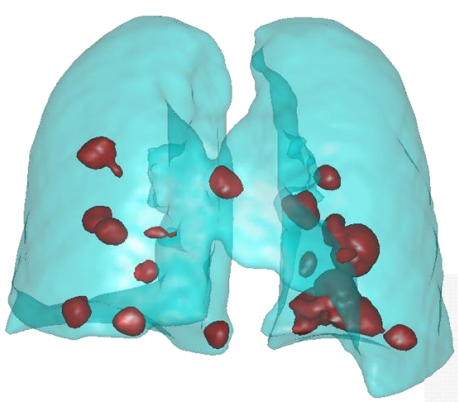
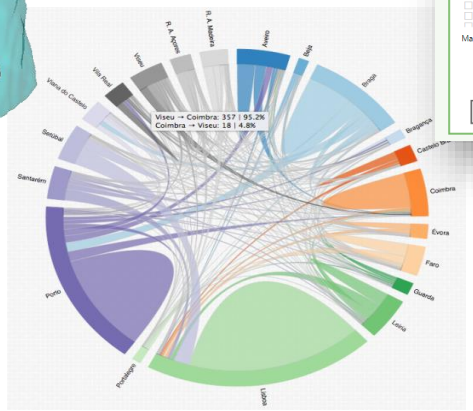
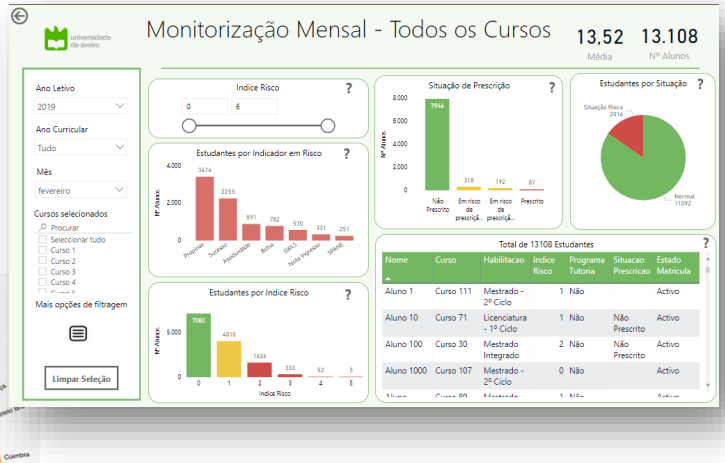
Universidade de Aveiro
Departamento de Electrónica,
Telecomunicações e Informática

Creating a Visualization

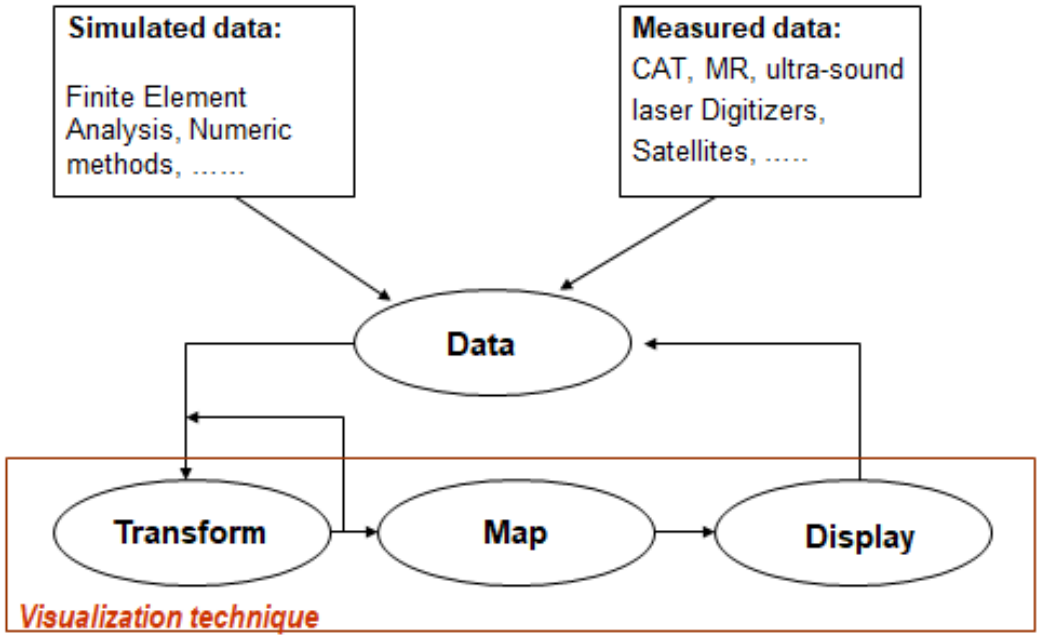






Beatriz Sousa Santos, 2021/22

Scientific Visualization reference model

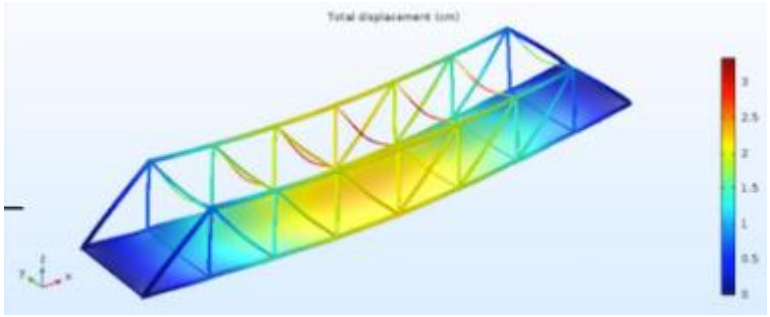


(adapted from Schroeder et al., 2006)

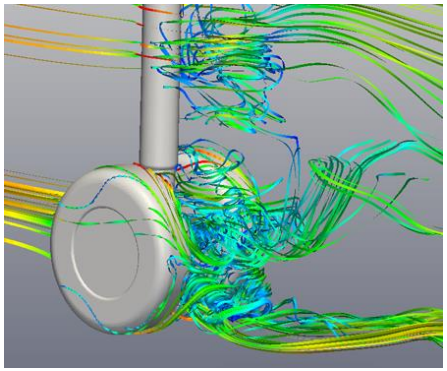
The visualization creator is involved in all phases

The user should get insights from the visualization

Visual mapping

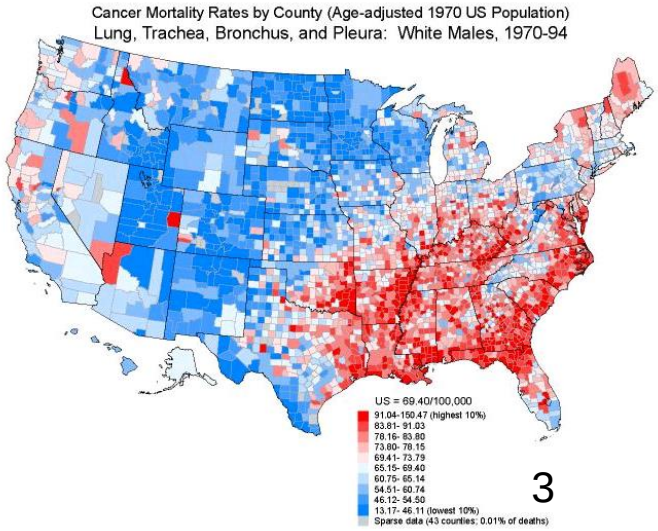


- It is necessary to decide:
  - which visual structures use to **represent** the data
  - their location in the display



- Some types of data can be easily mapped to a spatial location

- Examples:
. data with a topological or geographical structure



- Abstract data don't have an easy correspondence with the dimensions of the physical space around us

Three **structures** must be defined in the **visual mapping/encoding**:

- spatial substrate

- graphical elements

- graphical properties

- **Spatial substrate** - dimensions in physical space where the visual representation is created (can be defined in terms of axes and type of data)

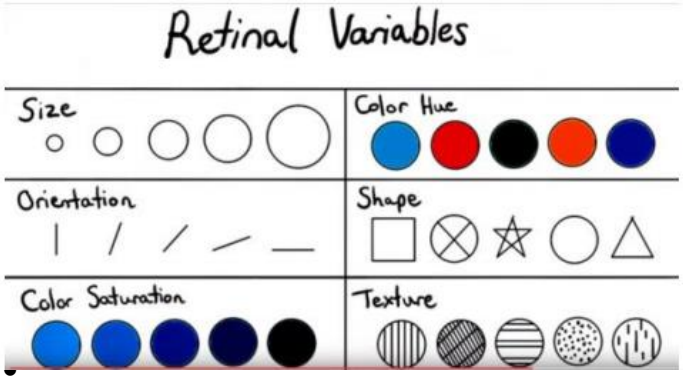
- **Graphical elements** - anything visible appearing in the space
  points, lines, surfaces, volumes

- **Graphical properties** – properties of the graphical elements to which the human retina is very sensitive - **retinal variables:**
  size, orientation, color, texture, and shape

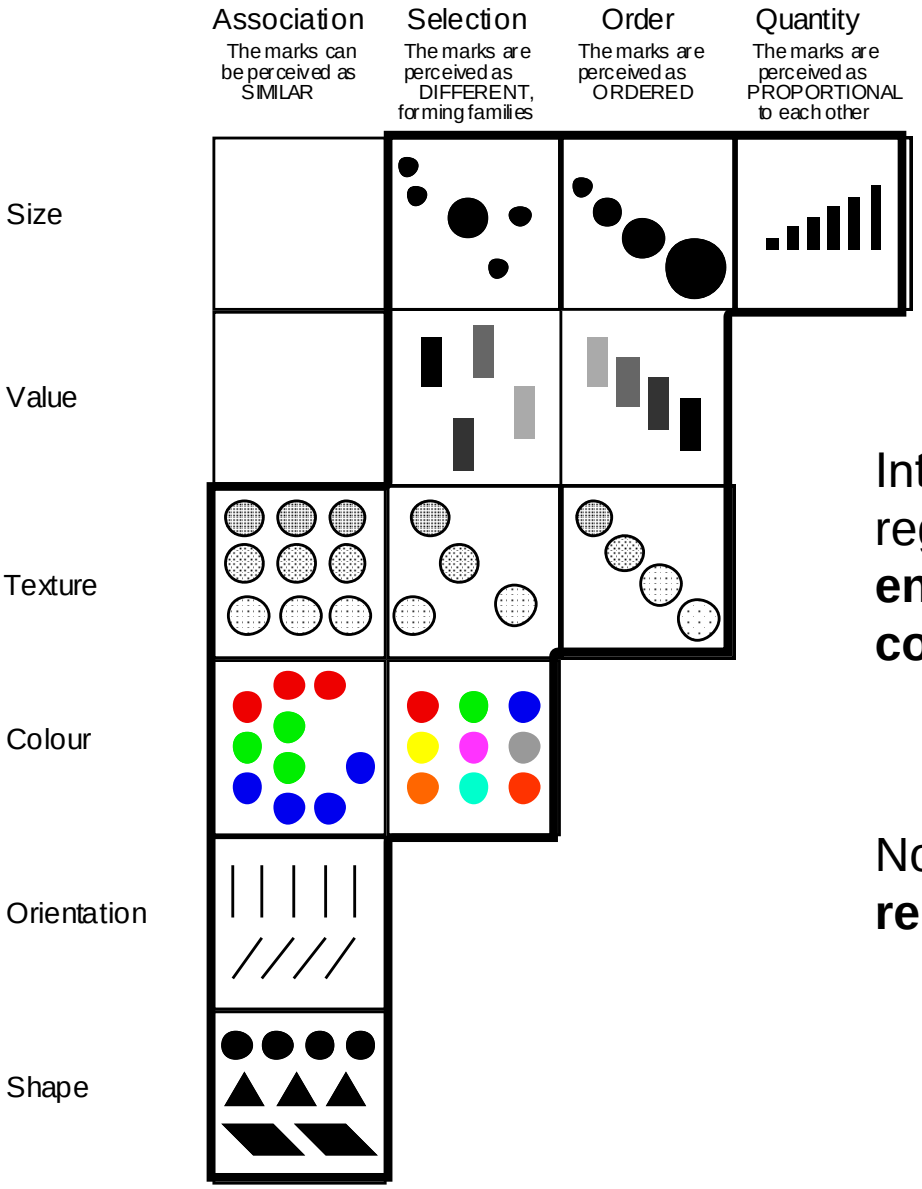
- **Spatial substrate** axes (x, y, …)
  type of data (quantitative, ordinal, categorical)

- **Graphical elements** points
  lines
  surfaces
  volumes

- **Graphical properties** retinal variables:
  size,
  orientation
  color (depends on physiology and culture)
  texture
  shape



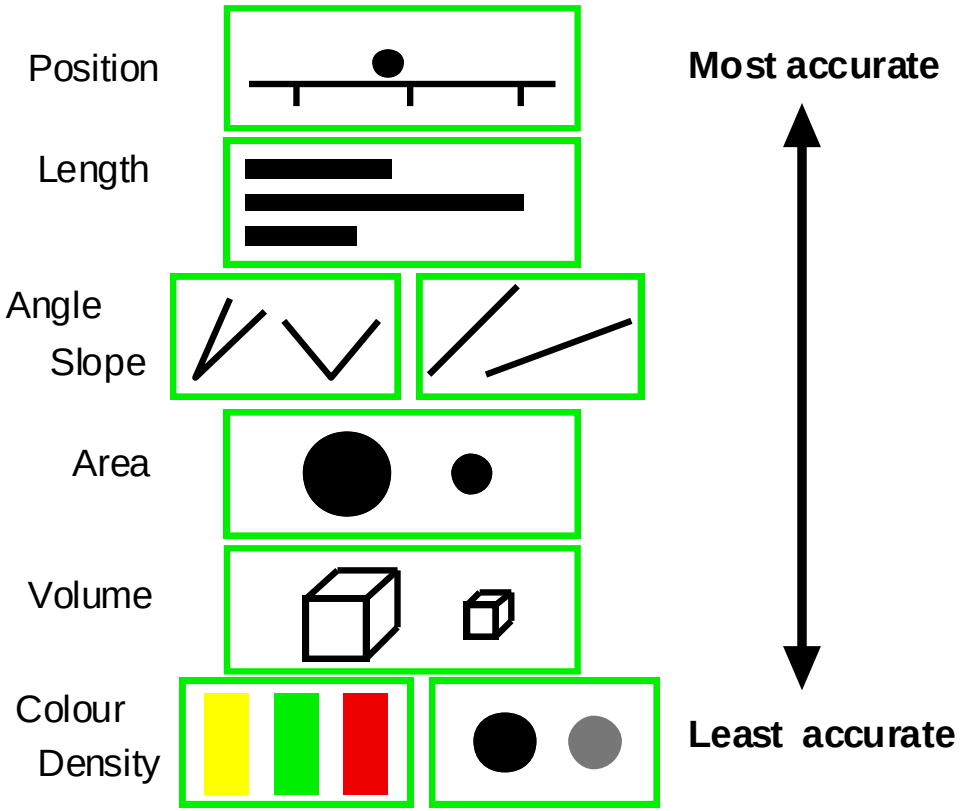
How to select visual encodings?



Interpretation of Bertin's guidance regarding the suitability of various **encoding methods to support common tasks** (Spence, 2007)

Note that **only size is adequate to represent quantity accurately**

How to select visual encodings to accurately represent quantity?



The relative difficulty of **assessing quantitative value** as a function of encoding mechanism, as established by Cleveland and McGill (Spence, 2007)

In a nut shell:
Do you have a lot of data?

- Visualization may be the solution (or part of it)

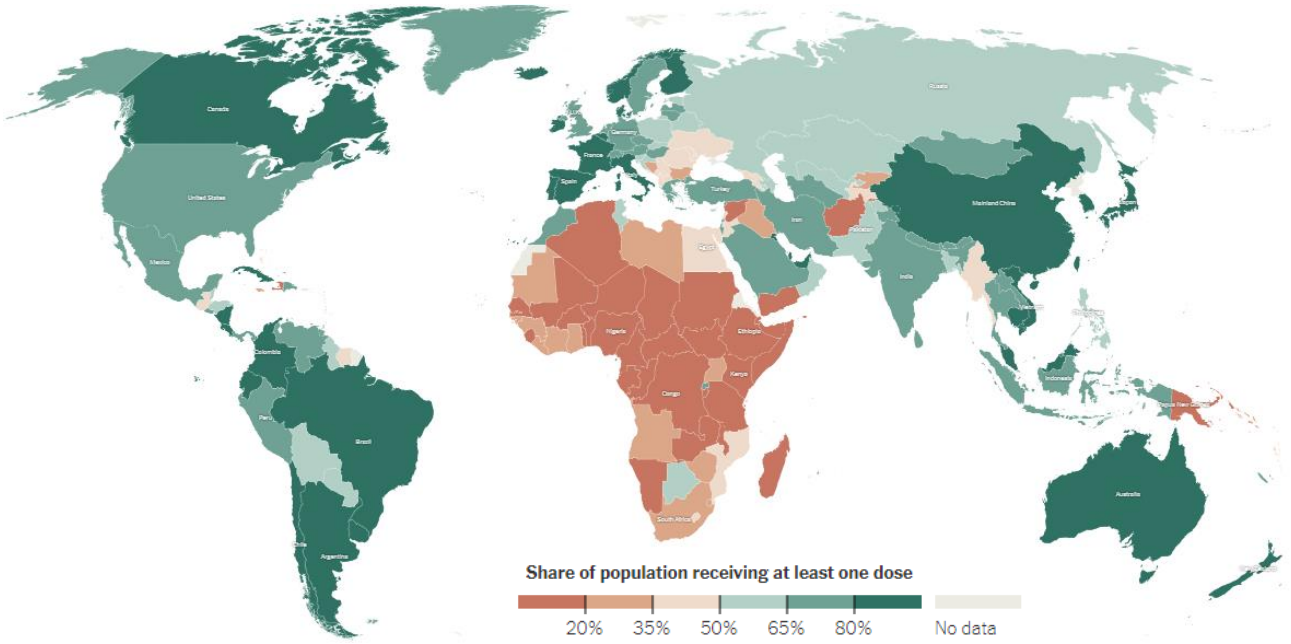
- Creating a Visualization has several phases

- Visual mapping is core

- There are several possible visual encodings/
  visualization techniques

- But,
  How to select techniques ? → next topic

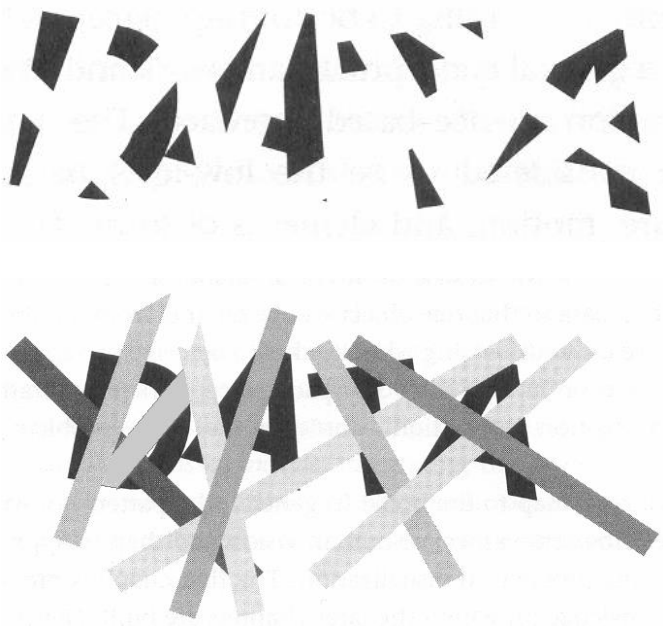
Mapping - Visually encoding value



https://www.nytimes.com/interactive/2021/world/covid-vaccinations-tracker.html

Remember:

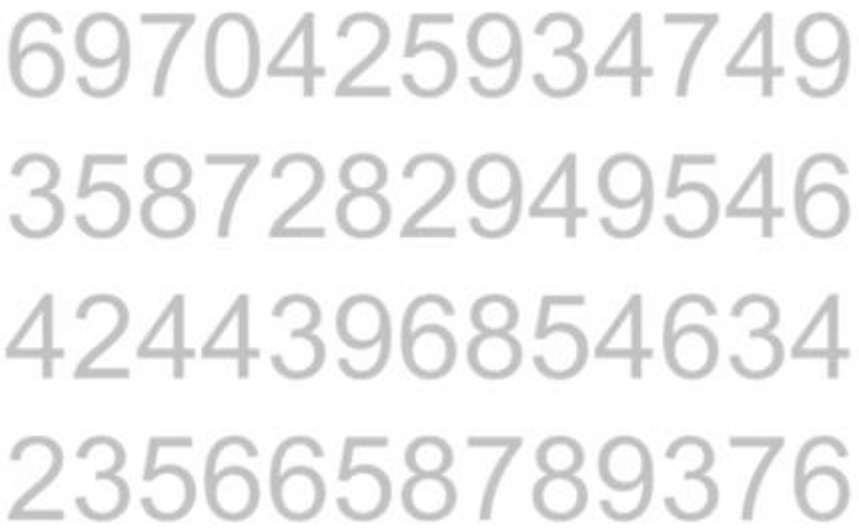
- The Human Visual system is the product of millions of years of evolution



- Although very flexible, it is tuned to data represented in specific ways

- If we understand how its mechanisms work we will be able to produce better results

Pre-attentive attributes can help observers to see before though

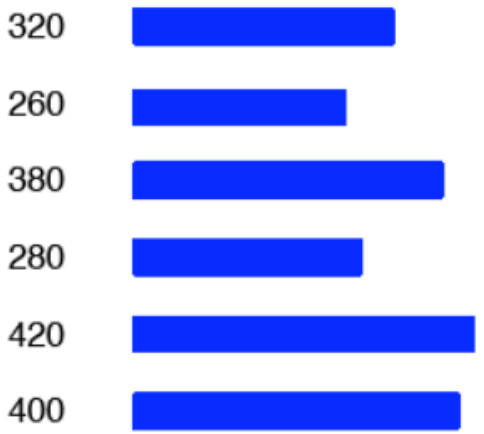


Example: Count the number of 7s

https://www.youtube.com/watch?time_continue=121&v=AiD6etOB6qI

- Some visual attributes as **size**, **proximity** are also quickly processed by visual perception, **before the cognitive processes** come into play

Example:
mapping numerical values
to the length of bars:



(Mazza, 2009)

Procedure to follow to create visual representations of data

1. Define the problem and the users' questions
2. Examine the nature of the data to represent and pre-process the data
3. Determine the number of attributes/variables/dimensions
4. Choose the visual structures to map

test several ideas …

Important aspects to consider:

nature of the problem
- communicate
- explore
- confirm

nature of the data to represent
- quantitative
- ordinal
- categorical

number of attributes
- univariate
- bivariate
- trivariate
- multivariate

Next: visualization techniques organized according the n. of attributes

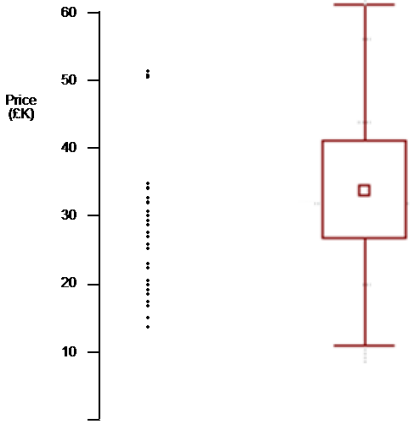
dataset types
- tables
- networks
- spatial or geographical
- fields
- geometry

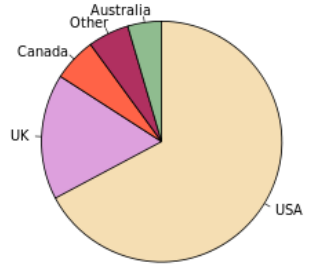
of tabular data

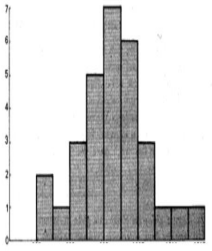
…

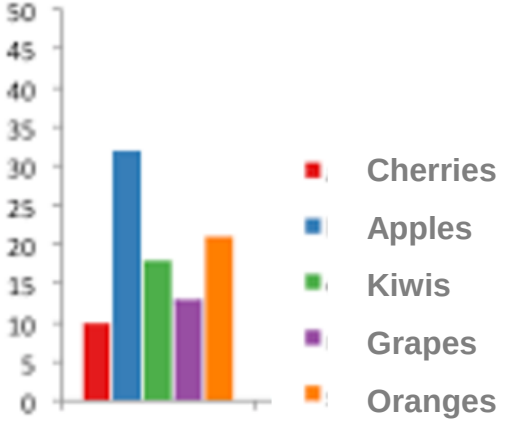
Common Visualization Techniques to visually represent univariate, bivariate data

Univariate data
- dot plot
- box plot
- bar chart
- histogram
- pie chart
- …



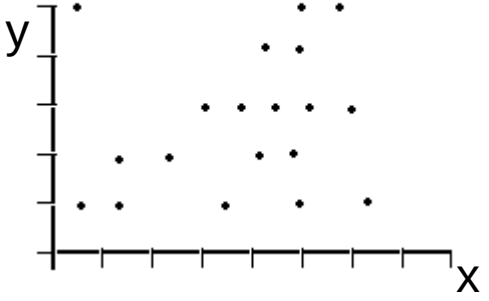


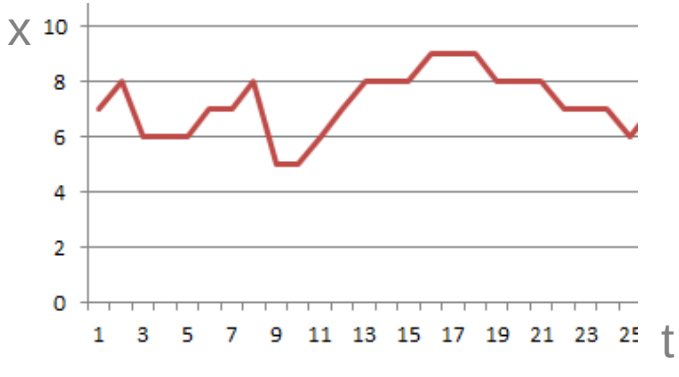




Bivariate data
- scatter plot
- line plot
- time series
- …

…





Representing univariate data

- A more common situation consists in representing a set of values
- Well established techniques exist
- But new ones can be invented!

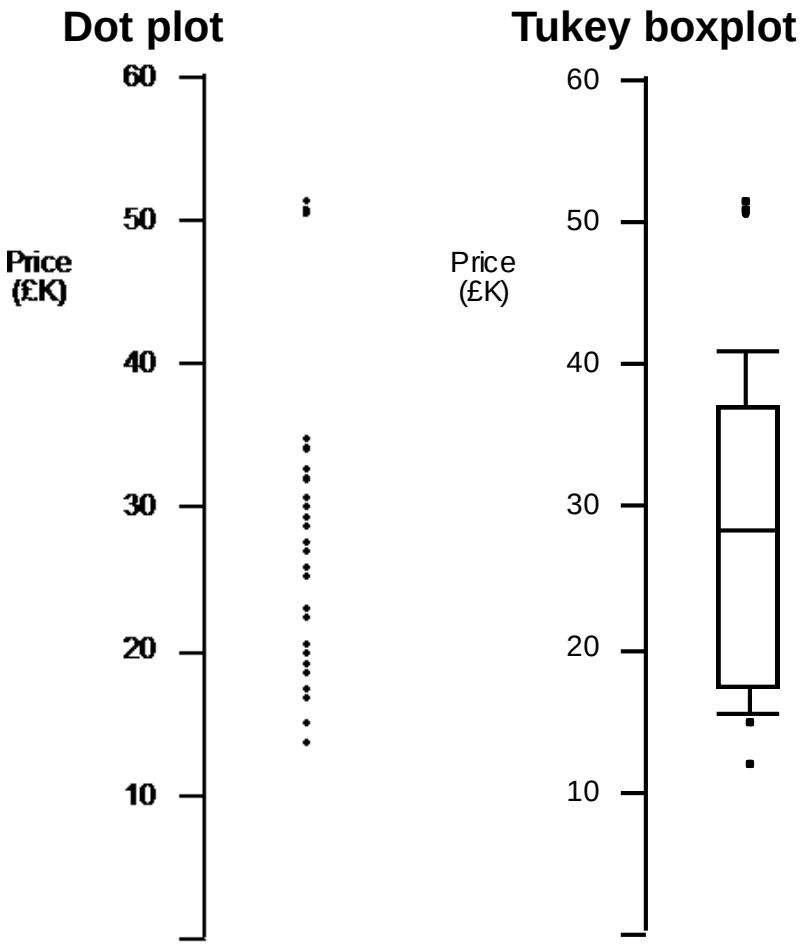
Example:

Price for a number of cars:

- dots on a linear scale
- box plot

(that will answer many questions: median value, outliers,...)

(Spence, 2007)



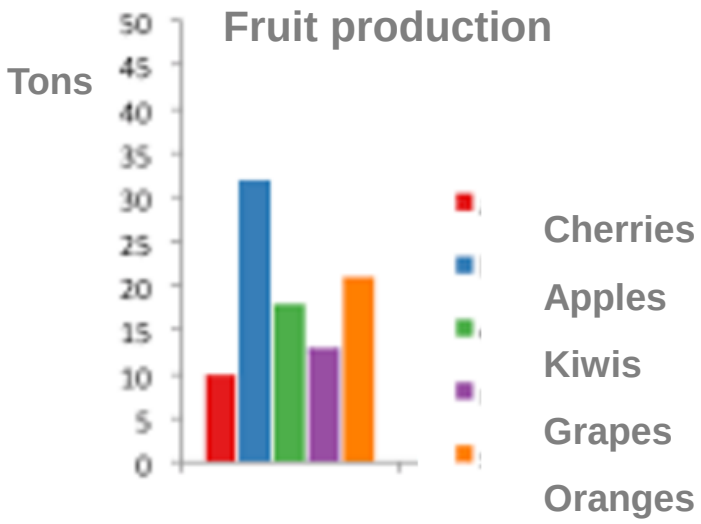
https://www.data-to-viz.com/caveat/boxplot.html

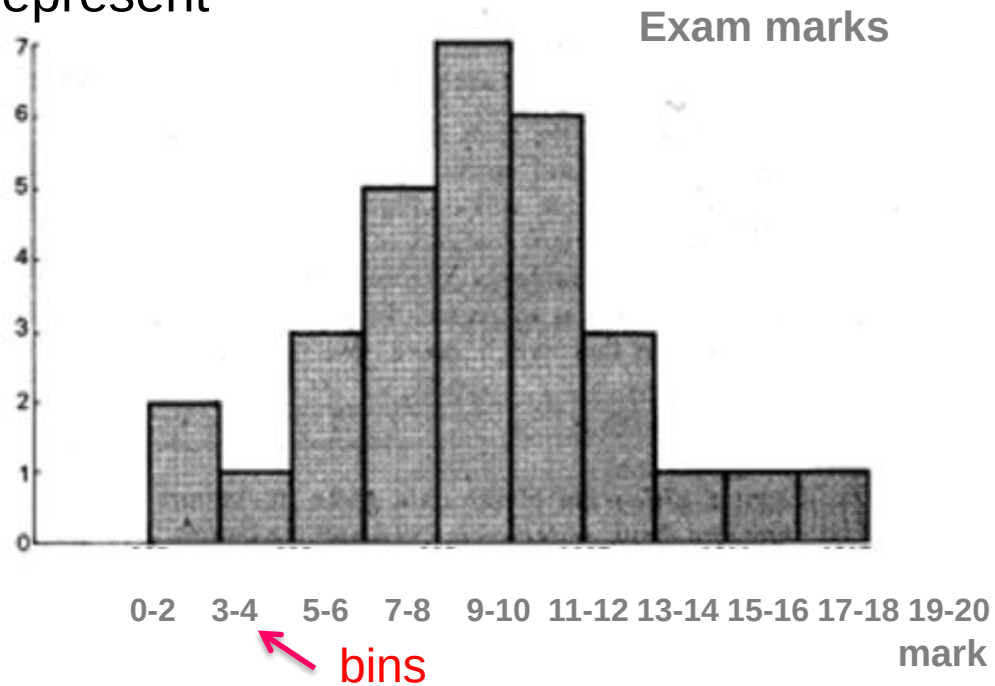
Two common techniques not to be confounded !

Histogram ⇨ represents a distribution of numerical data

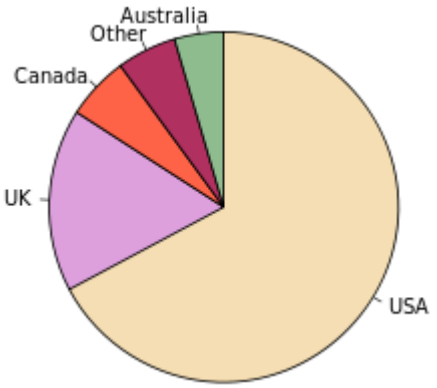
Bar chart ⇨ represents the number of occurrences of a categorical/ ordinal data

Both represent data by rectangular bars (vertical or horizontal) with length proportional to the values they represent





Another simple (and too common) technique



Native English speaking population

- Pie Chart

Represents numerical proportion, **parts of an whole**

The arc length of each slice (its central angle and area), is proportional to the quantity it represents

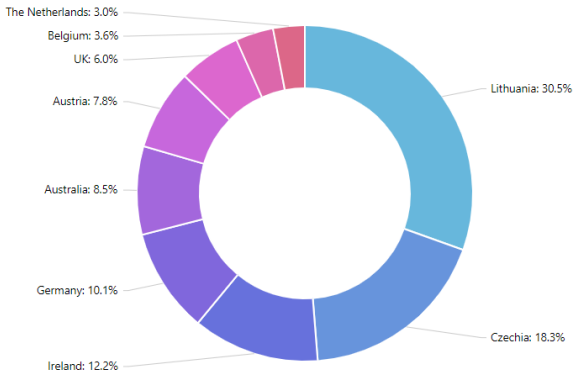
Are much controversial:

many experts recommend avoiding them

http://www.perceptualedge.com/articles/08-21-07.pdf

It is difficult to compare different sections of a pie chart, or to compare data across different pie charts

Variations of pie charts:



- Simple criteria to determine whether a pie chart is acceptable
- Consider it **only if**:
- **The parts make up a meaningful whole**
- **The parts are mutually exclusive**
- **There are <6 parts and slices have not very different sizes**

If the main purpose is to compare between the parts,
use a different chart!

https://eagereyes.org/techniques/pie-charts

Representing bivariate data

- The **scatterplot** is the conventional representation

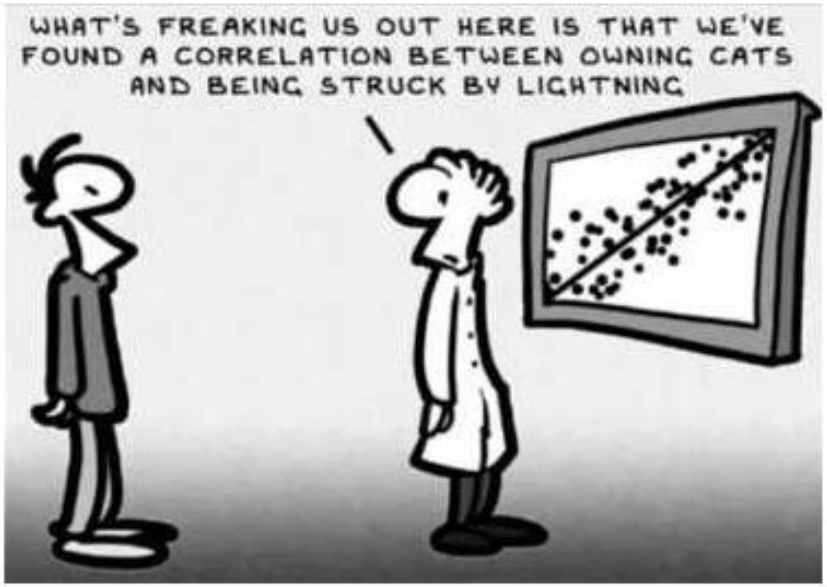
Each observation is represented by a point on a two dimensional space

The axes are associated with these two attributes

This representation affords awareness of:

- general trends
- local trade-offs
- outliers

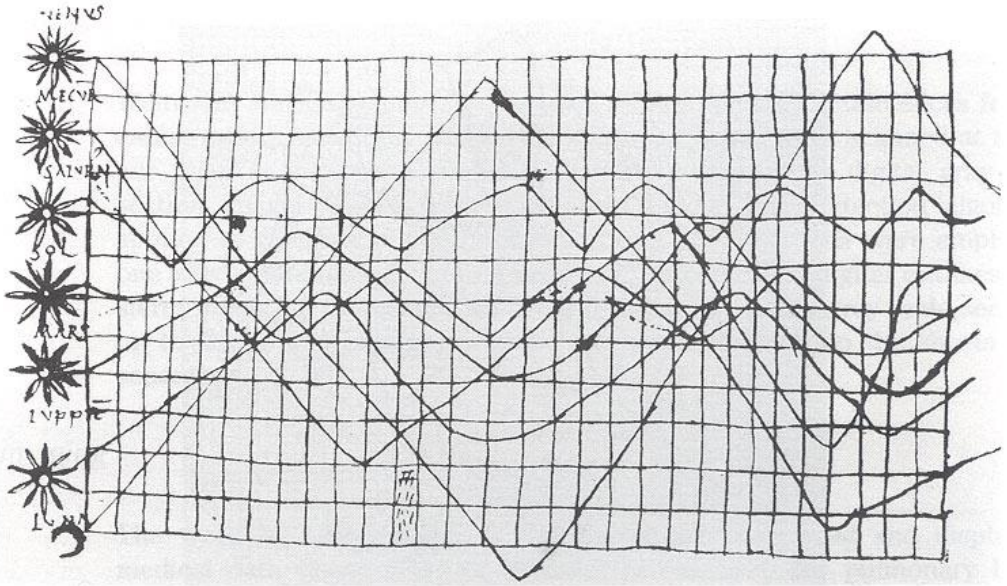
Correlation is not causation



Representing bivariate data

The **line chart**

One of the oldest known and ubiquitous Visualizations

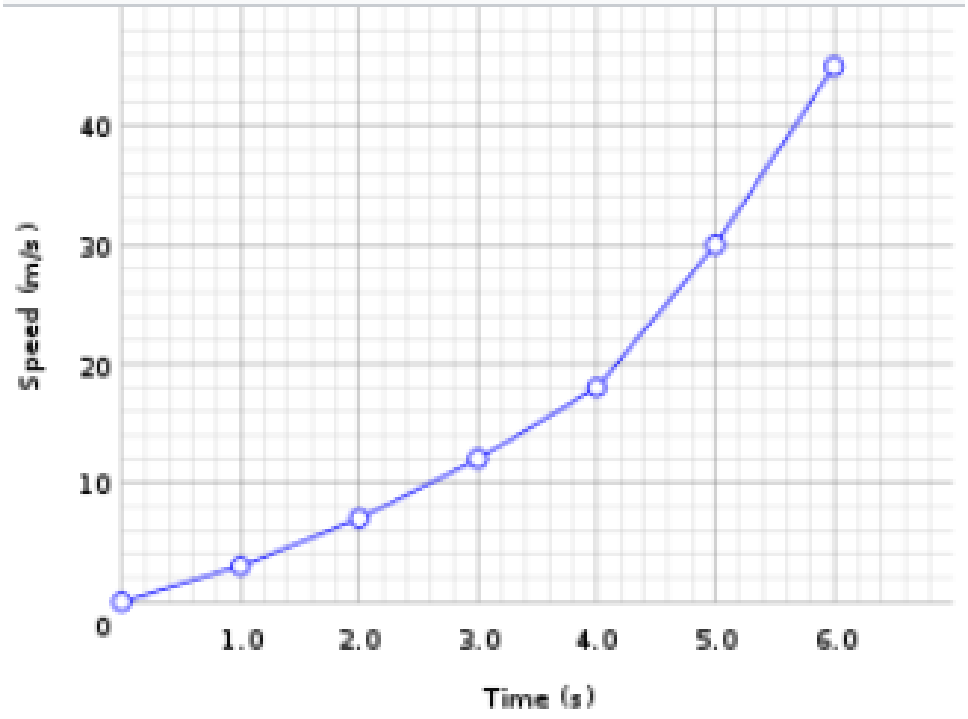


Inclination of orbits along the time - Xth century (Tufte,1983)

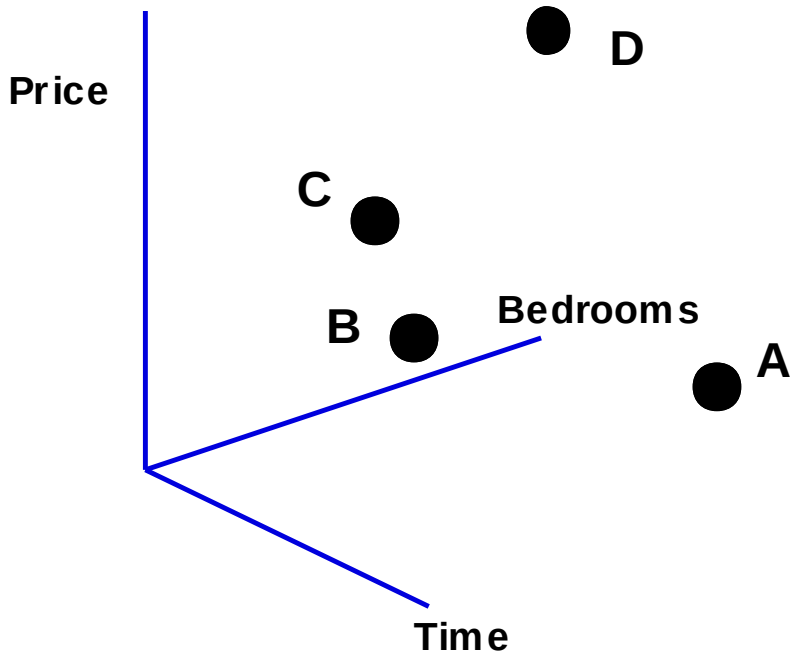
- A **line chart** or **line plot** or **line graph** or **curve chart** displays information as a series of data points called 'markers' connected by straight line segments

- Basic type of chart common in many fields

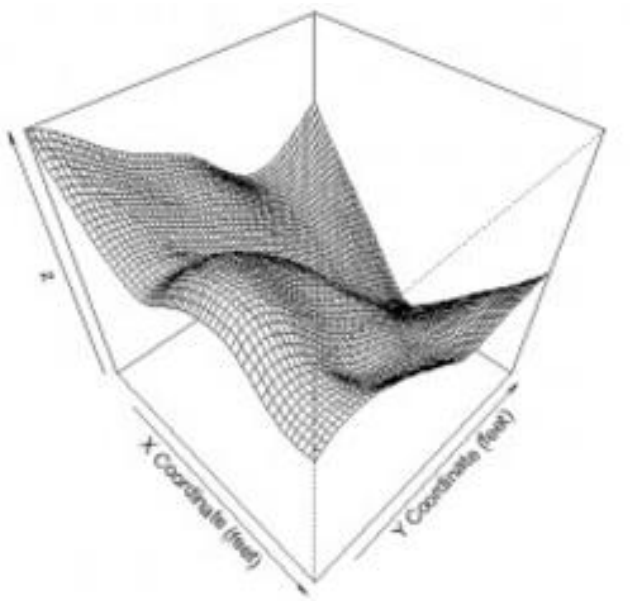
- Often used to visualize a trend in data over intervals of time

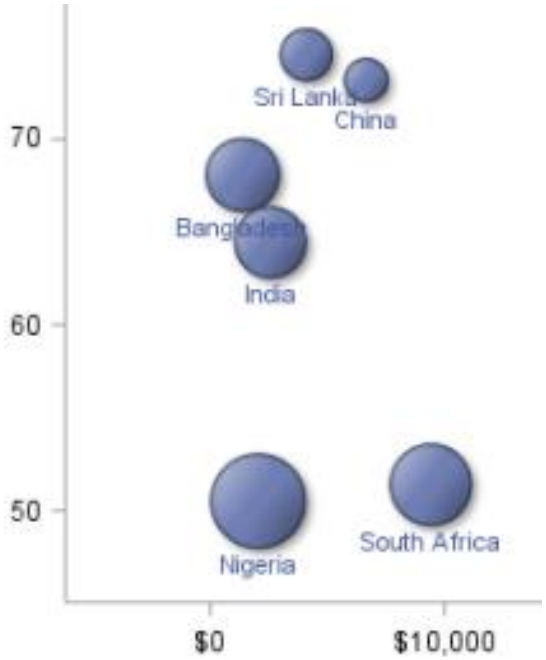


Common Visualization Techniques to represent trivariate data



Trivariate data
- surface plot
- contour plot
- 3D representation
- bubble plot
- …



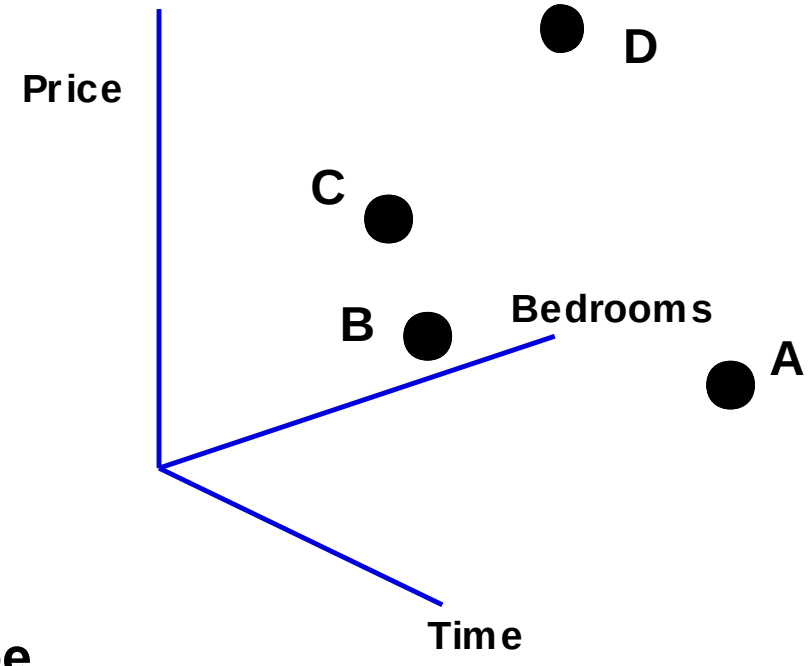


Representing Trivariate data

- Since we live in a 3D world, representing trivariate data as points in a 3D space and displaying a 2D view is natural

- However, these representations of abstract data can be ambiguous

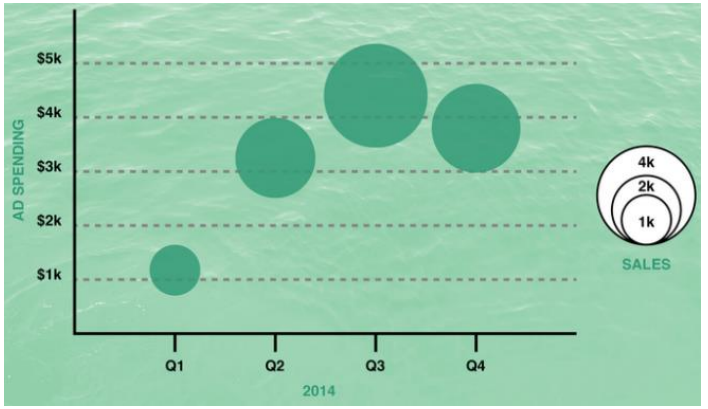
- This can be solved by interaction, allowing the user to reorient the representation



"**for 3D to be useful, you' ve got to be able to move it**" (Spence, 2007)

Other Simple (and common) representations of trivariate data

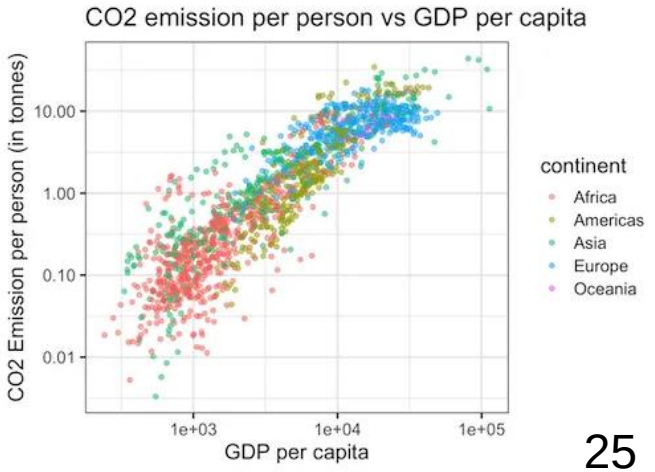
- In a **bubble chart** data are represented as a disk that expresses two of the values through the disk's *xy* location and the third through its size (radius or area?)



- Mapping the variable to size must be done carefully. The interpretation of size may be ambiguous

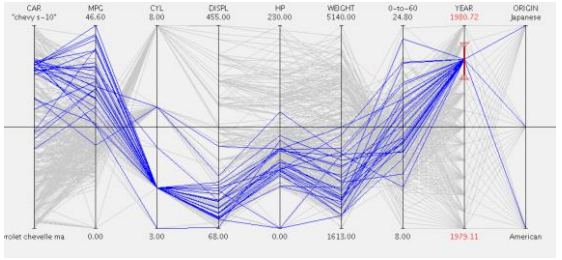
- Representing one more dimension through color

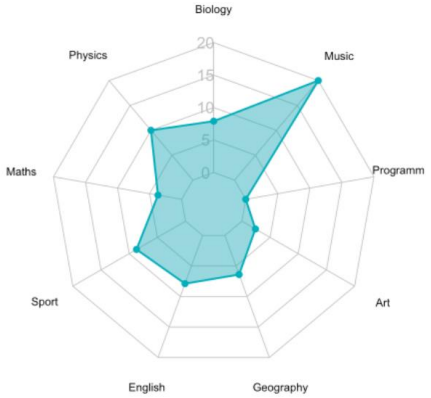
https://visage.co/data-visualization-101-bubble-charts/



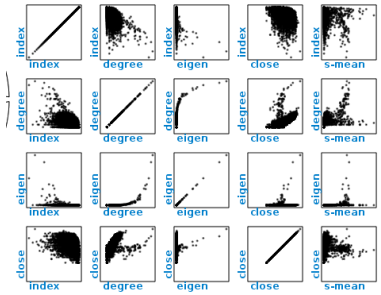
Techniques for Multivariate (or Hypervariate) data

- Coordinate plots
  - parallel coordinate plots
  - star (radar/spider) plots

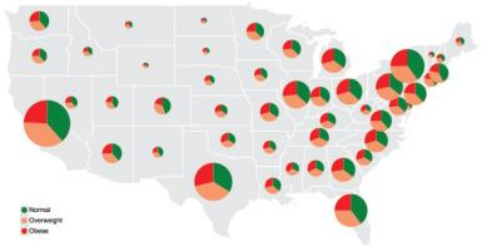




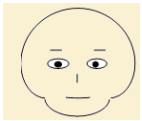
- Scatterplot Matrix



- Maps

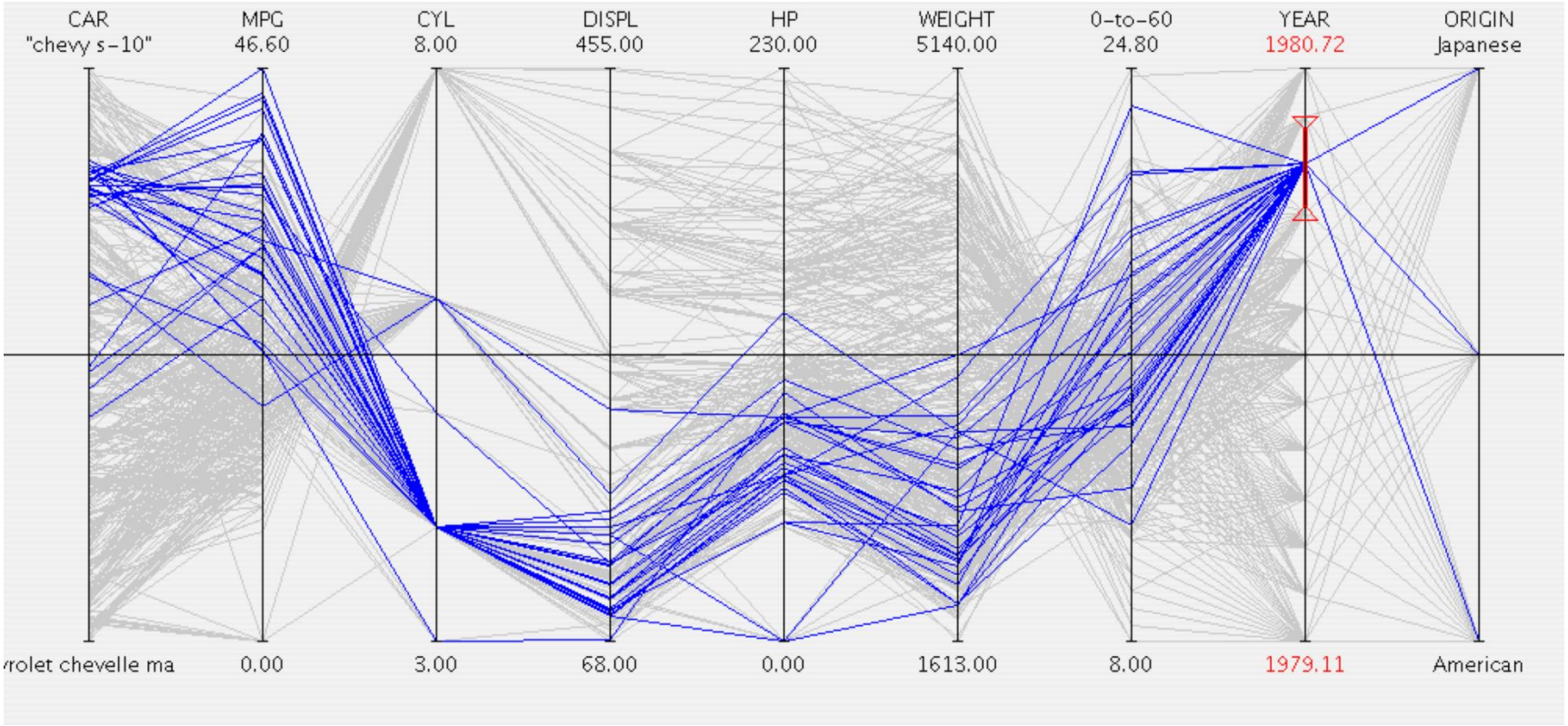


- Icons/glyphs



- **Parallel coordinates plots** are one of the most popular techniques for hypervariate data

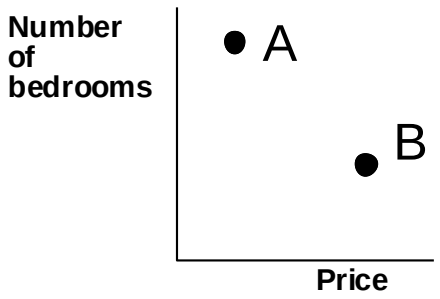
- They have a very simple basis



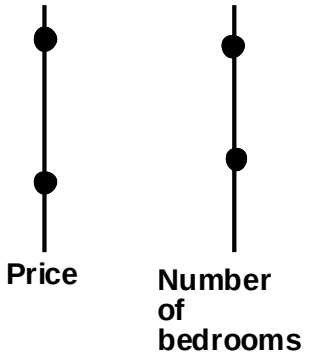
(Spence, 2007)

Consider a simple case of bivariate data:

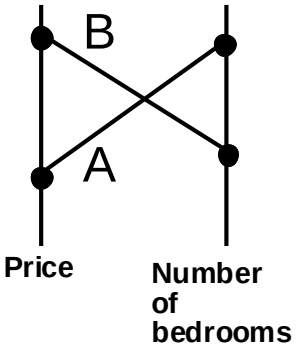
1- A scatterplot represents the price and number of bedrooms associated with two houses



2- the axes are detached and made parallel; each house is represented by a point on each axis

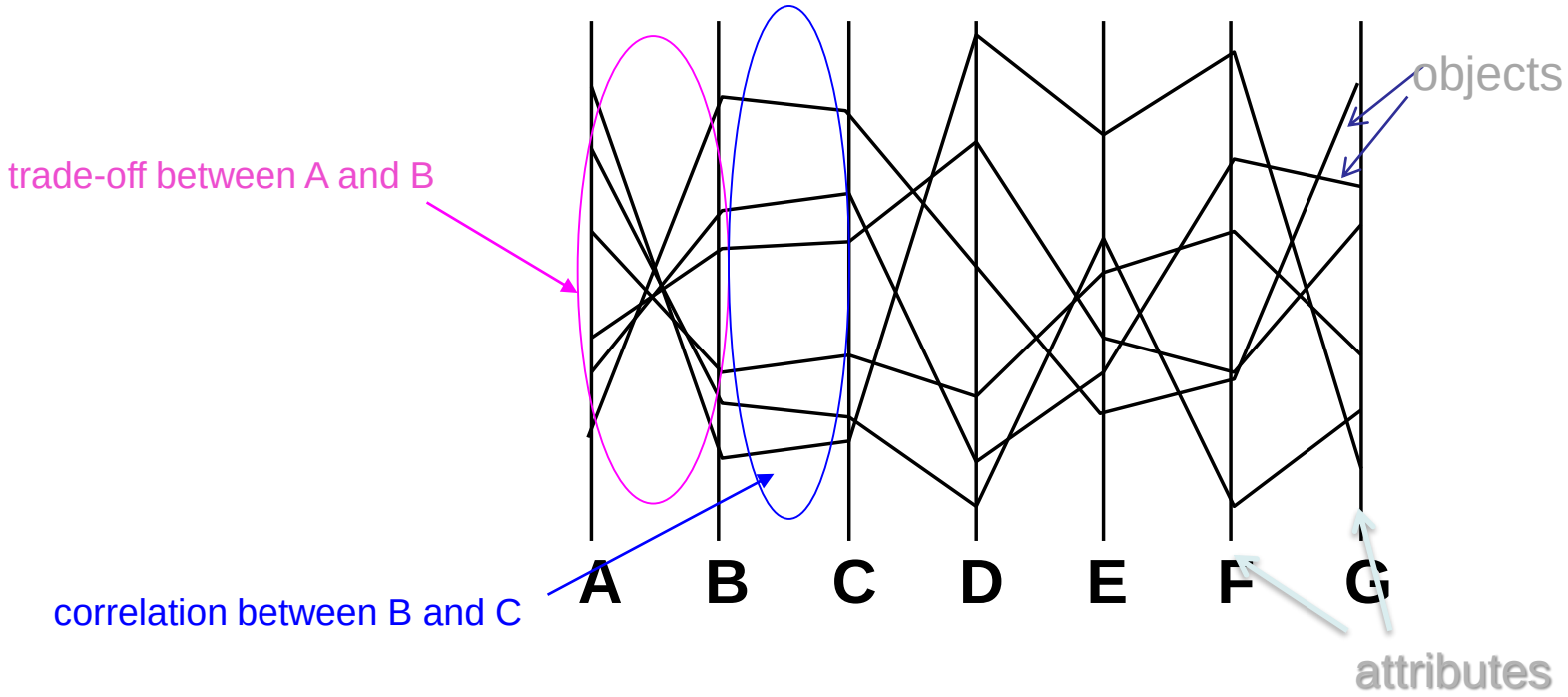


3- To avoid ambiguity the pair of points representing a house are joined and labeled



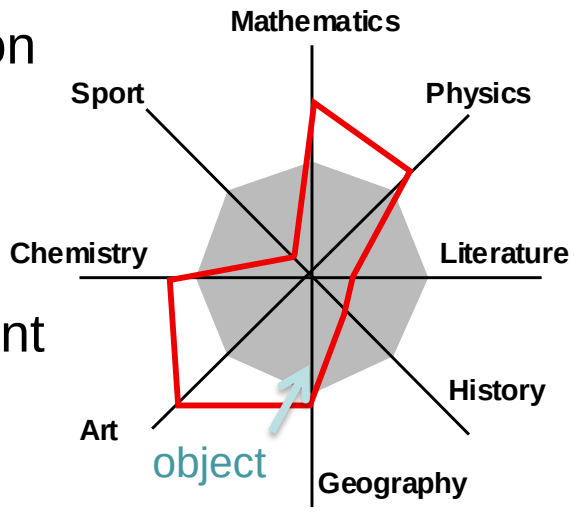
- For objects characterized by many attributes the parallel coordinate plots offer many advantages

A example for six objects, each characterized by seven attributes:



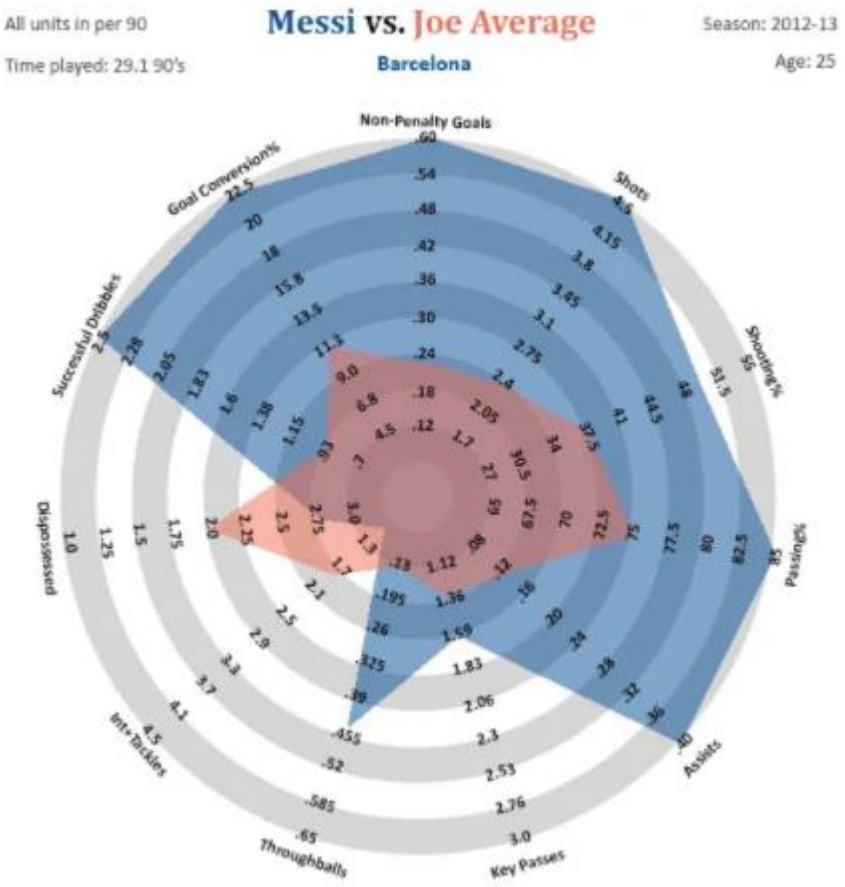
The trade-off between A and B, and the correlation between B and C, are immediately apparent. The trade-off between B and E, and the correlation between C and G, are not.

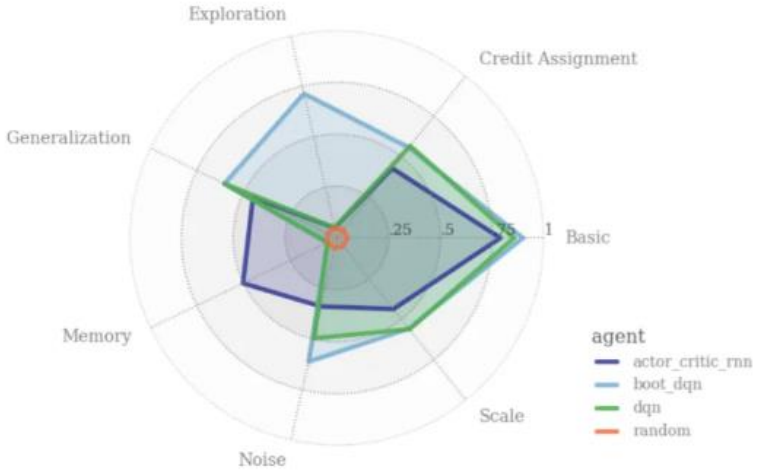
- **Star plots** have many features in common with parallel coordinate plots



(Spence, 2007)

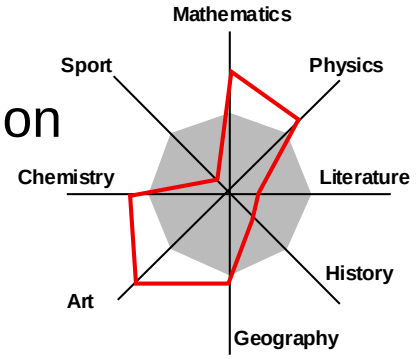
- An attribute value is represented by a point on a coordinate axis
- Attribute axes radiate from a common origin
- For a given object, points are joined by straight lines
- Other useful information such as average values or thresholds can be encoded





https://syncedreview.com/2019/08/16/deepmind-bsuite-evaluates-reinforcement-learning-agents/

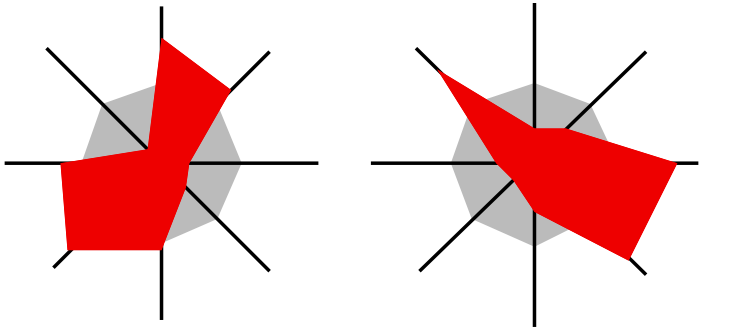
Properties of star plots:



- Their shape can provide a reasonably rapid appreciation of the attributes of the objects

- They offer **object visibility** and are suitable to compare objects

(by visibility it is meant the ability to gain insight pre-attentively; without a great cognitive effort)



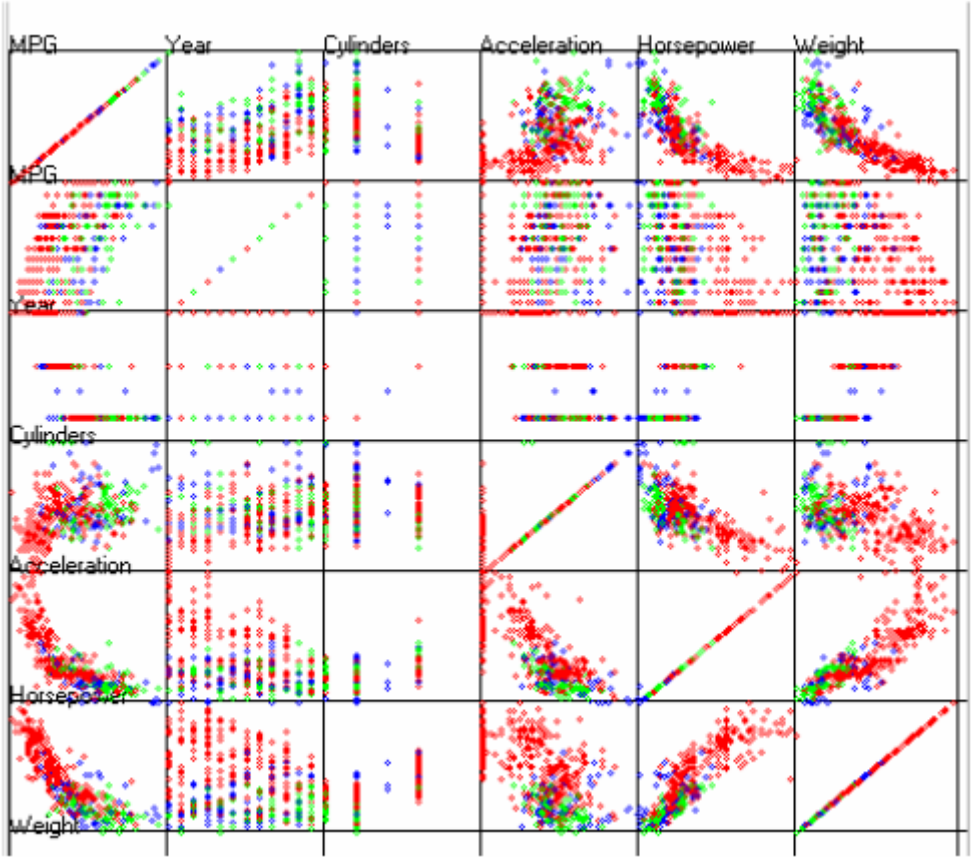
Bob's performance Tony's performance

(Spence, 2007)

- The scatterplot matrix (SPLOM) is applicable to higher n. of variables

- However, as the number of attributes increase, the number of different pairs of attributes increases rapidly:
  - 2 variables-> 1 scatterplot
  - 3 variables -> 3 scatterplots
  - 4 variables -> 6 scatterplots

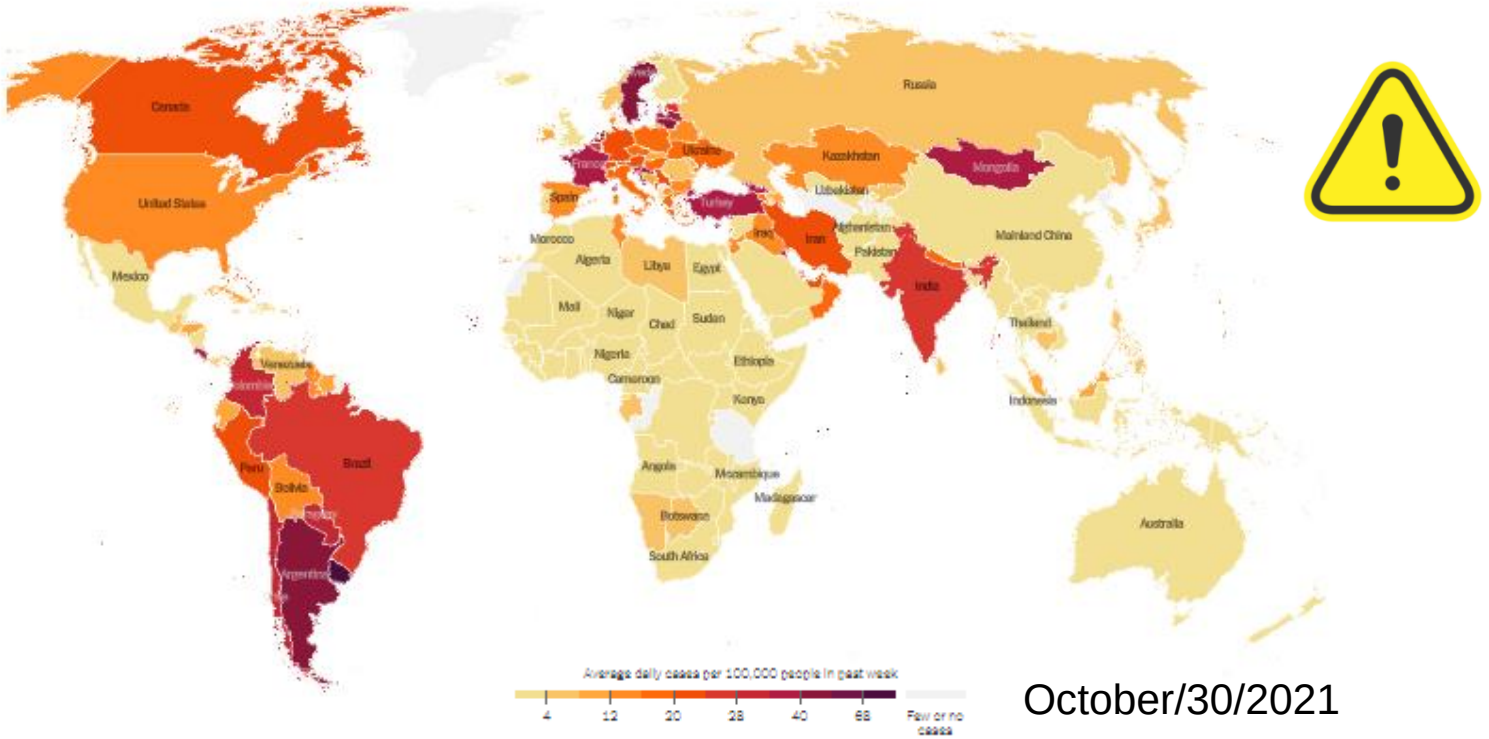
We may try to reduce the number of dimensions keeping the more relevant: **Dimensionality reduction!**



Scatterplot matrix for 6 attributes of a car dataset

Choropleth maps - A standard approach to communicating aggregated data by geographical areas using color encoding of the geographic area

They require some care: what are the possible issues?

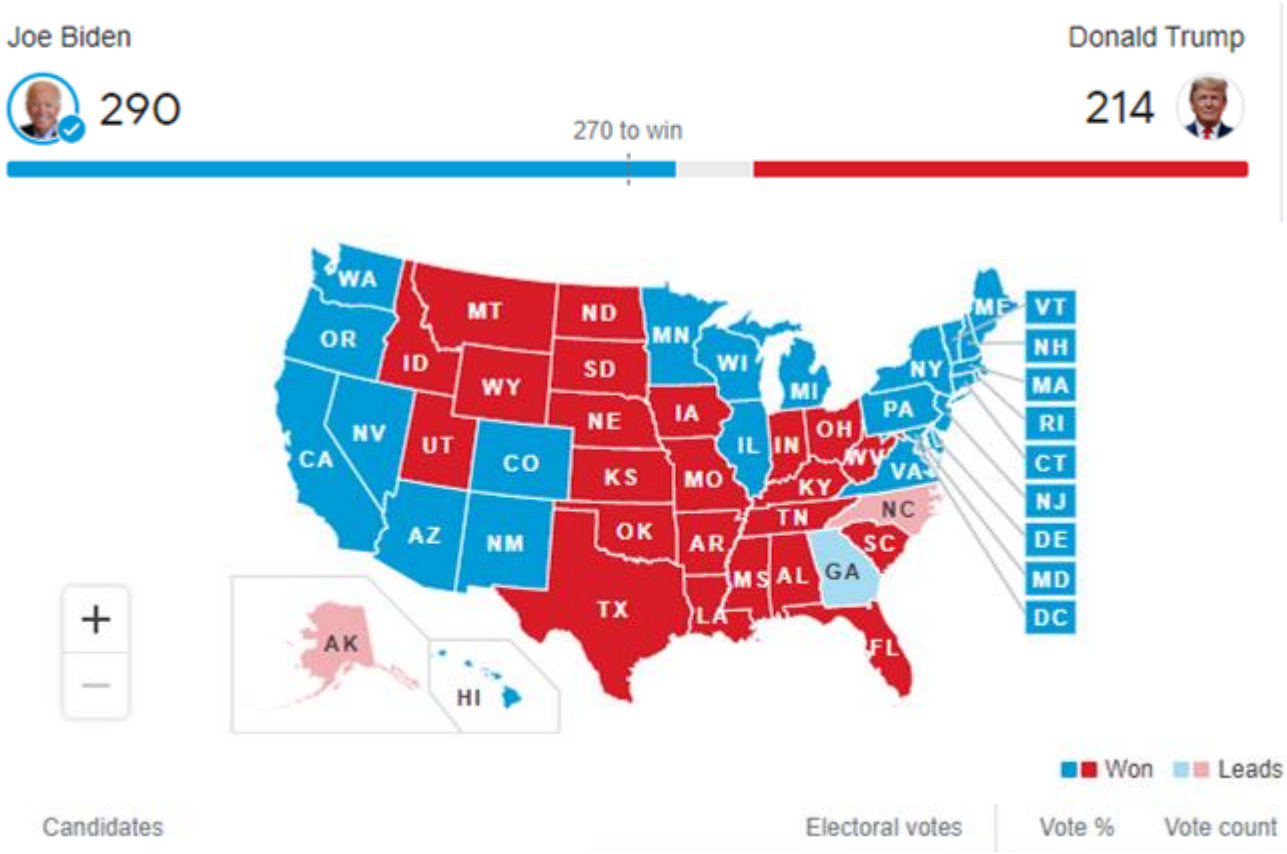


October/30/2021

https://www.nytimes.com/interactive/2020/world/coronavirus-maps.html

Visualizations of the US 2020 Election

(choropleth + bar)
the bar helps better understand the ratio of votes



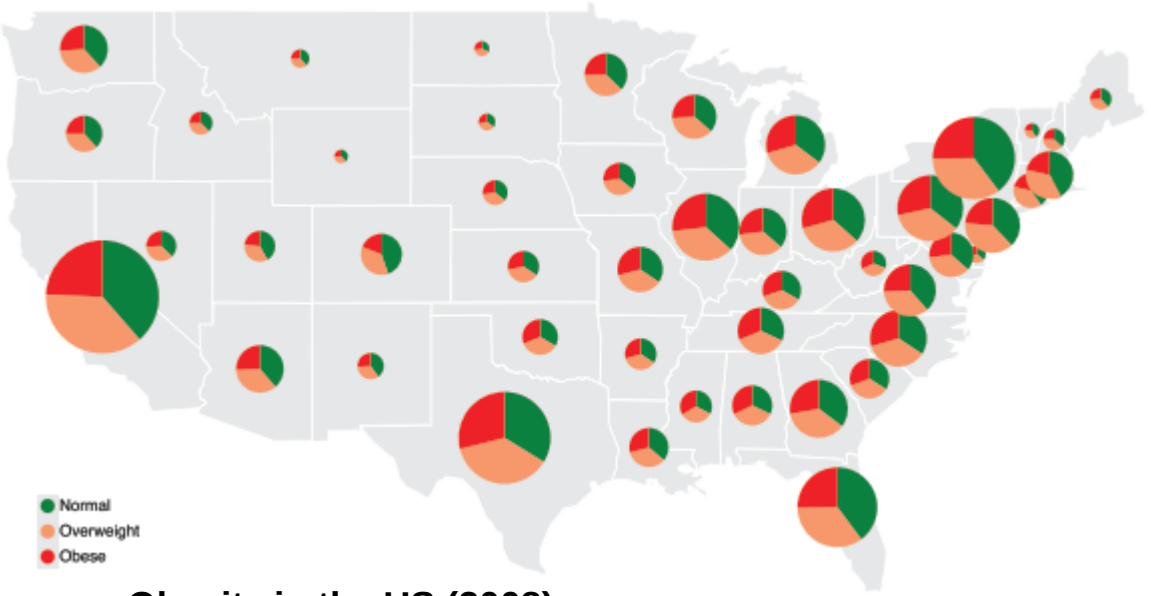
Simple representations of attributes on a map

- Graduated Symbol Maps are an alternative to the choropleth map;

- Symbols are placed over an underlying map; may show more dimensions

- Avoid confounding geographic area with data values

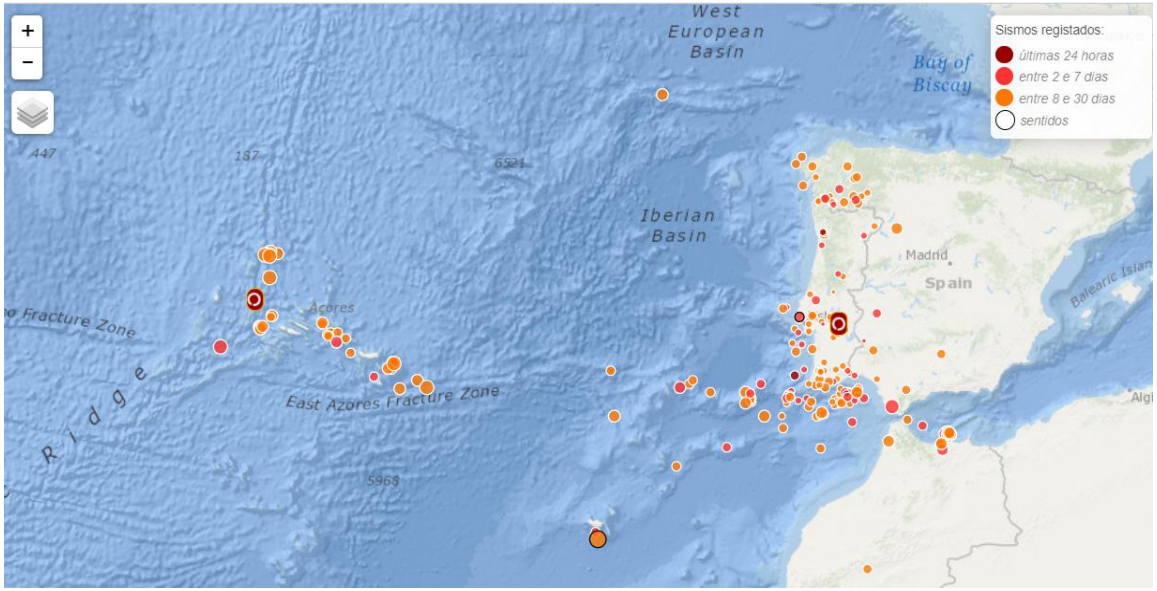
What is missing in this visualization?

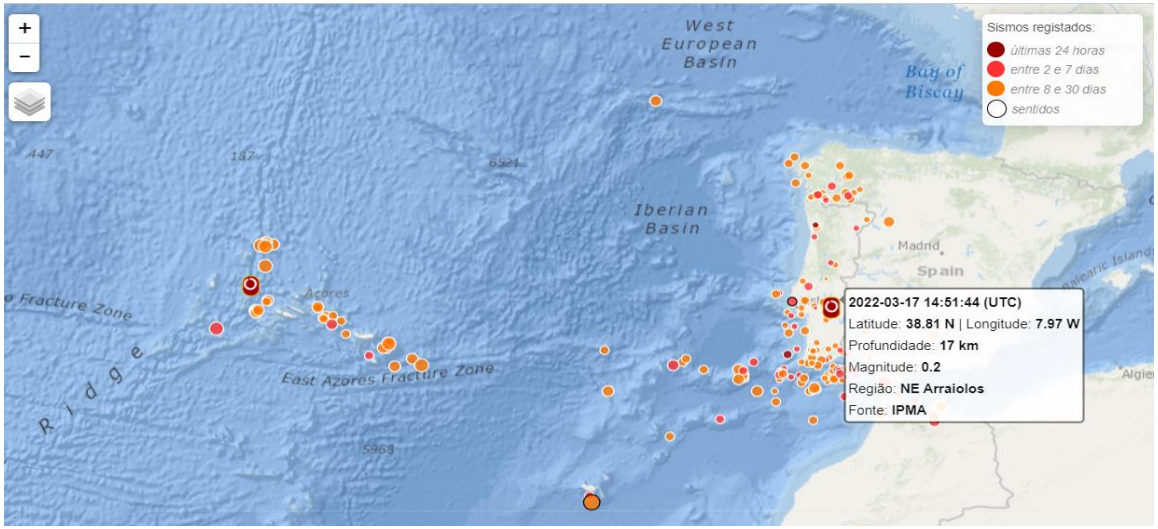


Obesity in the US (2008)
(Heer et al., 2010)

Seismic activity:

Is something missing in this visualization?

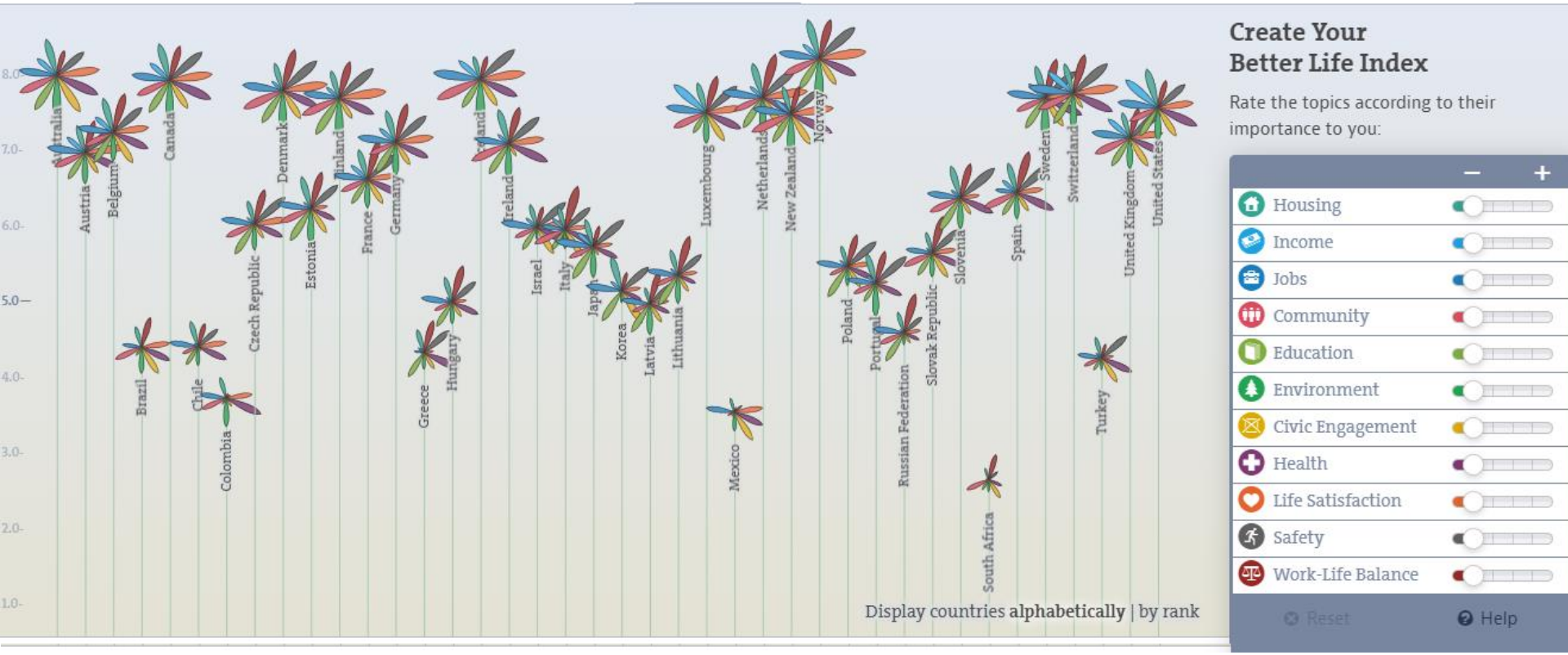




https://www.ipma.pt/pt/geofisica/sismicidade/index.jsp

Glyph chart example

The physical properties of the shape represent different categorical variables sized according to the associated quantitative value and distinguished through color



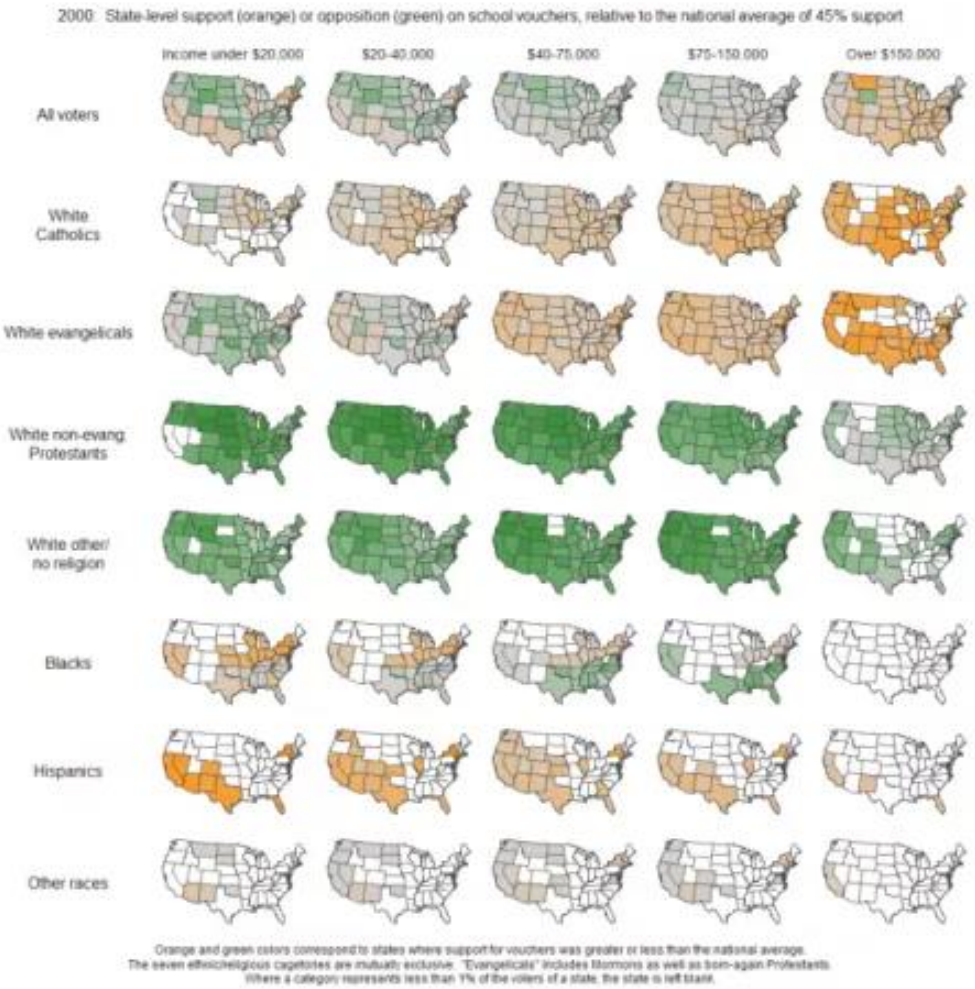
(Kirk, 2012)

http://oecdbetterlifeindex.org

Small multiples:

arrangement approach that facilitates efficient and effective comparisons

(Kirk, 2012)



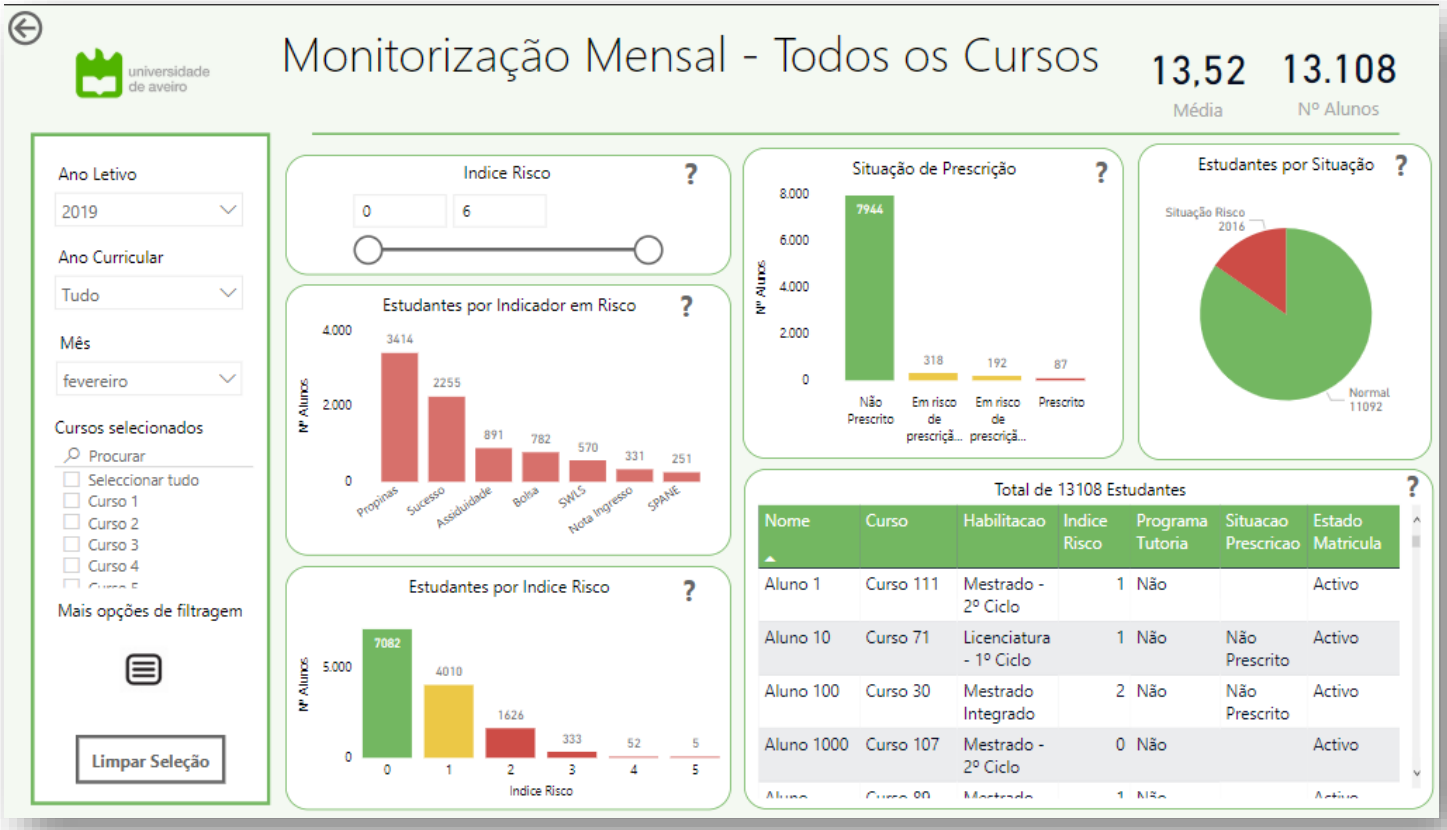
Dashboards

Visual display summarizing a dataset providing information at-a-glance (e.g. KPIs)

" A dashboard is a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance. " (Few, 2004)

https://www.academia.edu/1380138/Information_dashboard_design_The_effective_visual_communication_of_data

Prototype: "Portal dos indicadores, UA"



nature of the problem
- communicate
- explore
- confirm

nature of the data to represent
- quantitative
- ordinal
- categorical

number of attributes
- univariate
- bivariate
- trivariate
- multivariate

Next: visualization techniques organized according the n. of attributes

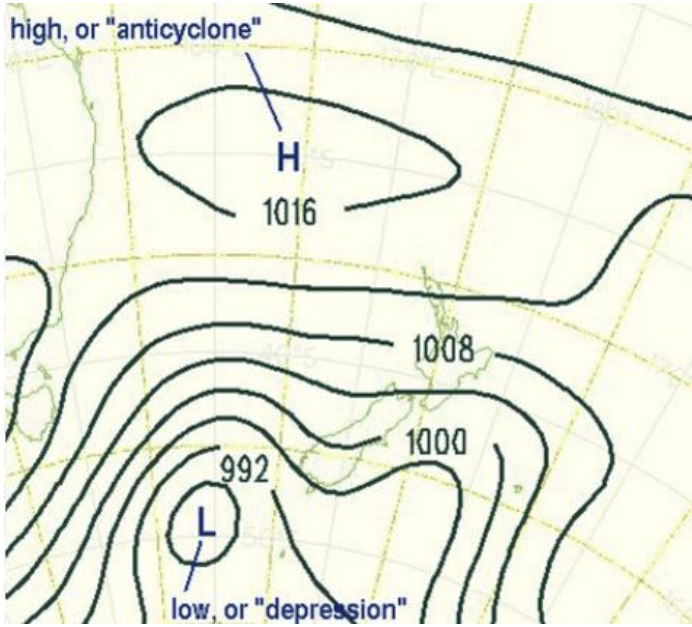
dataset types
- tables
- networks
- spatial or geographical
- fields
- geometry

of field and geometry data

…

Representations of a scalar in a 2D field

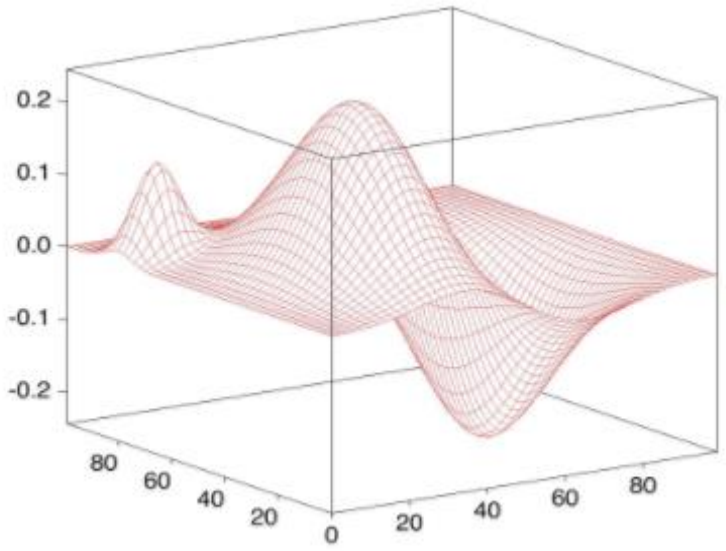
- Contour plots
- **contour line** (also **isoline**, **isopleth**, or **equipotential curve**) of a function of two variables is a curve along which the function has a constant value, so that the curve joins points of equal value.
- Typical in meteorological charts (isobars and isothermal curves)
- and maps (to represent altitude or depth)

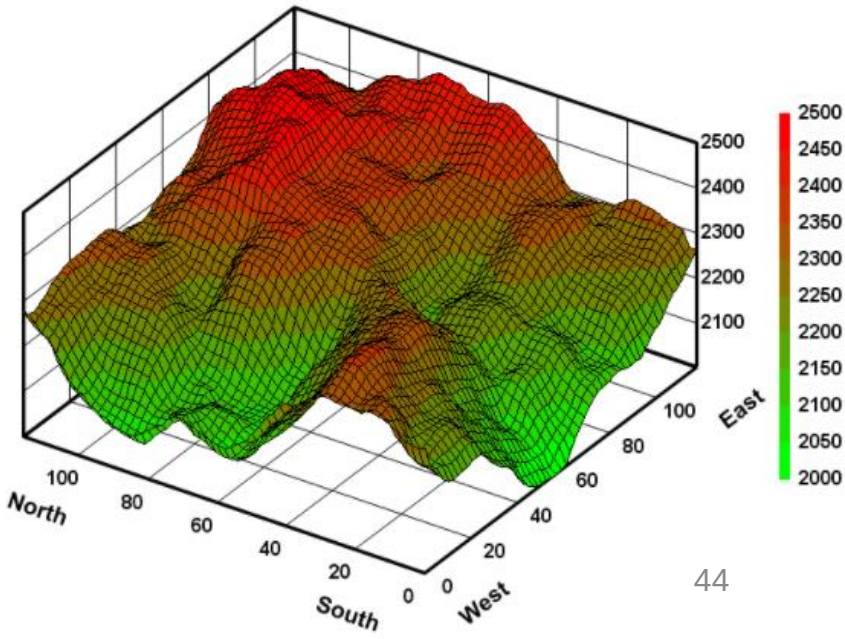


Representations of a 3D scalar function

- Surface plots
- May be combined with color

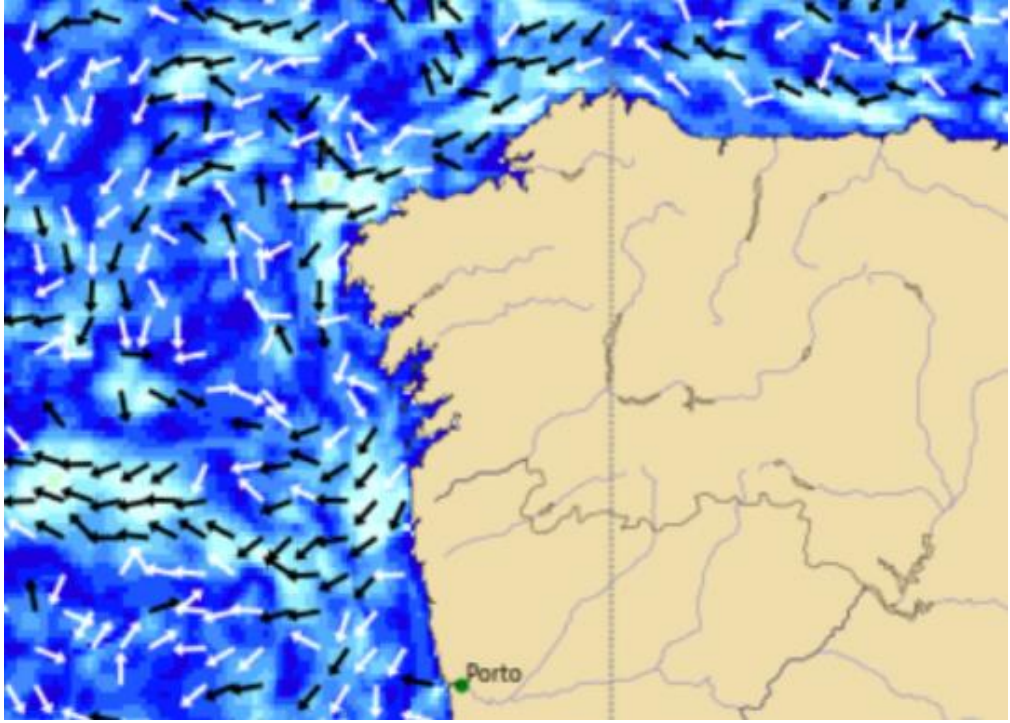
(preferably in a redundant way and carefully selecting the scale)



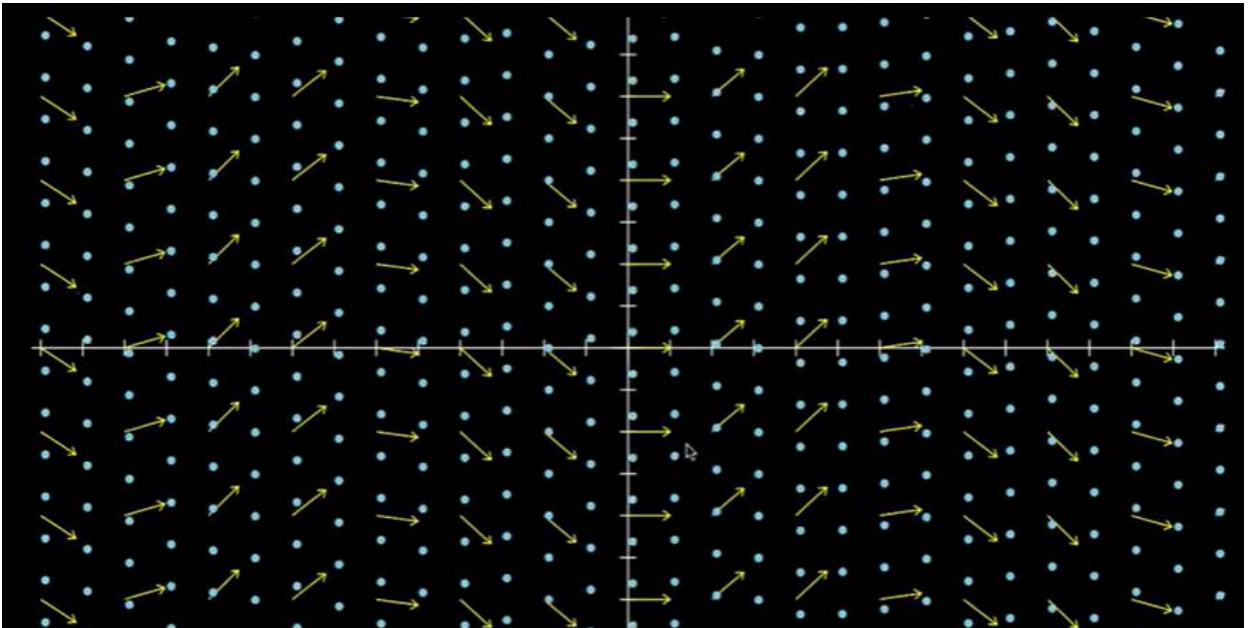


Representations of vectors in a 2D field

- Representing sea currents at the surface



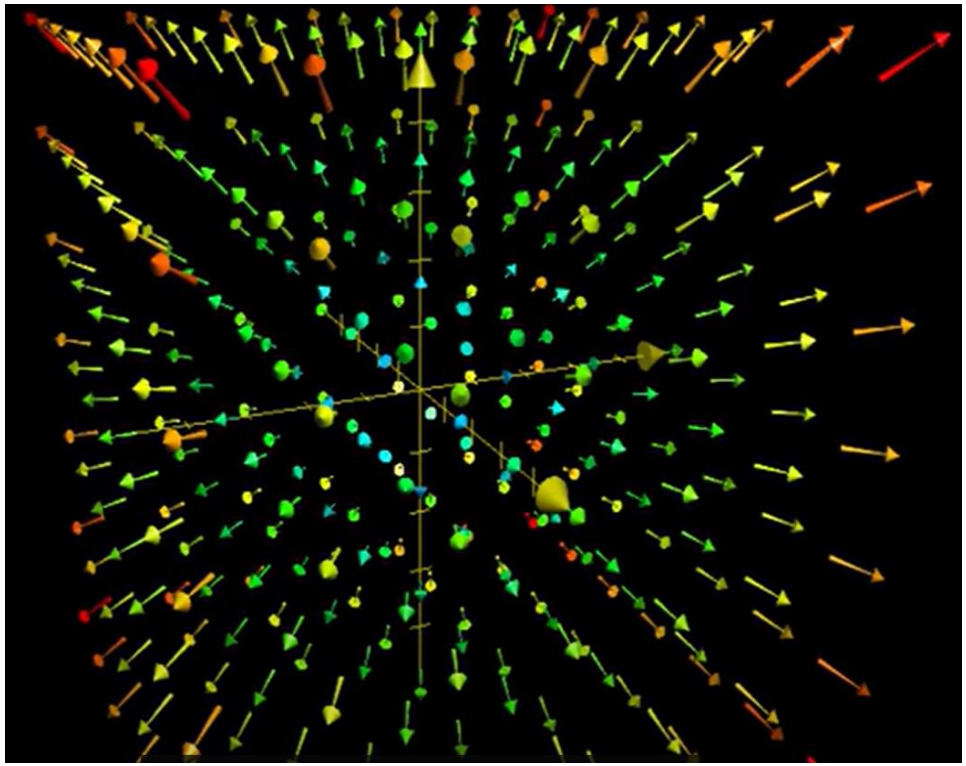
https://www.ipma.pt/pt/maritima/currents/



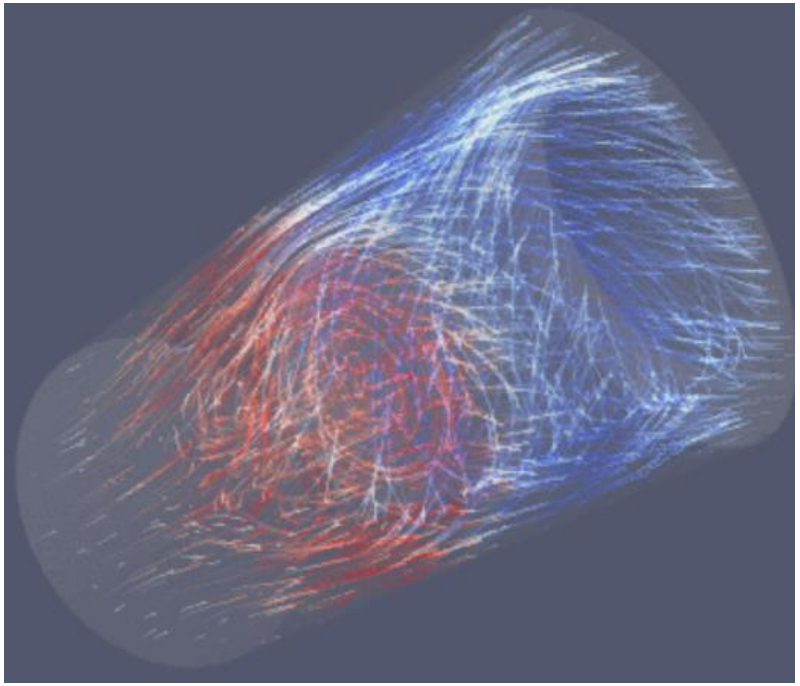
https://www.khanacademy.org/math/multivariable-calculus/thinking-about-multivariable-function/visualizing-vector-valued-functions/v/fluid-flow-and-vector-fields

Representations of vectors in a 3D field

Vector data visualization: in 3D space a vector variable is visualized



Stream Lines are another interesting representation

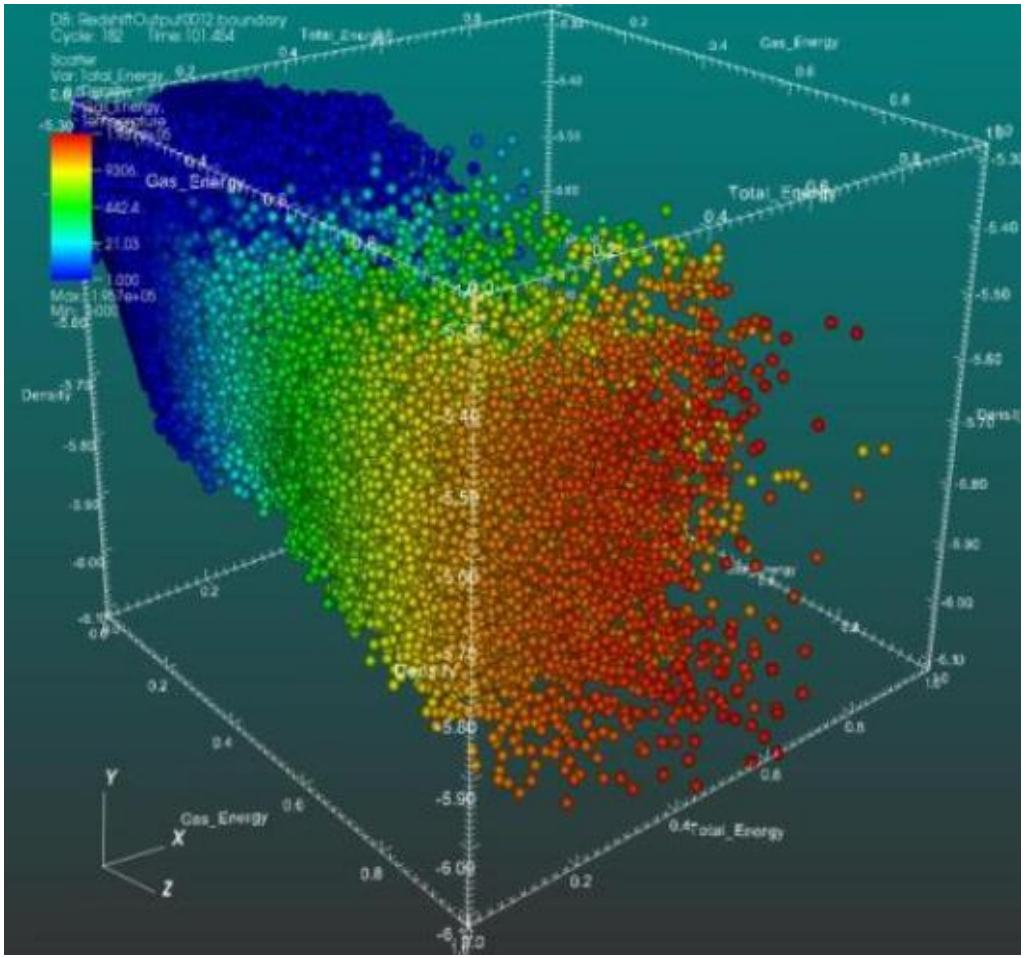


https://www.khanacademy.org/math/multivariable-calculus/thinking-about-multivariable-function/visualizing-vector-valued-functions/v/3d-vector-field-example

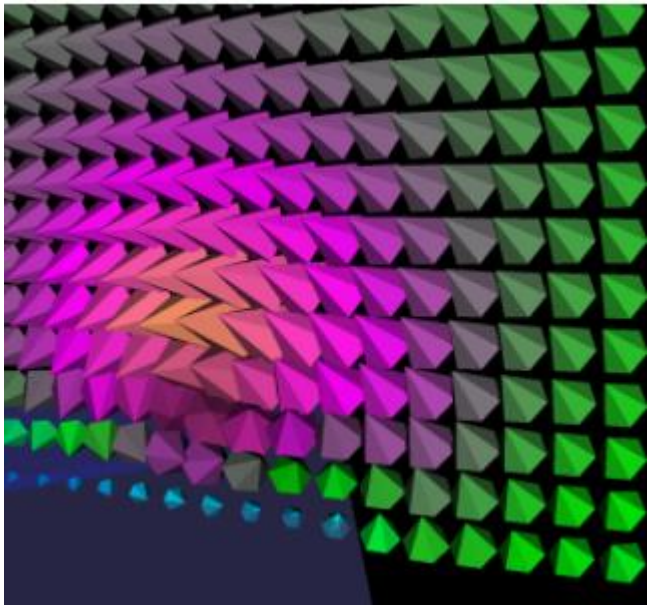
https://www.kitware.com/new-animated-stream-lines-representation-for-paraview-5-3/

Glyphs

Four-dimensional data visualization: in 3D space a fourth scalar variable is visualized using colored glyphs

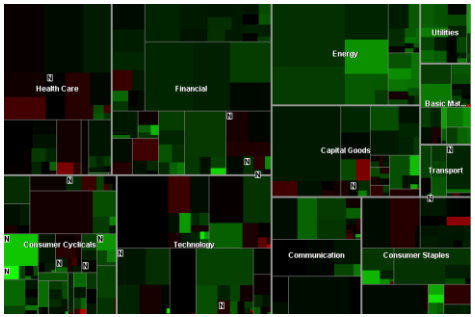


Glyphs for Visualizing a 3D Vector Field

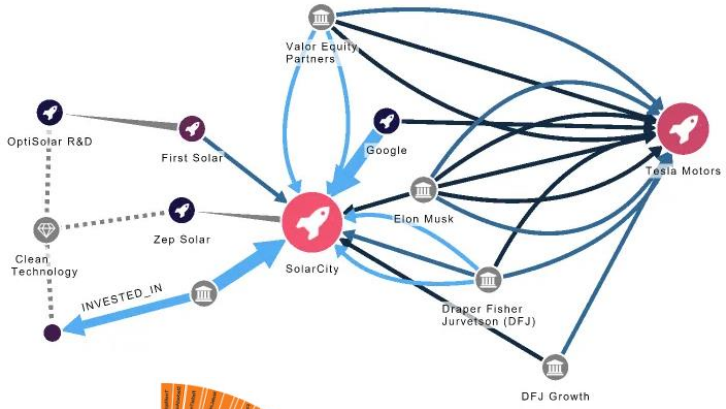


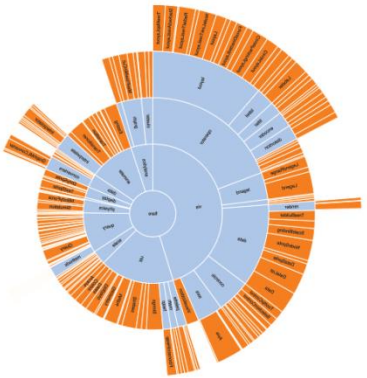
(Wikipedia/Glyph)

- These are only some of the visualization techniques to represent a value
- There are a lot more …
- And we may want to visually represent beyond value: relation
  - Networks
  - Hierarchical data



https://www.nngroup.com/articles/treemap/





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