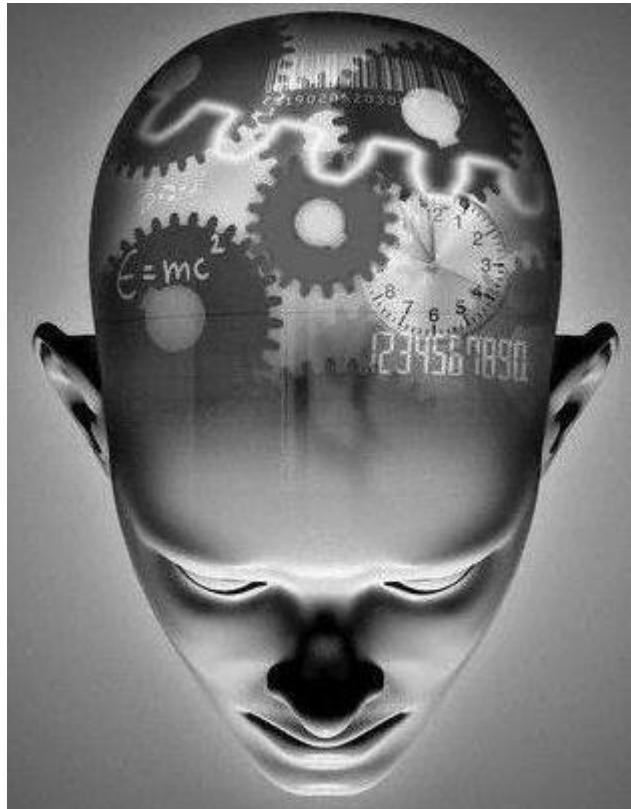
(a)



(b)

Analysis of graphics







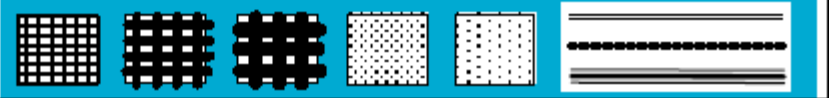
2) Cognitively we characterize these groups



Eight visual variables

- Variables maximizing the effectiveness of a given visualization:

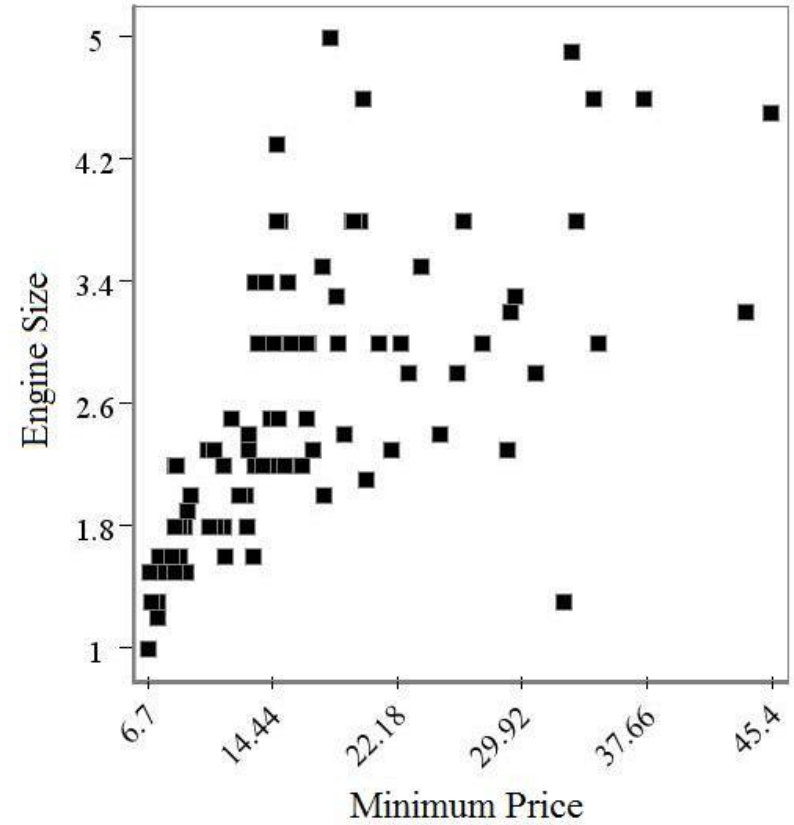
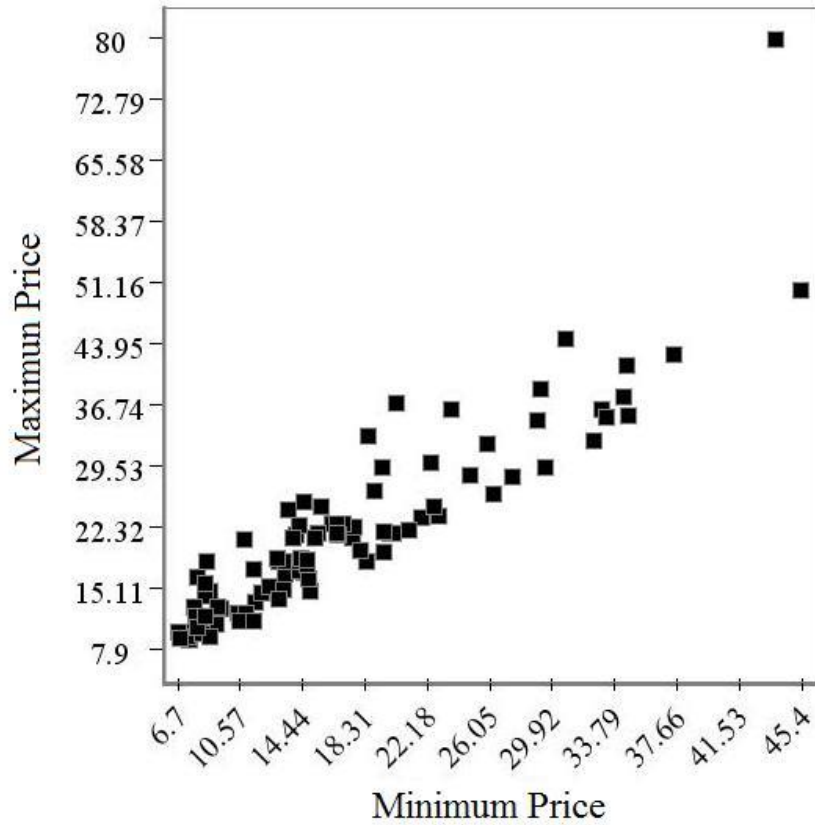
- Position
- Shape
- Size
- Brightness
- Color
- Orientation
- Texture
- Motion

Bertin's Original Visual Variables	
Position changes in the x, y location	
Size change in length, area or repetition	
Shape infinite number of shapes	
Value changes from light to dark	
Colour changes in hue at a given value	
Orientation changes in alignment	
Texture variation in 'grain'	

Position

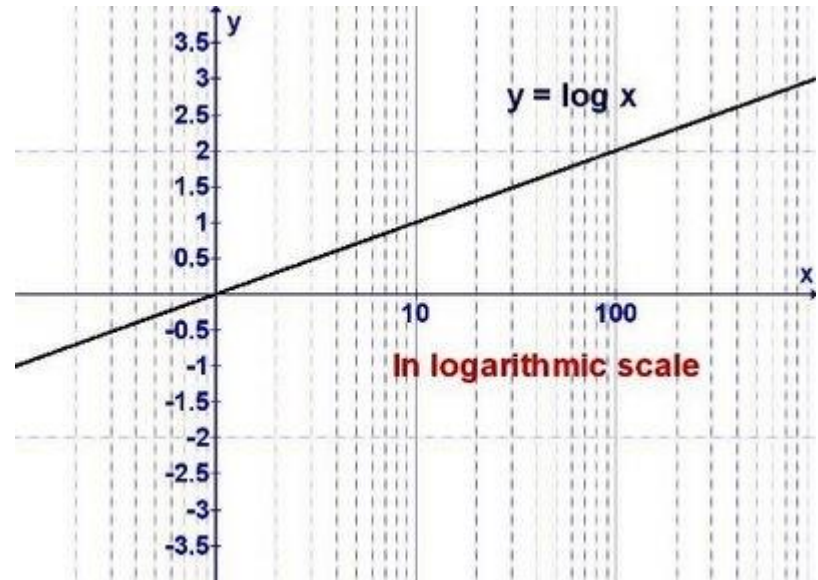
- The most important variable
- Positioning of graphical elements on screen
- Best case – each graphical symbol has its unique position, symbols do not overlap
- Worst case – all graphical symbols are positioned to a single spot

Position



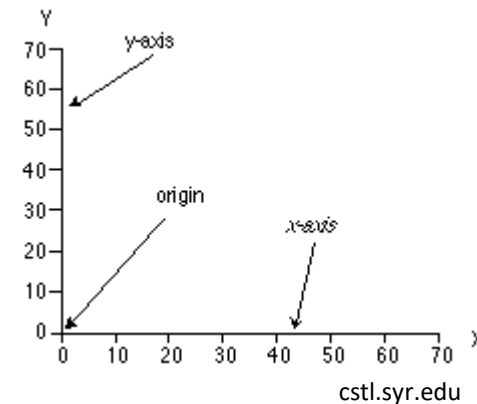
Position

- Linear scale
- Logarithmic scale



mathsisinteresting.blogspot.com

- Additional graphics - axes



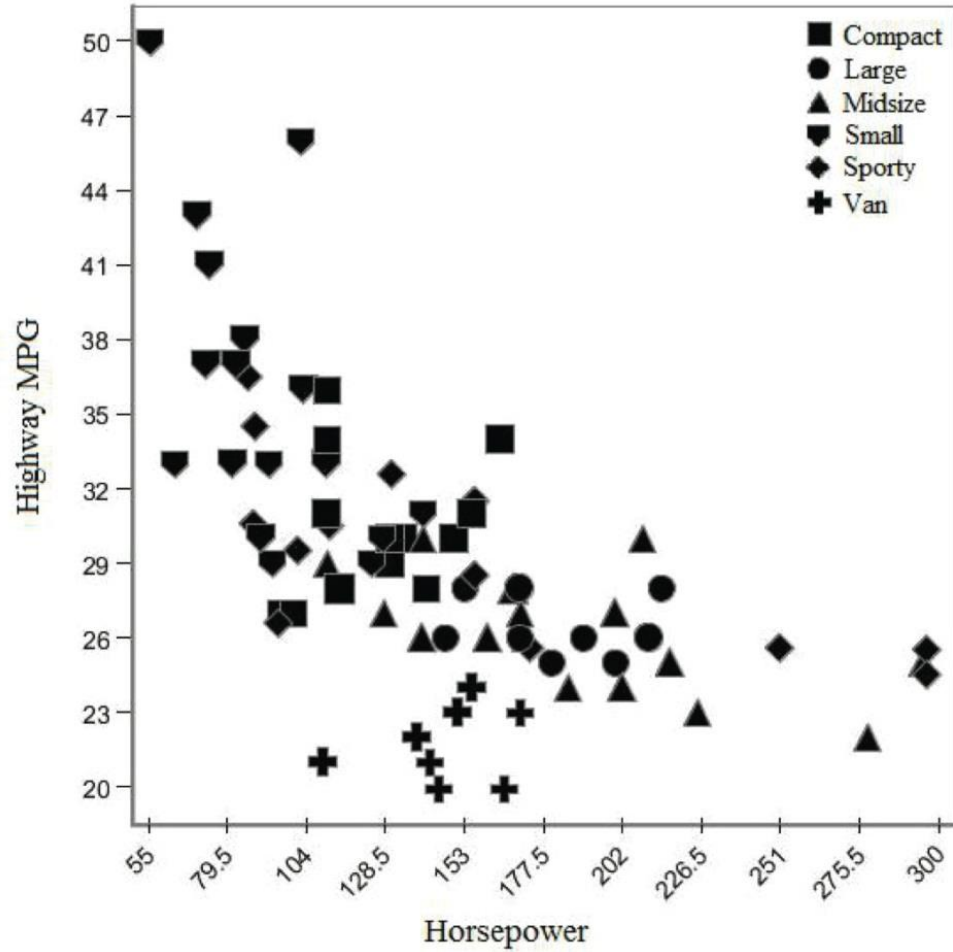
Shape

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



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

Shape



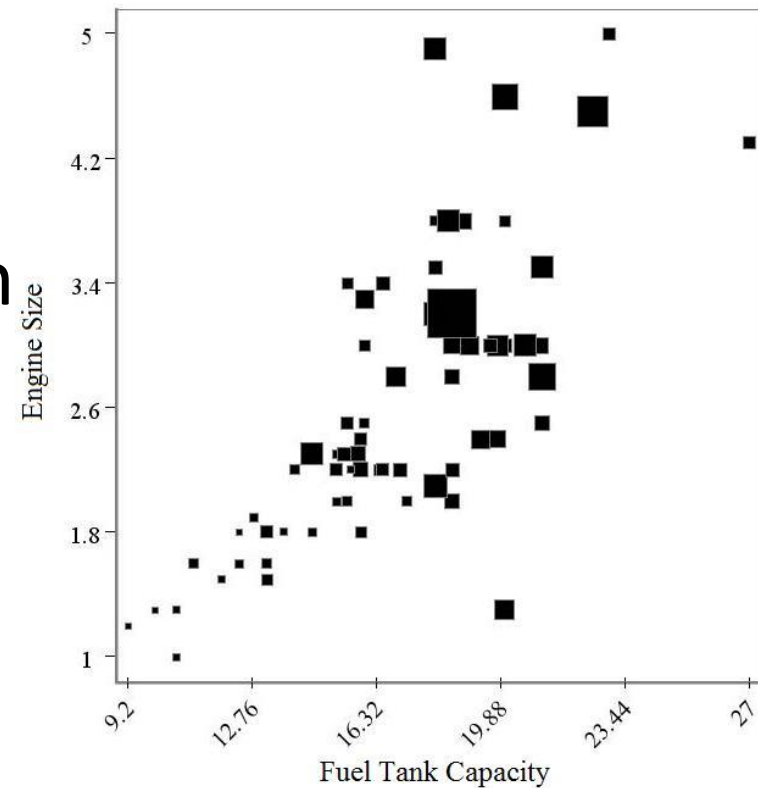
Size



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

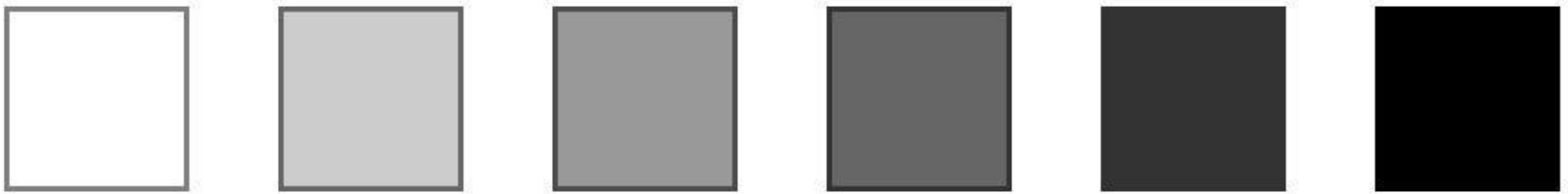
Size

- Depends on the symbol type selection
- Points, lines, curves are appropriate in combination with size
- Inappropriate for regions



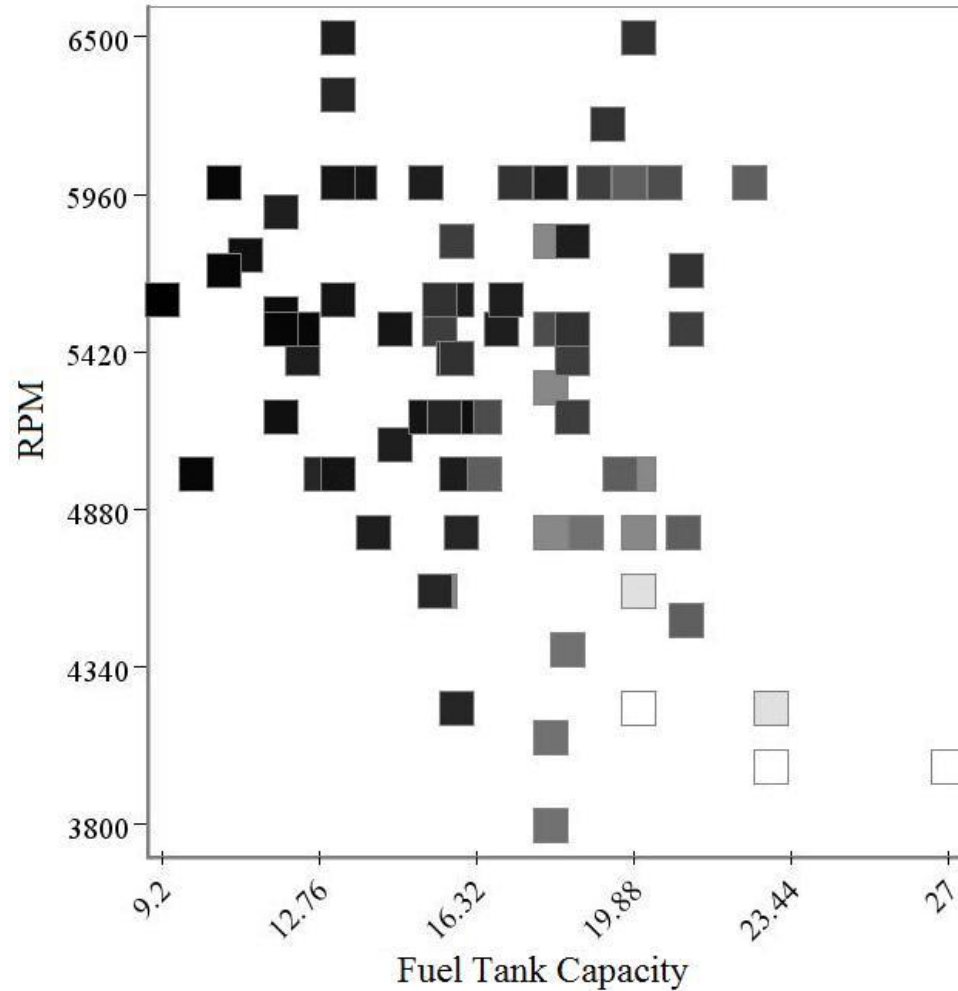
Brightness

- Brightness scale for mapping values :



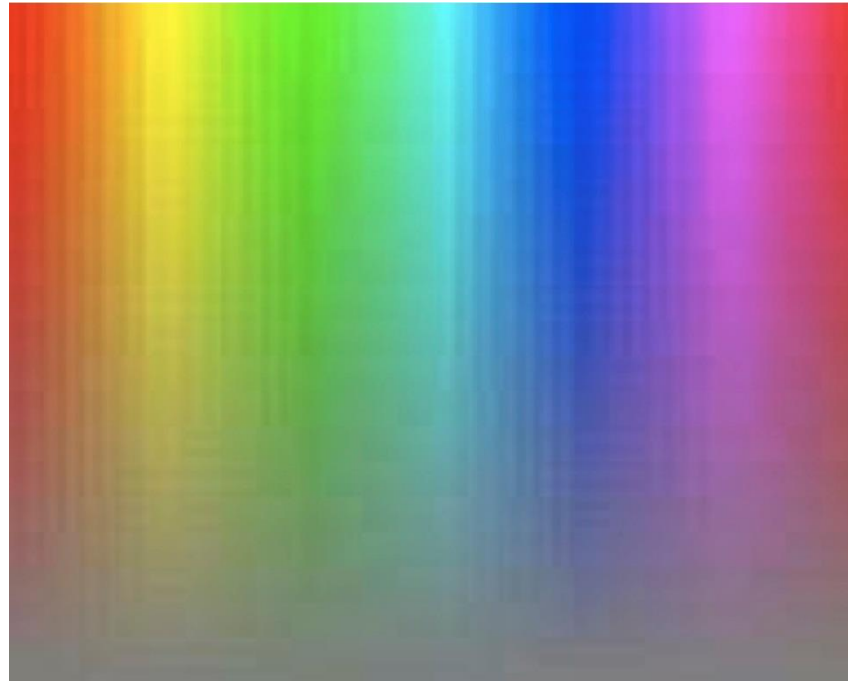
- Linear brightness scale

Brightness

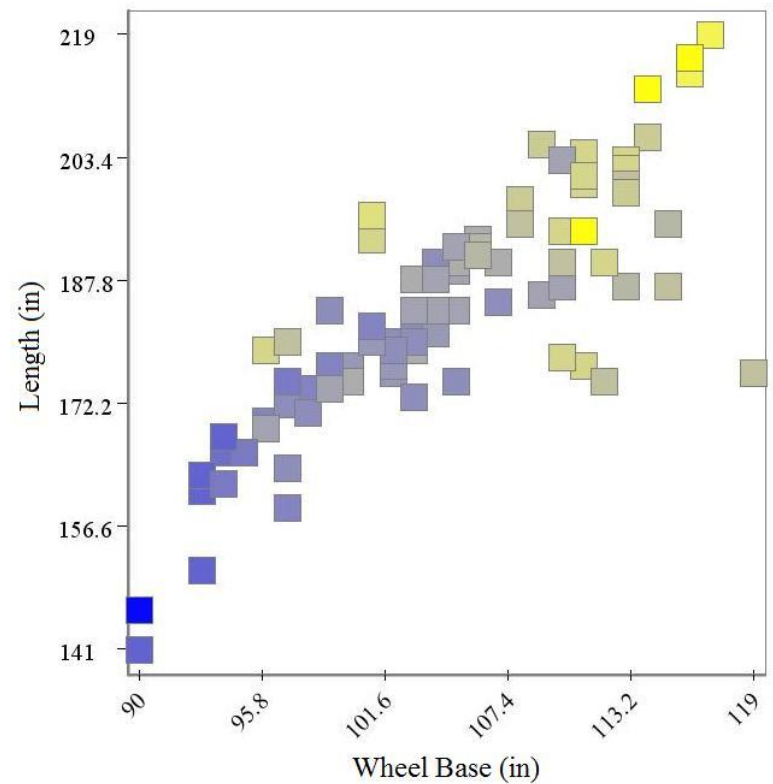


Color

- Hue, saturation



Color



- <http://colorbrewer2.org/>

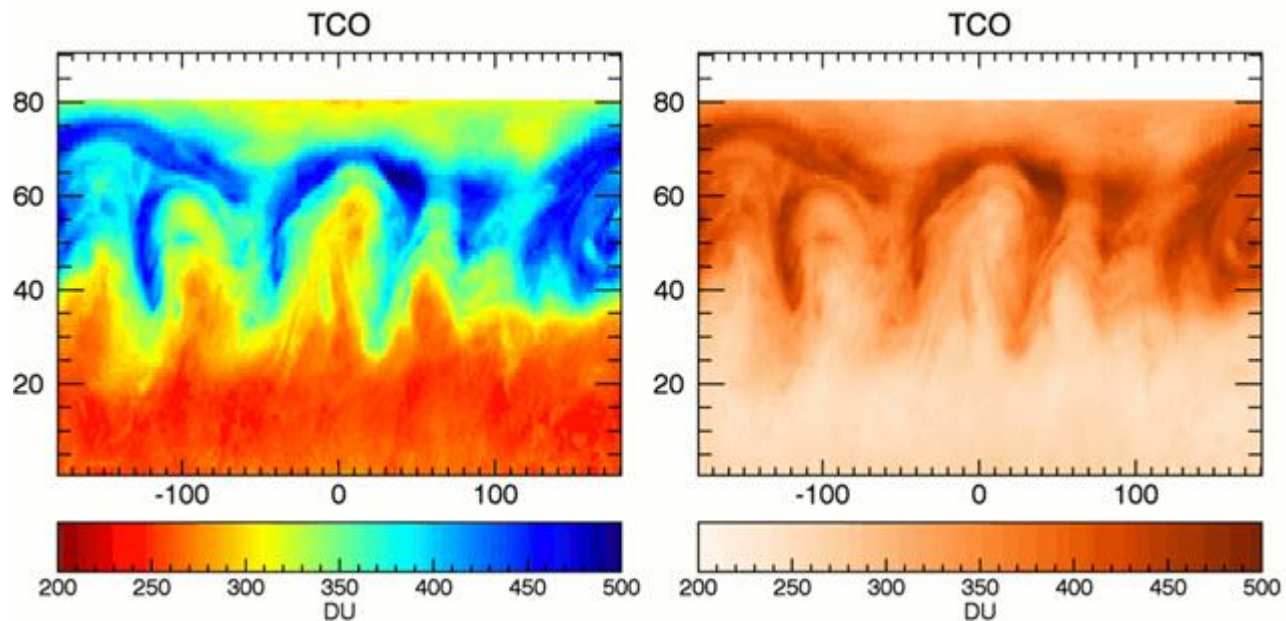
Color

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



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 representative of the underlying data.

Problem with rainbow scale

SANFORD AND SELNICK

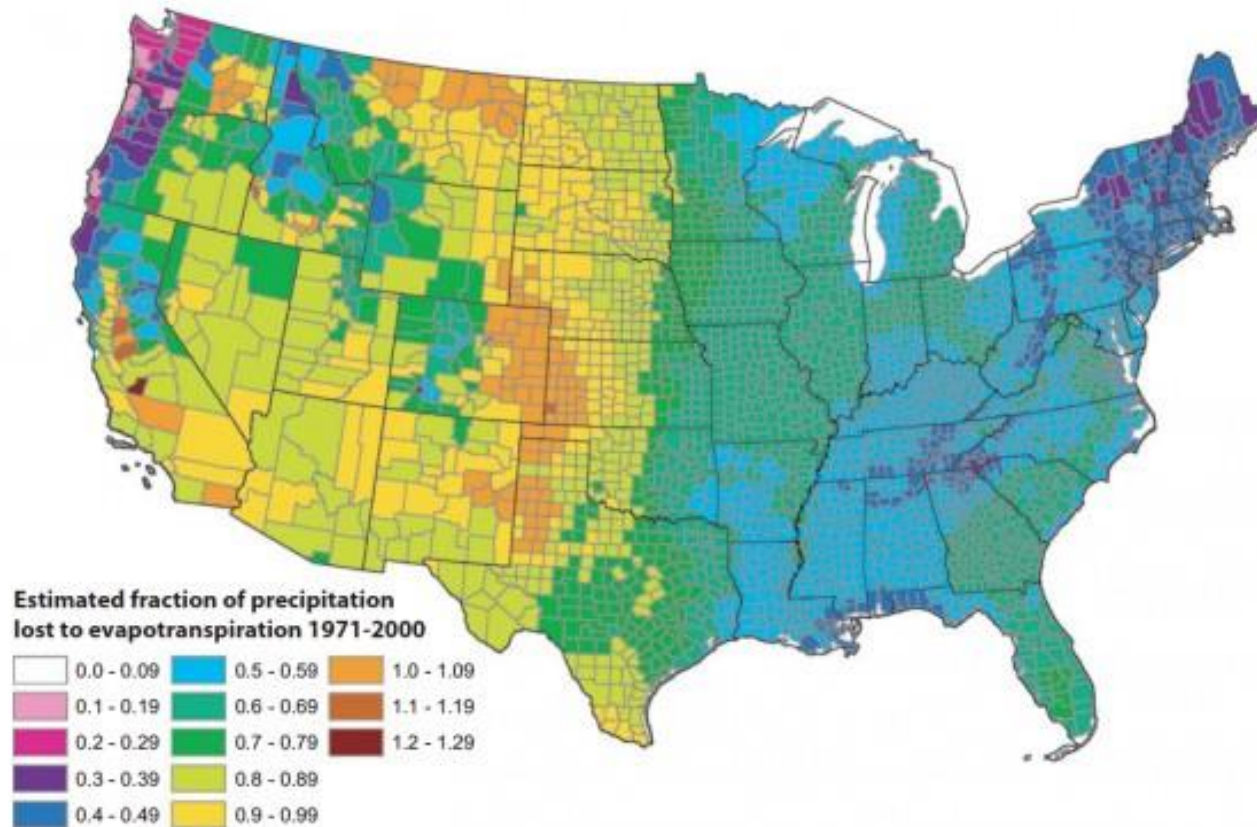
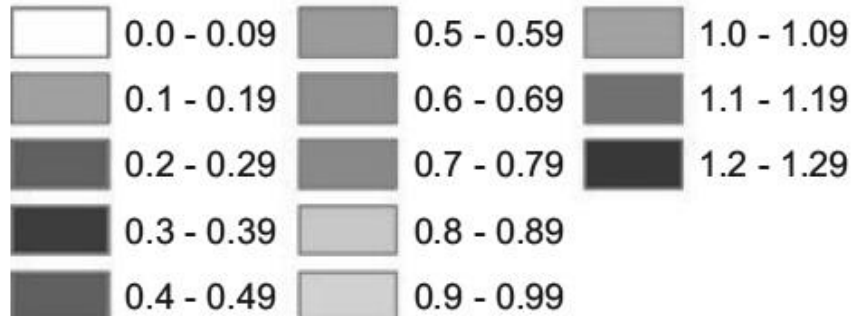


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM 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



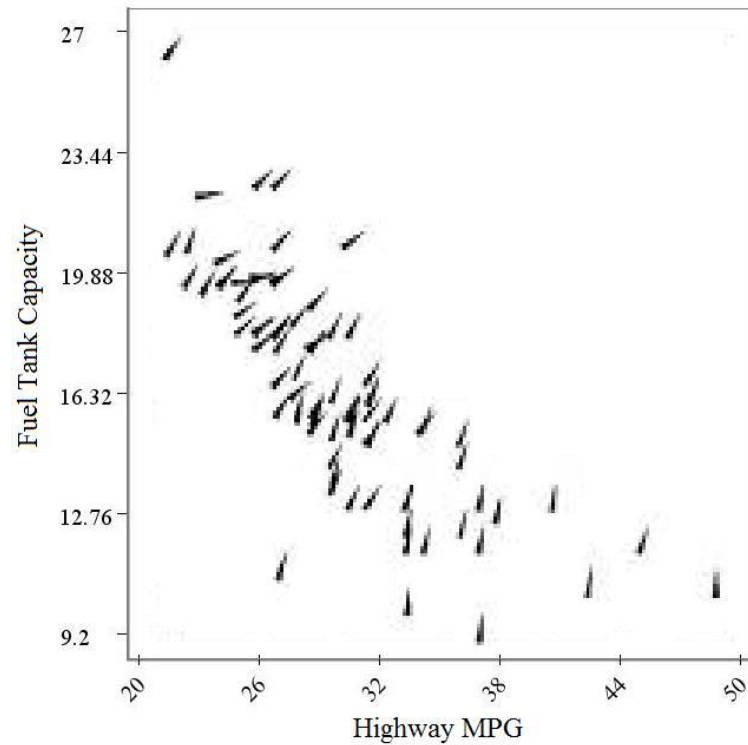
Why rainbow?

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

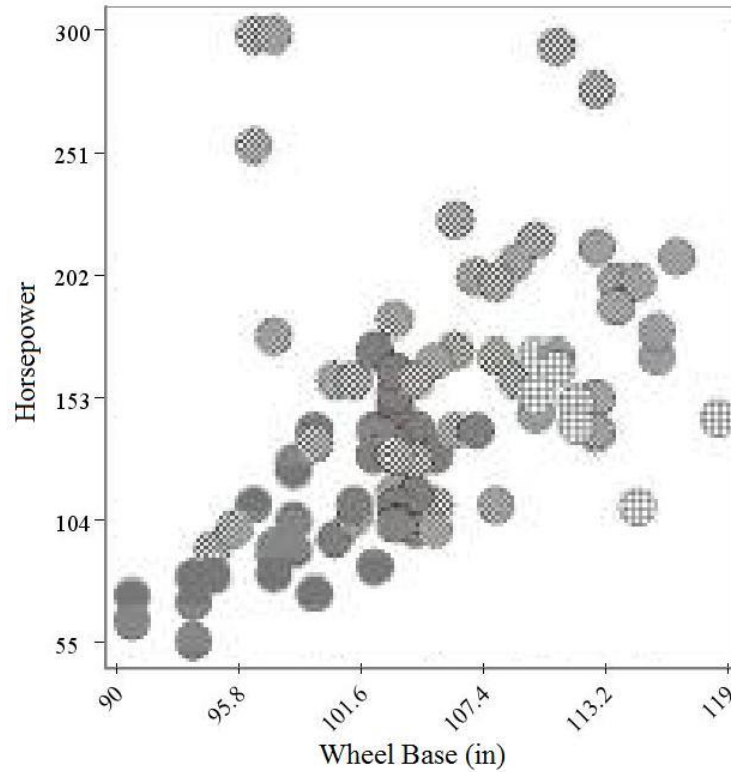


- Rainbow can introduce a lot of artifacts
- Use ColorBrewer!

Orientation



Texture

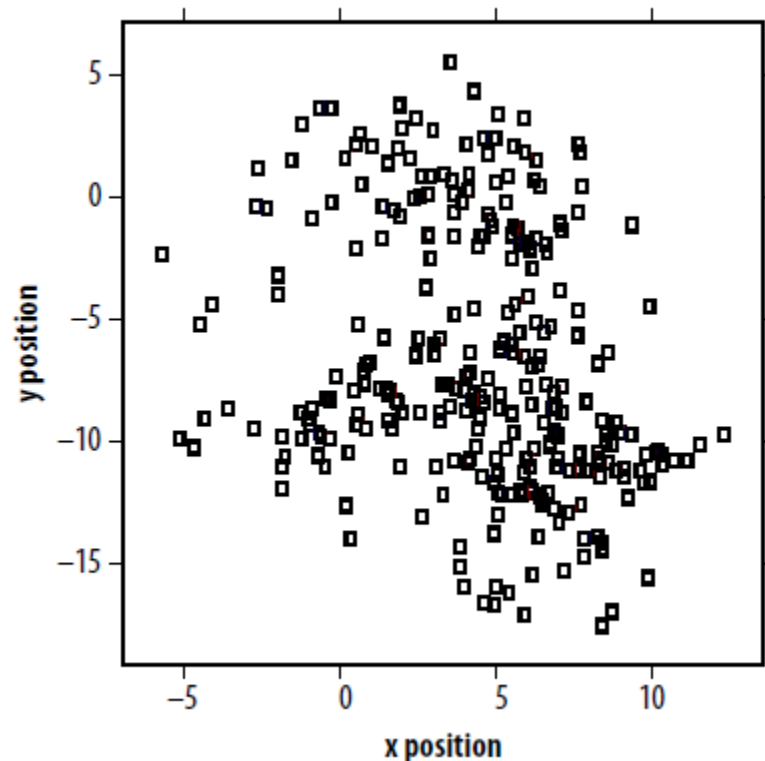


Motion

- Can be associated with any other visual variable
- Position – direction of movement
- Size – increase/decrease
- Brightness – lighter/darker
- Orientation – bigger/smaller angle

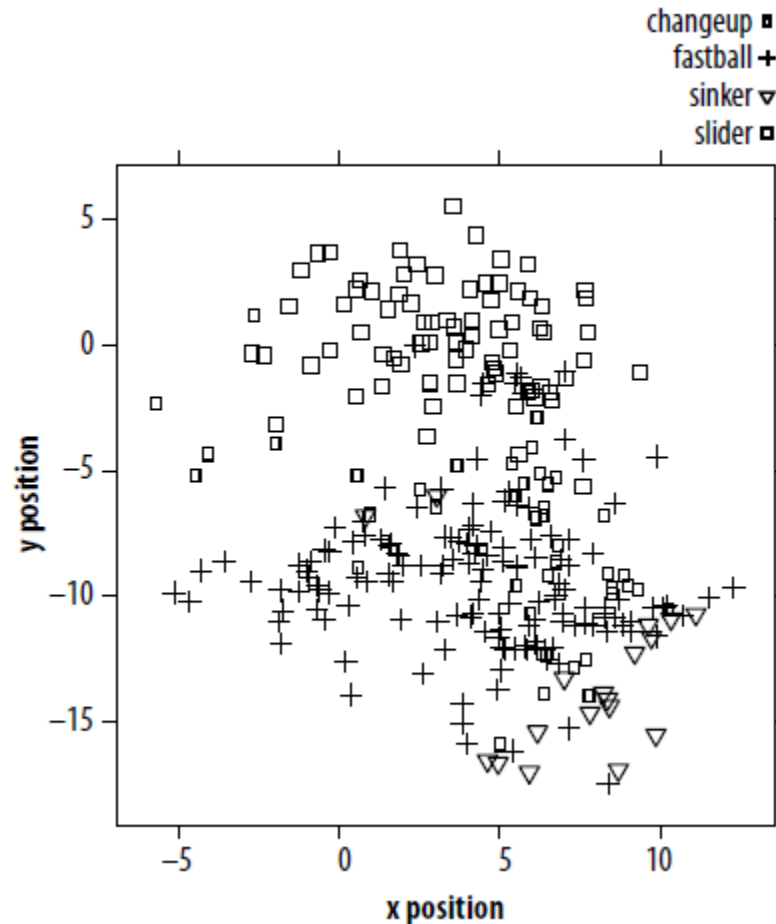
Example – baseball

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



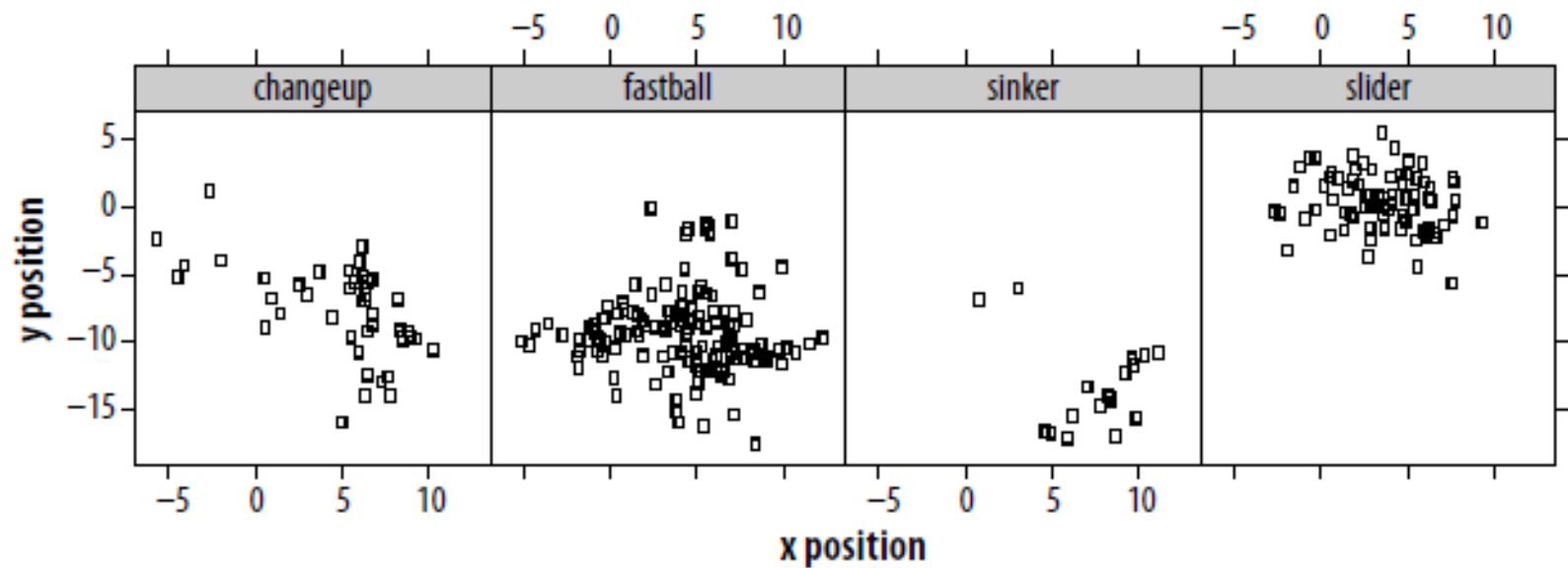
Example – baseball

- Type of hit mapped to different types of glyphs



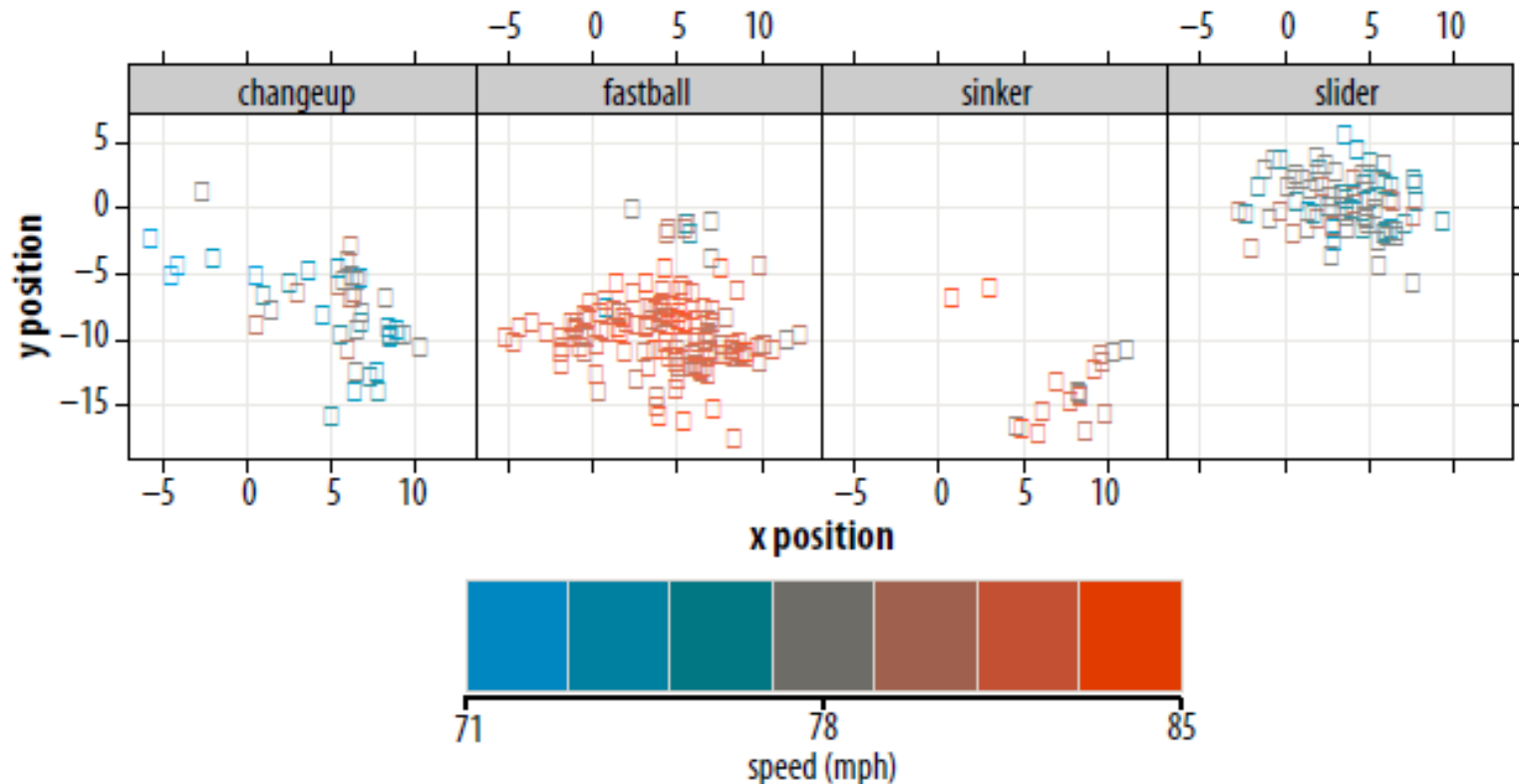
Example – baseball

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



Example – baseball

- Adding color to express the hit speed

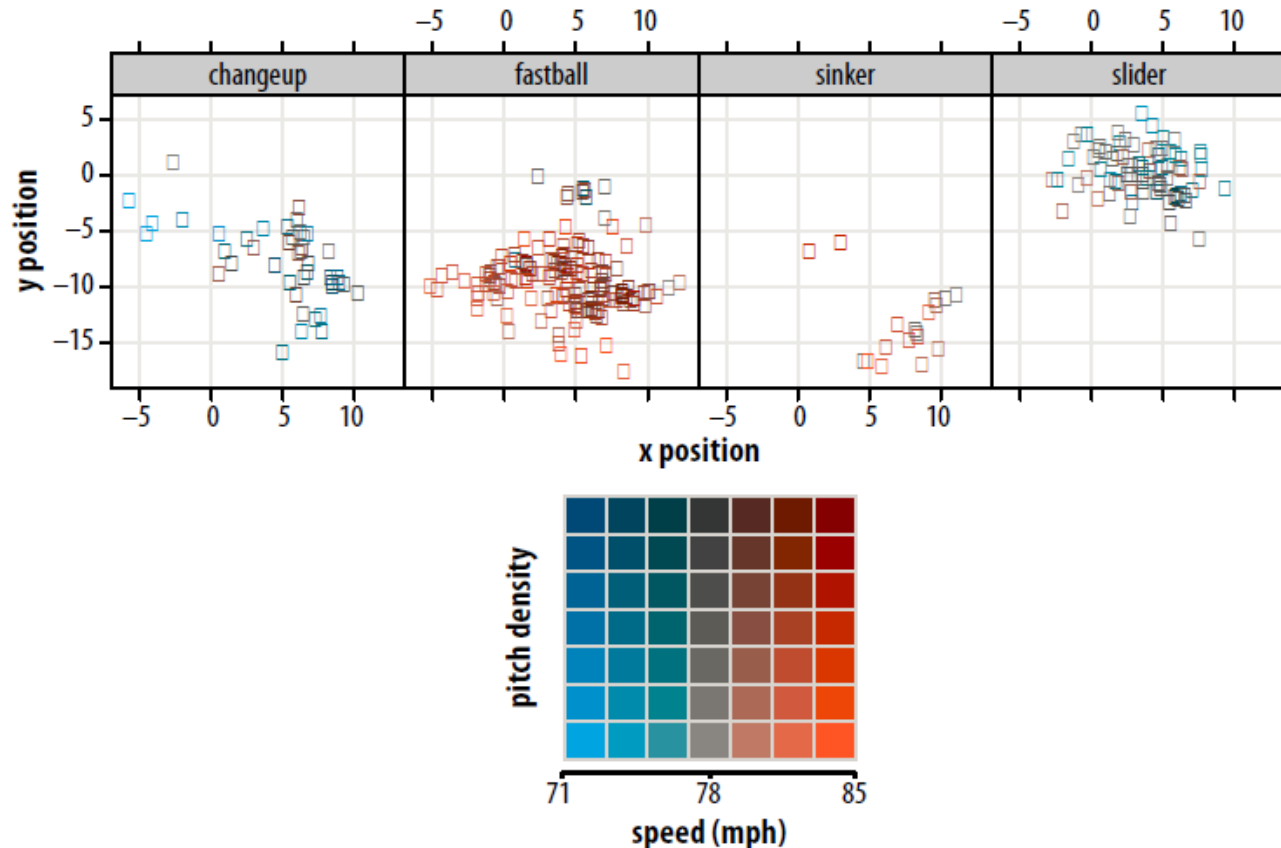


Color perception

- Differences in color can be detected already in 200 milliseconds – 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