

Visual Data Analysis Visualization Mapping II

Dr. Johannes Kehrer

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Mapping techniques

- From derived data to a renderable representation

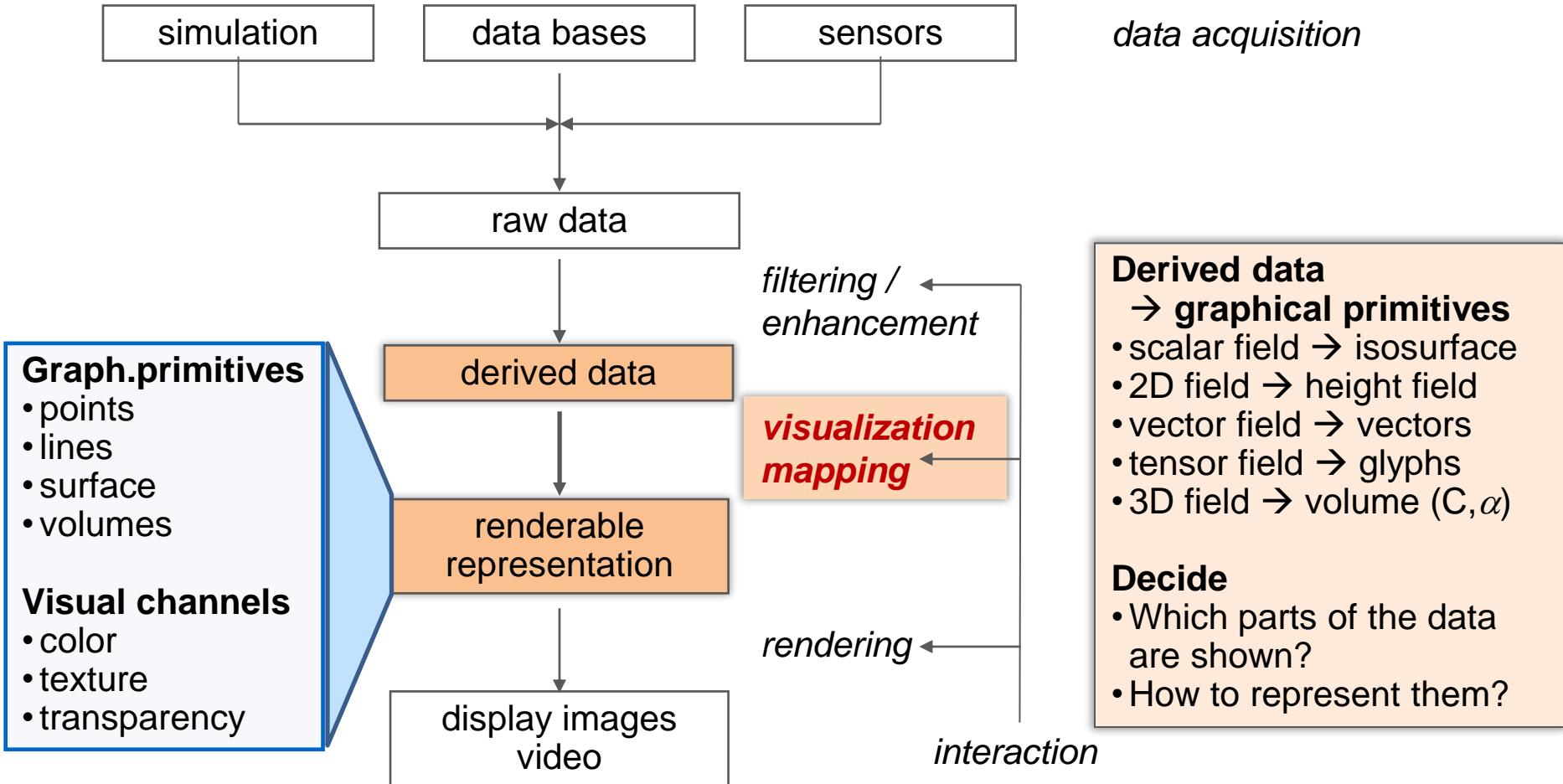


Diagram techniques

- Categorical + quantitative data
 - Bar/pie chart, stacked bars
- Time-dependent data
 - Line graph, ThemeRiver, Horizon graph
- Single and multiple variables
 - Histogram, scatterplot, parallel coordinates
 - Glyphs, color mapping

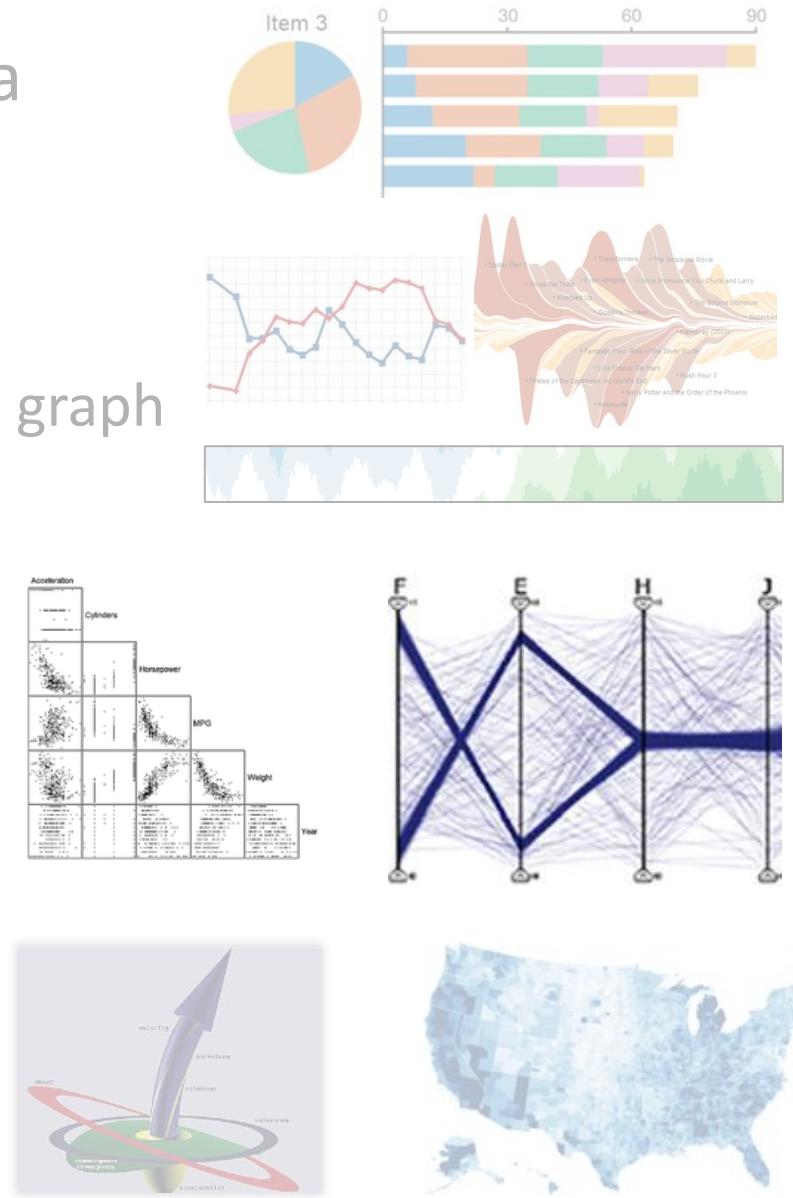


Diagram techniques

- Histogram (graphical display of statistics)
 - Special kind of bar chart
 - Show **frequency of occurrence** of values for 1 variable

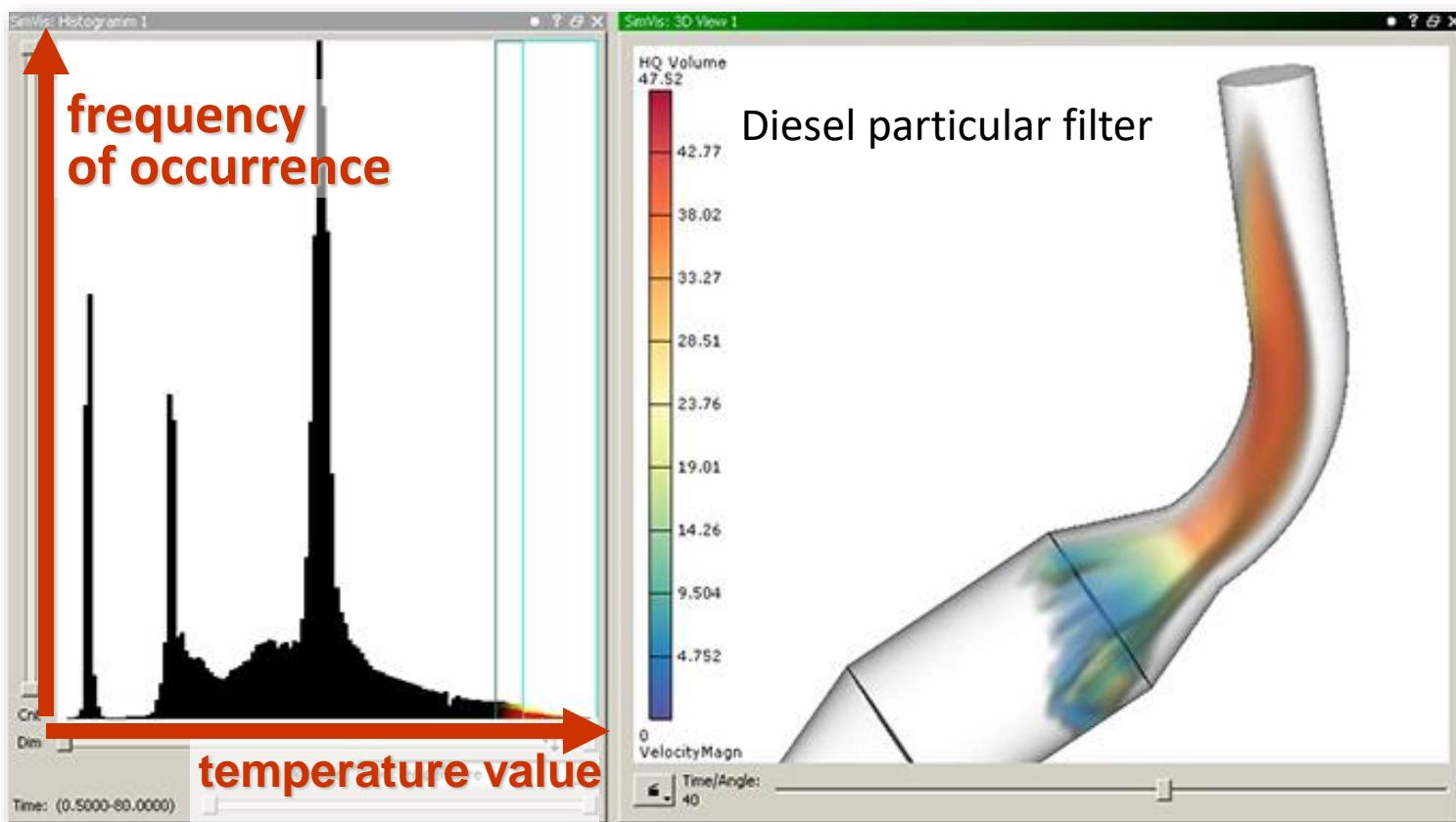
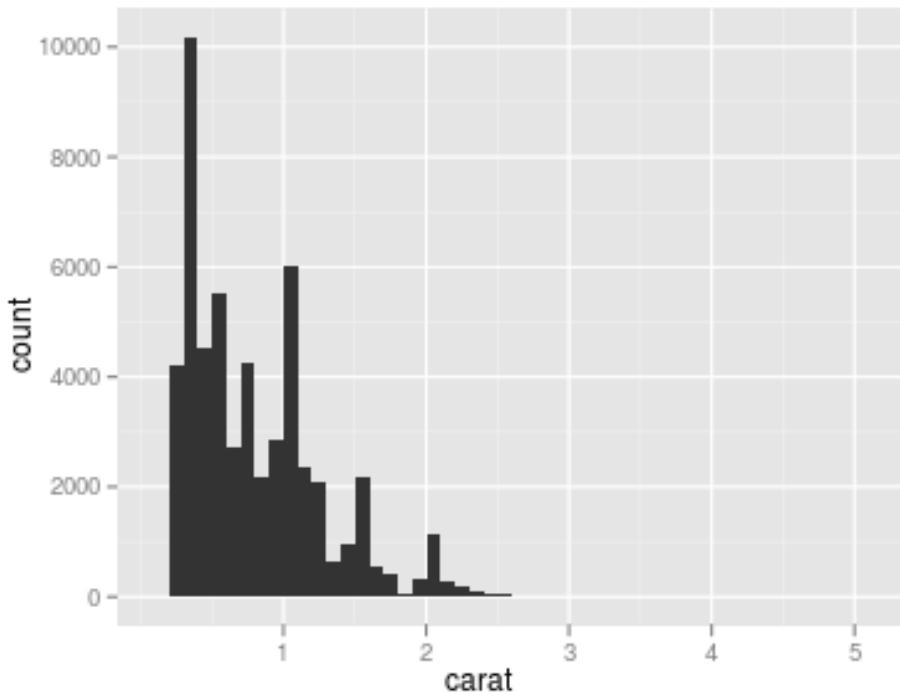
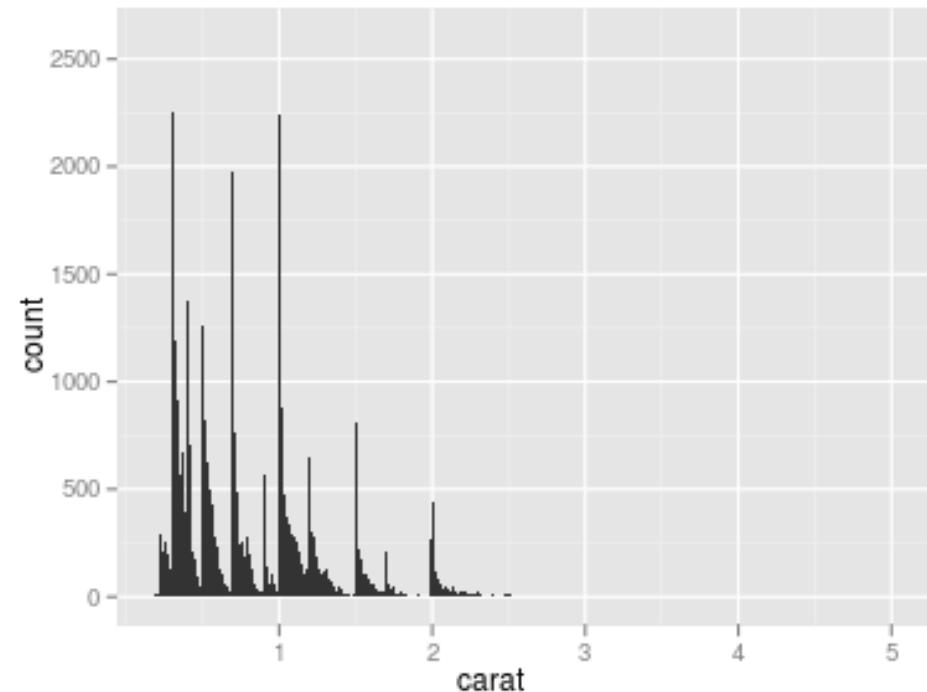


Diagram techniques

- Histogram
 - Binning: group values into equally spaced intervals (bins)
 - Bin width affects representation



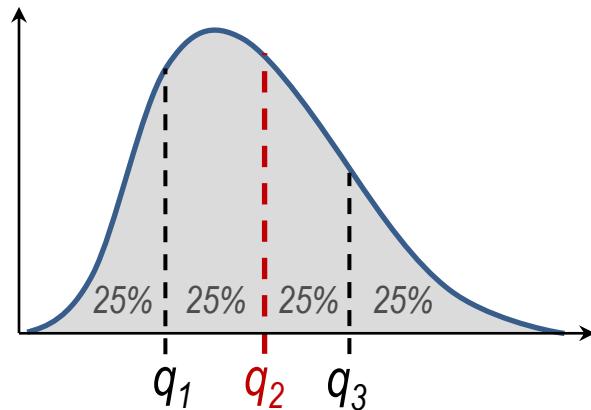
bin width = 0.1



bin width = 0.01

Diagram techniques

- Box plot variations
 - Shows summary statistics of a distribution (1 variable)

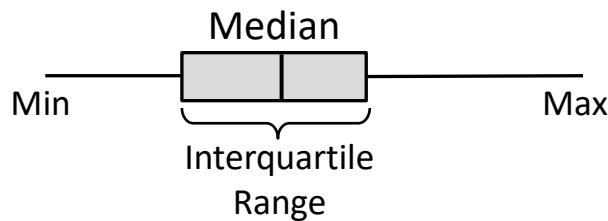


Probability density function (PDF)

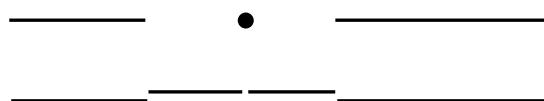
q_1 ... lower quartile

q_2 ... median

q_3 ... upper quartile



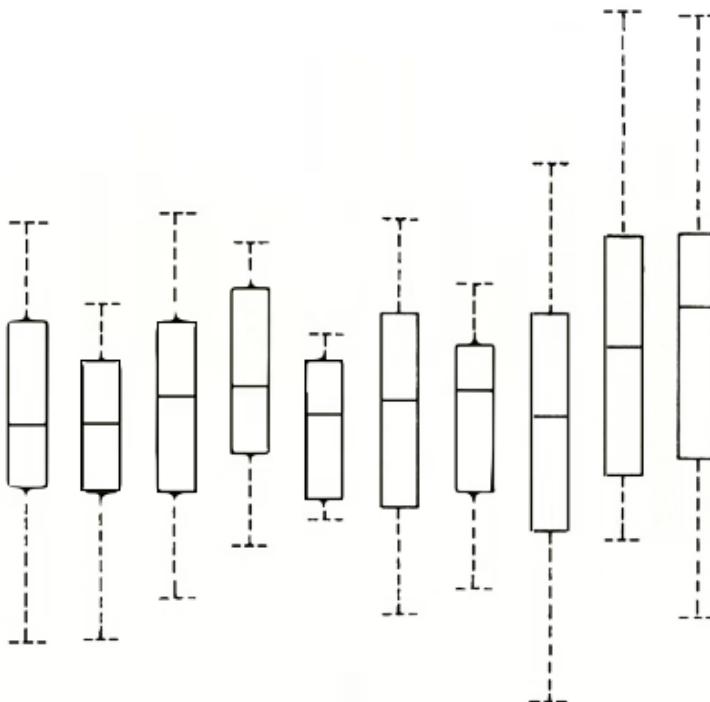
Tukey's box plot



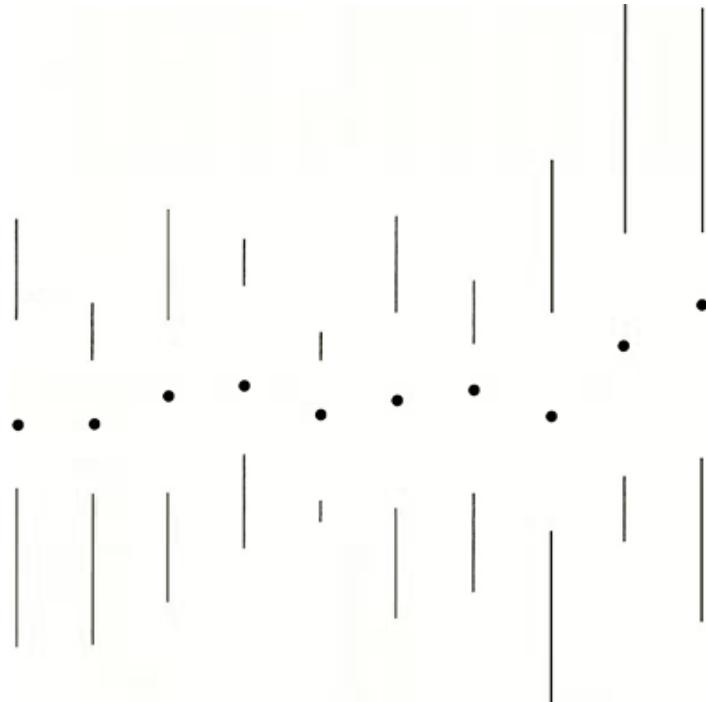
Tufte's quartile plot variations

Diagram techniques

- Box plot variations



Tukey's box plot



Tufte's quartile plot

Diagram techniques

- Scatterplots
 - Show correlations between 2 dependent variables
 - Typically quantitative (measurable) data attrib.
 - Find trends, outliers, distributions, correlations, clusters, ...

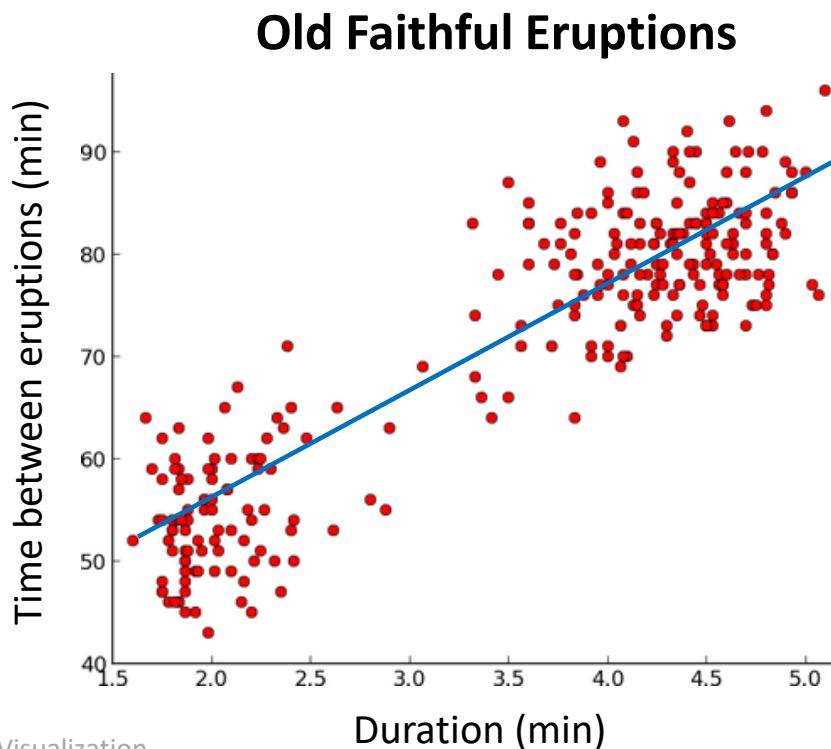


Diagram techniques

- Scatterplot variations
 - Encode additional attributes by size, color, shape, ...

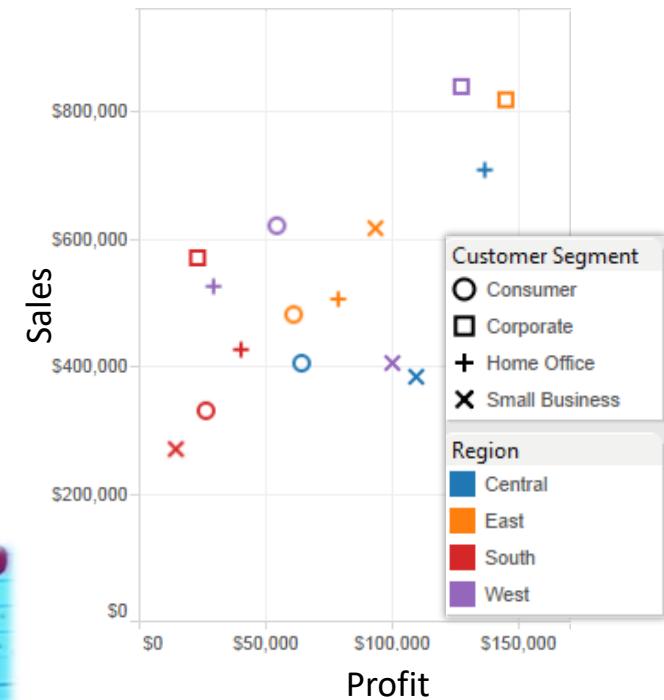
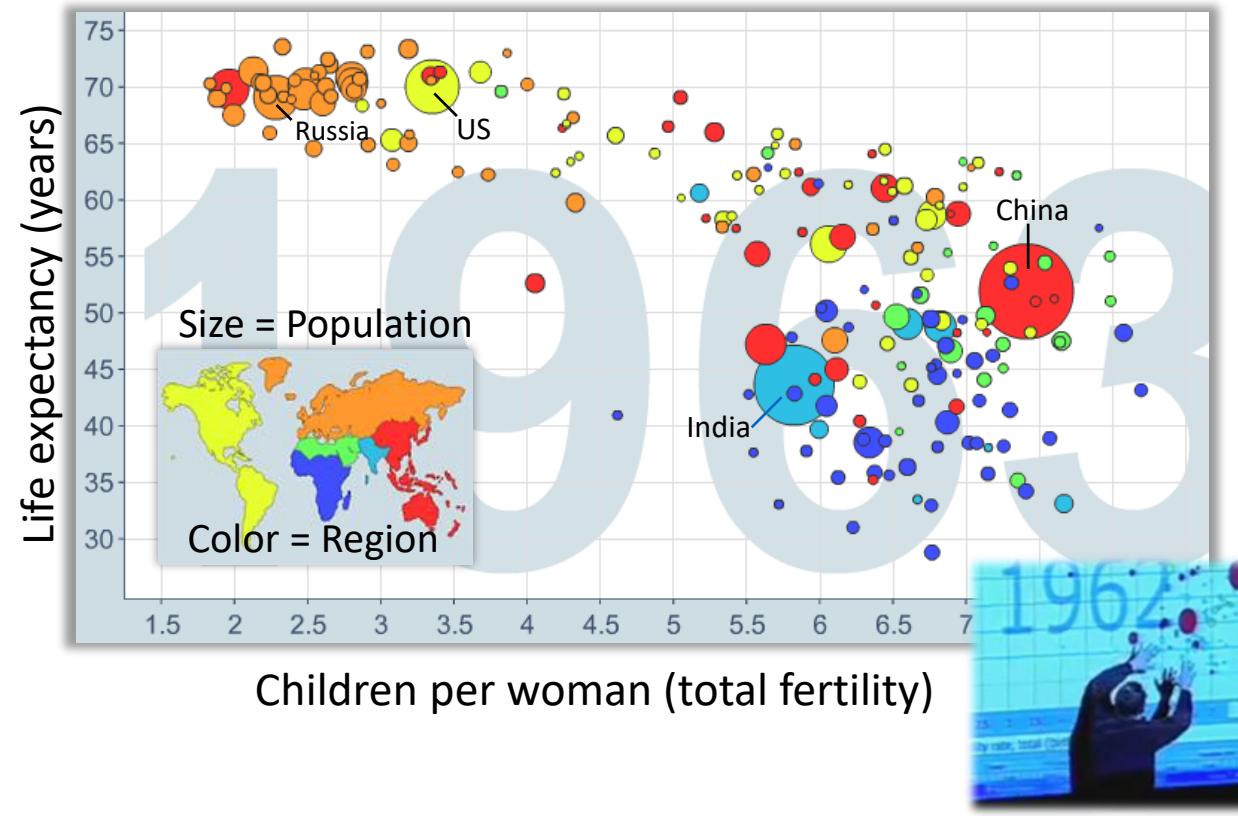


Diagram techniques

- Scatterplot matrix
 - Show (all possible) combinations of attributes in a scatterplot matrix
 - Each row/column is one attribute
 - Overview of correlation and patterns between data attributes

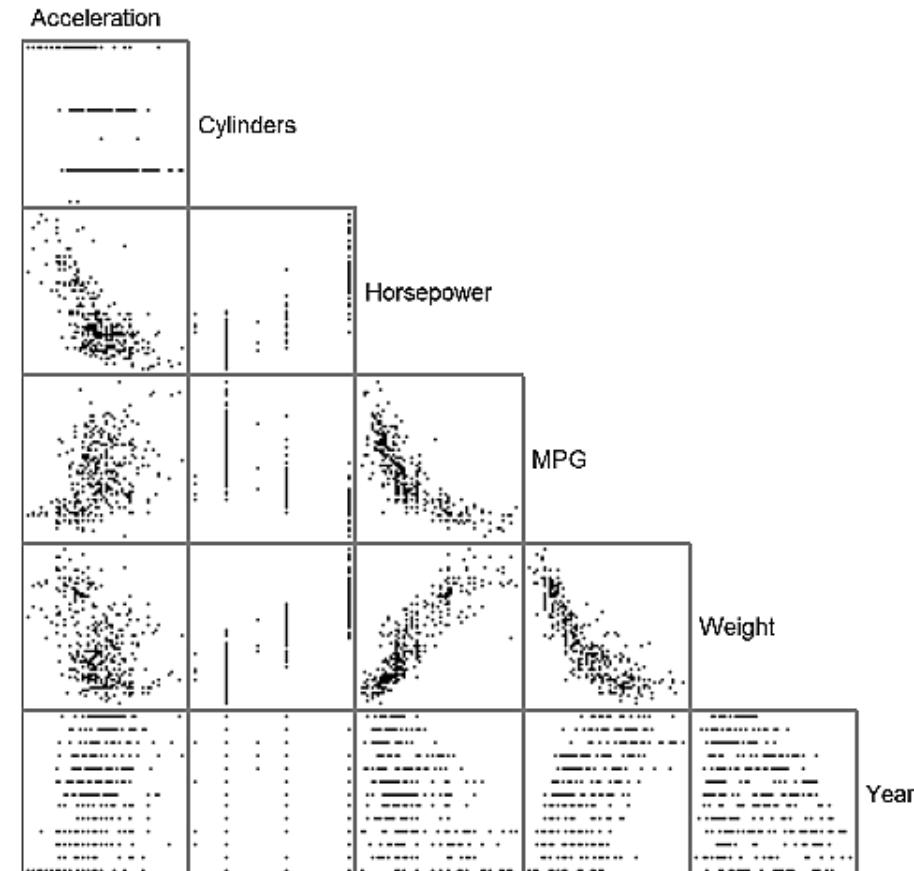
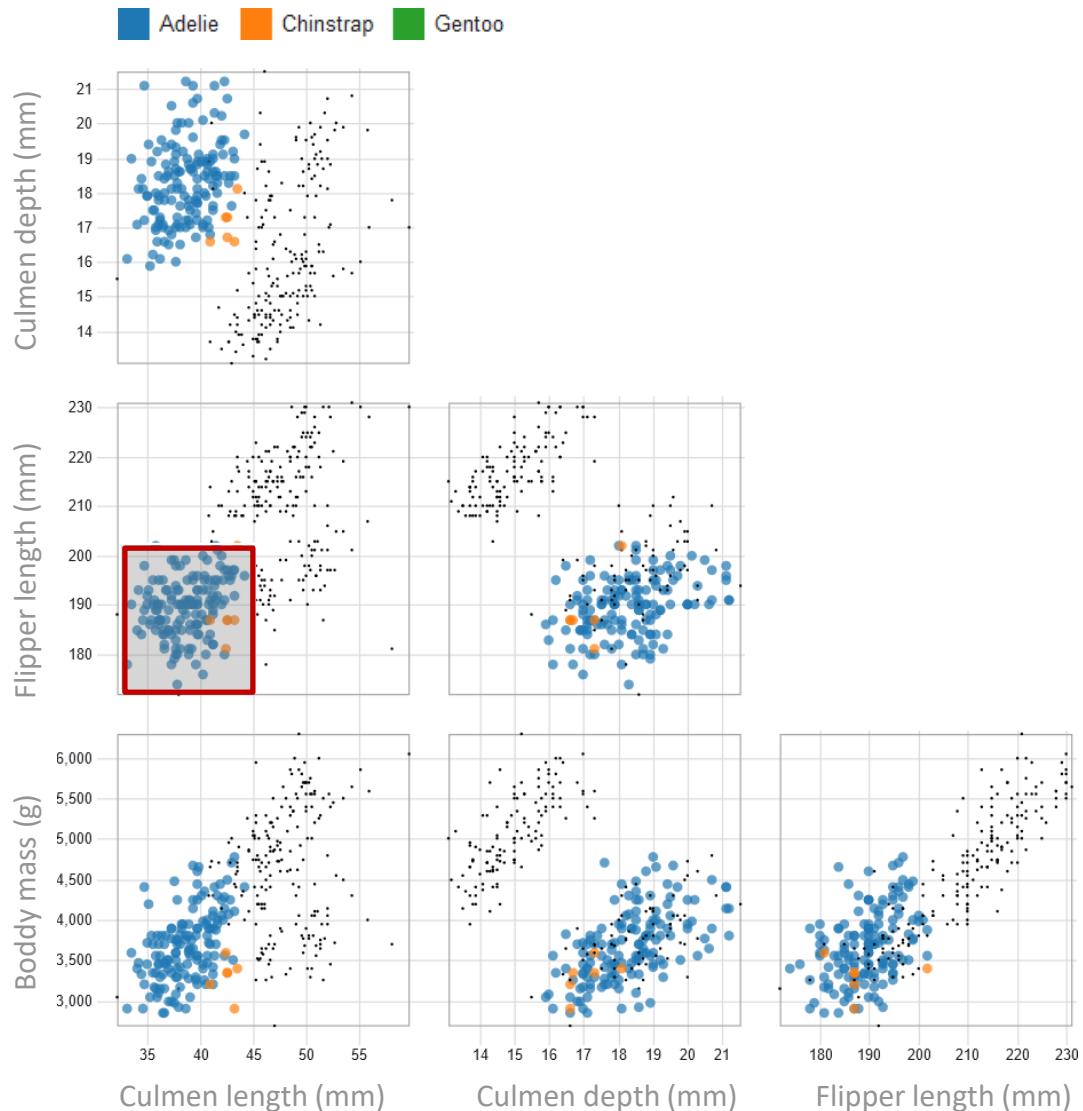


Diagram techniques

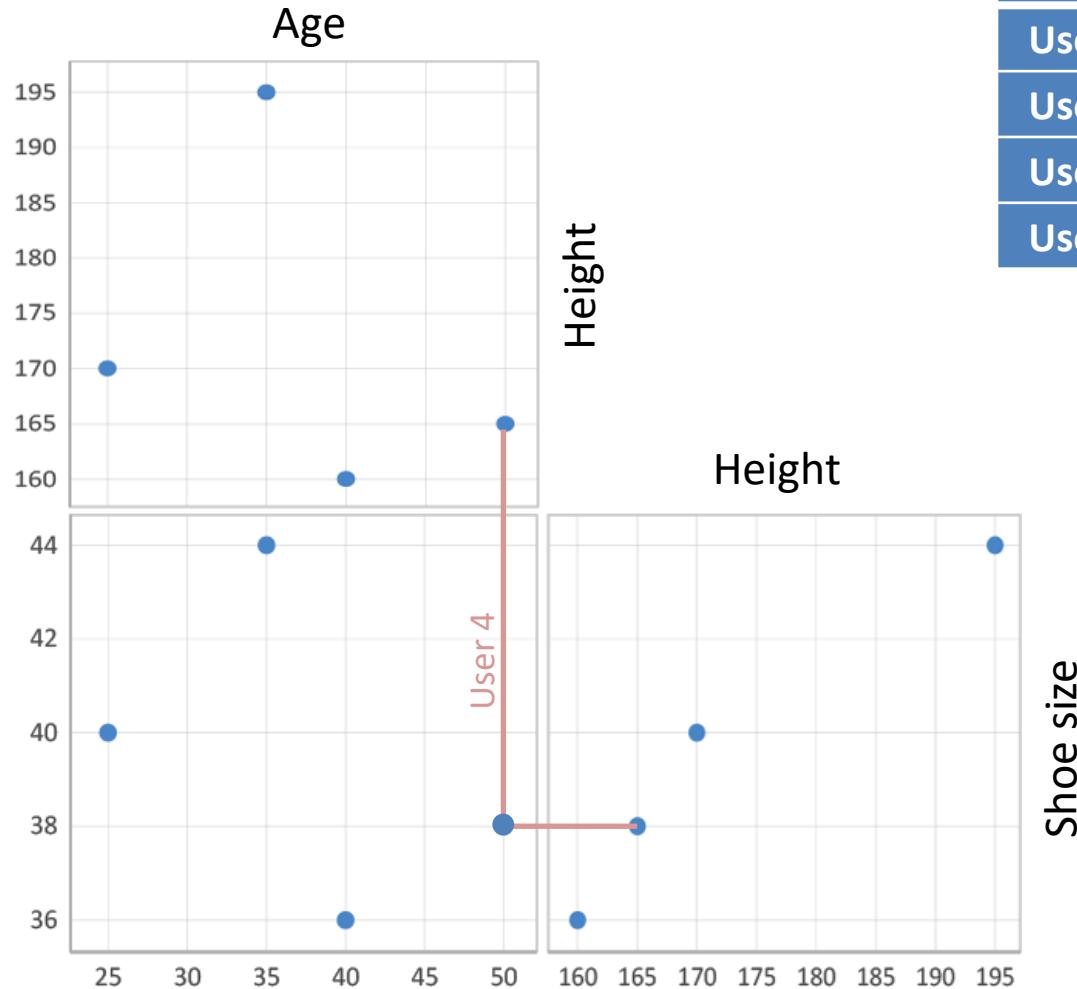
- Scatterplot matrix
 - **Brushing:** mark data subset
 - **Linking:** highlight brushed data in linked views
 - Move/alter/extend brush



<https://observablehq.com/@d3/brushable-scatterplot-matrix>

Diagram techniques

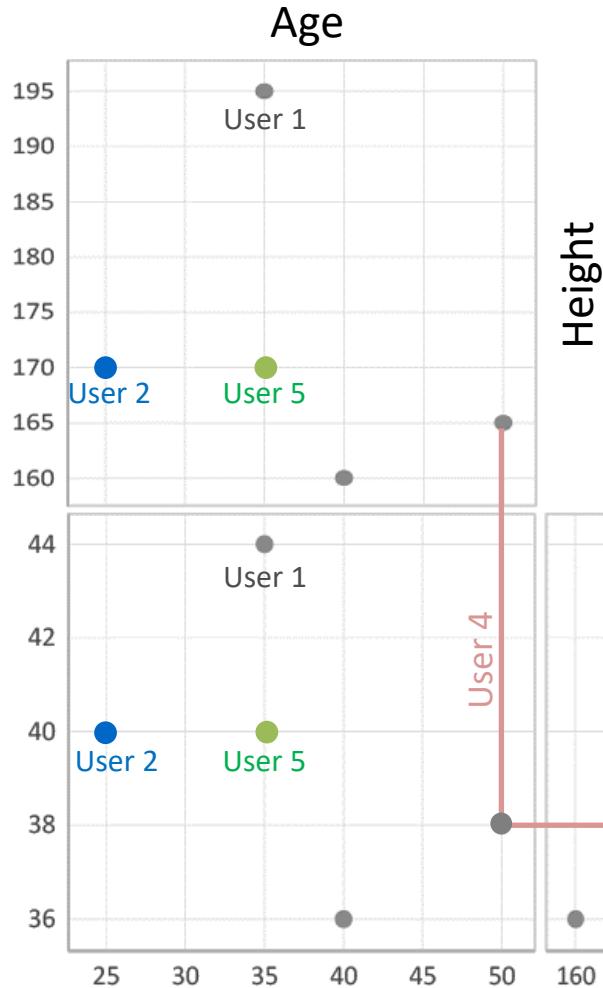
- Scatterplot matrix



Normalize to min/max

Diagram techniques

- Scatterplot matrix

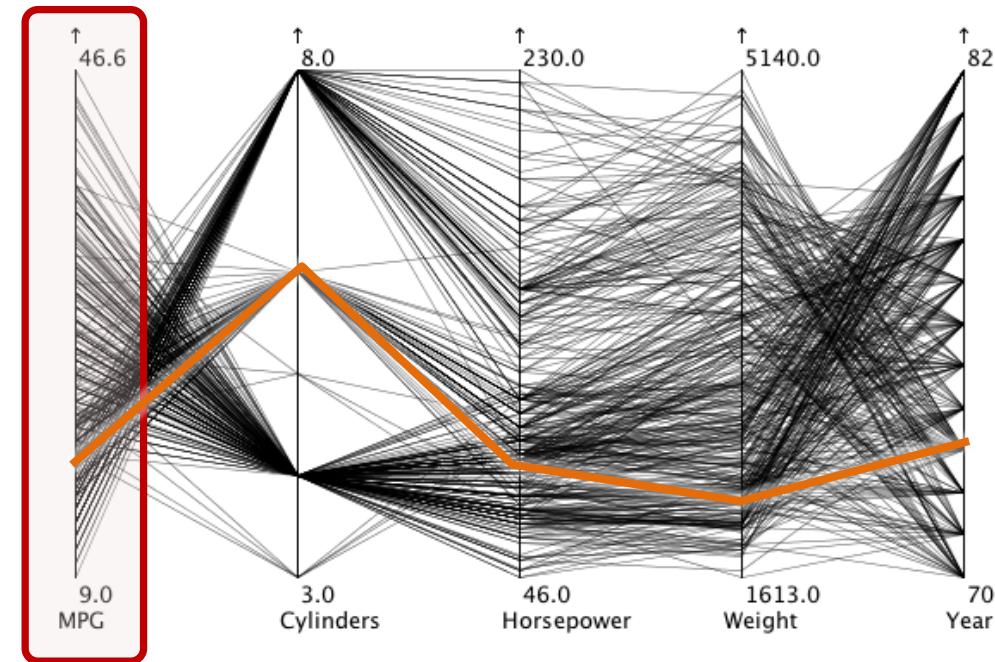


	Age	Height	Shoe size
User 1	35	195	44
User 2	25	170	40
User 3	40	160	36
User 4	50	165	38
User 5	35	170	40

Normalize to min/max

Diagram techniques

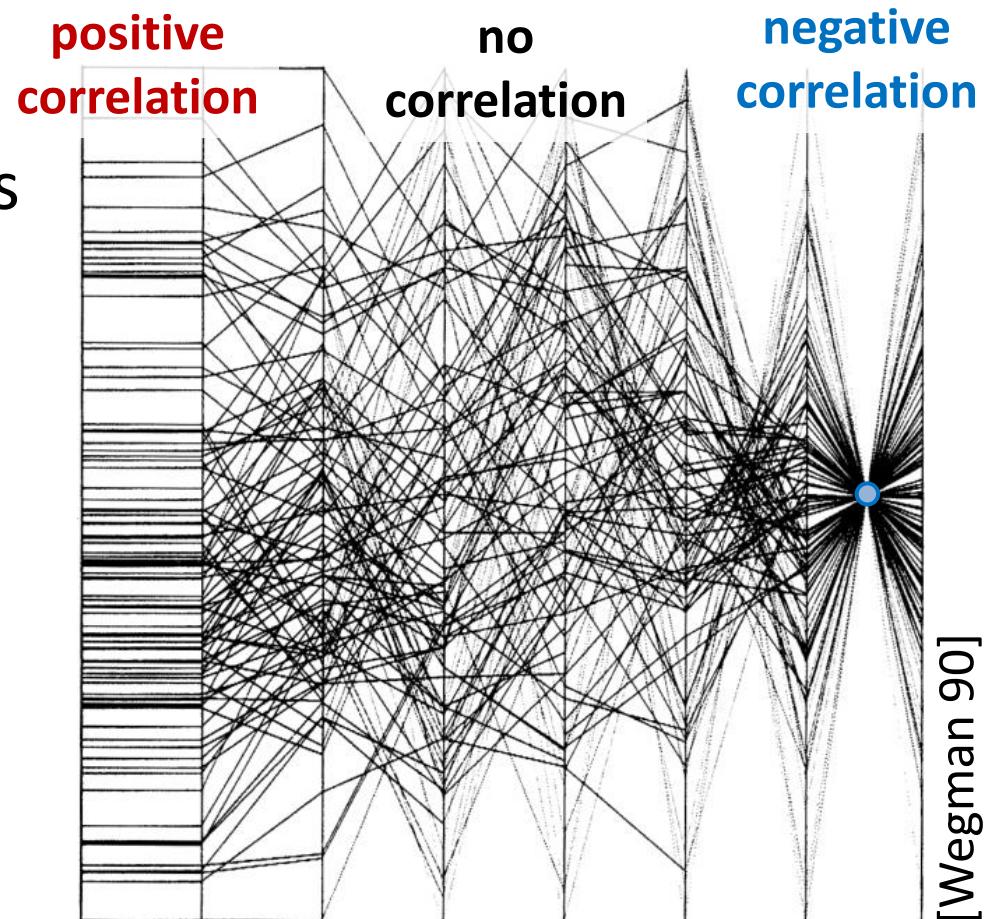
- Parallel coordinates
 - Represent multiple data variables
 - Each variable is represented by a **vertical axis**, which are organized as evenly spaced parallel lines
 - Data on each axis is normalized to min/max
 - One data sample is represented by a **connected set of points**, one on each axis



Attribute /
Dimension

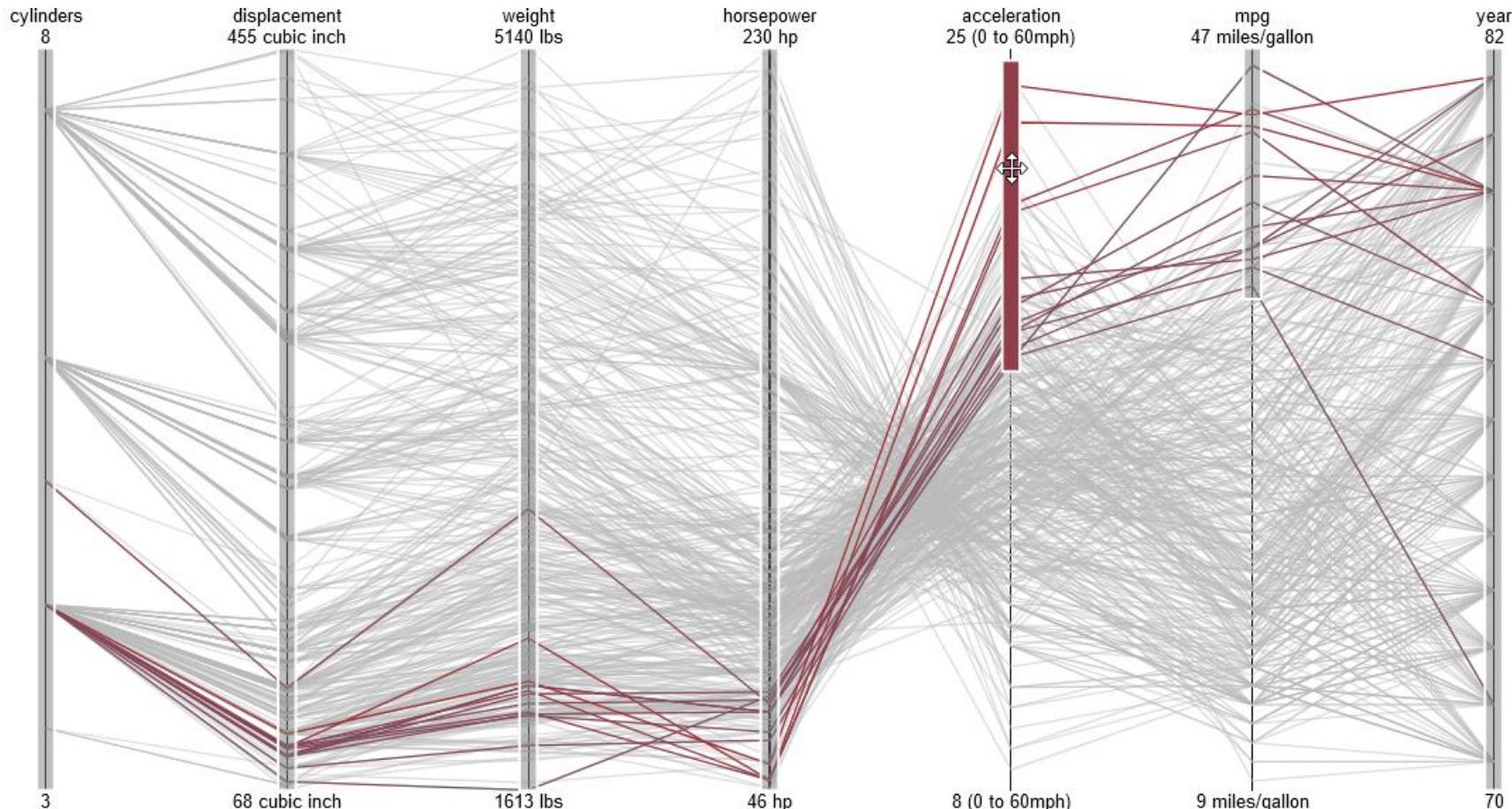
Diagram techniques

- Parallel coordinates
 - Recognize patterns between adjacent axes
 - Steep learning curve for novices
 - Brushing (mark interesting data subset)



Parallel coordinates illustrating correlation
of $\rho = 1, 0.8, 0.2, 0, -0.2, -0.8, -1$

Parallel Coordinates of Automobile Data



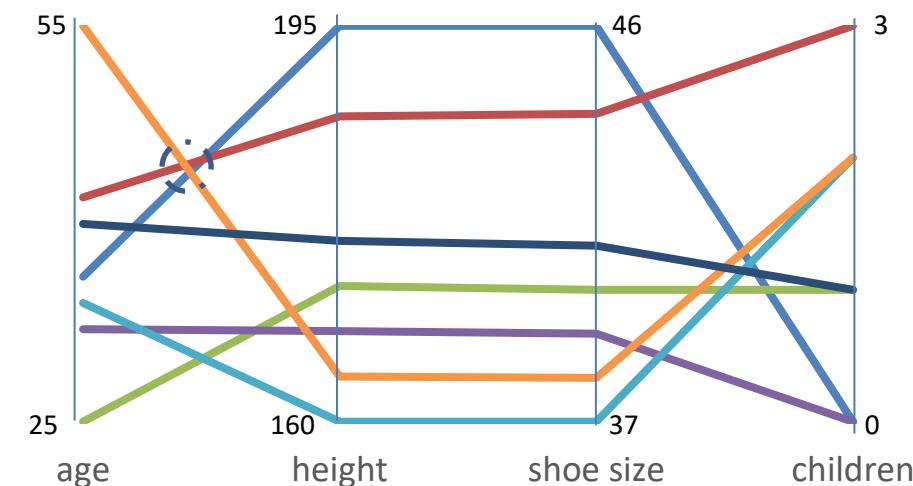
A database of cars is plotted in seven coordinate dimensions; each path represents one car.
Drag and resize the coordinate selection sliders to filter the cars in any dimension.

Source: [GGobi](#)

Diagram techniques

- Example: Parallel coordinates

	Age	Height	Shoe size	No. of children
User 1	36	195	46	0
User 2	42	187	44	3
User 3	25	172	40	1
User 4	32	168	39	0
User 5	34	160	37	2
User 6	55	164	38	2
User 7	40	176	41	1



Normalize each attribute to min/max

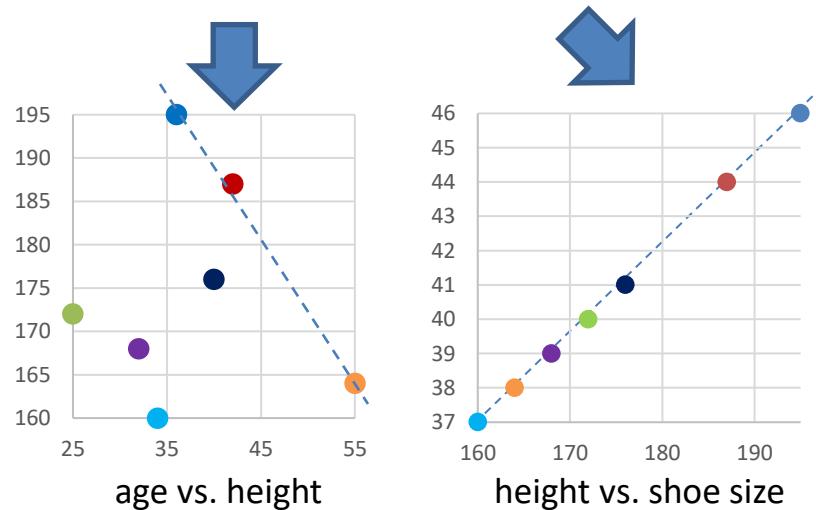


Diagram techniques

- Parallel coordinates
 - Line point duality
 - Points in scatterplot map to lines in parallel coordinates
 - Points in parallel coordinates map to lines in scatterplot

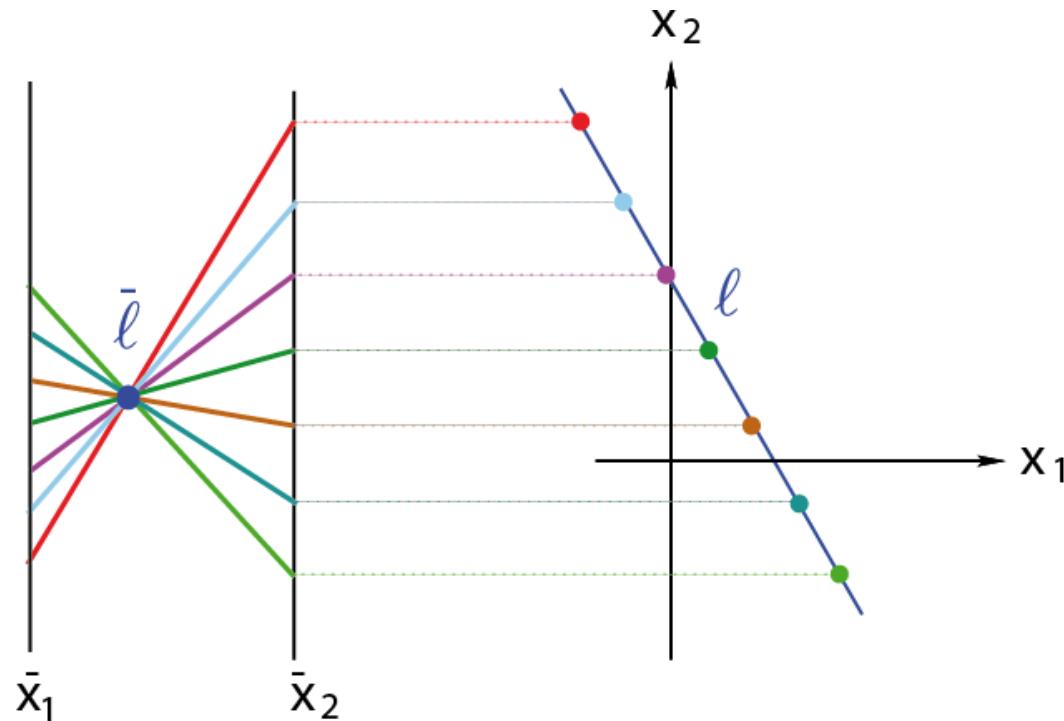


Diagram techniques

- Parallel coordinates
 - Axis ordering is a major challenge
 - Order by quality metrics

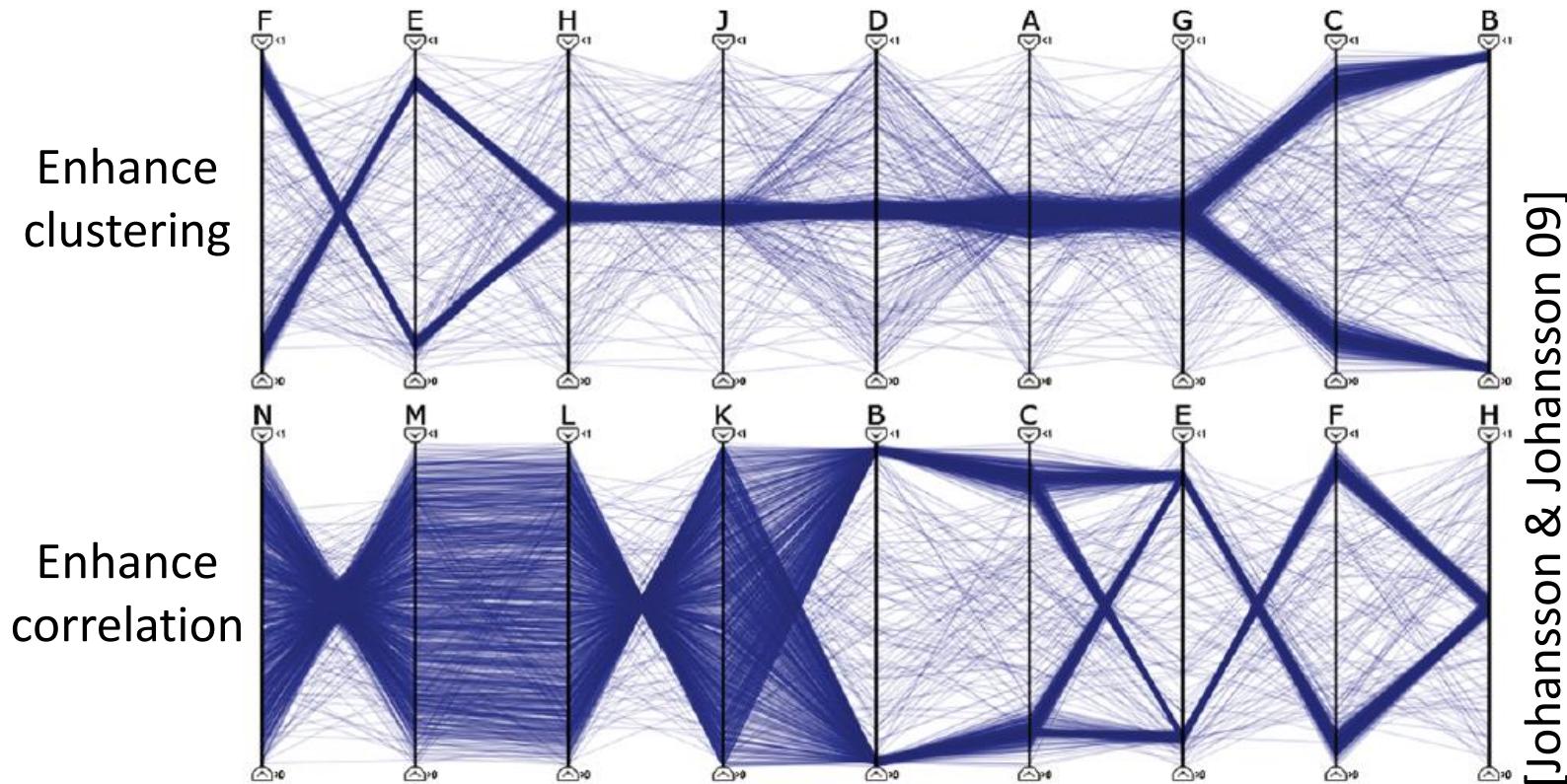


Diagram techniques

- Radar chart (star plot, spider chart)
 - Radial axes arrangement
 - Items are polylines

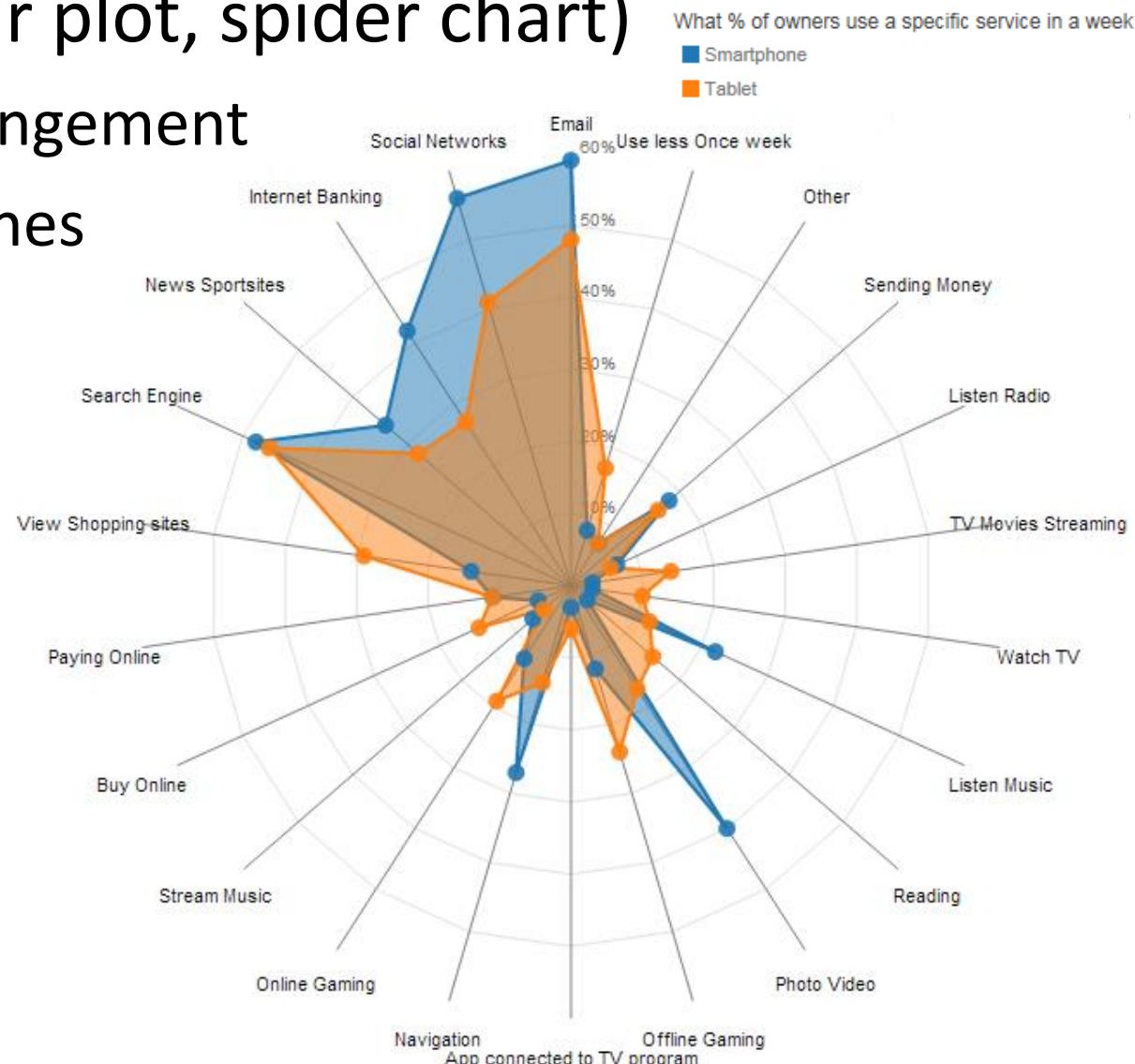


Diagram techniques

- Function plot for a 1D scalar field
 - Points $\{(x, f(x)) \mid x \in \mathbb{R}\}$
 - 1D curve
 - Mapping of a discrete set of points to a set of lines by connecting adjacent points

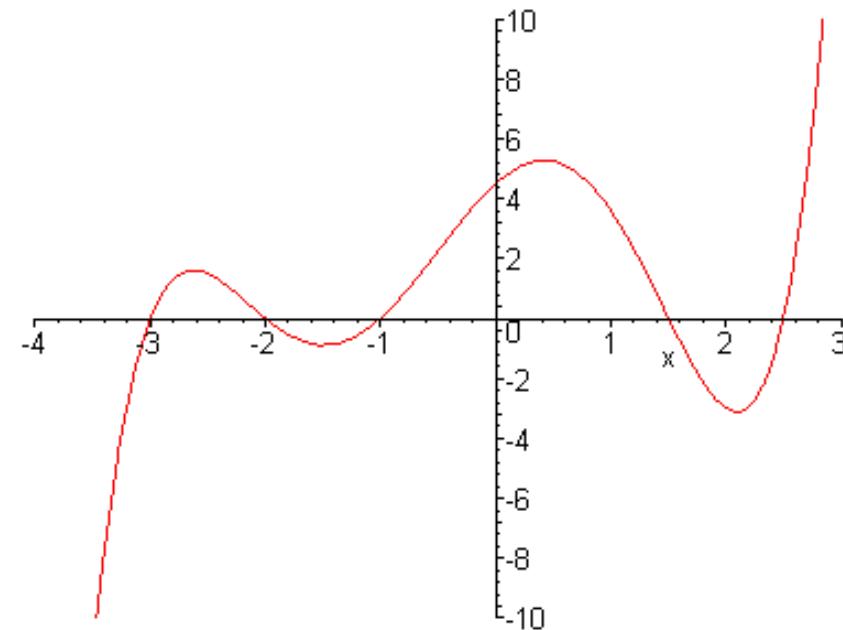


Diagram techniques

- Height field for a 2D scalar field
 - Points $\{(x, y, f(x, y)) \mid (x, y) \in \mathbb{R}^2\}$
 - 2D surface, $f(x, y)$ can be interpreted as height value at (x, y)
 - Mapping of a discrete set of points to a set of faces by connecting adjacent points

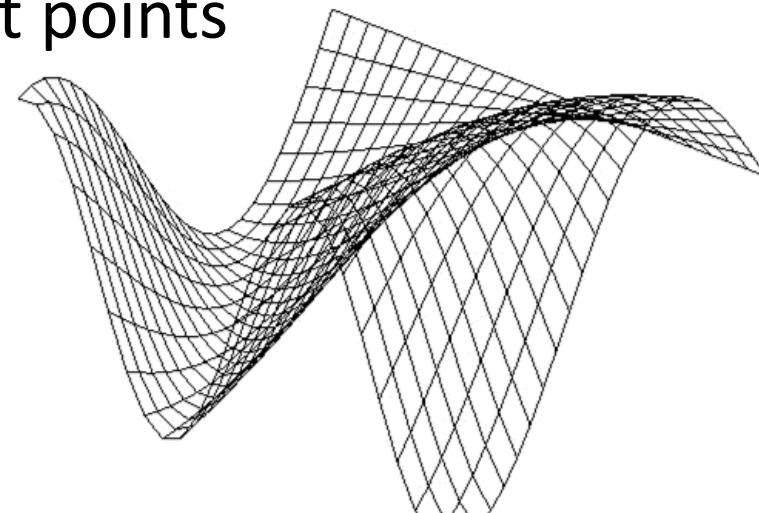
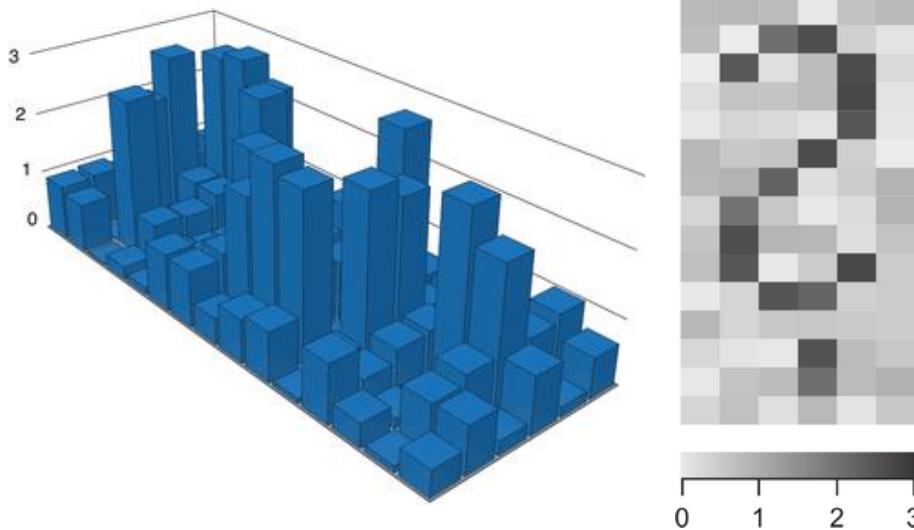


Diagram techniques

- 3D Pitfalls: Occlusion and Perspective



Which one is the tallest bar?
What is the pattern in the data?

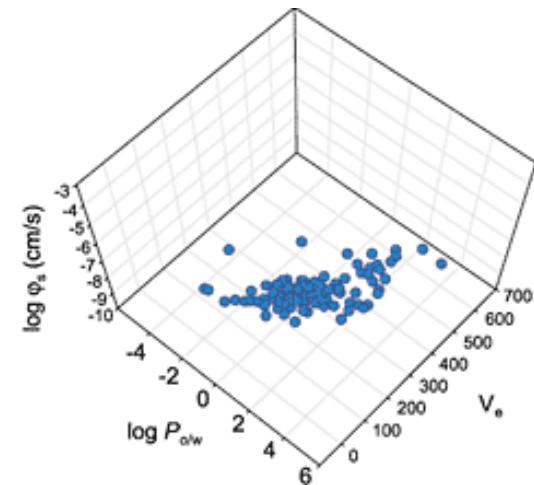
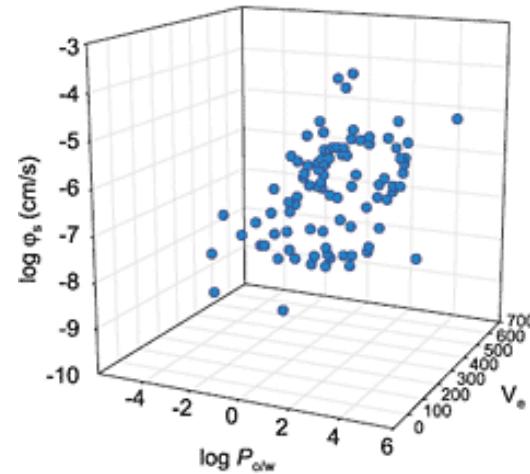
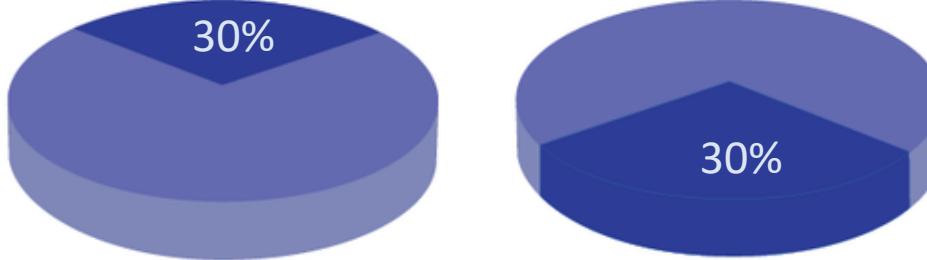
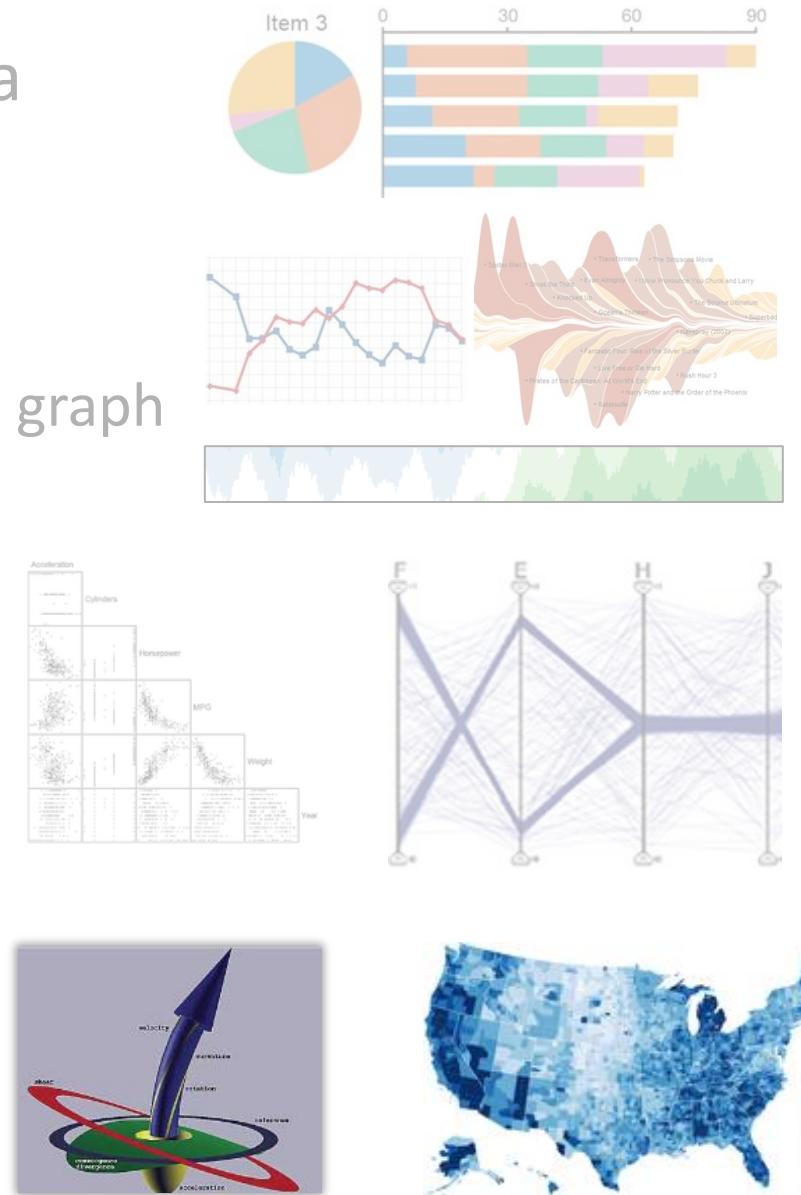


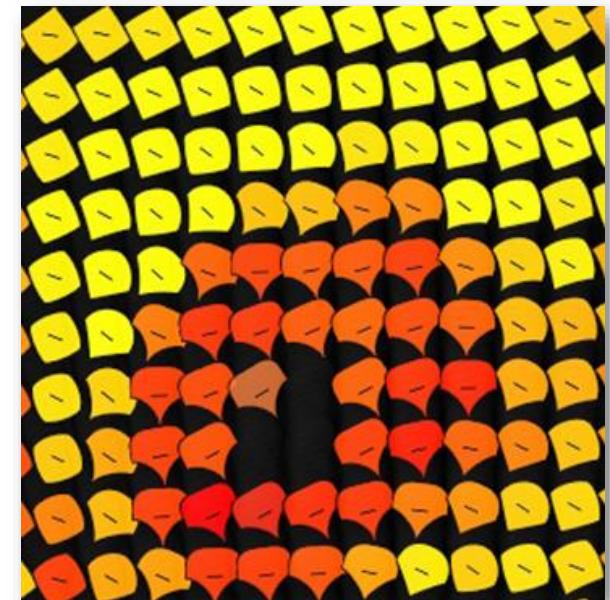
Diagram techniques

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 - Bar/pie chart, stacked bars
- Time-dependent data
 - Line graph, ThemeRiver, Horizon graph
- Single and multiple variables
 - Histogram, scatterplot, parallel coordinates
 - Glyphs, color mapping



Glyphs and icons

- **Glyphs:** Small independent visual objects that depict attributes of a data record
 - Discretely placed in a display space
 - Data attributes are represented by different **visual channels** (e.g., shape, color, size, orientation)
 - Visual channels should be easy to distinguish and combine
 - Mainly used for multivariate data



Glyphs and icons

2D glyphs



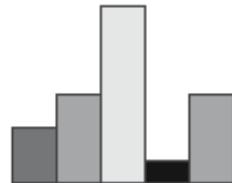
Star glyphs



Stick figures

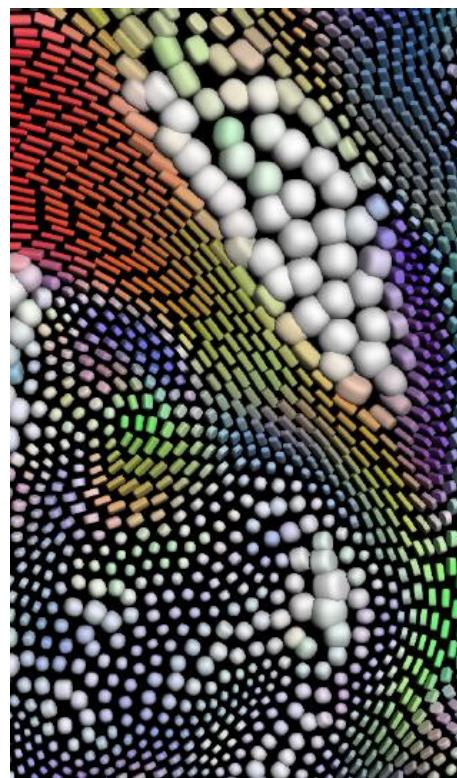


Chernoff
faces



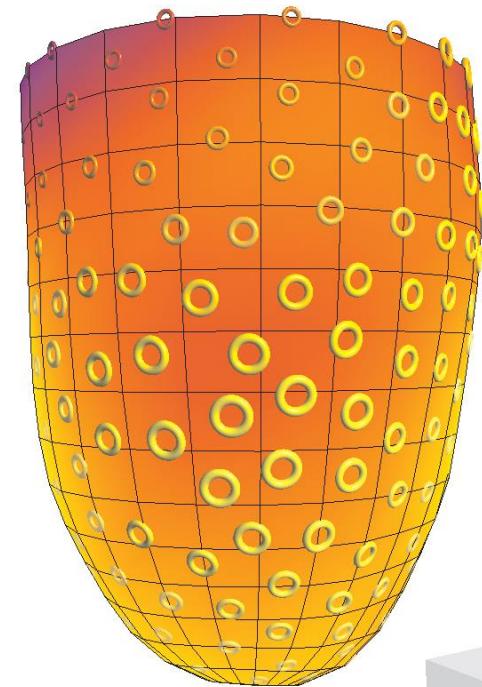
Profile glyphs

3D glyphs



[Kindlmann&Westin 06]

Surface glyphs



[Meyer-Spradow et al. 08]

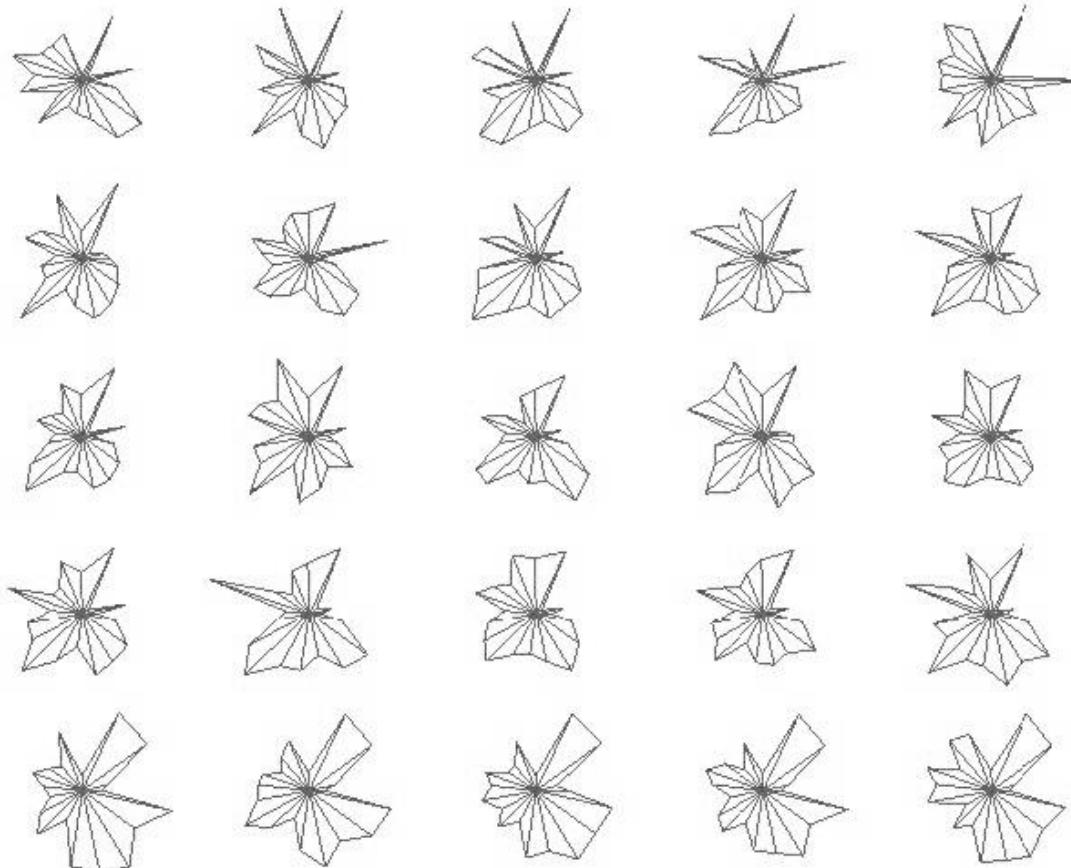


[Borgo et al. 13]

Glyphs and icons

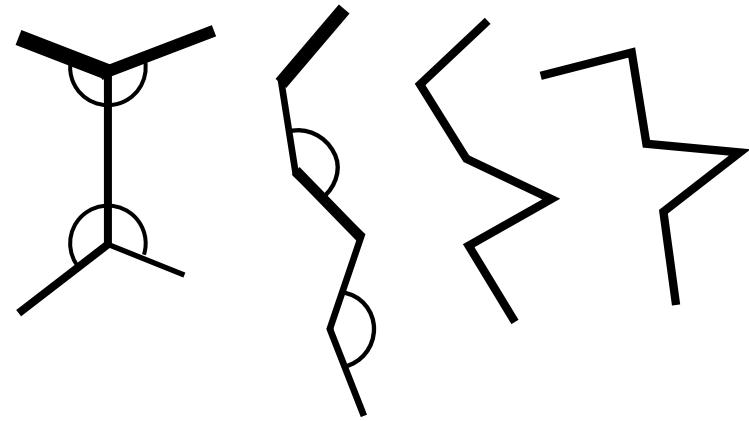
- Star glyphs

- A star is composed of equally spaced spikes, originating from center
- Length of the spikes represents value of respective attribute
- End of rays connected by line



Glyphs and icons

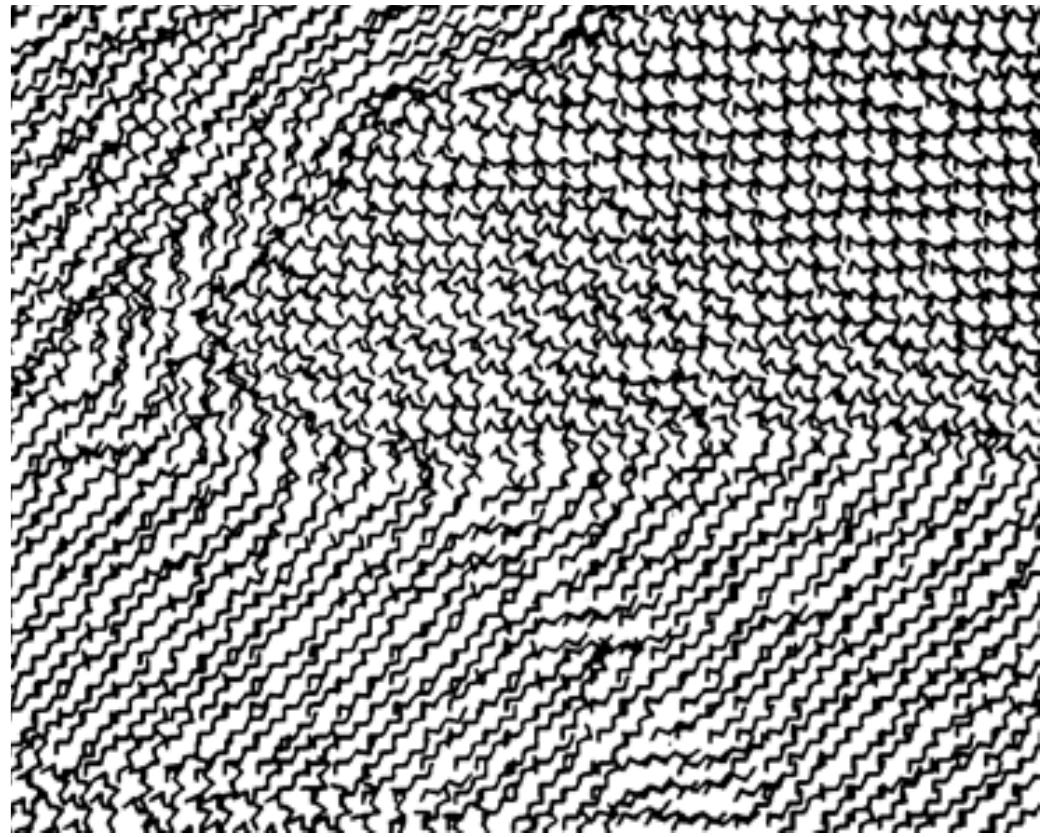
- Stick figures
 - 2D figure with limbs
 - Data encoded by
 - length
 - line thickness
 - angle between lines



[Pickett&Grinstein 88]

Glyphs and icons

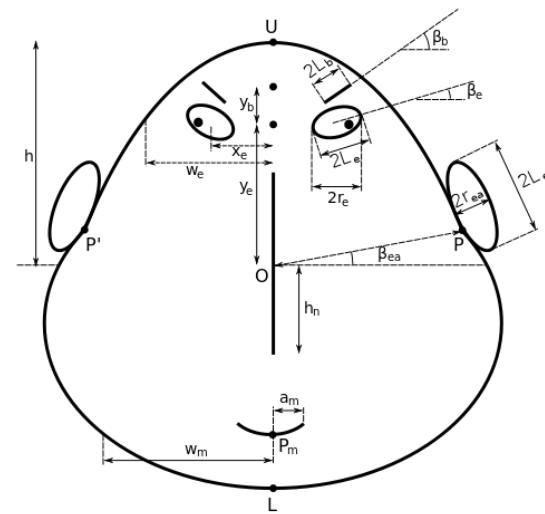
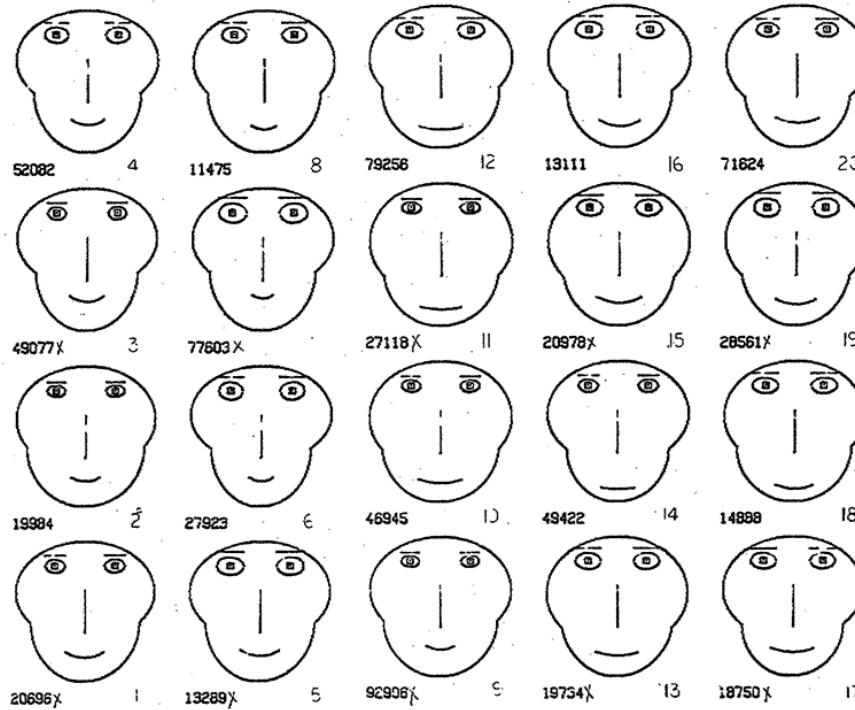
- Stick figures
 - 2D figure with limbs
 - Data encoded by
 - length
 - line thickness
 - angle between lines
 - Recognize texture patterns



[Pickett&Grinstein 88]

Glyphs and icons

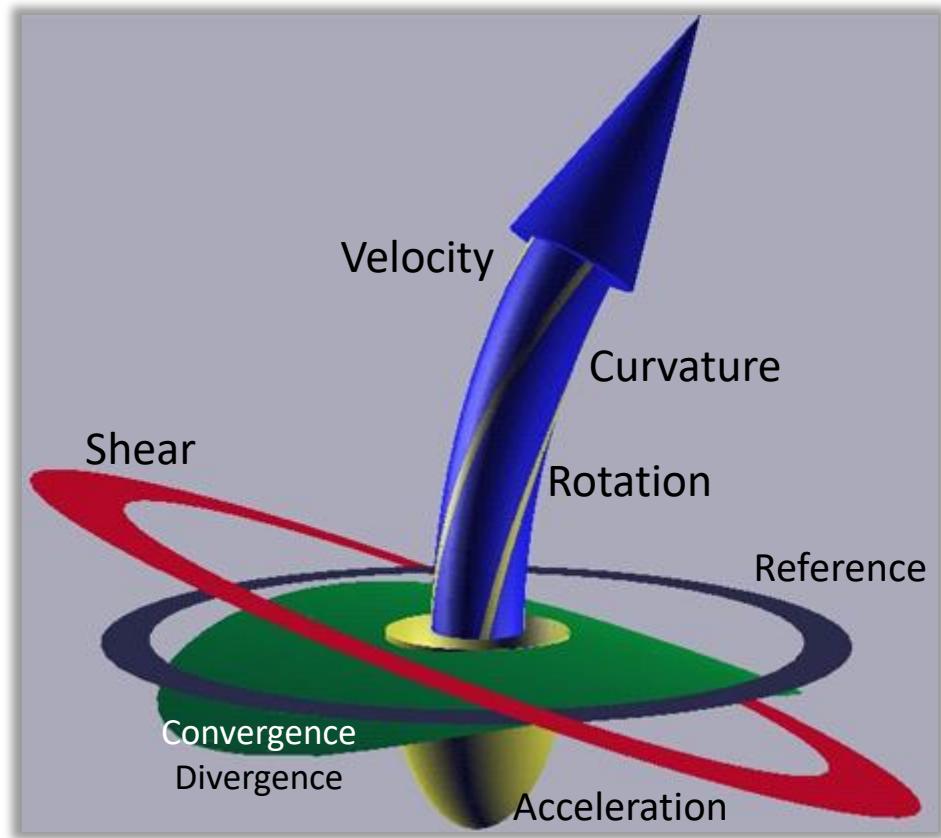
- Chernoff faces
 - Data attributes represented by features of a face
(eye position, nose length, mouth form, etc.)



- Faces are perceived holistically
- Efficiency?

Glyphs and icons

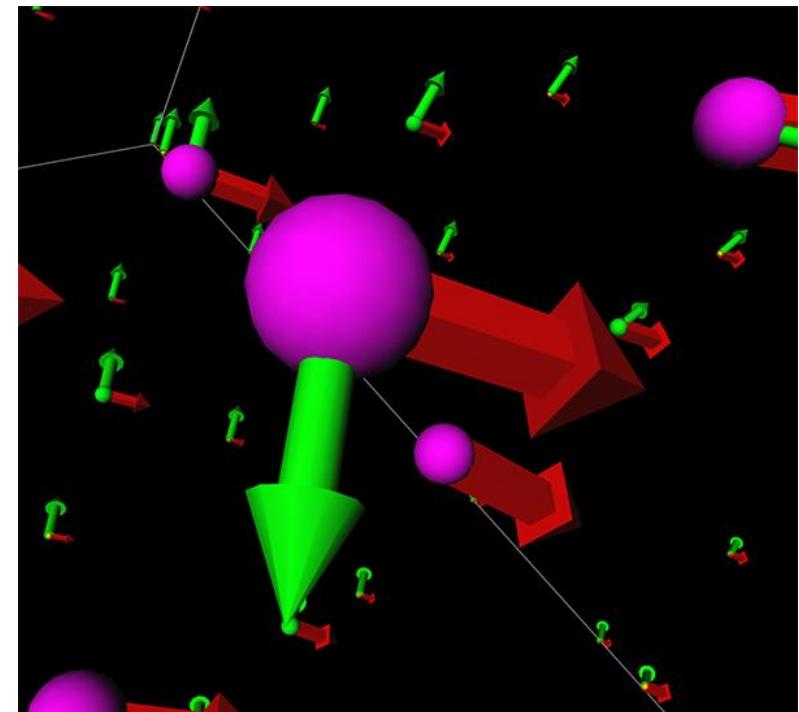
- Local flow probe
 - Depicts multiple flow characteristics
 - Large & complex glyphs need to be sparsely placed to avoid occlusion



[de Leeuw and van Wijk 93]

Glyphs and icons

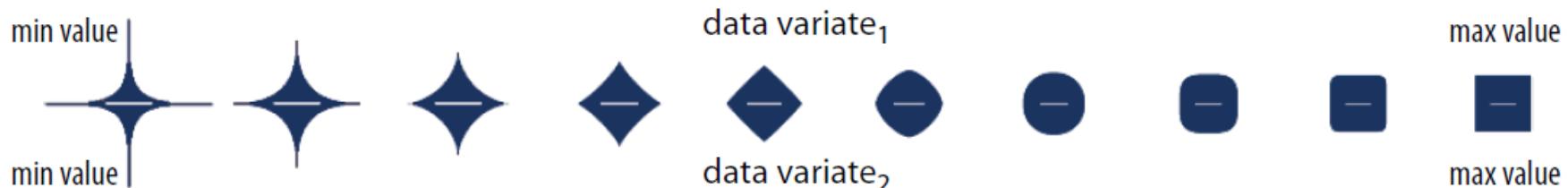
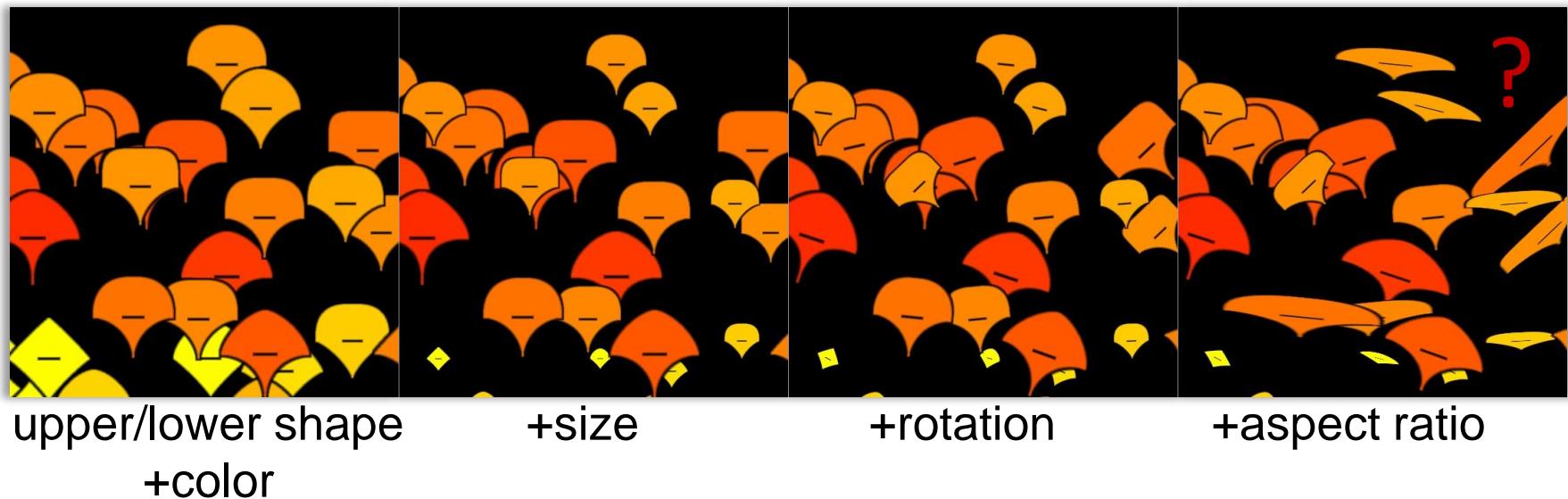
- Glyph shapes
 - Complex combinations of basic primitives (e.g., box, sphere, torus, ellipsoid)



Customized glyphs [Kraus&Ertl 01]

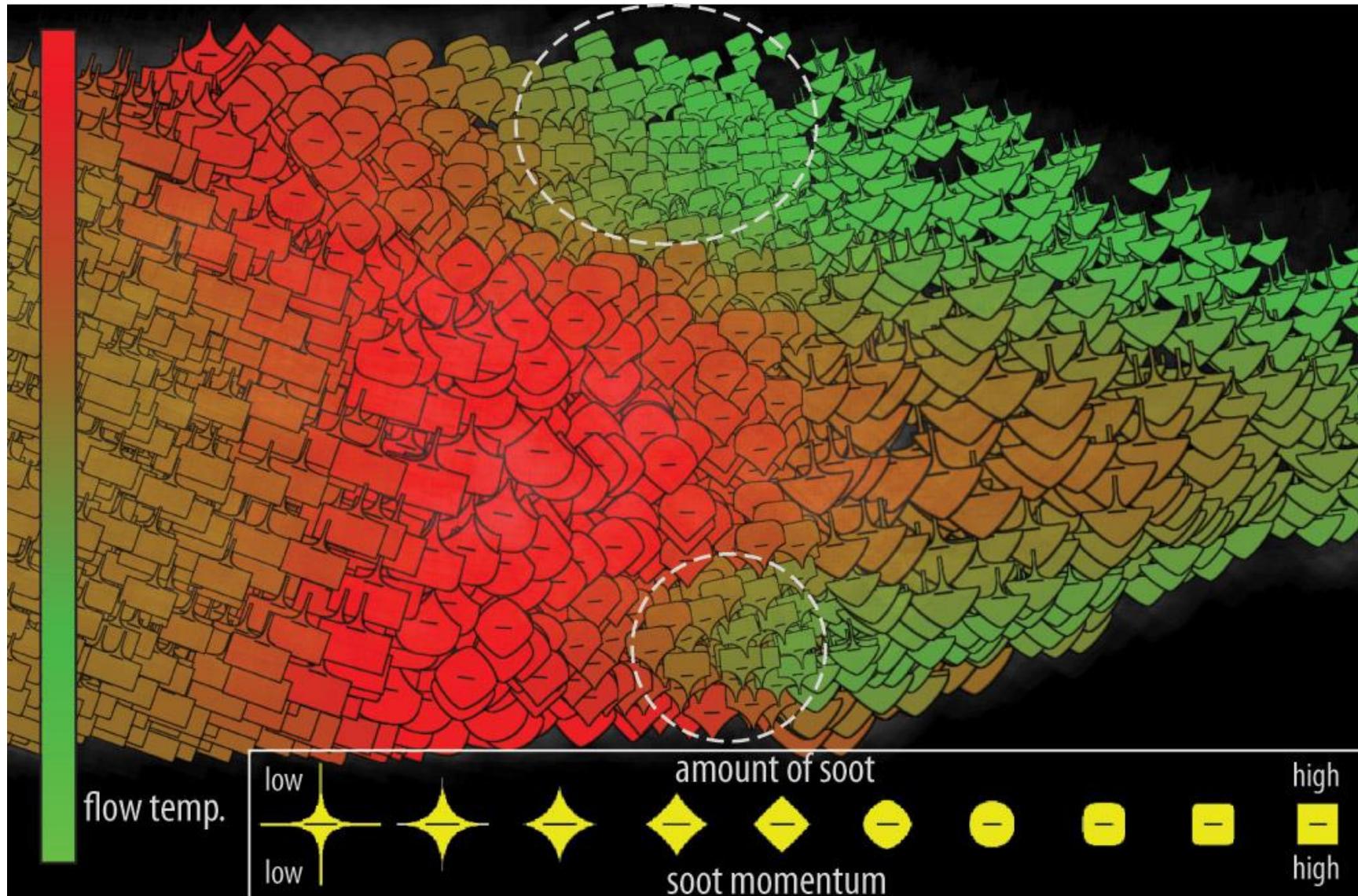
Glyphs and icons

- Separable vs. integral visual channels
 - Perceive each channel independently



Diesel Particulate Filter

SIEMENS
Ingenuity for life

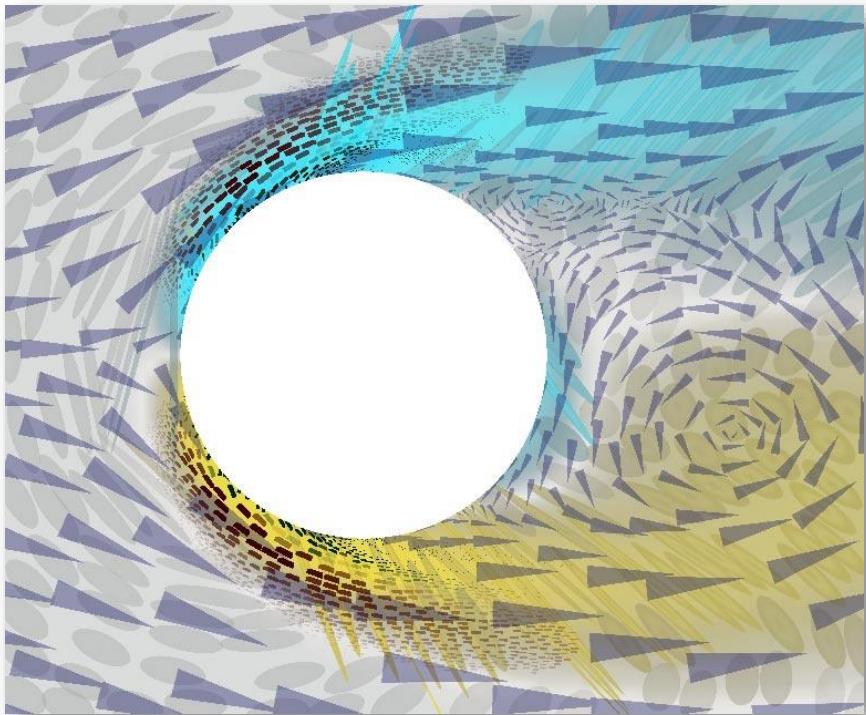


Size & color: flow temp.

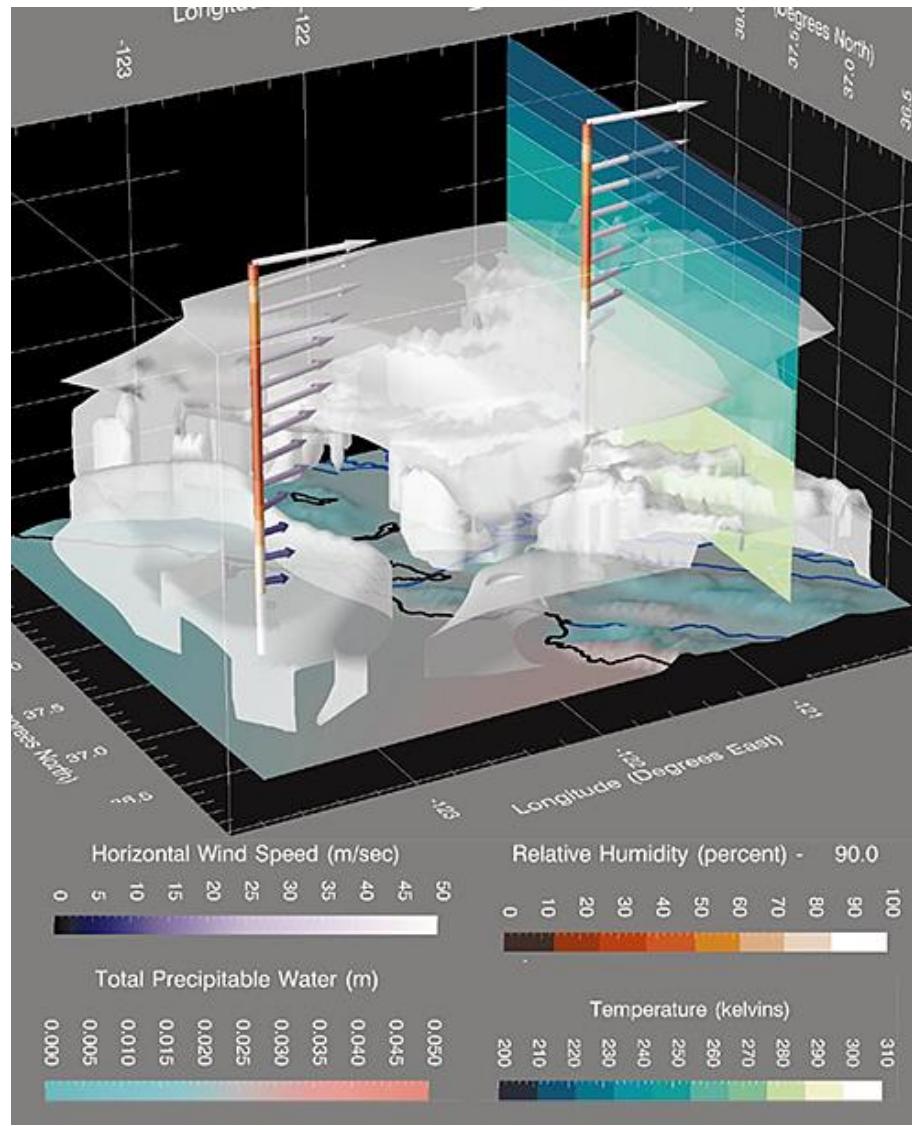
Glyph rotation (-45°, 45°): O₂ fraction

Glyphs and icons

- Hybrid Visualizations
 - Combine glyphs with other visualization techniques



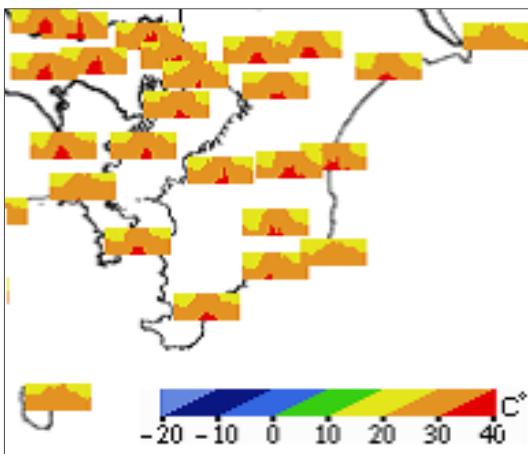
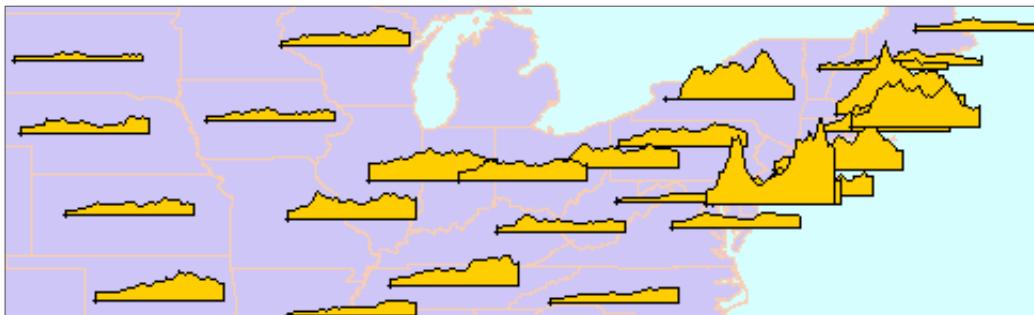
Layering [Kirby et al. 99]



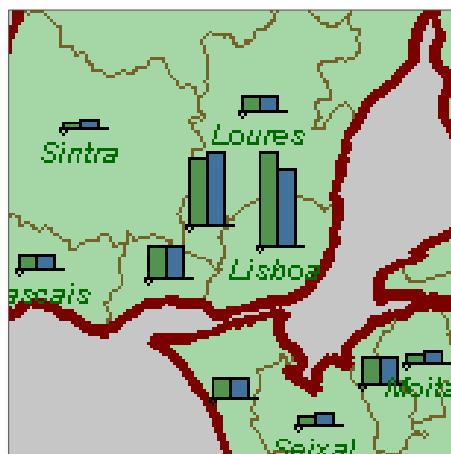
Arrow glyphs, ISO-surfaces [Treinish 99]

Glyphs and icons

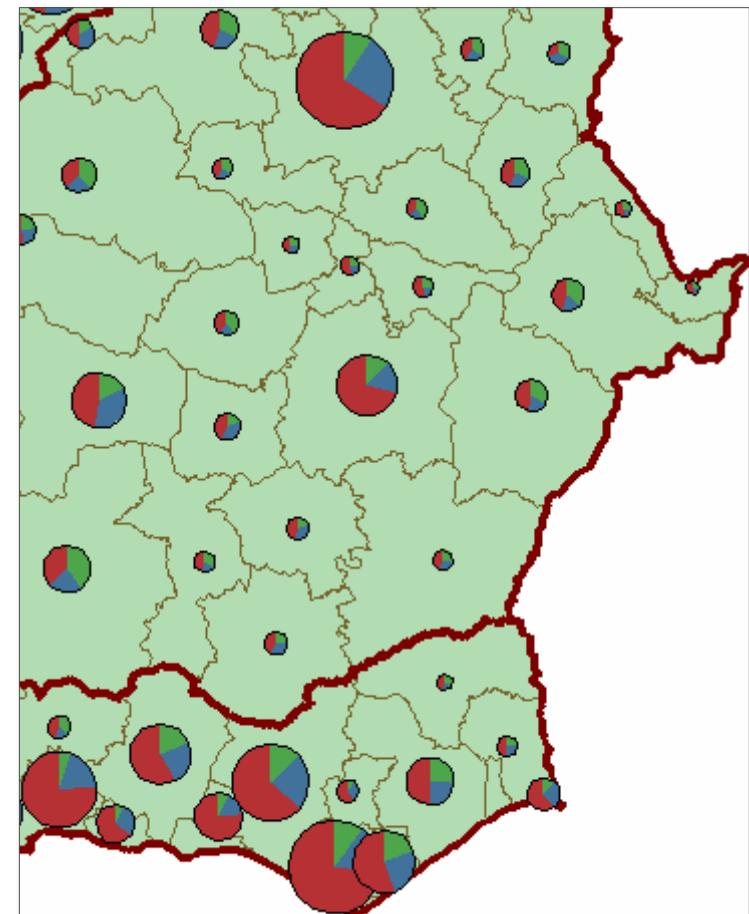
- Glyphs on maps



Two-tone colormap
[Saito et al. 05]



Pop. density 1981
Pop. density 1991



◆ Total employment in agriculture
◆ Total employment in industry
◆ Total employment in services
Glyph size = sum of attribute values

Glyphs and icons

- Summary
 - Local & compact representation of many data attributes
 - Just combining visual channels is not enough
 - Glyph design restricted by perceptual limits
 - Design considerations (e.g., separability, perceptually uniform channels, semantics, density vs. complexity, view-point independence)

EUROGRAPHICS 2013 / M. Shert, L. Soimay-Kahn

STAR – State of The Art Report

Glyph-based Visualization: Foundations, Design Guidelines, Techniques and Applications

R. Borgo¹, J. Kehrer², D. H. S. Chung¹, E. Maguire³, R. S. Laramee¹, H. Haaser⁴, M. Ward⁵ and M. Chen³

¹ Swinburne University, UK; ² University of Bergen and Vienna University of Technology, Austria; ³ University of Oxford, UK;
⁴ University of Bergen, Norway; ⁵ Worcester Polytechnic Institute, USA

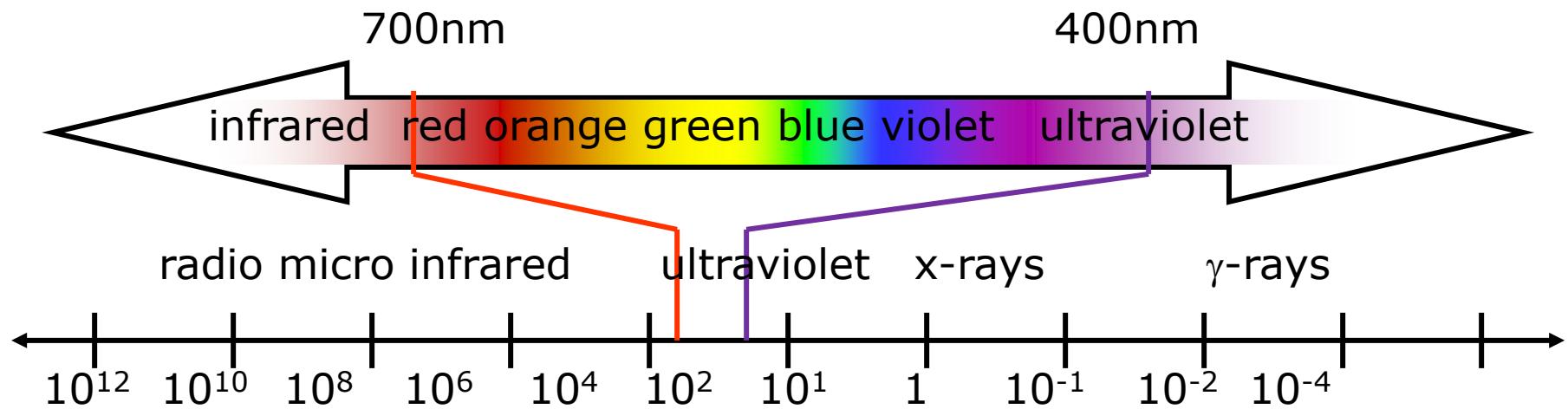
Abstract

This state of the art report focuses on glyph-based visualization, a common form of visual design where a data set is depicted by a collection of visual objects referred to as glyphs. Its major strength is that patterns of multivariate data involving more than two attribute dimensions can often be more readily perceived in the context of a spatial relationship, whereas many techniques for spatial data such as direct volume rendering find difficult to depict with multivariate or multi-field data, and many techniques for non-spatial data such as parallel coordinates are less able to convey spatial relationships encoded in the data. This report fills several major gaps in the literature, drawing the link between the fundamental concepts in semiotics and the broad spectrum of glyph-based visualization, reviewing existing design guidelines and implementation techniques, and surveying the use of glyph-based visualization in many applications.

[Borgo et al. 13]

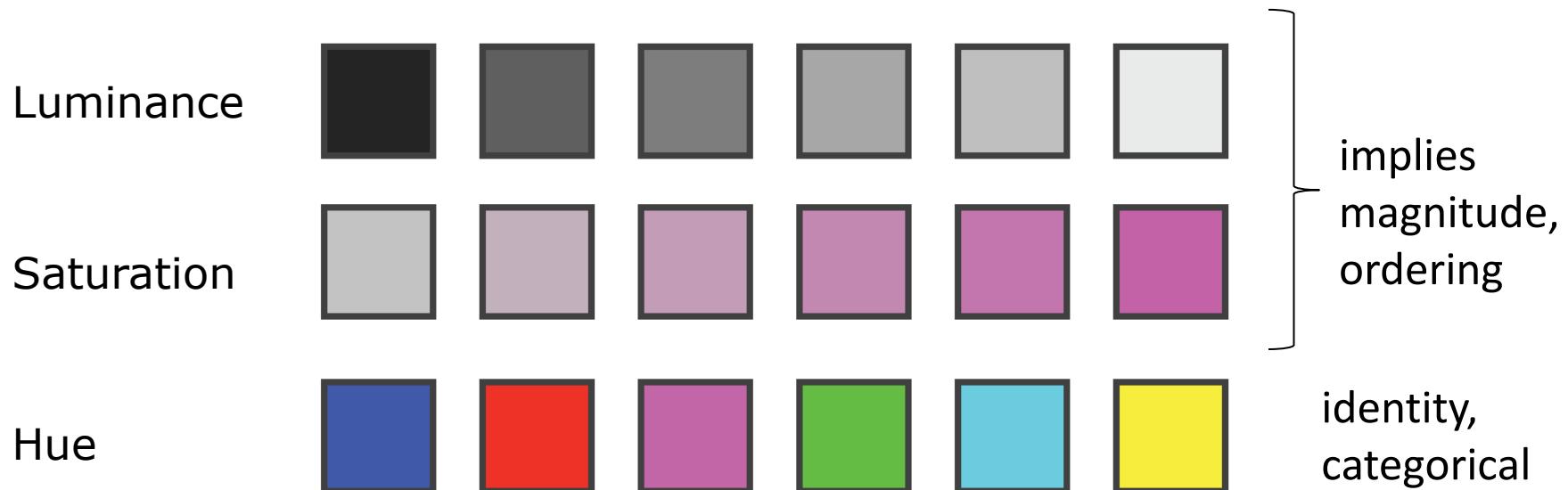
Color

- Light is electro-magnetic radiation
- Different wavelengths are perceived as different colors
 - Human eye can only see light between 380nm and 780nm (visible spectrum)



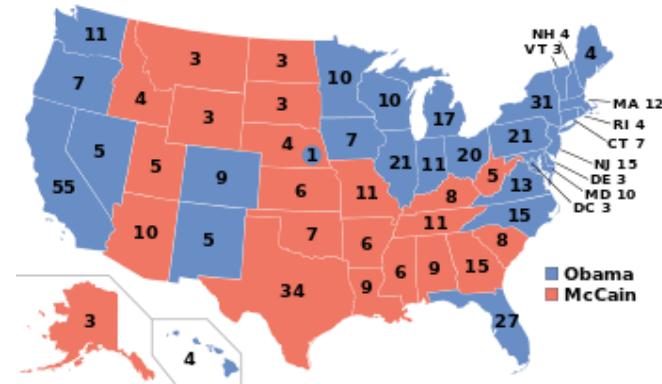
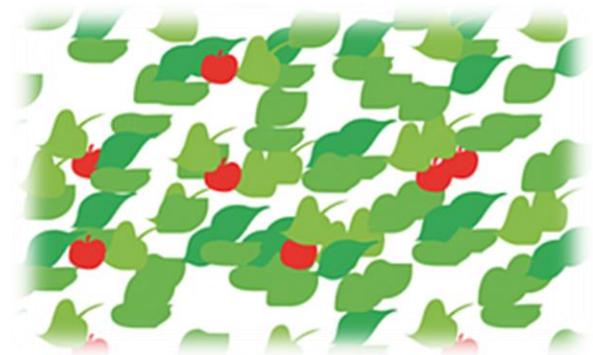
The human visual system

- Visual effect of chromatic light (light spectrum) can be characterized by 3 channels
 - **Hue:** dominant wavelength
 - **Saturation:** pureness, amount of white light
 - **Luminance/Brightness:** intensity of light



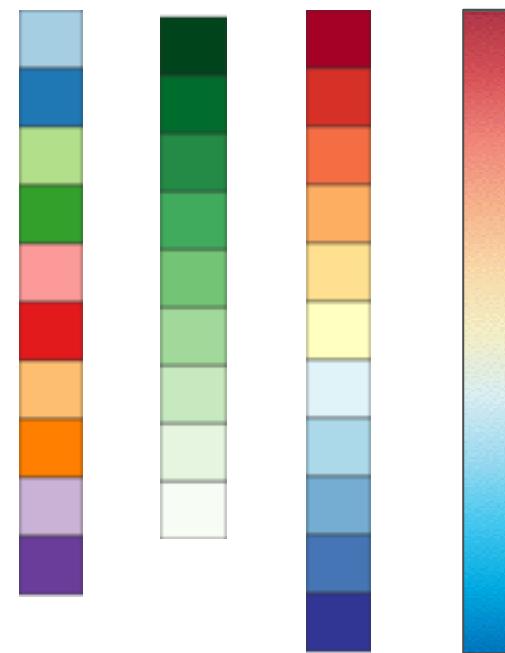
Color mapping

- Color mapping tasks
 - Emphasize a specific target in a crowded display (pop-out)
 - Group, categorize, and chunk information
- Possible problems:
 - Dependent on viewing and stimulus conditions
 - Distract the user when inadequately used
 - Ineffective for color deficient individuals
 - Results in information overload



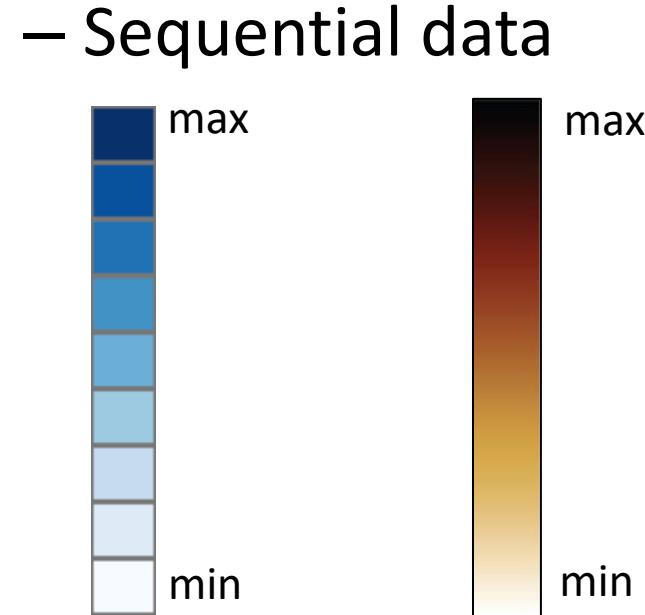
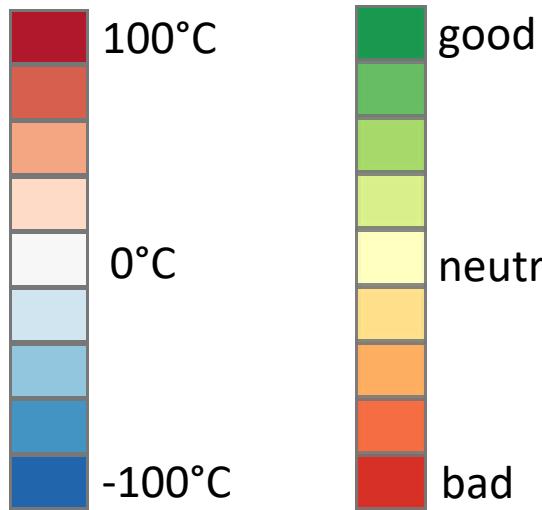
Color mapping

- Color maps can be
 - categorical vs. ordered
 - sequential vs. diverging
 - discrete vs. continuous



Color mapping

- Use color map that fits data characteristics
 - Diverging data
 - Sequential data

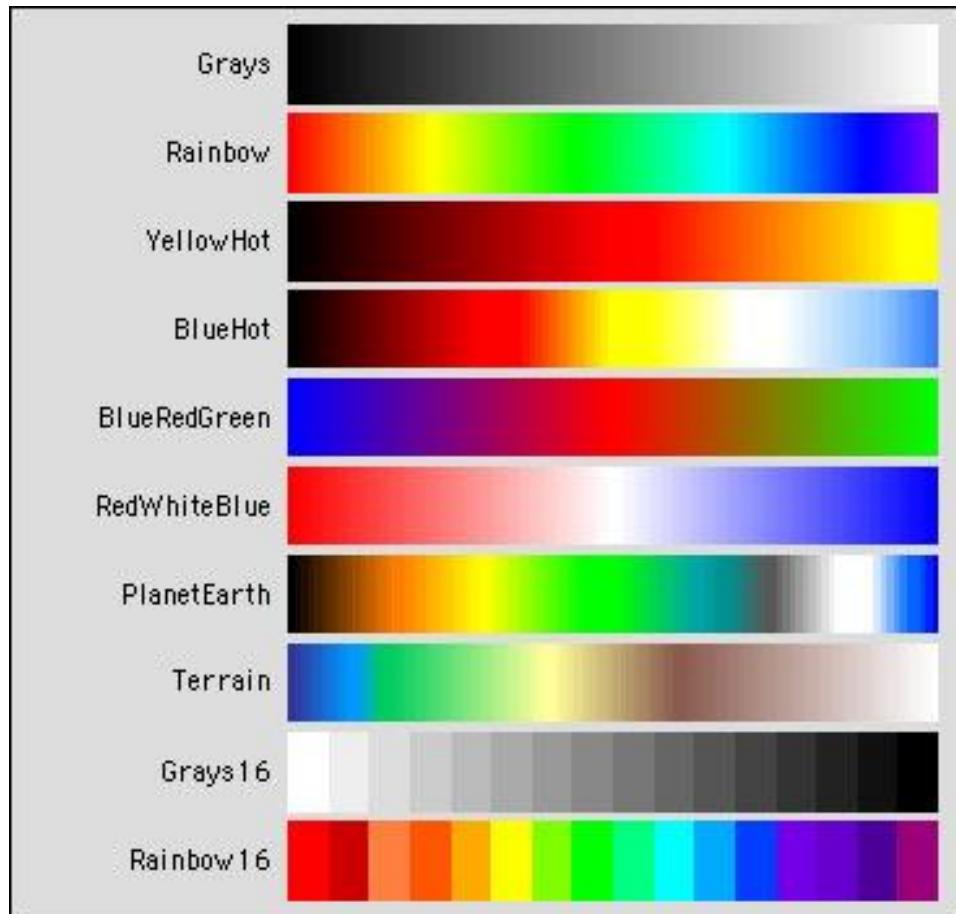


- Categorical data



Color mapping

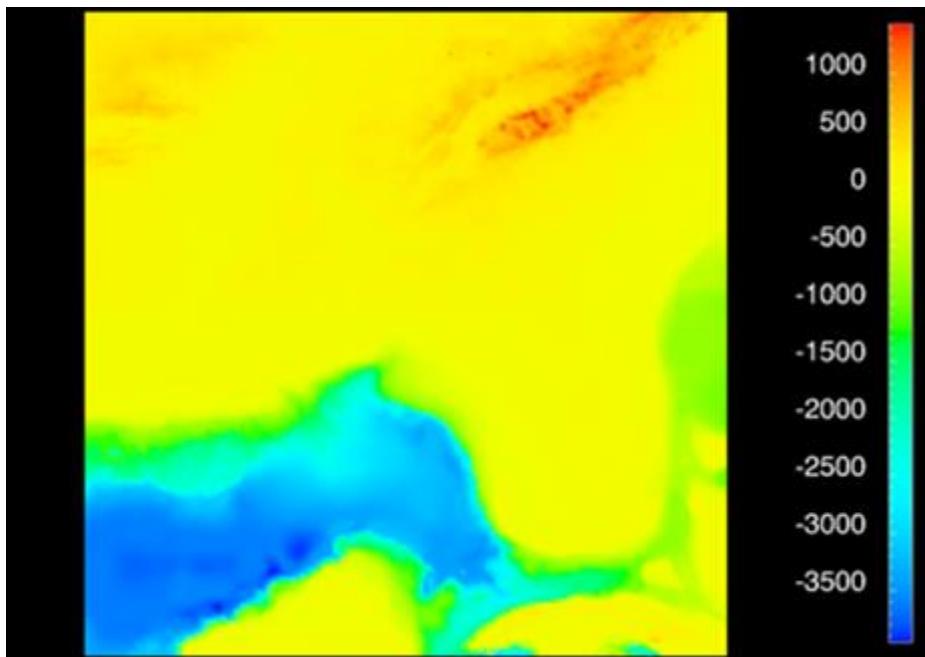
- Some prominent color maps



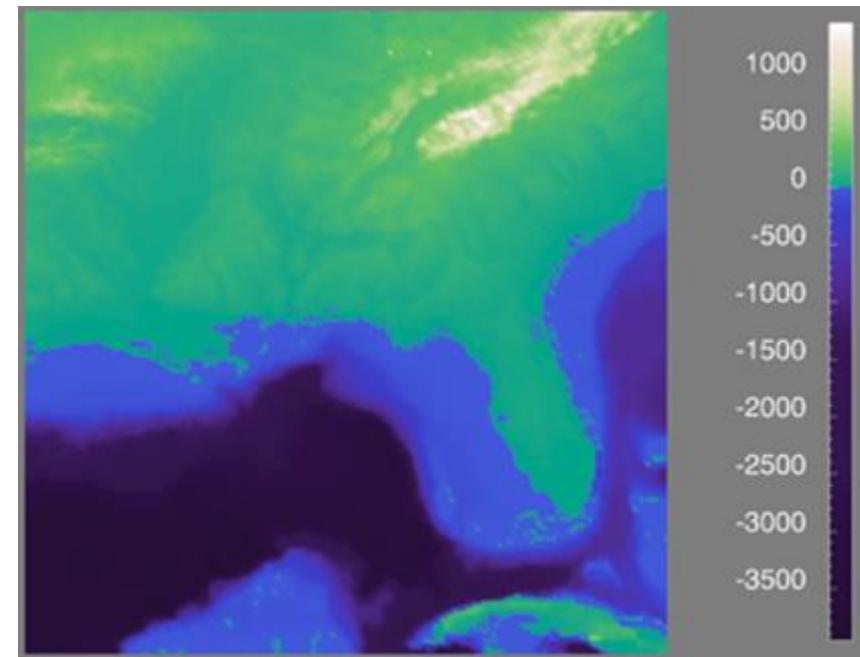
<http://www.exelisvis.com/docs>LoadingDefaultColorTables.html>

Color mapping

- Rainbow color map: A useful default?



Rainbow colormap

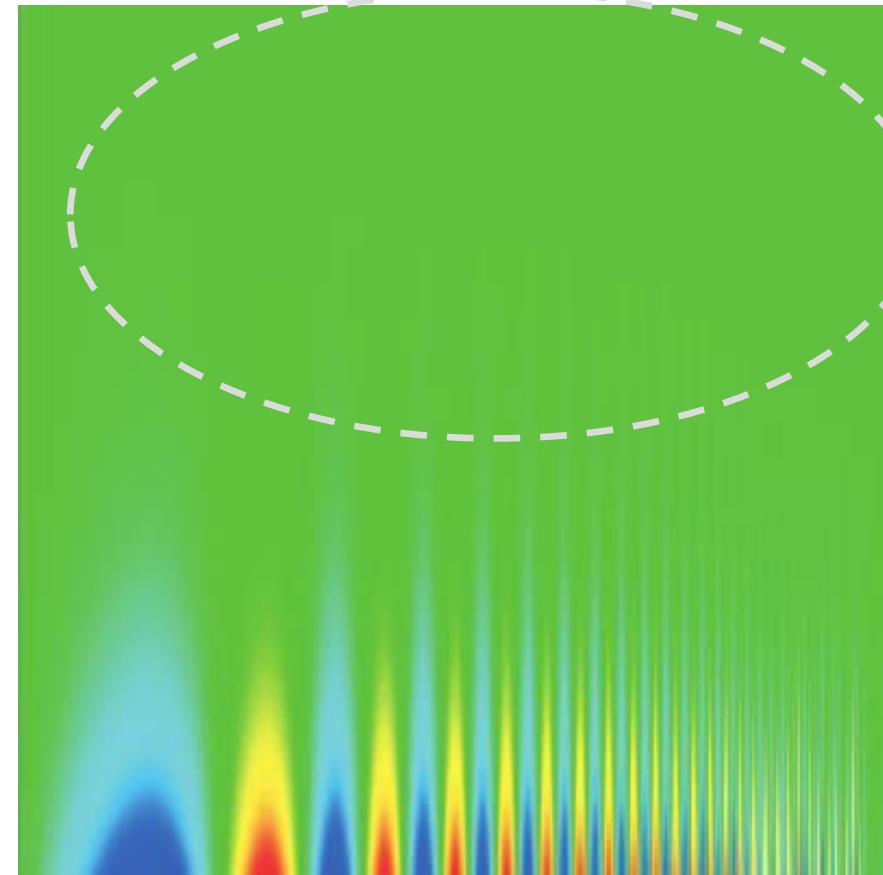
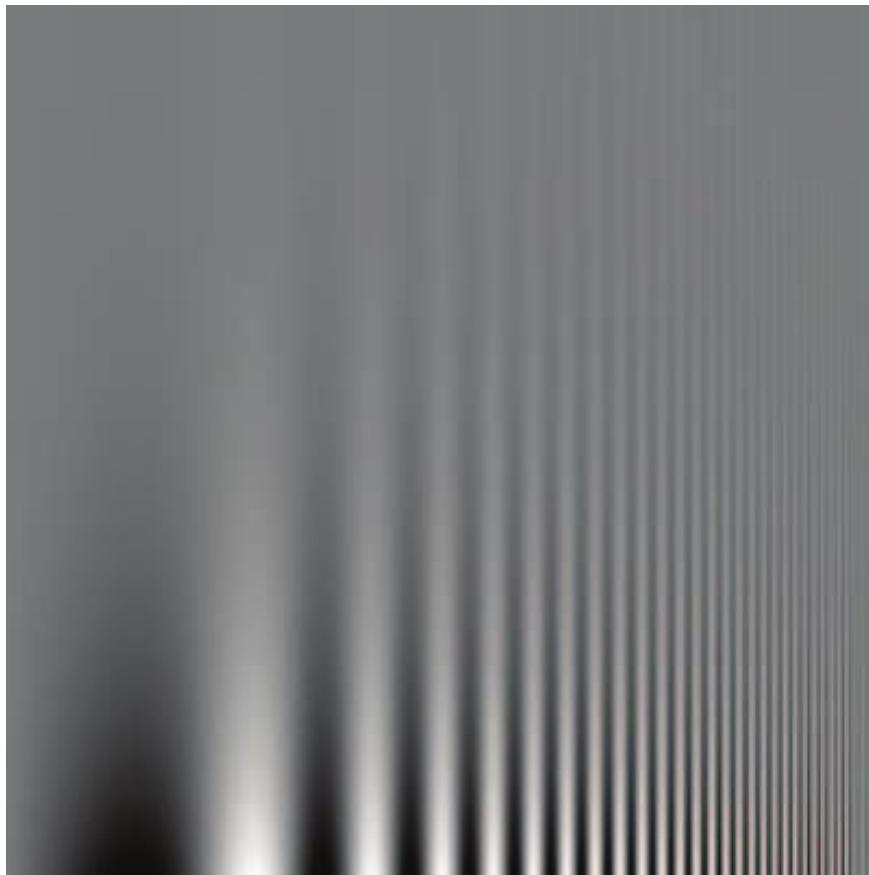


"Perceptual" colormap

Florida peninsula with coastline clearly visible – Appalachian Mountains in lighter colors

Color mapping

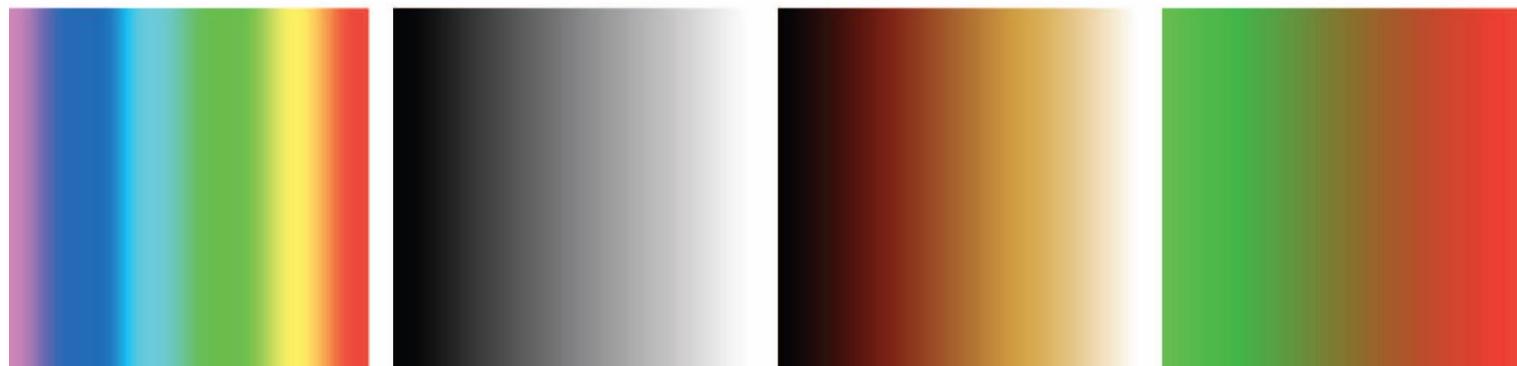
- Rainbow color map: A useful default?



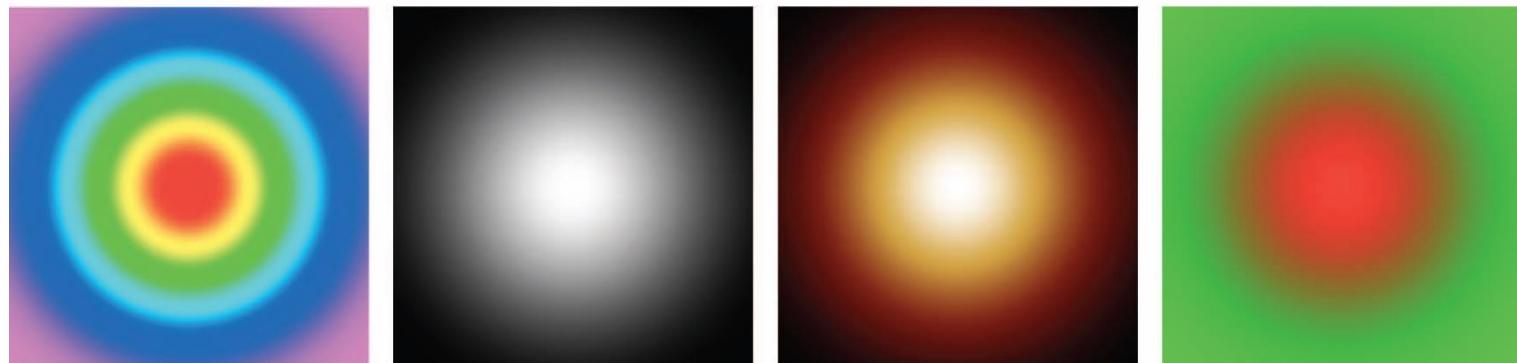
Color mapping

- **Perceptual linear:** equal steps in color map (i.e., magnitude of data) should be perceived equally

Data: Linear increase in values from left to right



Data: Radial symmetric decrease from center



Rainbow colormap

Grayscale colormap

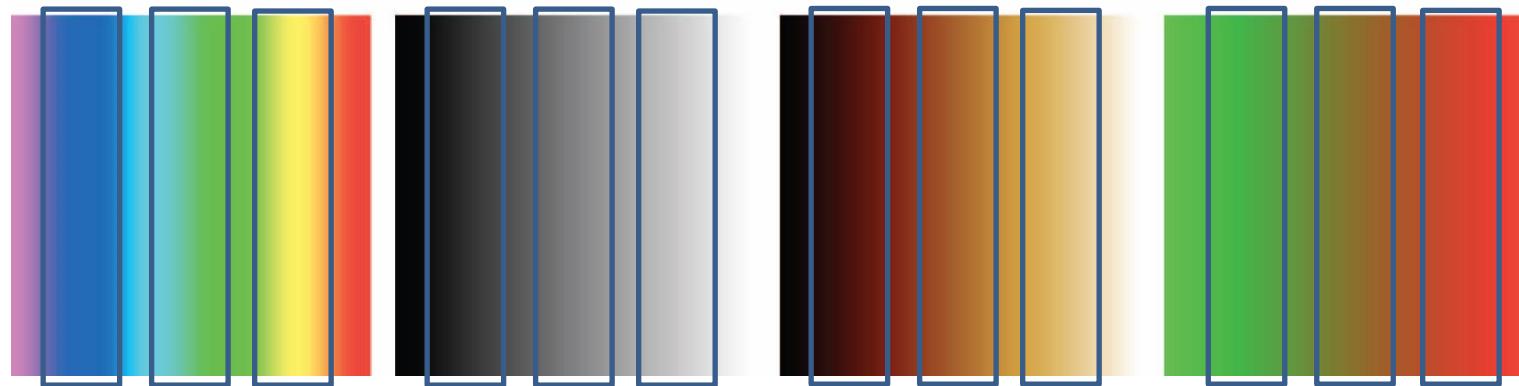
Black-body radiation

Green-red isoluminant

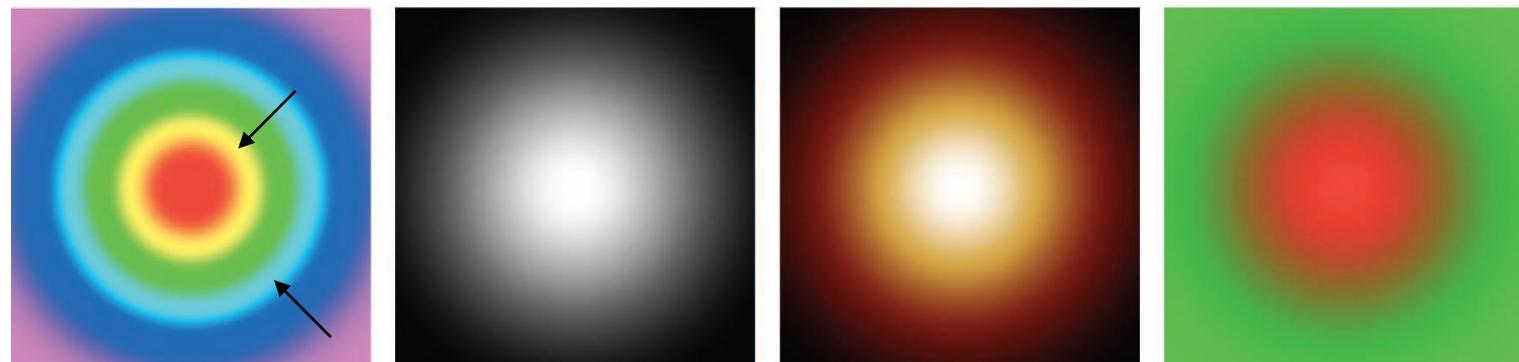
Color mapping

- **Perceptual linear:** equal steps in color map (i.e., magnitude of data) should be perceived equally

Data: Linear increase in values from left to right



Data: Radial symmetric decrease from center



Rainbow colormap is perceptually **nonlinear** & introduces artifacts

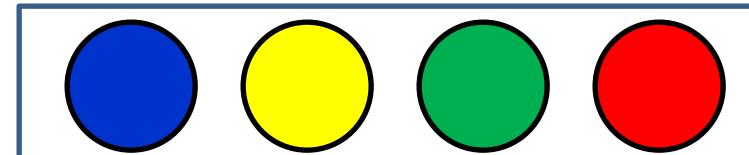
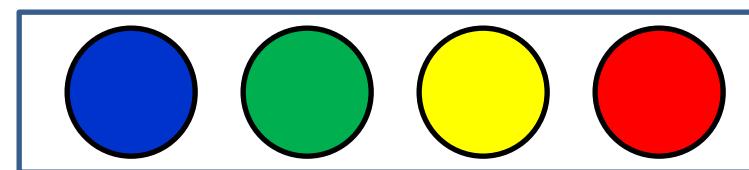
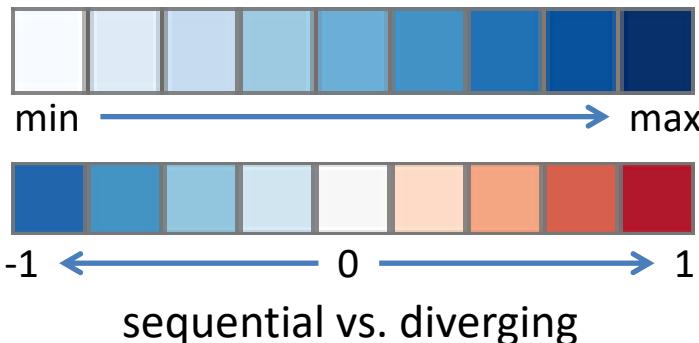
Grayscale colormap

Black-body radiation

Green-red isoluminant

Color mapping

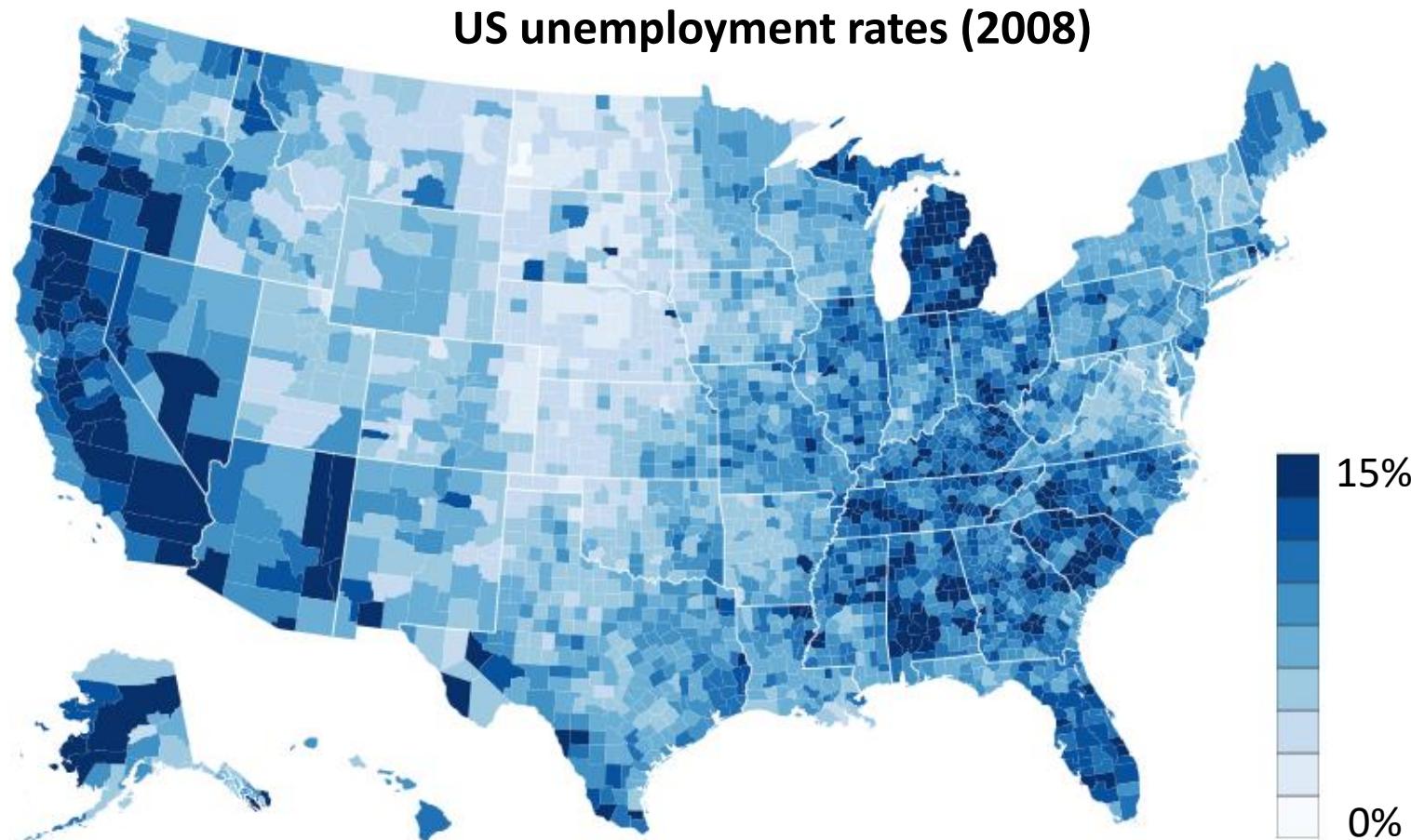
- **Perceptual ordering:** ordering of data should be represented by ordering of colors
 - $x_1 < x_2 < \dots < x_n \rightarrow E(c_1) < E(c_2) < \dots < E(c_n)$ E : visual sensation



Rainbow colormap is perceptually unordered

Color mapping

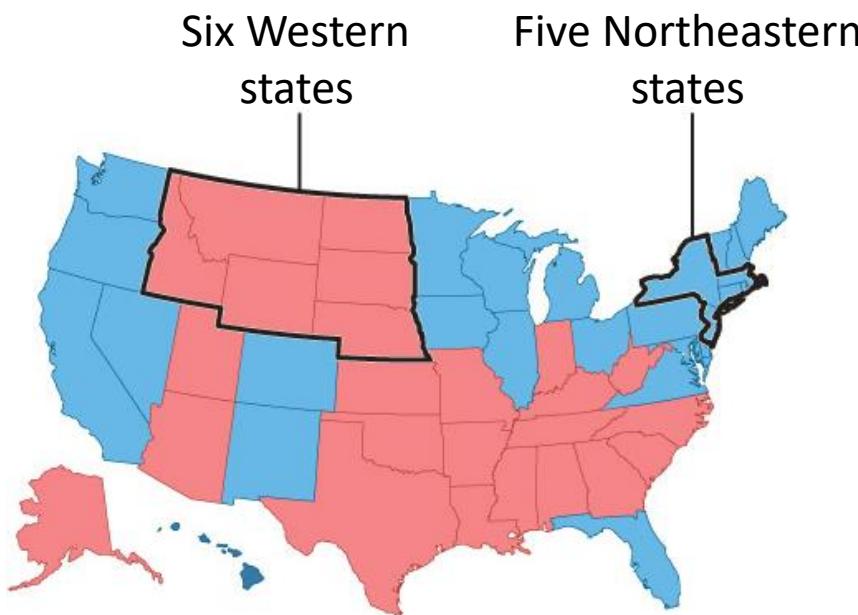
- Color coding of quantitative data
 - Choropleth map



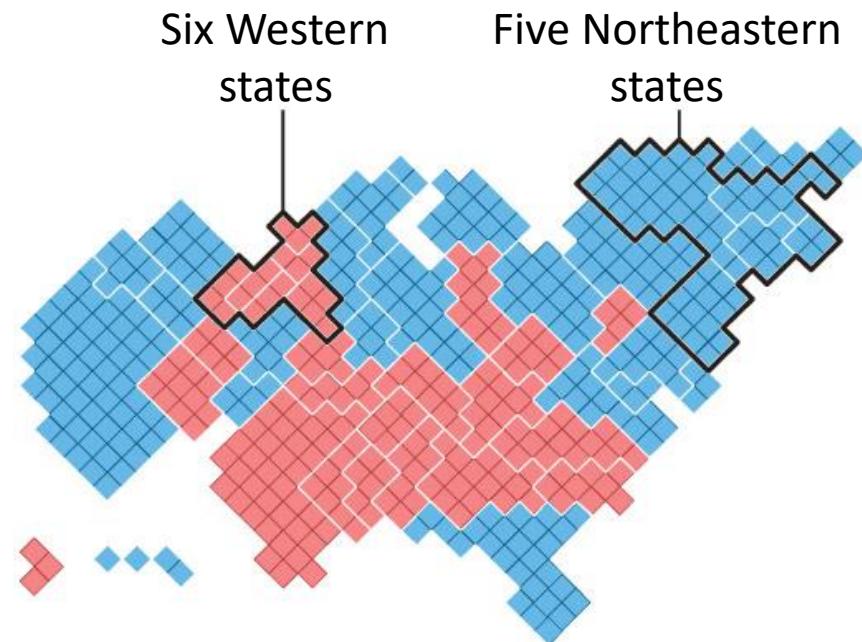
Color mapping

- Color coding of categorical data

2016 presidential election



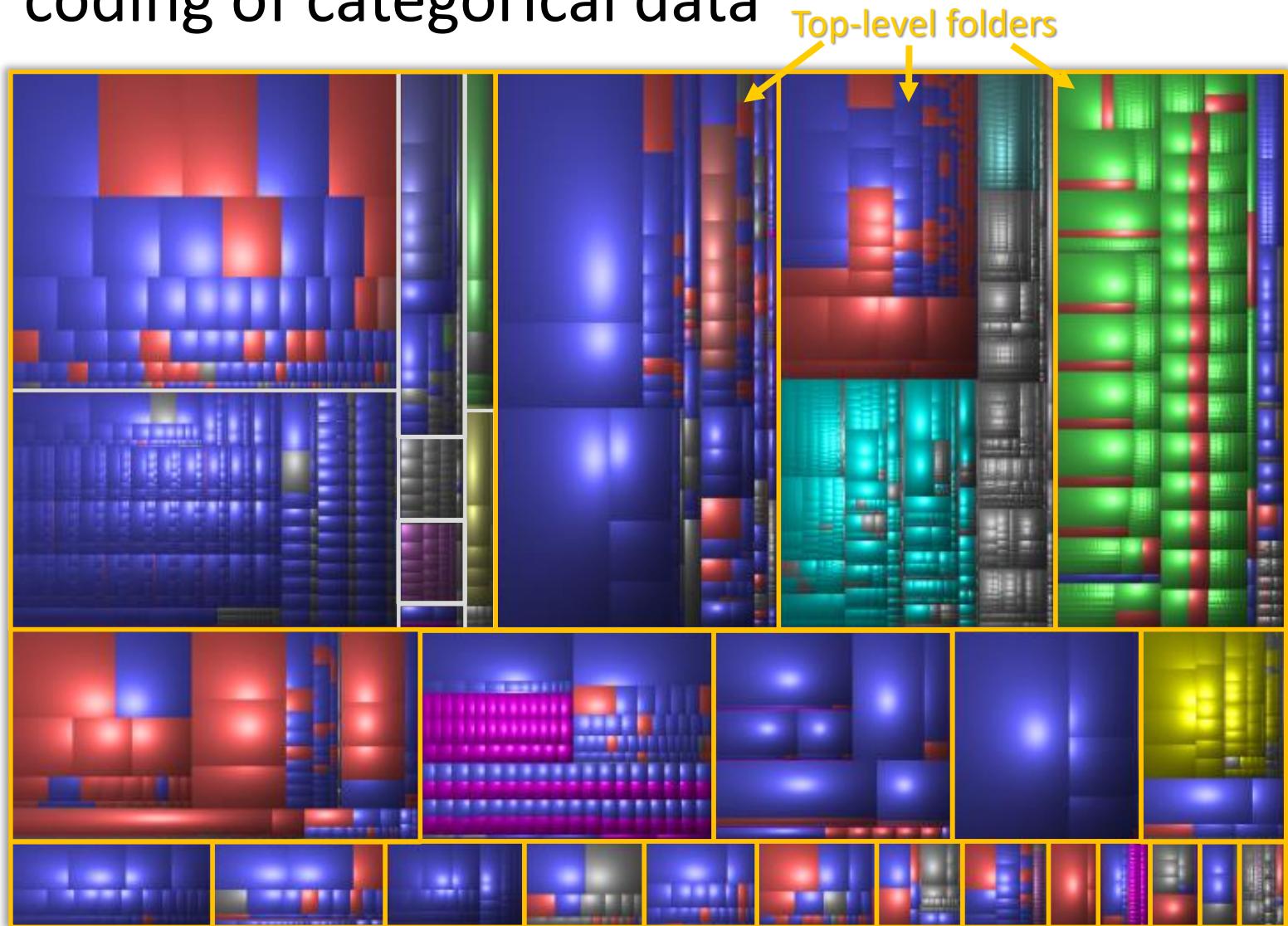
Geographic map



Cartogram of Electoral votes

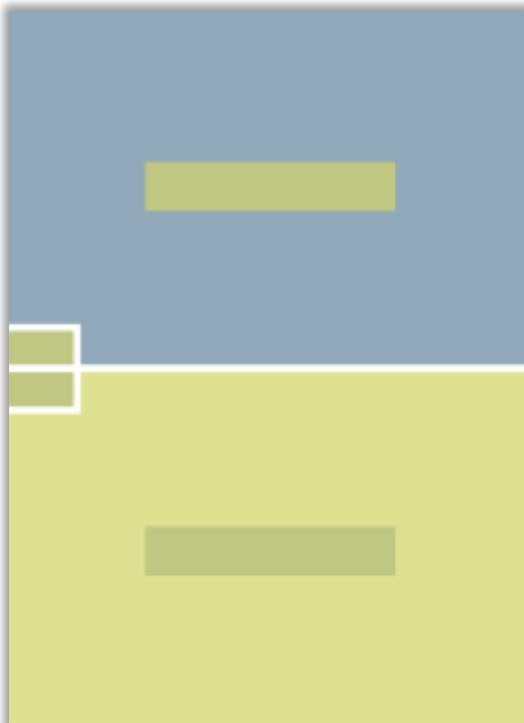
Color mapping

- Color coding of categorical data



Color mapping

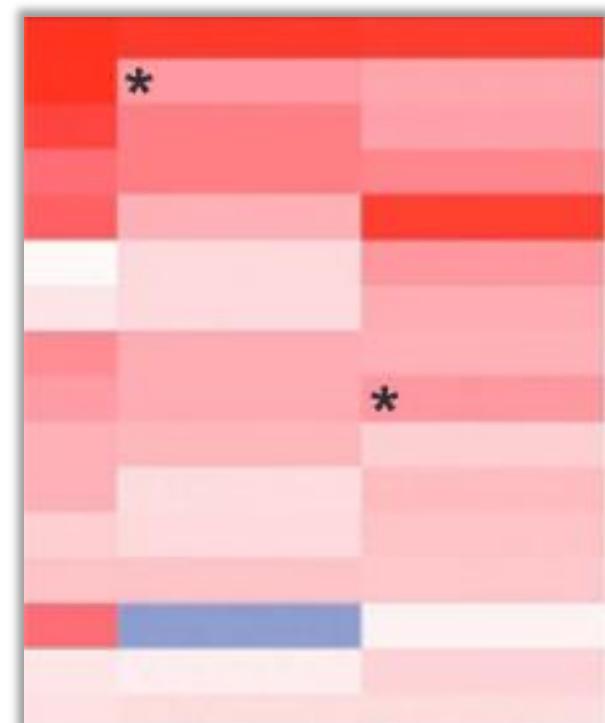
- Things to know when mapping data to colors
 - Perceived color is highly context dependent



Same color can look
different



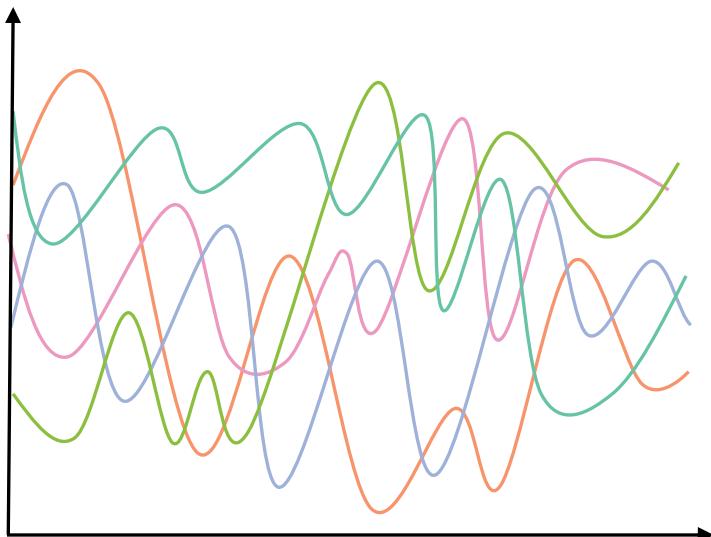
Different colors can look
nearly the same



Rectangles with * are
the same color

Color mapping

- Things to know when mapping data to colors
 - Size matters



[Stone / van Wijk 12]

Color mapping

- Things to know when mapping data to colors
 - Vary luminance too



Colors with different luminance

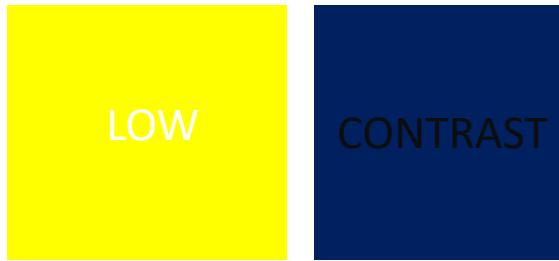


Colors with similar luminance

[Stone / van Wijk 12]

Color mapping

- Things to know when mapping data to colors
 - Make sure contrast is high



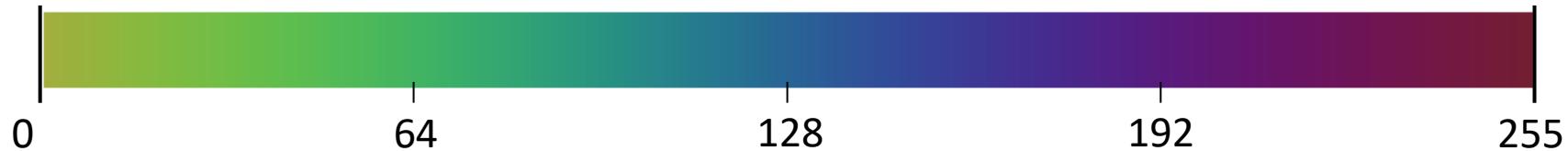
```
fBright = 0.213 * Background.R +  
        0.715 * Background.G +  
        0.072 * Background.B;
```

```
Text.color = (fBright > 0.5) ? BLACK : WHITE;
```

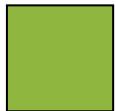
[van Wijk 12]

Color mapping

- Things to know when mapping data to colors
 - Colors are more useful for qualitative statements
 - Do not use color if it is necessary to read out precise values

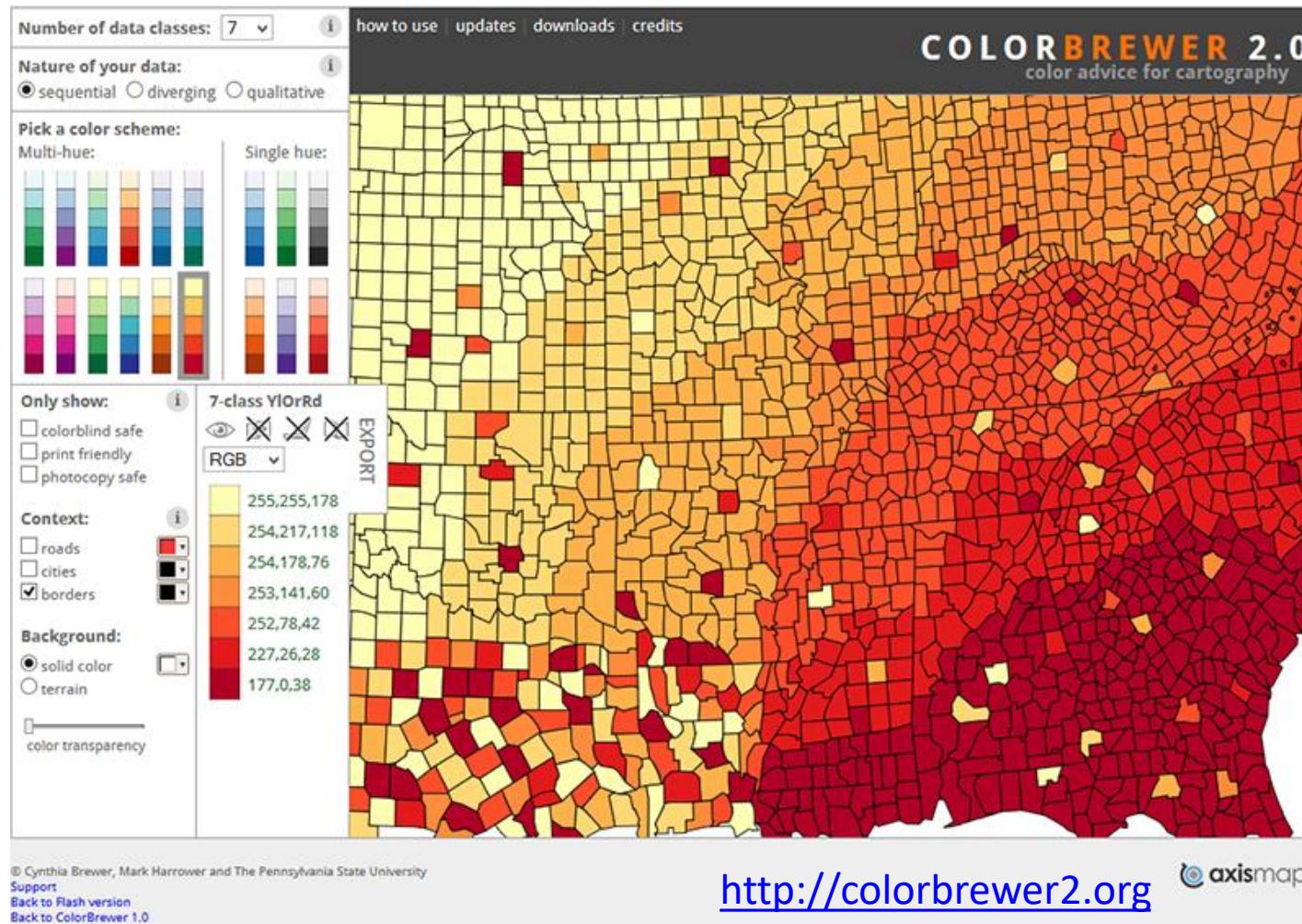


What's the value of these colors?

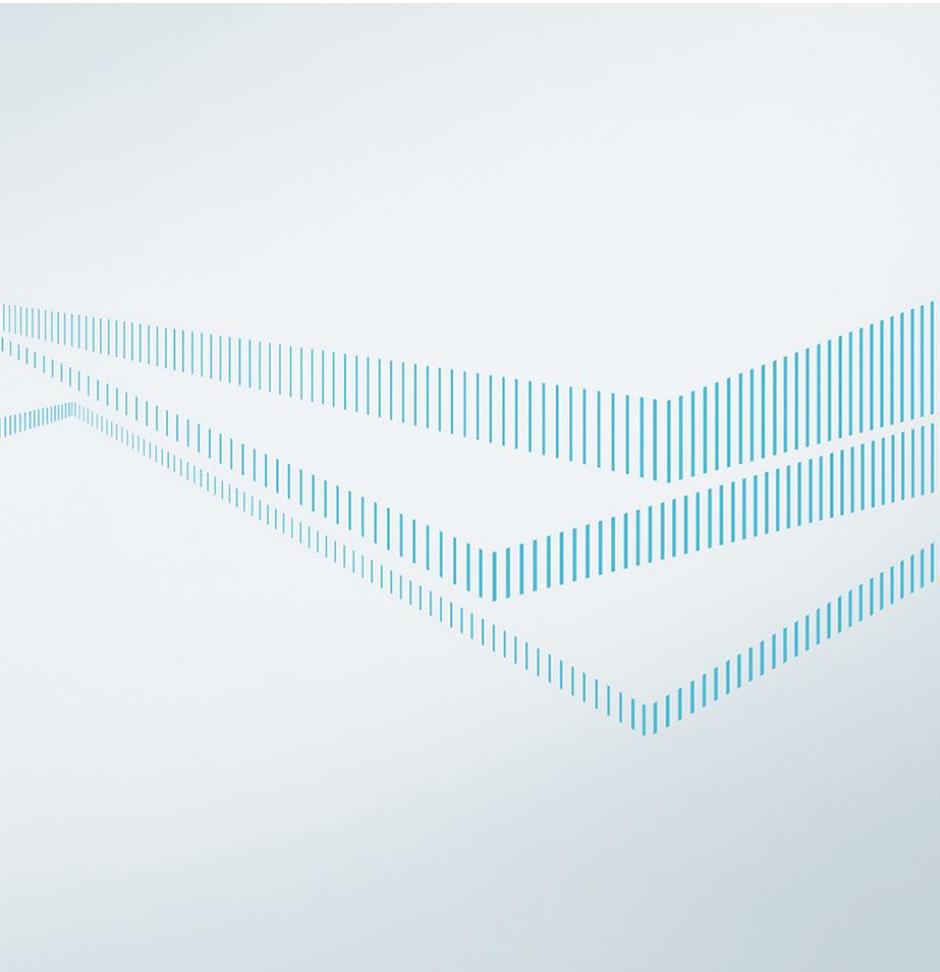


Color mapping

- Use “good” color maps



Contact information



Dr. Johannes Kehrer

Siemens Technology
T RDA BAM IBI-DE
Otto-Hahn-Ring 6
81739 München, Deutschland

E-mail:
kehrer.johannes@siemens.com

Internet
siemens.com/innovation

Intranet
intranet.ct.siemens.com

