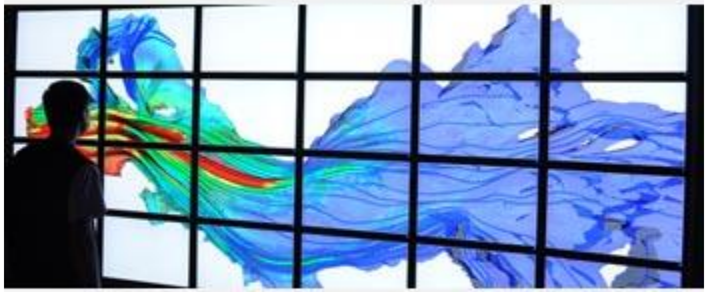
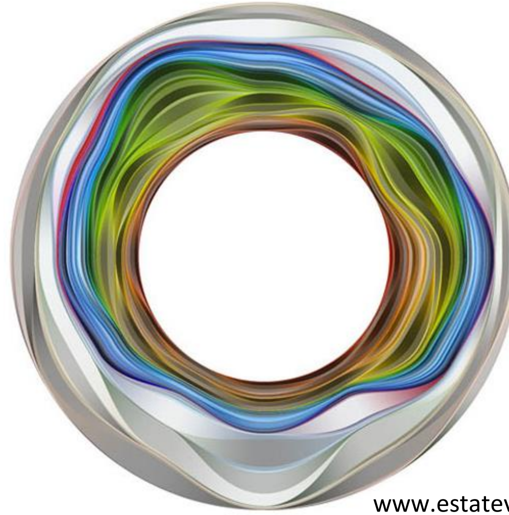
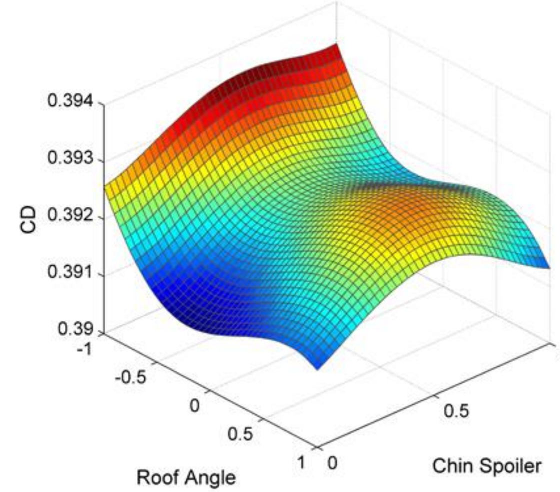


www.nsf.gov



www.estatevaults.com



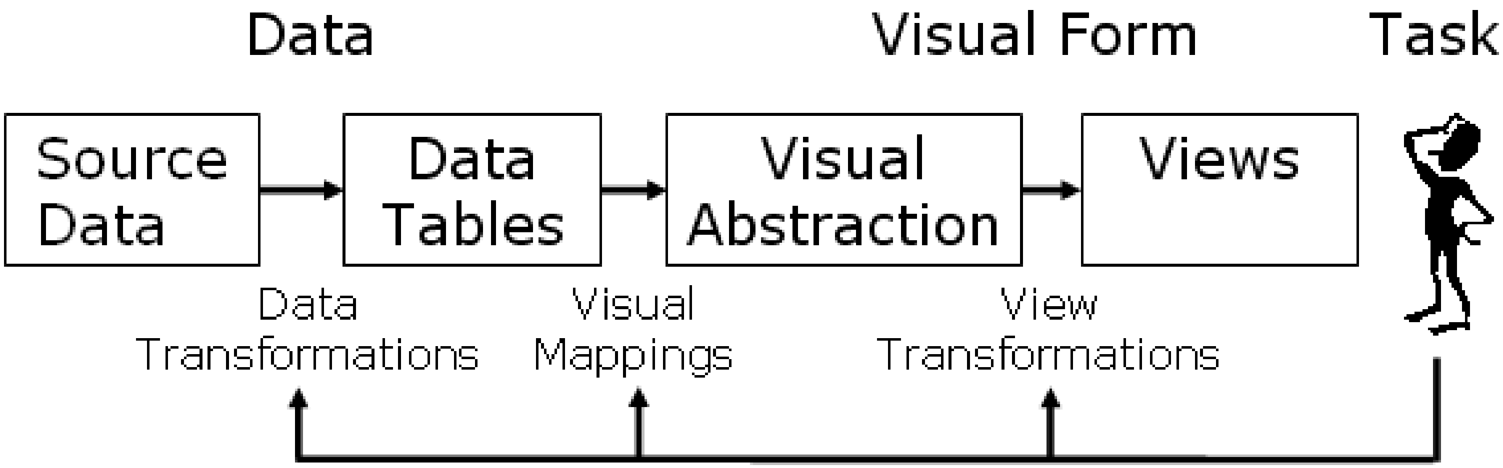

exa.com

# 3. Basic principles of visualization

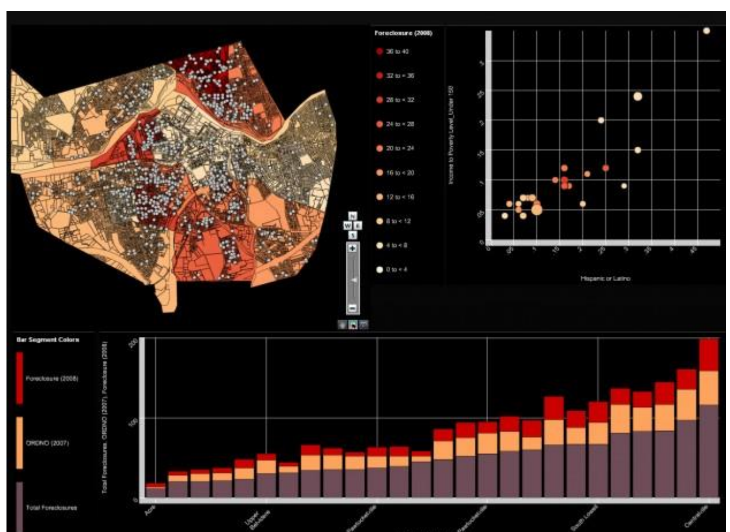

www.usingmindmaps.com

www.cg.tuwien.ac.at

# Visualization pipeline



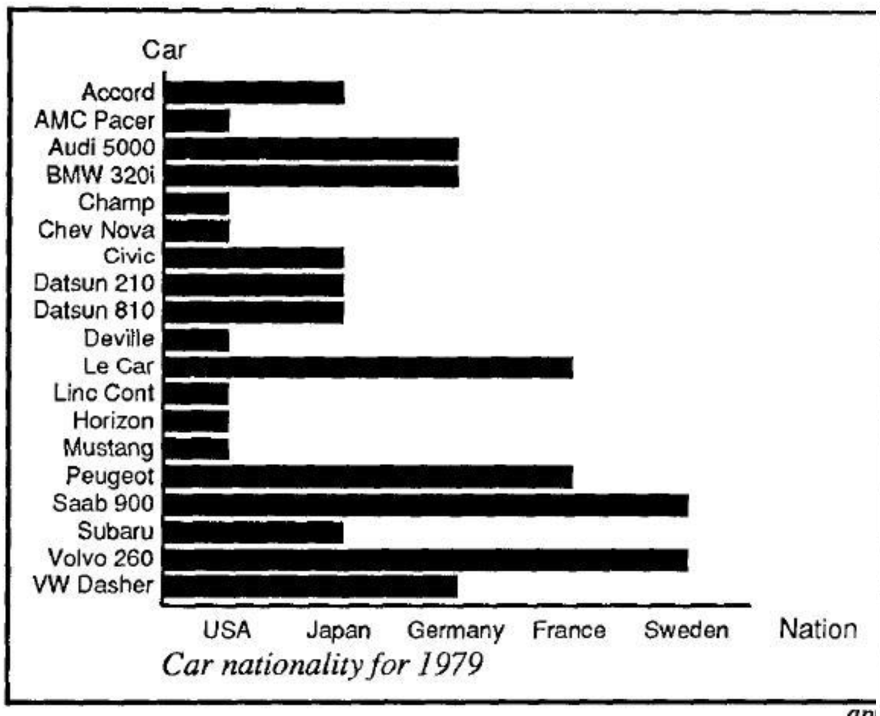

prefuse.org

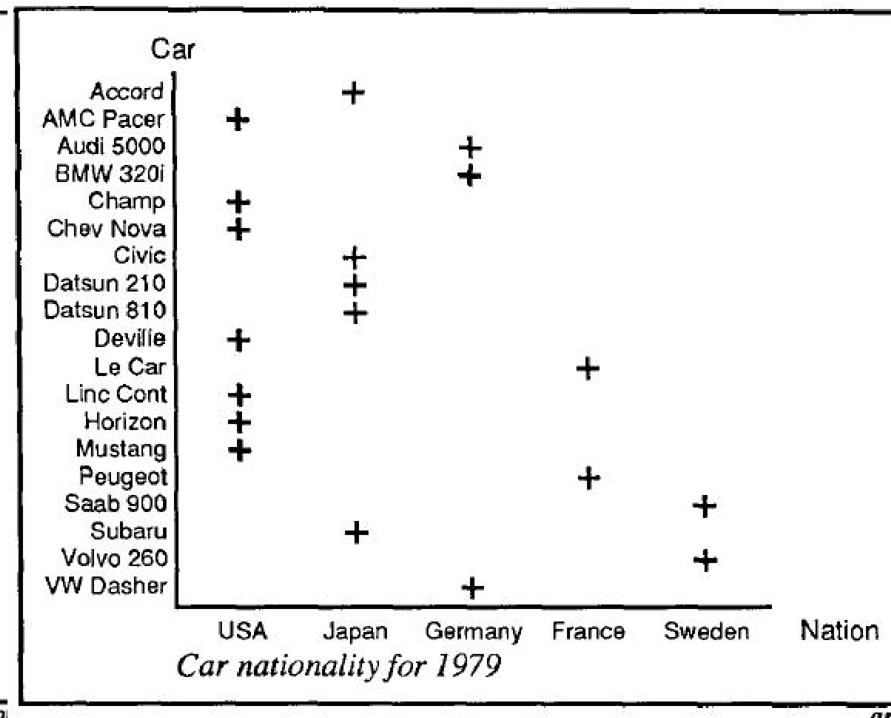


flowingdata.com

# Working with data

- Data preprocessing
  - last lecture
- Data mapping to visualization




Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

# 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**

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

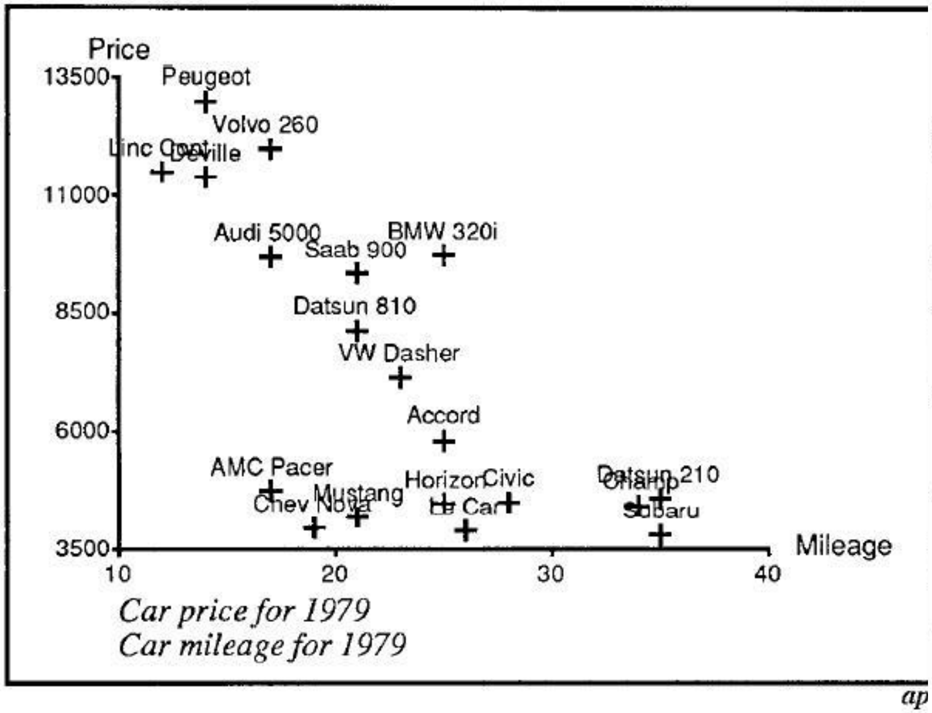
- Visualization is effective:
  - Correct and fast interpretation
  - Fast rendering

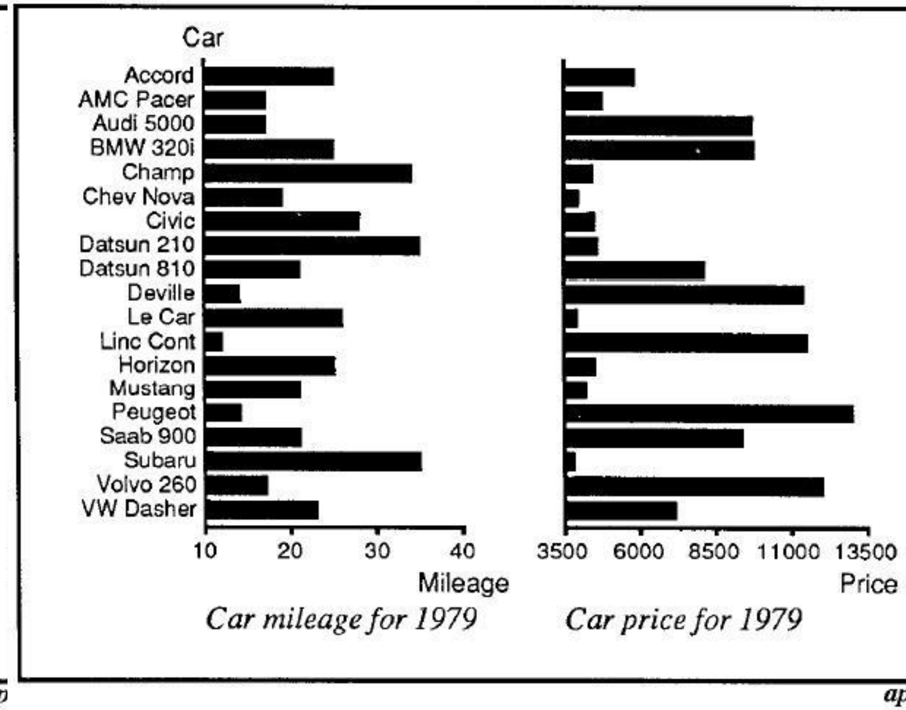
$$\mathbf{M_{eff} = 1/(1 + interpret + render)}$$

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

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

# Example



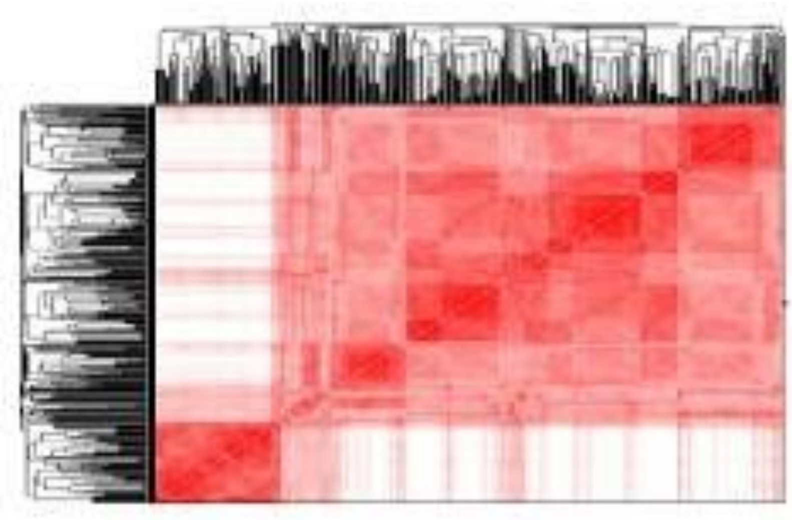




Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

# Graphical symbols

- Easily recognizable graphical symbols

Clear meaning



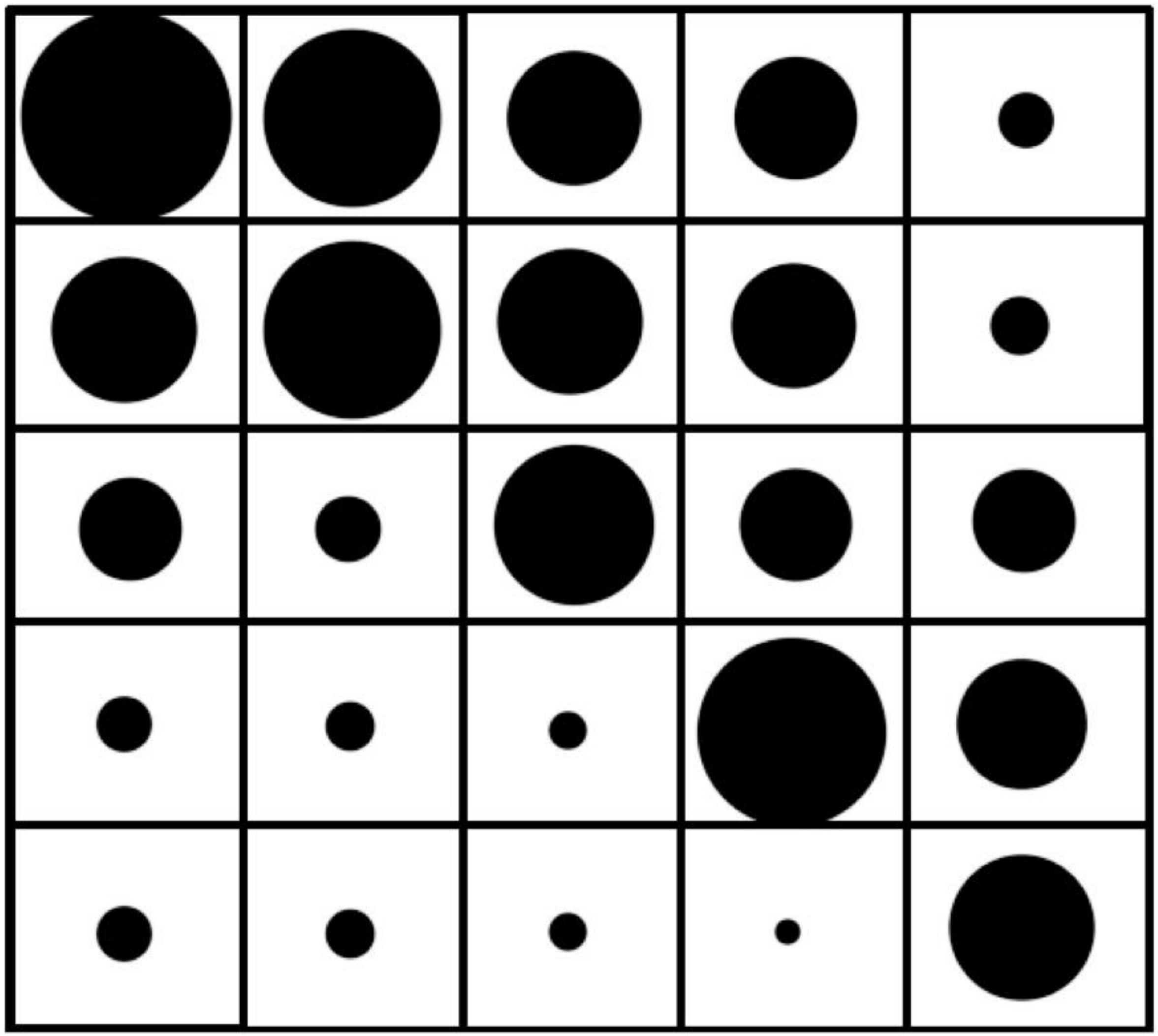
Complex meaning

Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

# 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**

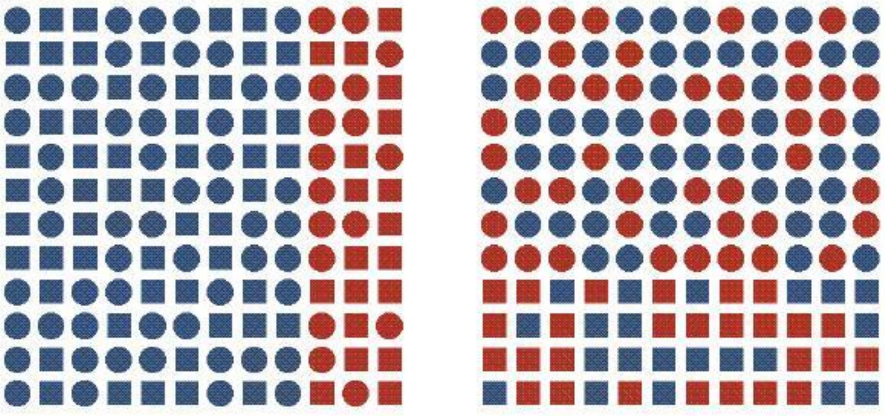
# Dimensionality of 2D graphics



Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

# Analysis of graphics

1) Subconsciously we perceive grouping of objects



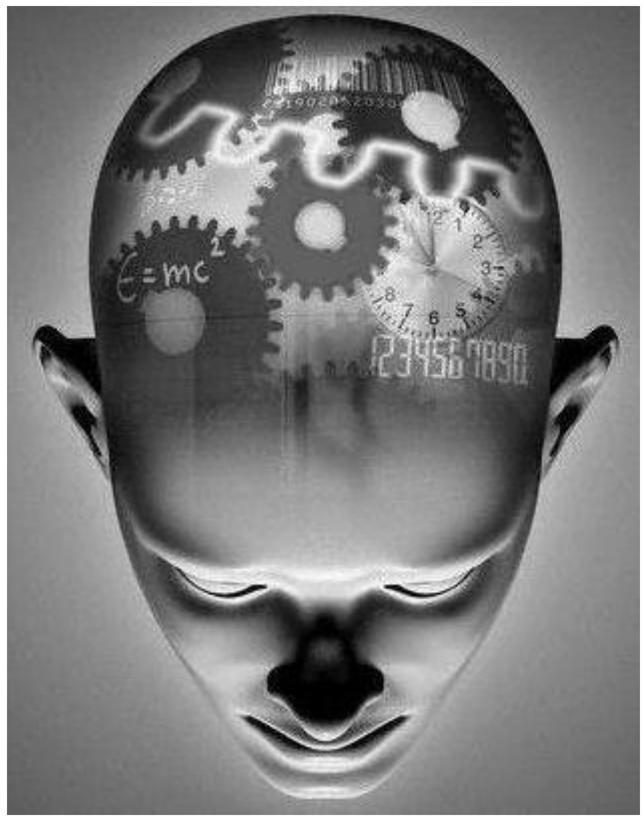
(a) (b)

| 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] |

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

# Analysis of graphics

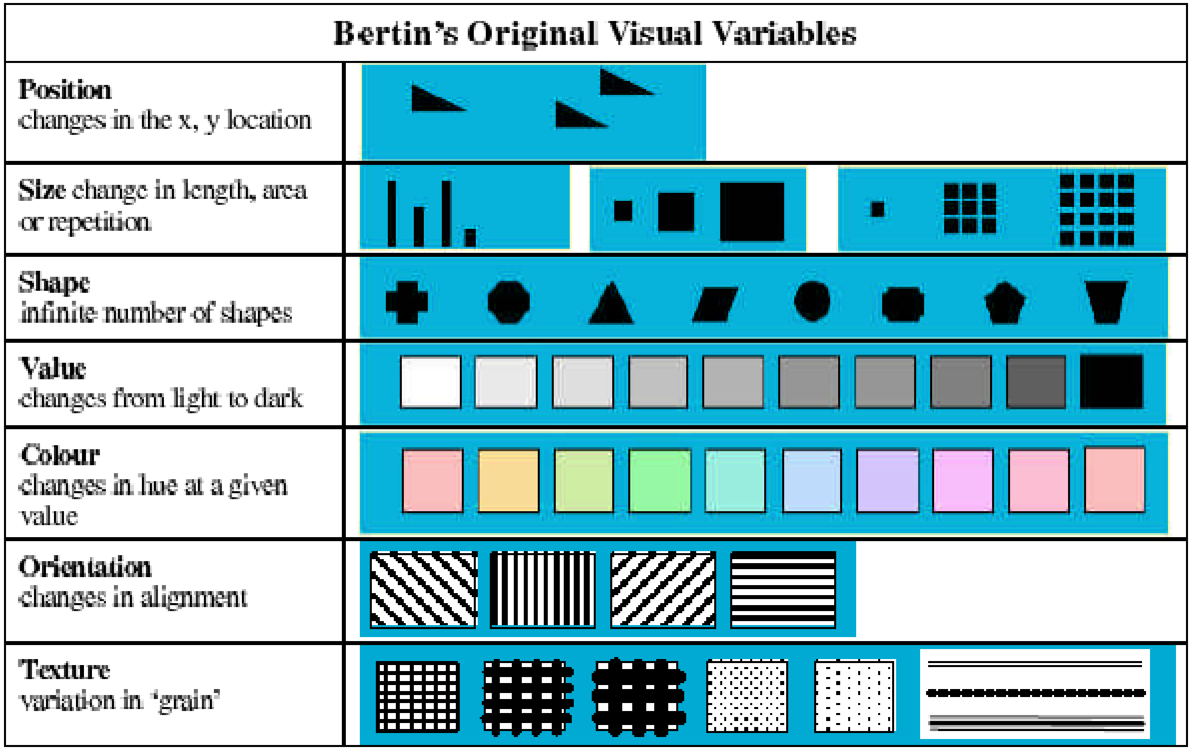
2) Cognitively we characterize these groups




elearningbuzz.wordpress.com

# Eight visual variables

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



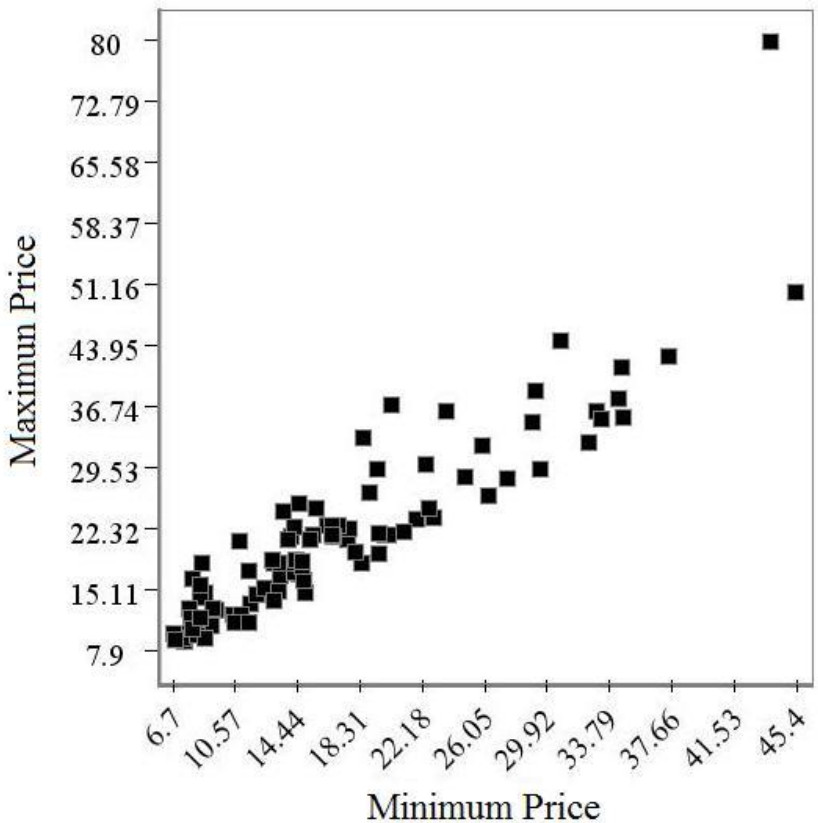

www.infovis-wiki.net

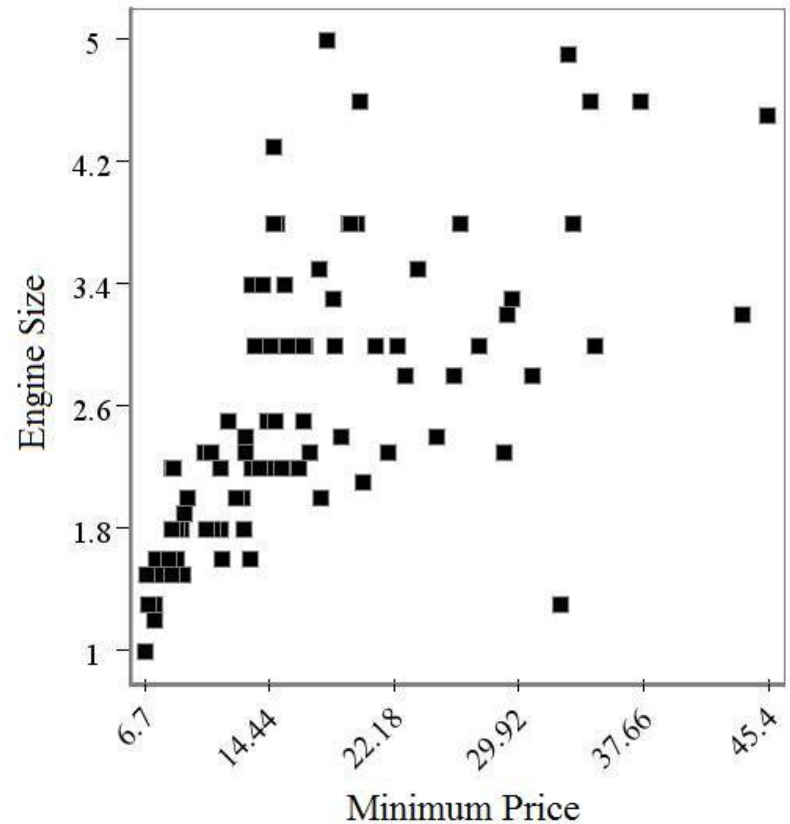
# Position

- 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

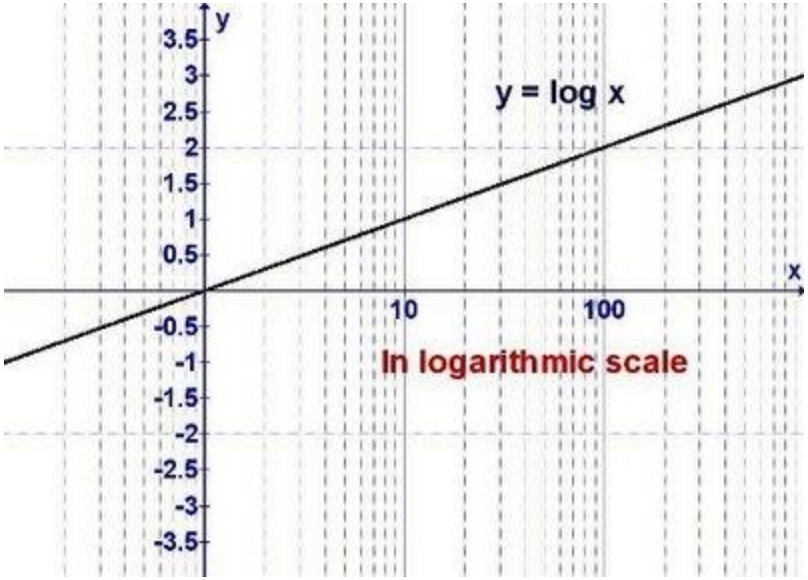



Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

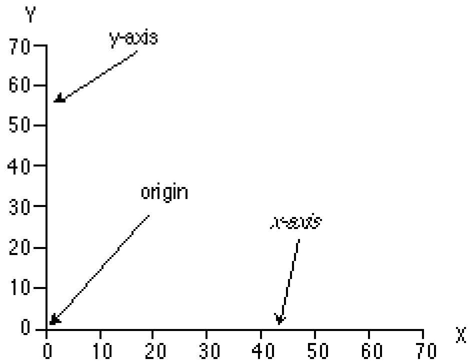
# Position

- Linear scale
- Logarithmic scale




mathsisinteresting.blogspot.com

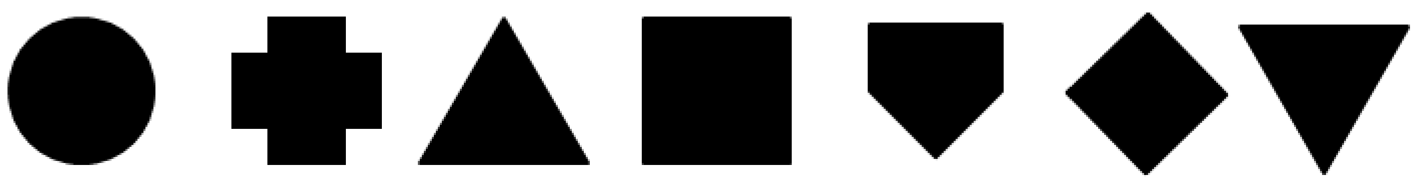
- Additional graphics - axes




cstl.syr.edu

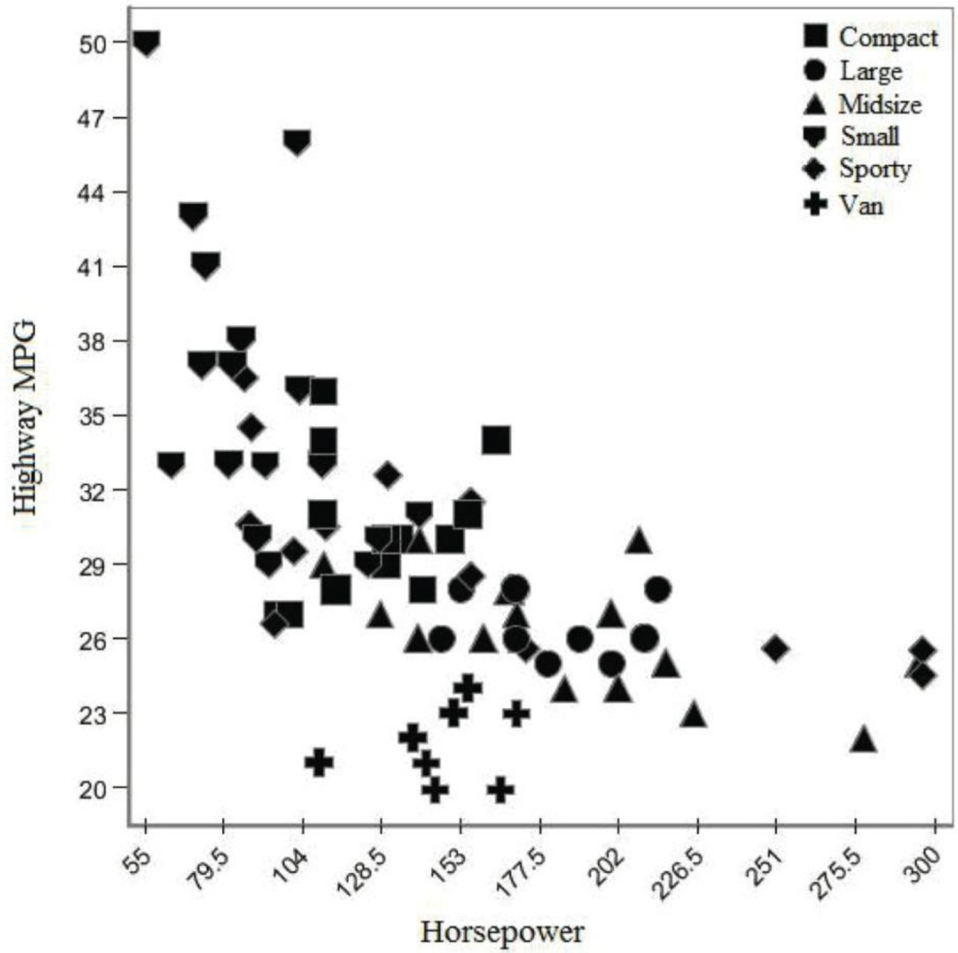
# Shape

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



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

# Shape



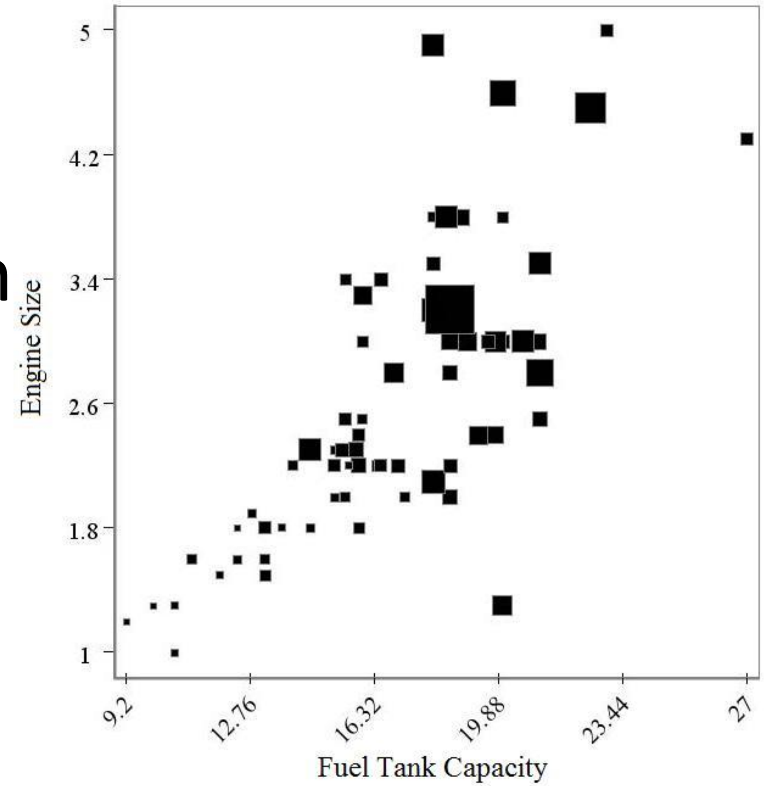

Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

# Size

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

# Size

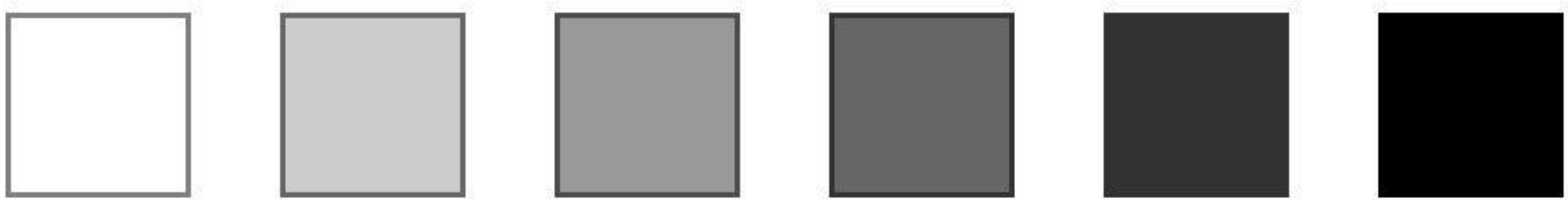
- Depends on the symbol type selection
- Points, lines, curves are appropriate in combination with size
- Inappropriate for regions




Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

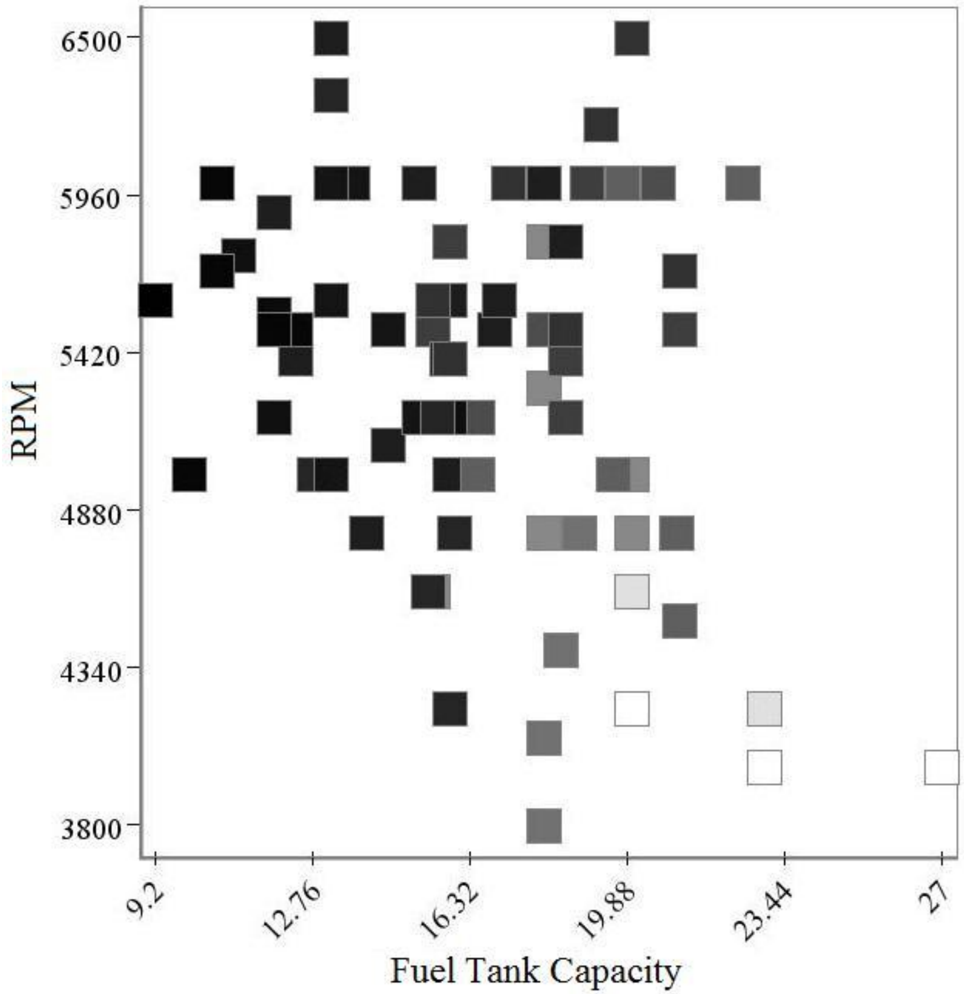
# Brightness

- Brightness scale for mapping values :



- Linear brightness scale

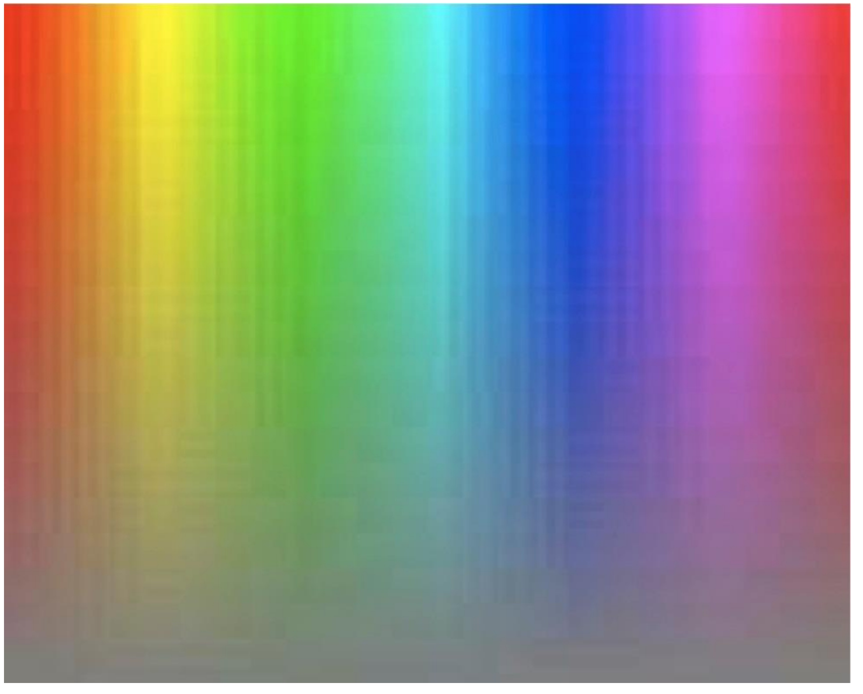
# Brightness



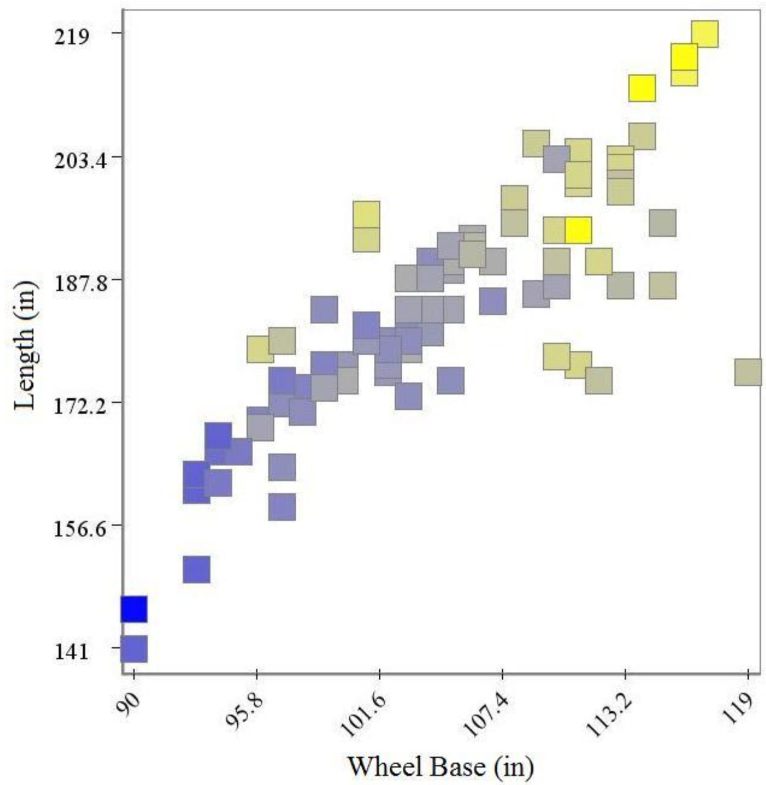

Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

# Color

- Hue, saturation



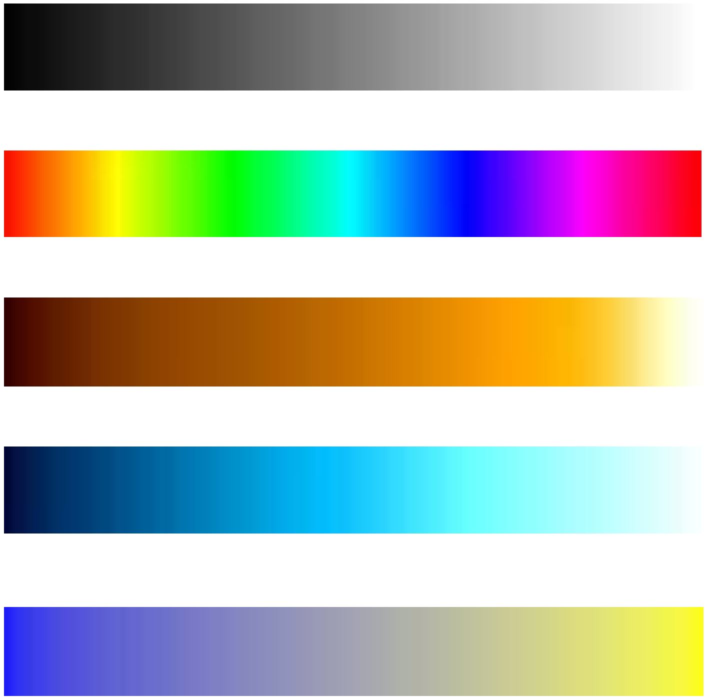
# Color




- http://colorbrewer2.org/

# Color

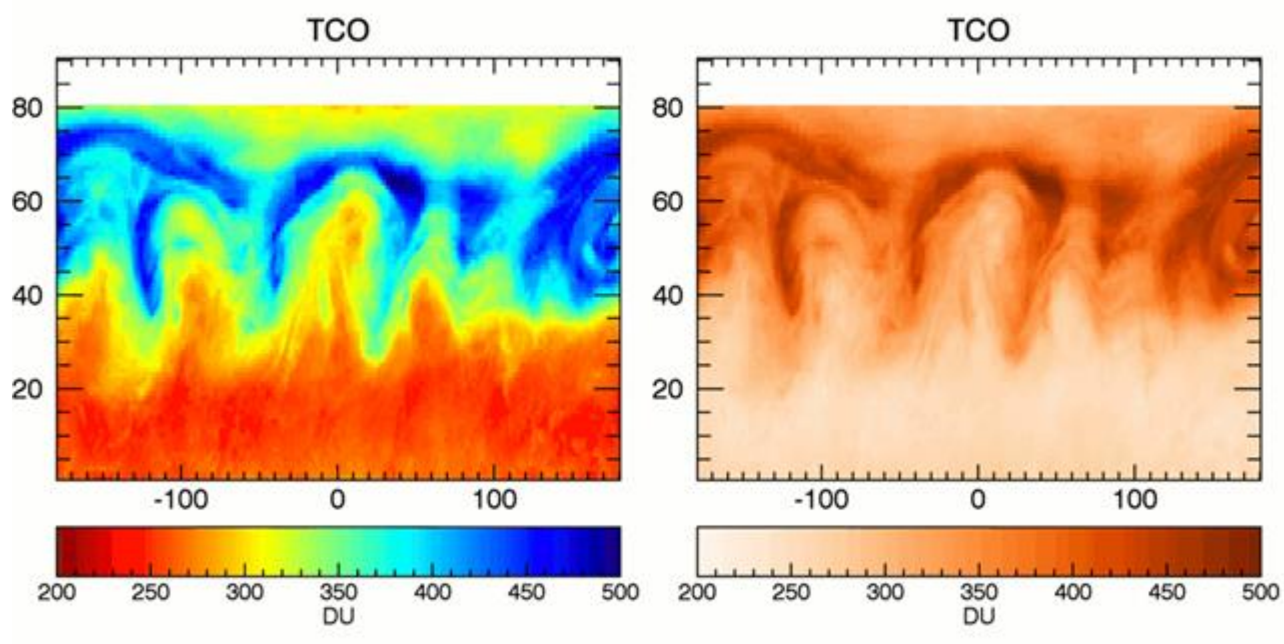
- Standard linear grayscale
- Rainbow
- „Heated“
- Blue to cyan
- Blue to yellow



Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

# 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

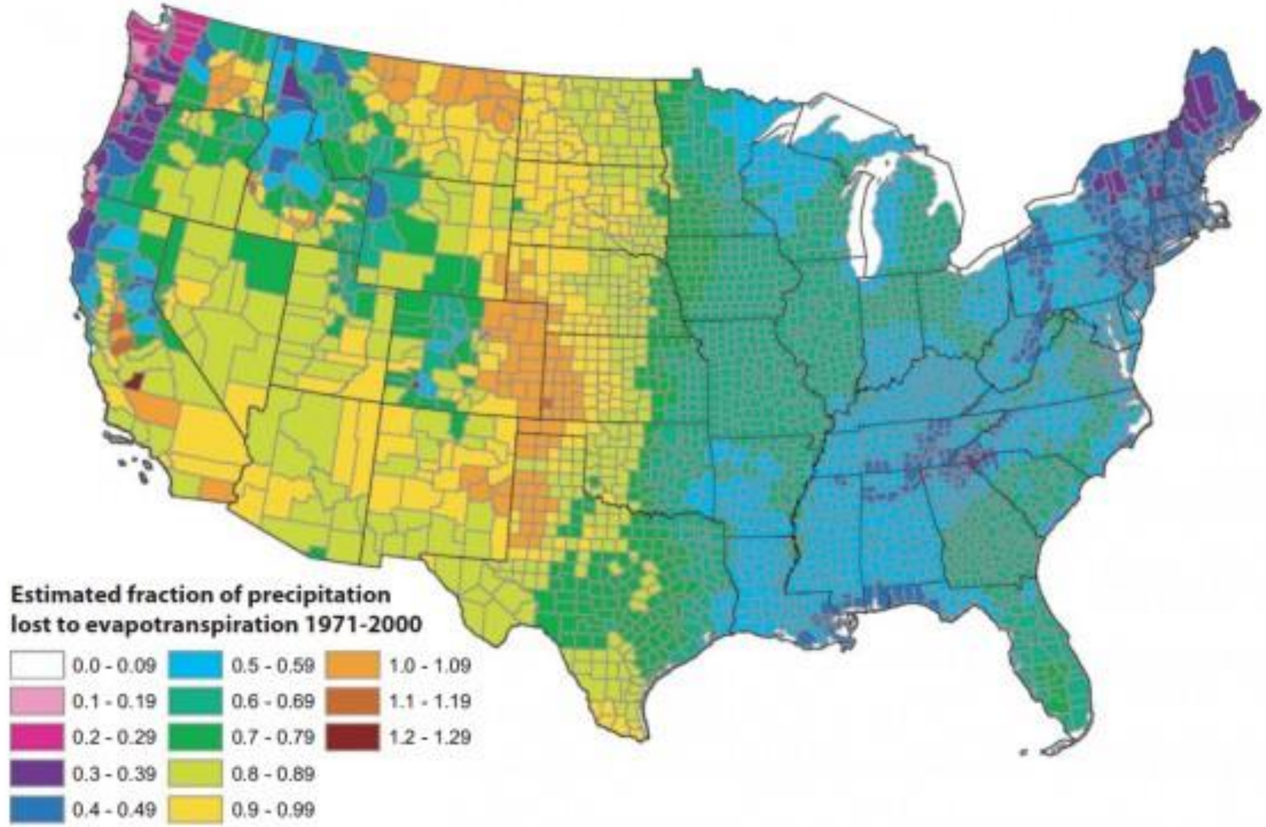
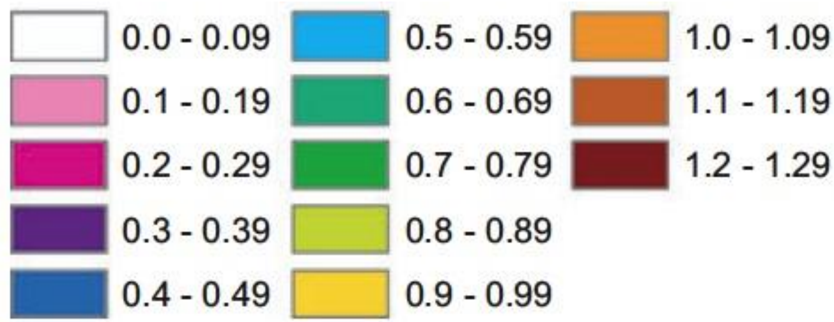
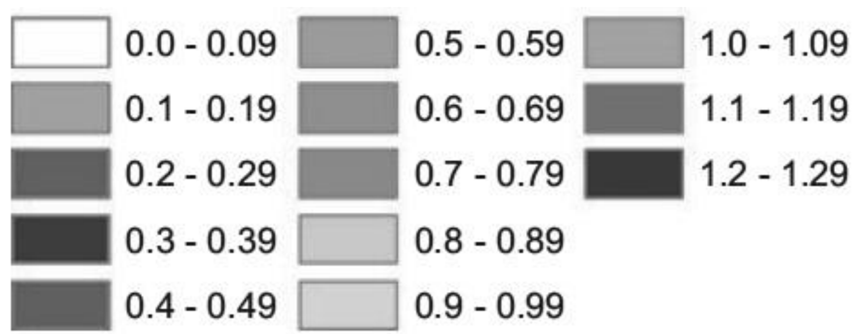



FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM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

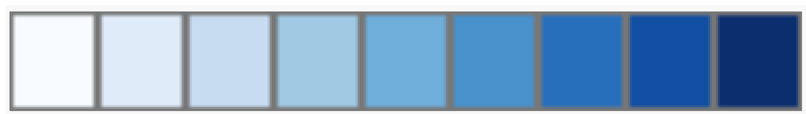



## Luminance



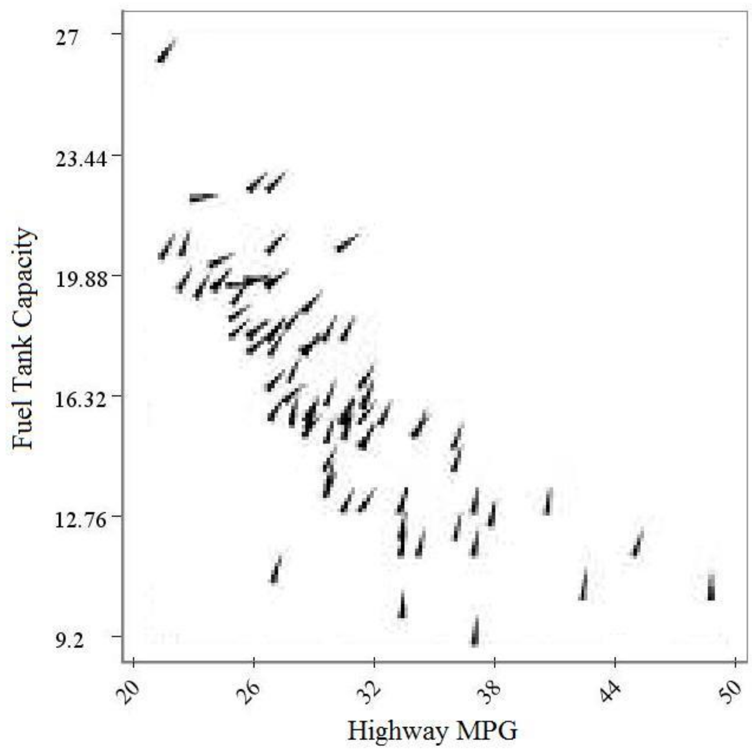
# Why rainbow?

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



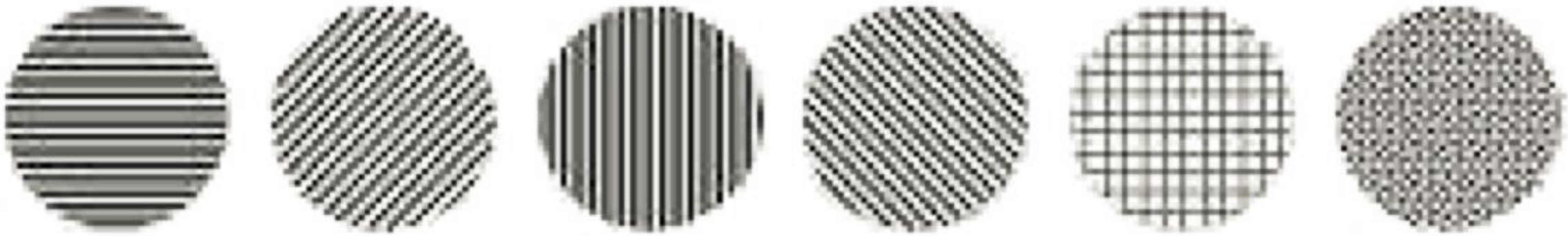
- Rainbow can introduce a lot of artifacts
- Use ColorBrewer!

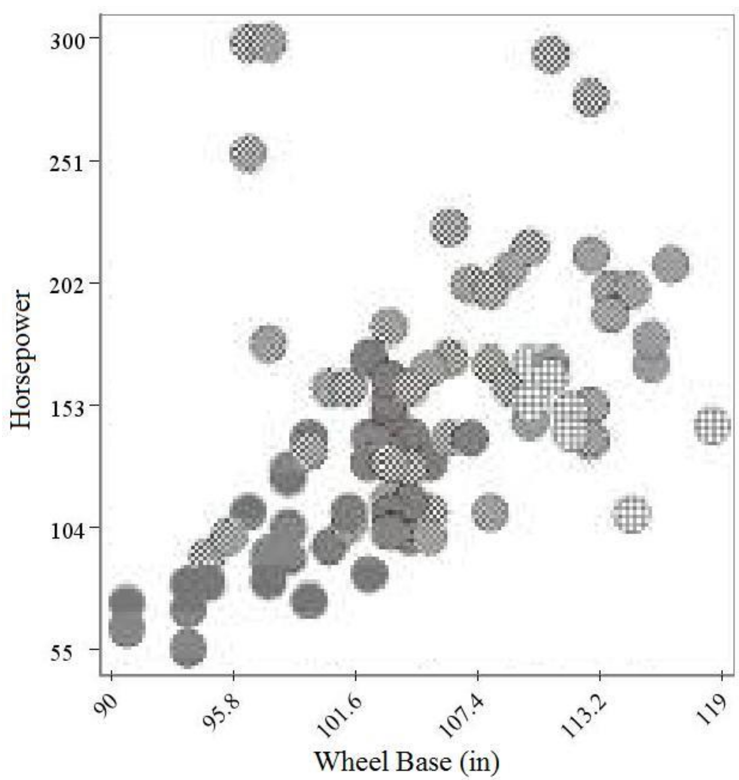
# Orientation




Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

# Texture






Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

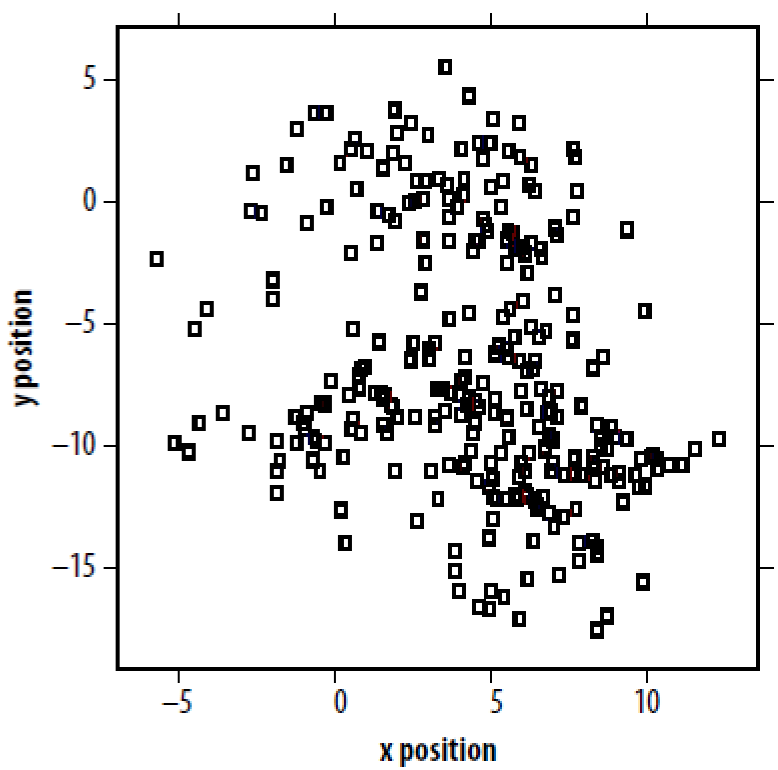
# Motion

- Can be associated with any other visual variable

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

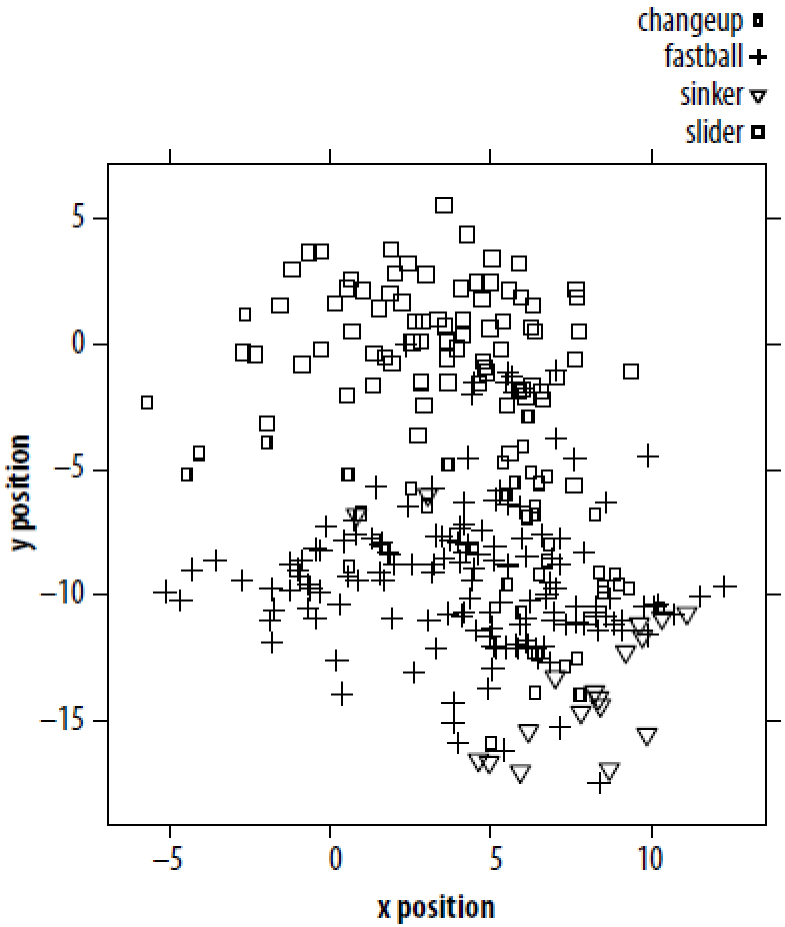
# Example – baseball

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



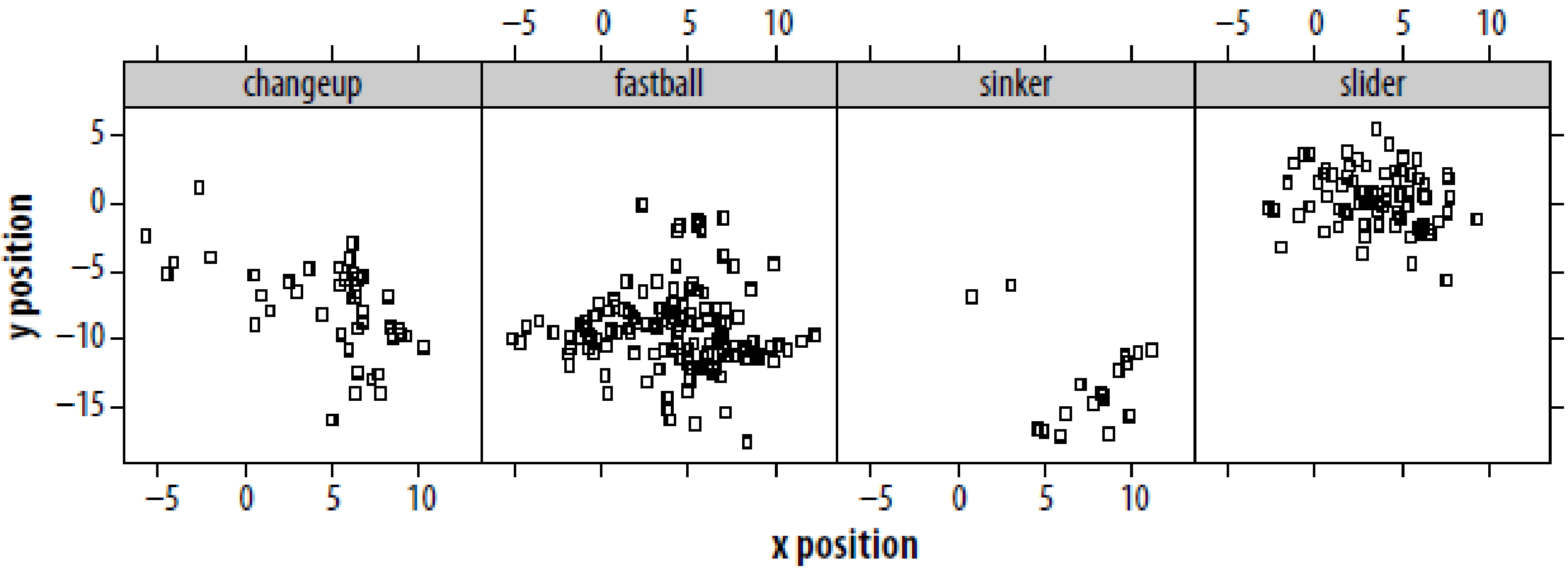
# Example – baseball

- Type of hit mapped to different types of glyphs



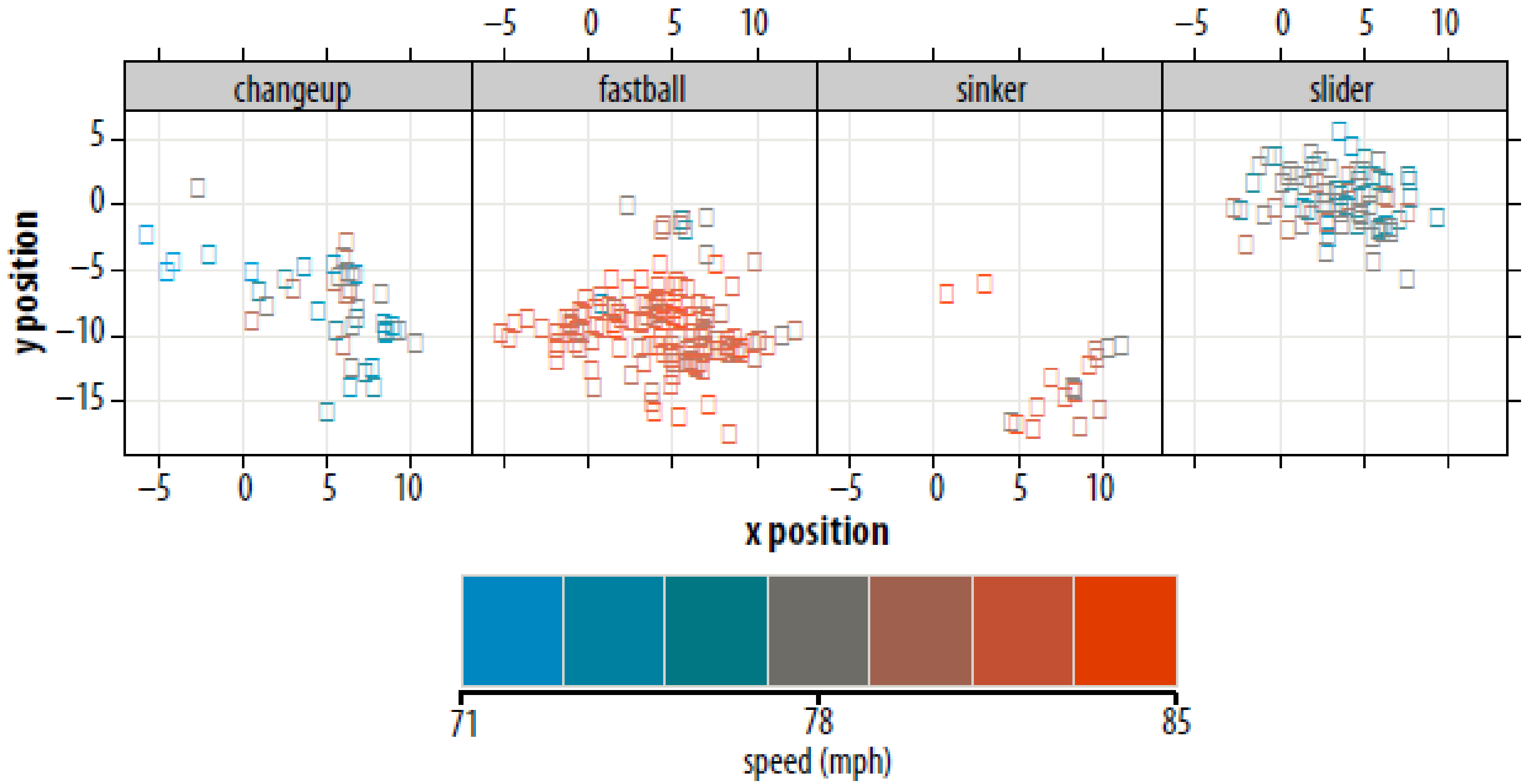
# Example – baseball

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



# Example – baseball

- Adding color to express the hit speed

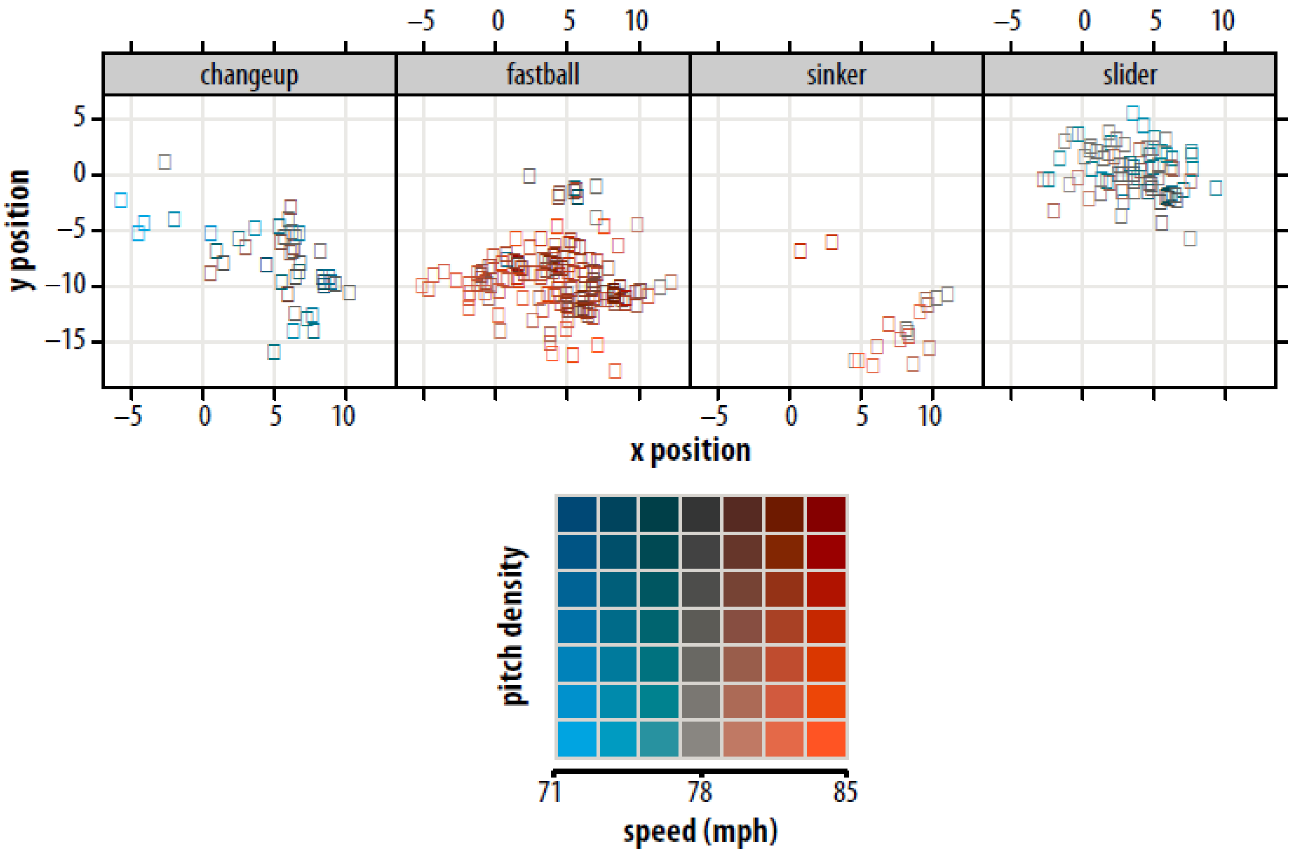


# Color perception

- 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 |