Scientific and Large Data Visualization
19 October 2018
Information Visualization Basics

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InfoVis – Next Lessons

- Information Visualization – Introduction and Motivations
- Data Types, Graph Types and Visual Perception
- Visualization in Python
- Multidimensional Data
- Time Series
- Graph Drawing
- Practice
  - D3.js

InfoVis – Basics

- Introduction and motivations
- Ingredients of effective visualization
- Data types
- Graph types
- Visual perception

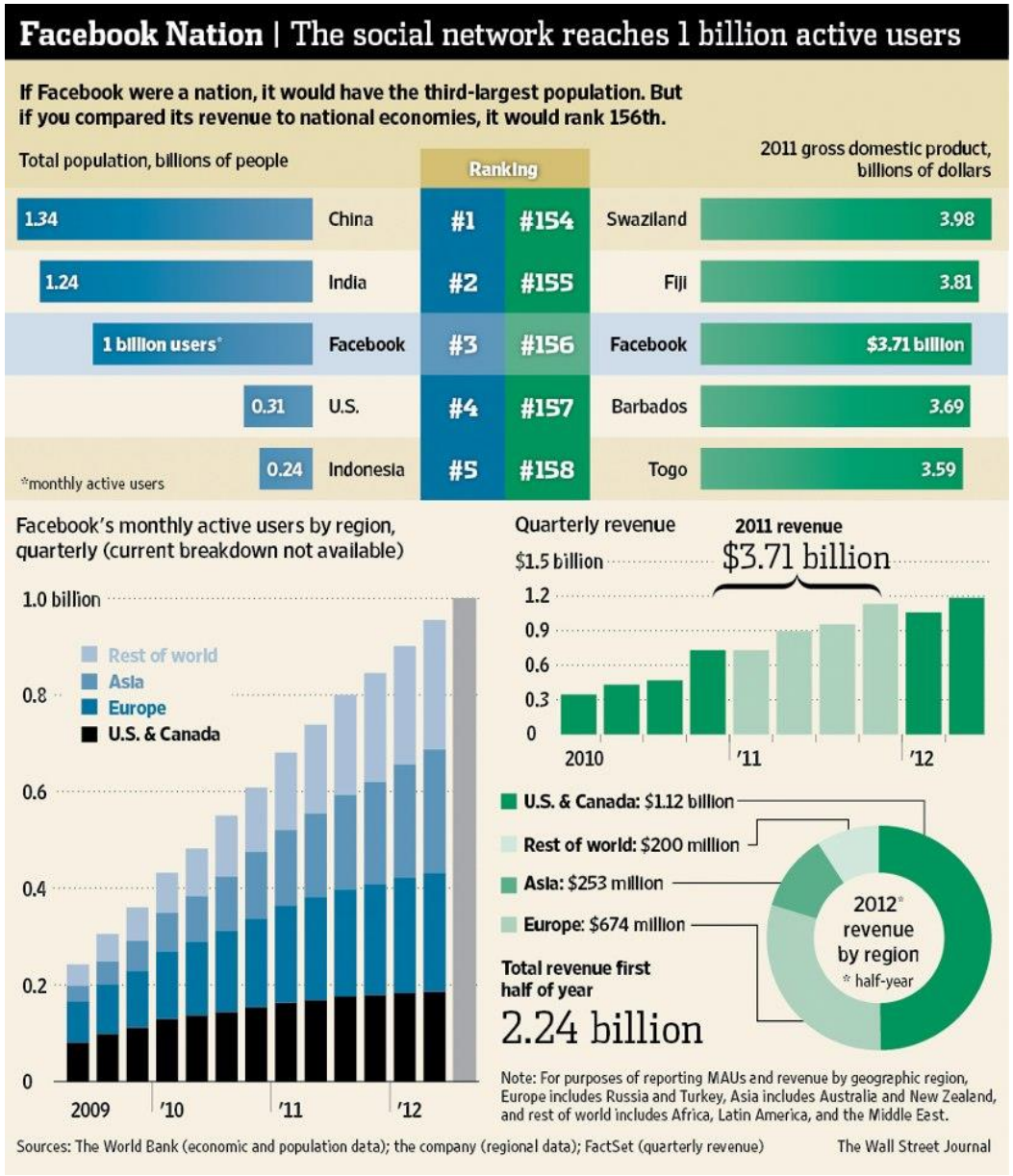
Information Visualization

- Information visualization is the study of (interactive) visual representations of abstract data to reinforce human cognition. [Wikipedia]
- The use of computer-supported, interactive, visual representations of abstract data to amplify cognition. [Card et al. 1999]
- The use of computer graphics and interaction to assist humans in solving problems. [Purchase et al. 2008]

Information Visualization

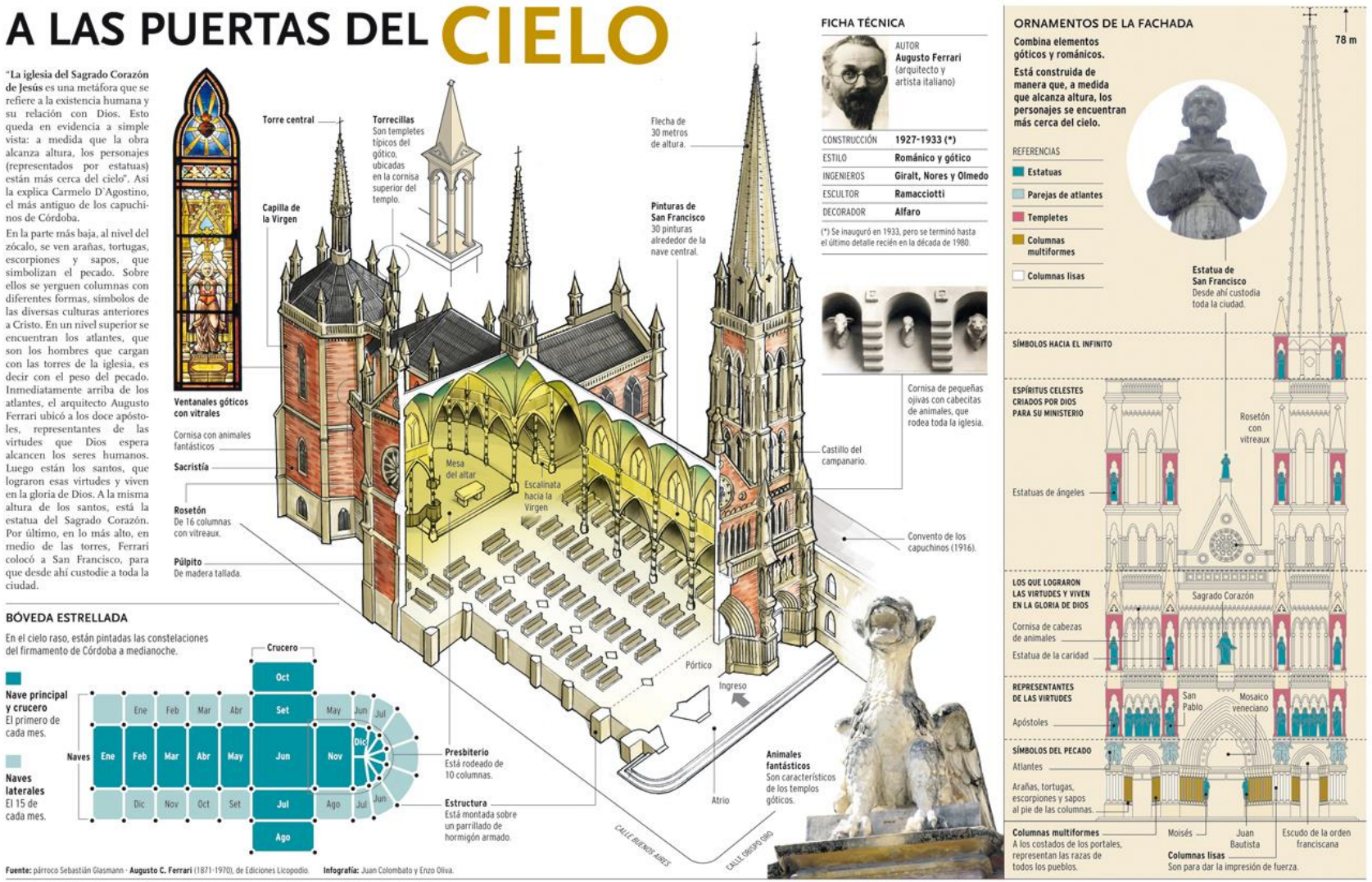
- The purpose of information visualization is to amplify cognitive performance, not just to create interesting pictures. [Card 2007]
- *Infographics* is a visual tool for communication, for the understanding and for the analysis. [Alberto Cairo]

InfoGraphics – Charts



From the Wall Street Journal

InfoGraphics – Diagrams

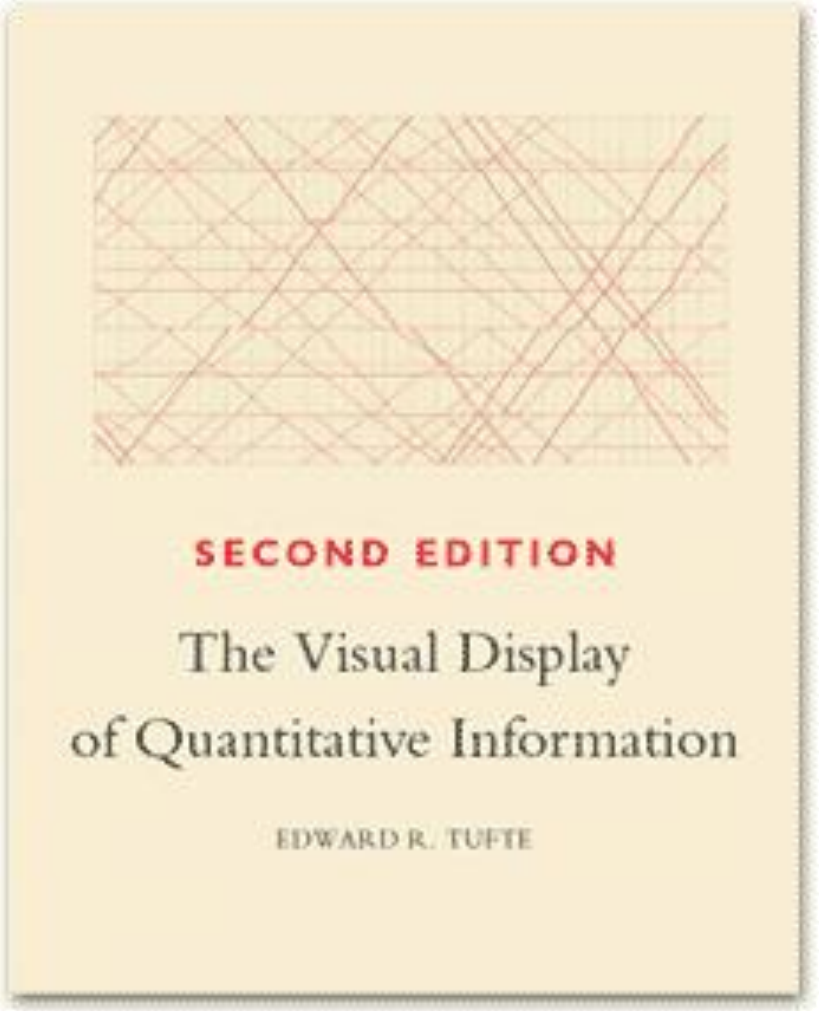


Juan Colombata & Enzo Oliva – La Voz del Interior (Argentina)

Information Visualization

- Difference from *Scientific Visualization:*
  - Information visualization treats also abstract data (numerical and non-numerical data).
  - In scientific visualization spatial representation is given.
- Difference from *Visual Analytics:*
  - In Visual Analytics the accent is on the reasoning/interaction loop.

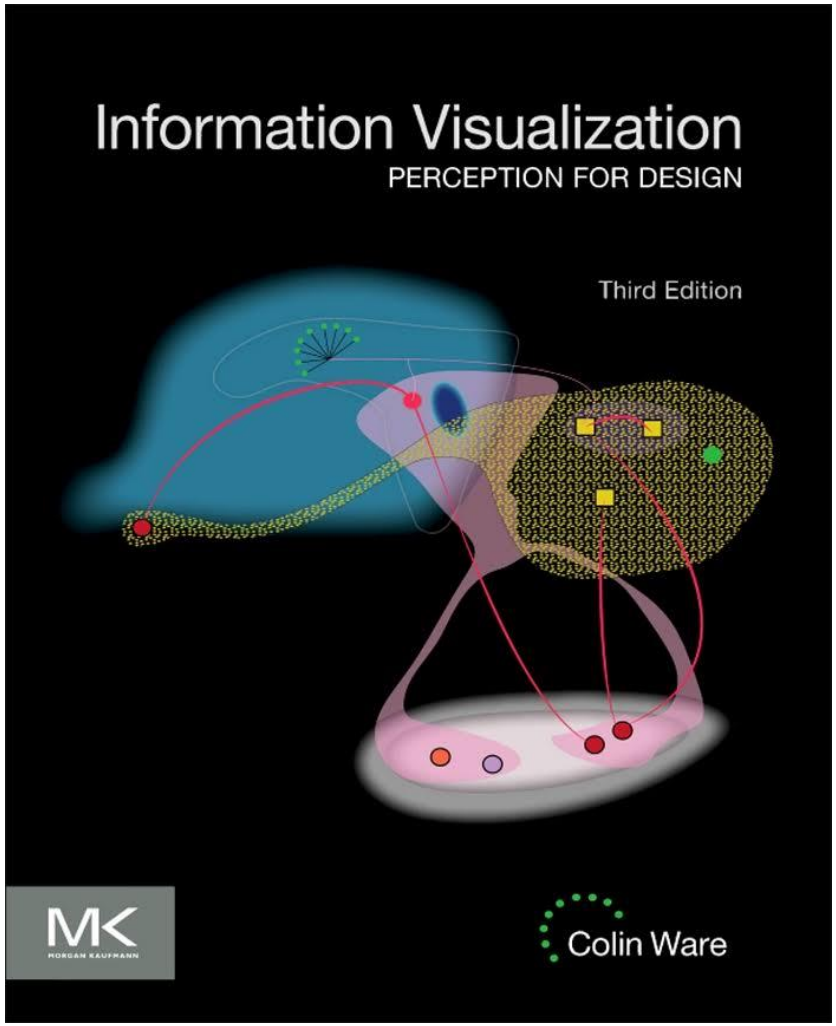
Data Visualization



A classic book on statistical graphics, charts, tables. Theory and practice in the design of graphics to visualize data.

Very practical, very classic.

Information Visualization

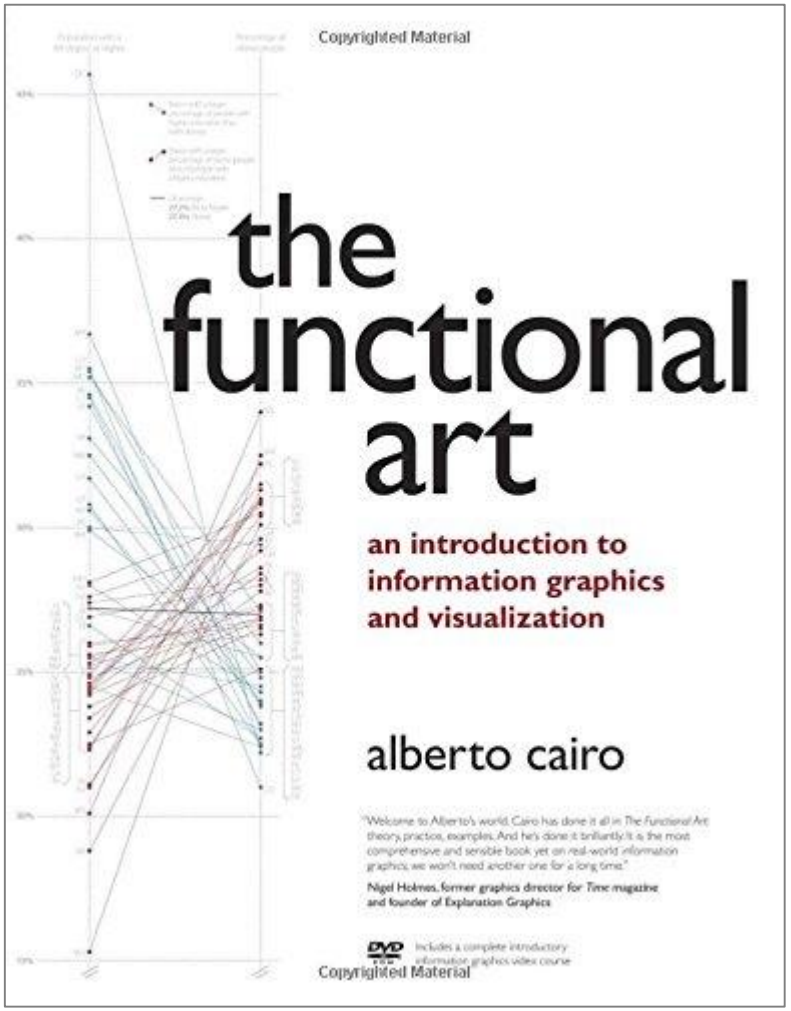


A very interesting aspect:

why we need to consider visualization as a *SCIENCE*

Functional Art

- Function does not *dictate* but *restrict* our choices.
- This is particularly true for infographics.



Motivations

Unemployment rate (%)

	CURRENT	Historical maximum	Historical minimum
Alabama	6.7	14.4	3.3
Alaska	7.5	11.5	5.9
Arizona	6.9	11.5	3.6
Arkansas	6.2	10.2	4.1
California	9.3	11.0	4.7
Colorado	6.1	9.1	2.5
Connecticut	7.1	10.0	2.1
Delaware	6.1	8.2	2.9
Florida	8.1	9.7	3.3

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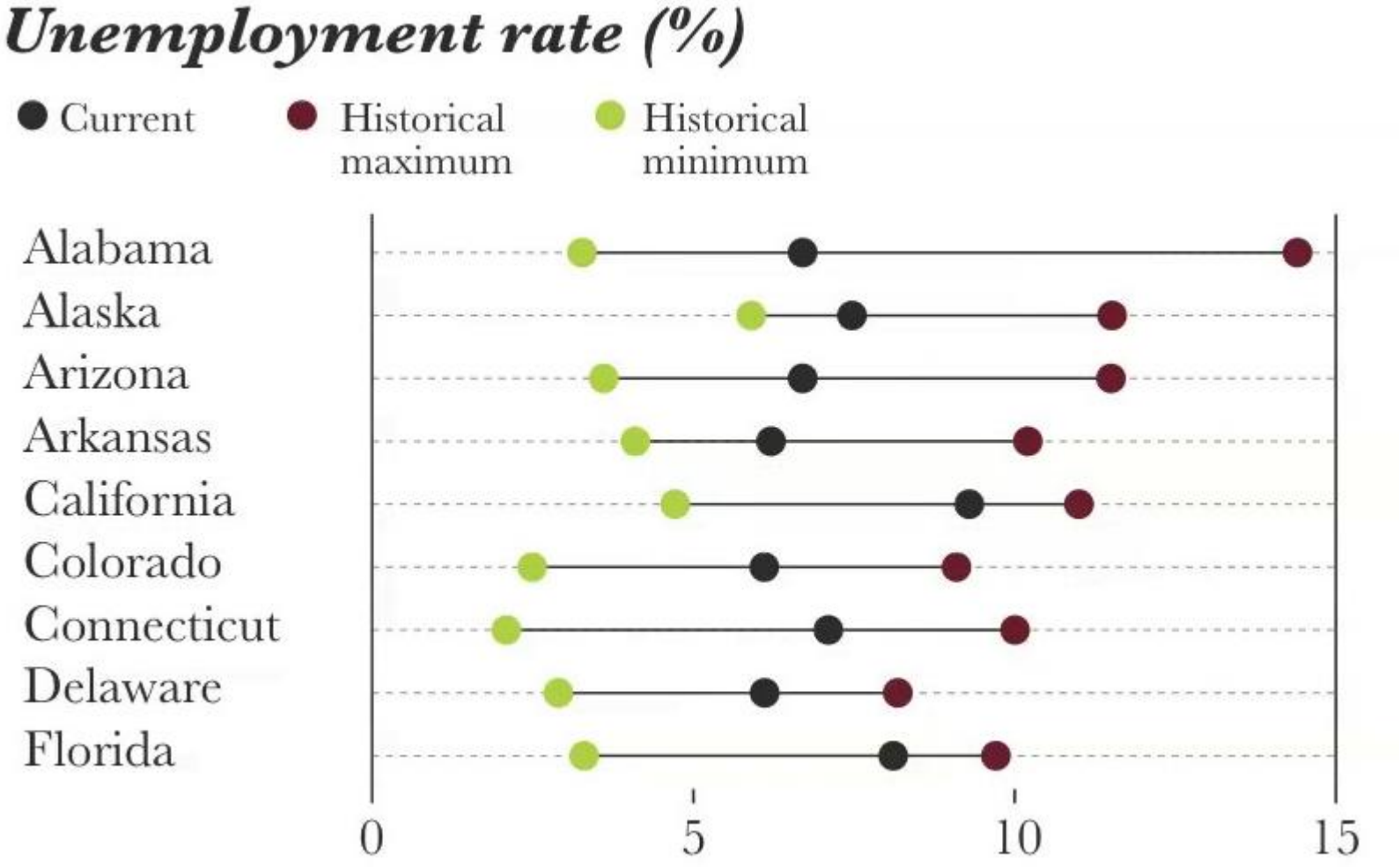
Which country is close to its historical maximum ?

Motivations



Easier to answer… Why ?

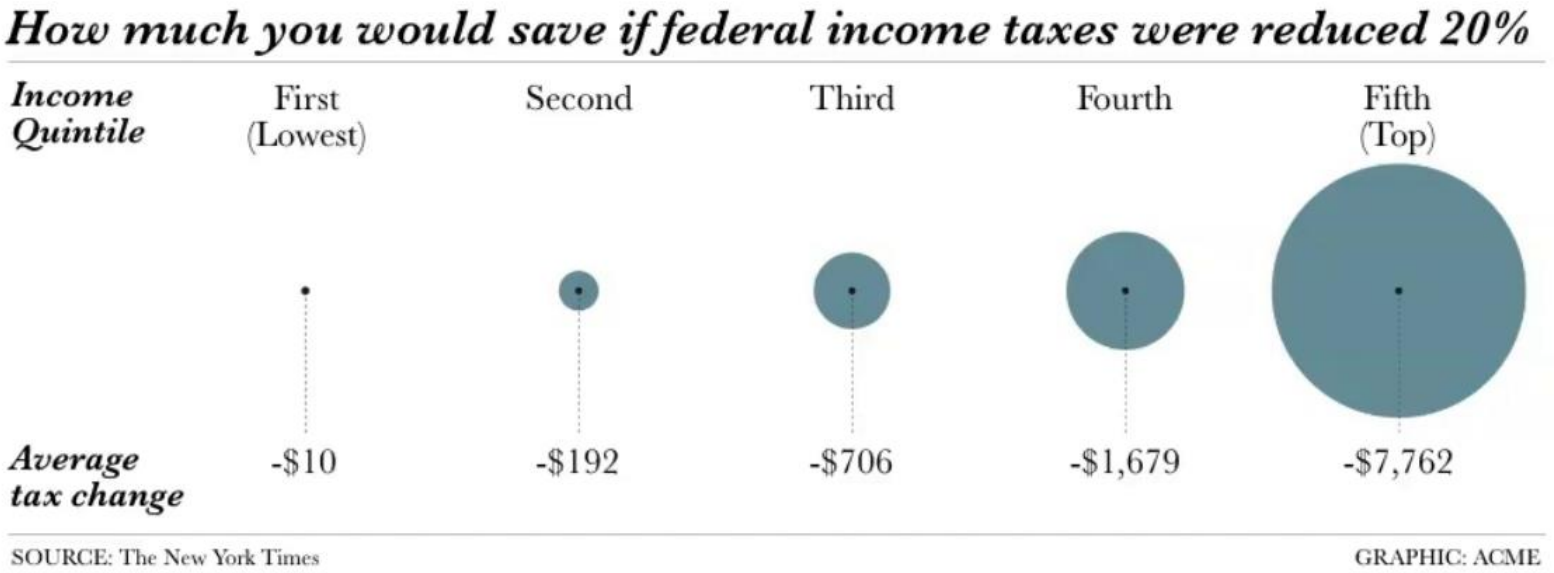
Rationale

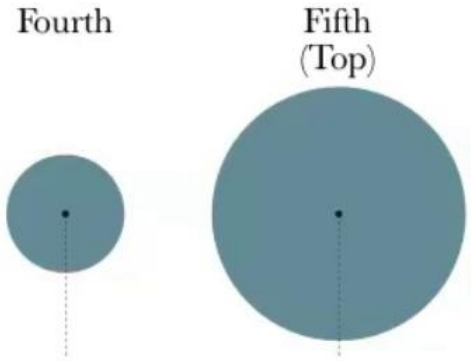
- The human visual system (HVS) is very good at identifies and analyzes patterns.
- We can visualize data to make easy for our brain to analyze them, for example to do comparisons.

Effectiveness

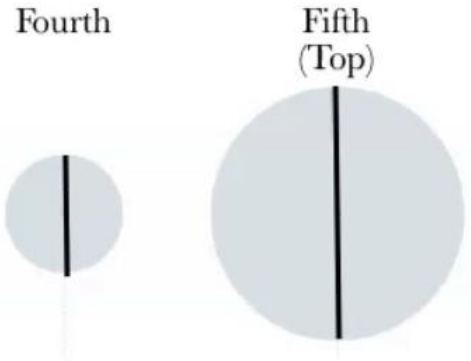
- To be effective, data visualization should be taken into account several factors:
  - Data type
  - Goal (function)
  - Visual Perception System

Example – Comparisons





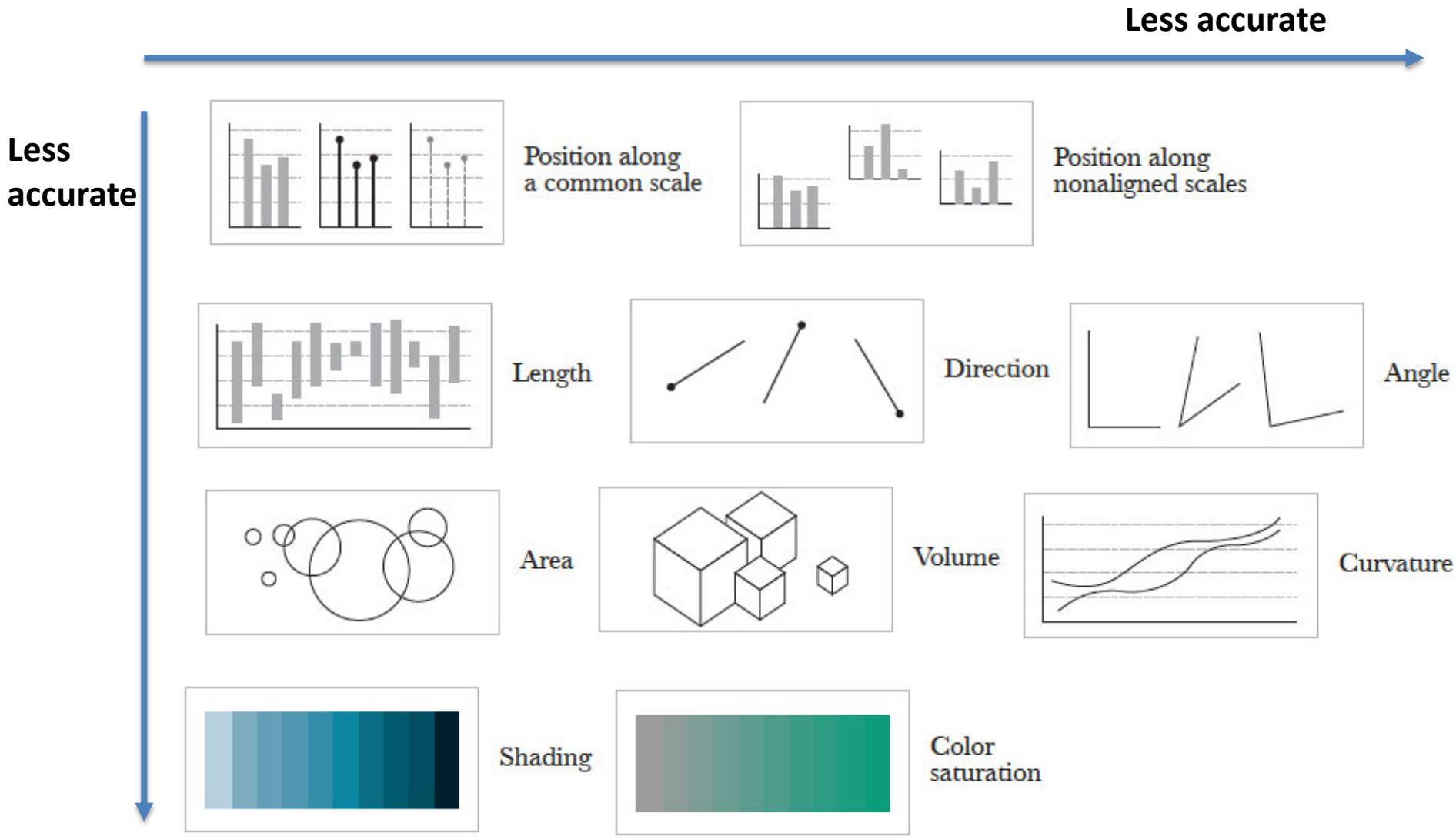
You want readers to compare areas



But they will tend to compare the diameters

From *"The functional art"* by Alberto Cairo

Cleveland and McGill 1984



Adapted from *"The functional art"* by Alberto Cairo

Key Ingredients

- In the following we focus on:
  - Data types
    - One dimension, two dimensions, N-dimensions
    - Quantitative, Ordinal, Nominal
  - Graph types
  - Visual Perception
- We give some design guidelines time by time.

Data

- Information is obtained from data (!)
- Structured / Unstructured.
- Generated by sensors, by computers, by humans, etc.

Variable Types

- According to Stevens (1946):
  - Nominal
    - Labels (e.g. apples, oranges, bananas)
  - Ordinal
    - To ordering things (e.g. ranks of movies)
  - Interval
    - Interval scale of measurements (e.g. time of departure-arrival)
  - Ratio
    - Measures defined on a ratio scale (e.g. the mass of an object)

S. S. Stevens, *"On the theory of scales and measurements."*, Science, 103, pp. 677-680, 1946.

Variable Types

- Category
  - Steven's nominal class (e.g. country names, type of disease)
- Ordinal
  - Labels expressing degree (e.g. cold, hot, very hot)
  - In general, encoded as integer data.
- Quantitative
  - Intervals, measures, etc.
  - In general, real-numbered data.

Data Dimensions

- Common dimensions:
  - Univariate, bivariate, trivariate
  - Multi-variate (N>3 dimensions)
- Variables can be dependent or independent.
- Each case is a point in a space with *N* dimension (*data point*).

Data Dimensions

- A set of data can be represented by a table with N columns (one for each variable).

	Variable 1	Variable 2	Variable 3
Data 1			
Data 2			
Data 3			
Data 4			
…			

Data Relationships

- A table can be used to represent a relationship between different data.

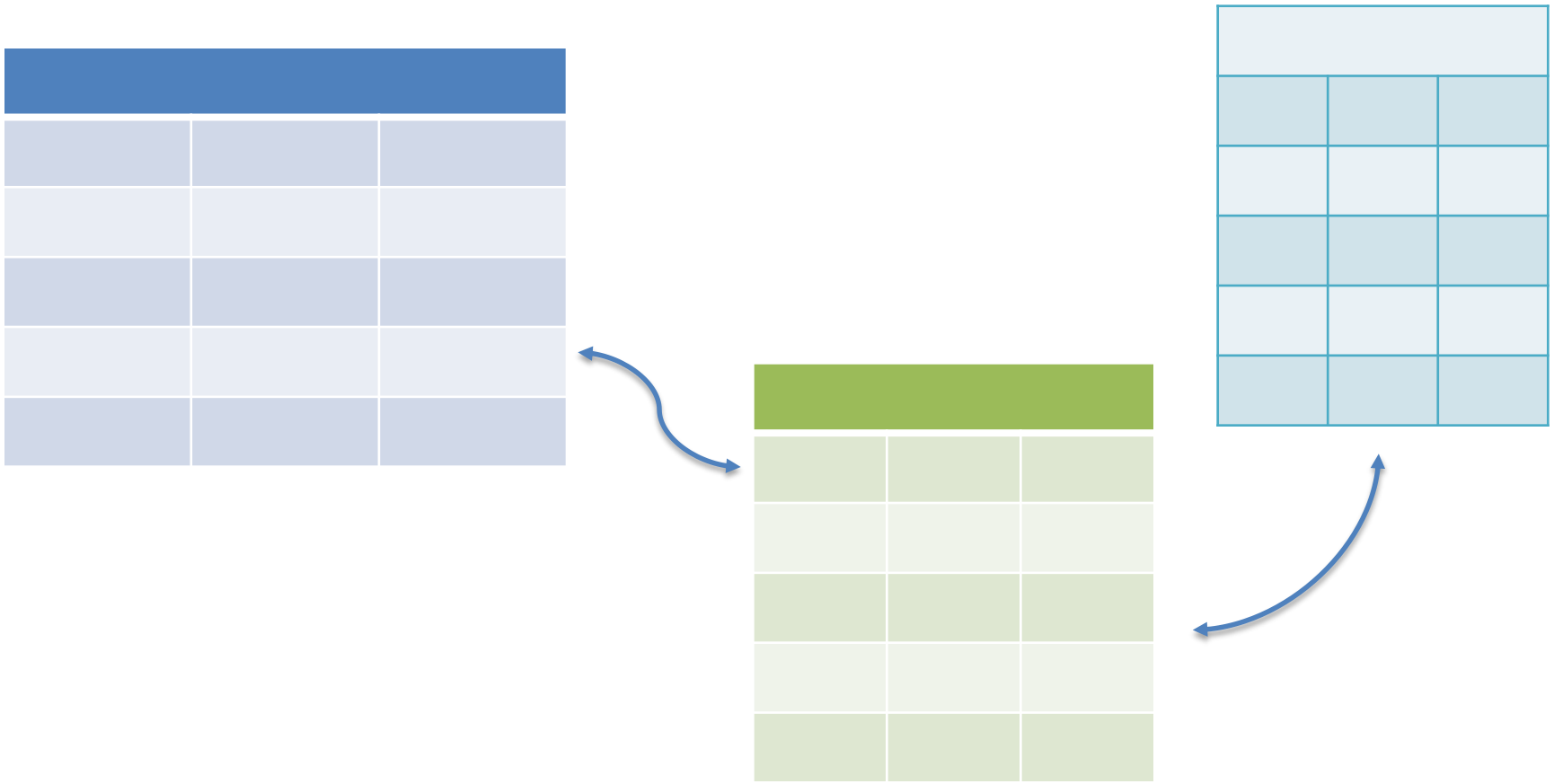
	User Id	Game id
Data 1	Smith	023923
Data 2	James	238548
Data 3	Frank	385753
Data 4	Powell	357352
…		

Data Relationships

- 1-to-1
- 1-to-many
- Many-to-many
- Relationships may also have attributes

What we want..

- A set of well formed and interconnected tables of data.



What we have..

- Data does not come in the form we would like.
- Data may have inconsistencies:
  - Corrupted data
  - Missing data
  - Several data may be equivalent (e.g. text field “R&D”, “Research”, “Research and Development”, “r*d”)

Data Processing Pipeline

- Data does not come in the form we would like.
- Typical data processing pipeline (from raw data to clean structured data):
  1. Collect data.
  2. Data simplification (extract a subset of interest).
  3. Clean and structure them.
- An output of the pipeline can be also *metadata*.

Data Collection

- Search and download data.
- Parse text.
- Convert between different formats.
  - Examples: CVS to JSON , MySQL to HTML , etc.
- Merge heterogeneous sources.

Data Simplification

- Filter / Selection
  - Remove unwanted data
  - Remove invalid data (null values)
- Aggregation
  - Collapse several data points into a single one
  - Replace some values with minimum, maximum, average, total, etc.

Data Processing Pipeline

- Typically performed automatically using *scripts*.
- Human-guided data transformations is possible (through macro-operations)
  - Use appropriate tools (e.g. OpenRefine - *http://openrefine.org*)

Metadata

- Data which describes the data
  - Role of variables
  - Type of variables
  - Constraints
  - Dependencies
- Collection and processing operations can be also described.

How to Present Data ?

- How to present data graphically ?
  - To allow visual analysis
  - To highlight patterns
  - To answer some specific questions
  - Etc.

Quantitative Values

- We have just mentioned the work by Cleveland & McGill (1984)
  - Position
  - Length
  - Angle / slope
  - Area
  - Volume
  - Color saturation / shading

Perceptual Accuracy

QUANTITATIVE	ORDINAL	NOMINAL
Position	Position	Position
Length	Density	Hue
Angle	Saturation	Texture
Slope	Hue	Connection
Area	Texture	Containment
Volume	Connection	Density
Density	Containment	Saturation
Saturation	Length	Shape
Hue	Angle	Length
	Slope	Angle
	Area	Slope
	Volume	Area
		Volume

From *"Data Visualization"* Course by John C. Hart, for *Coursera*, 2015.

Table vs Graphs

- Present tables directly is preferred when:
  - *Few* data points
  - Precise values are important

Univariate Data

- Few interesting solutions.
- Statistical description:
  - Mean, median, standard deviation, quartiles.
- Warning! (some data that appears to be univariate are actually bivariate).

Stemplots

- Also called *stem and leaf* plot.
- Used to display quantitative data, generally from small data sets (50 or fewer observations).
- Easy to print.
- Easy to read.

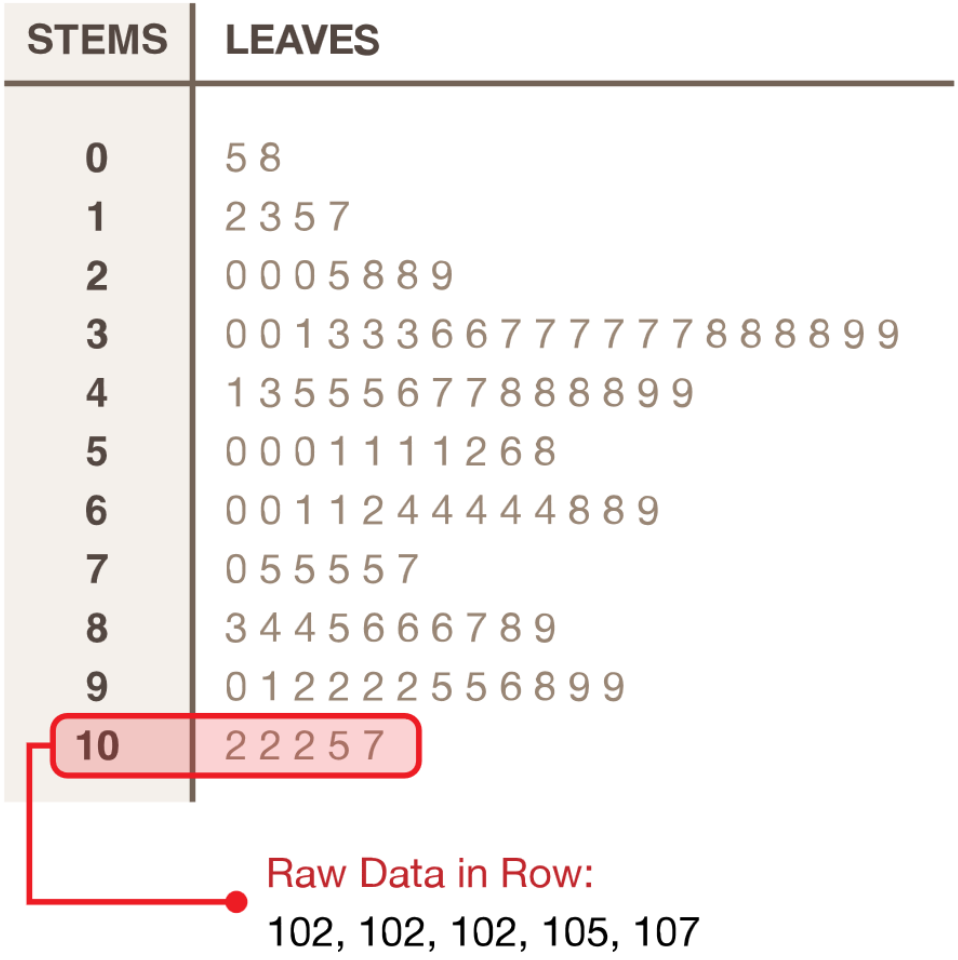


Figure from *Data Visualization Catalogue (http://datavizcatalogue.com)*

Stemplots

Northbound	Hour	Southbound
45 20 03	5	05 48
55 49 32 20 13 01	6	02 23 35 57
58 53 49 44 38 32 25 19 13 08 02	7	00 07 16 20 26 30 37 46 52 59
59 57 54 50 47 44 39 35 31 28 24 21 18 14 09 05 00	8	01 08 12 17 21 29 31 35 39 44 49 53 58
52 48 44 39 34 29 23 18 12 05	9	03 10 18 27 32 37 45 51 58
53 47 41 37 32 27 22 15 07	10	00 07 14 21 30 39 48 57
55 49 35 29 23 16 08 01	11	06 11 19 27 34 41 50 59
56 48 44 39 32 27 21 14 05	12	02 15 30 45 57
50 45 35 30 25 20 15 05	13	03 10 18 23 29 37 45 56
52 43 32 24 12 03	14	00 09 18 27 39 48 57
58 44 31 26 15 06	15	01 17 29 41 55
56 40 30 22 11	16	10 25 38 50
55 41 32 23 14 01	17	00 20 34 53
58 49 42 36 28 22 16 09	18	05 14 21 29 37 45 56
57 51 46 39 33 28 23 17 13 08 02	19	02 09 14 19 23 27 32 36 40 44 48 53 57
52 43 30 21 15 06	20	09 17 26 34 40 49 55
45 30 16 03	21	10 20 30 40 50
50 30 10	22	15 35 55

Figure from *Data Visualization Catalogue (http://datavizcatalogue.com)*

Box and Whisker Plots

- *Box and Whisker Plot (or Box Plot)* is a convenient way of visually displaying a data distribution through their quartiles.
- Advantages:
  - Key values (average, median, 25th percentile, etc.)
  - If there are any outliers and what the values are.
  - If the data is skewed and in what direction.

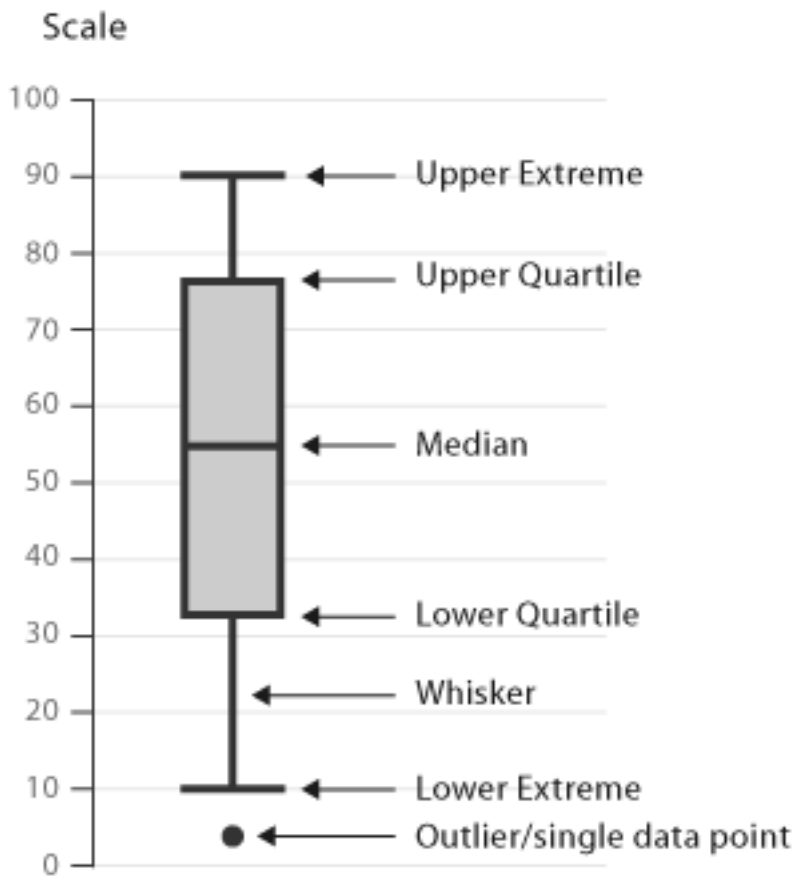


Figure from *Data Visualization Catalogue (http://datavizcatalogue.com)*

Box and Whisker Plots

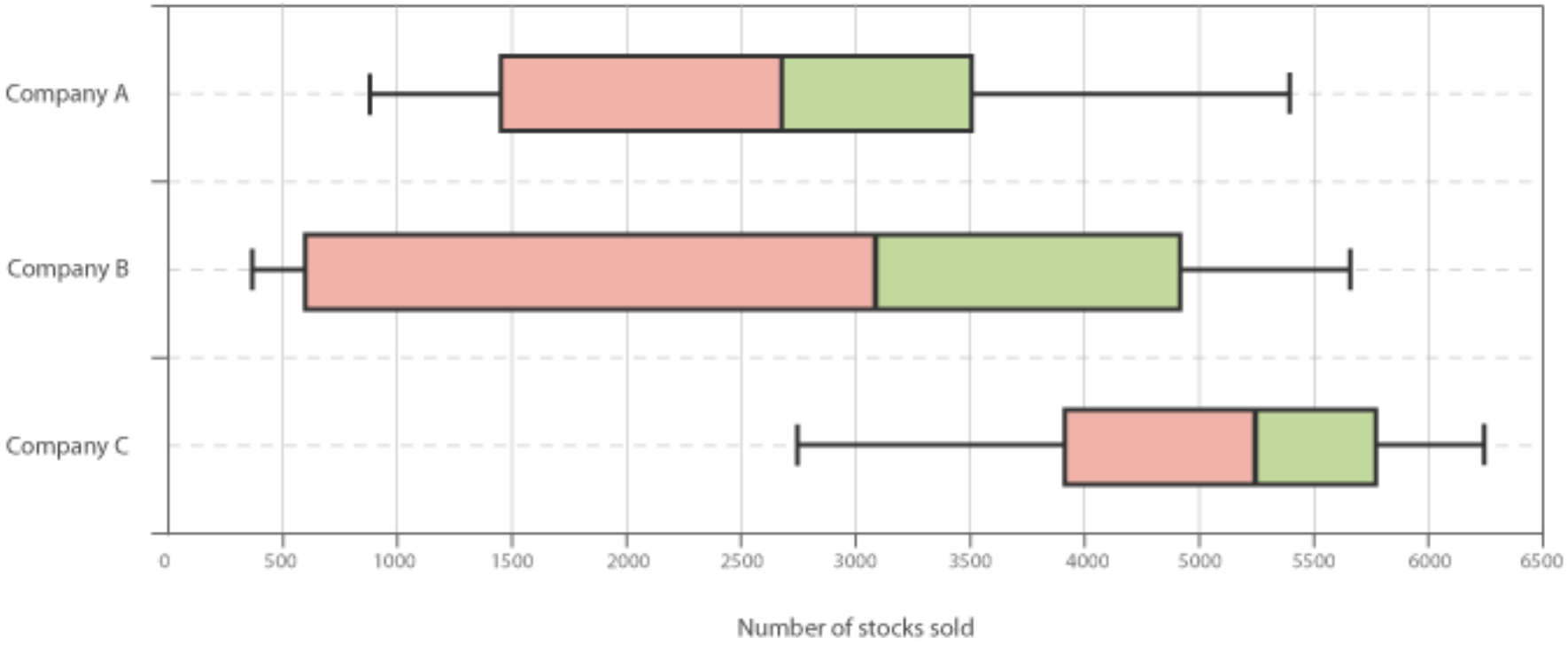
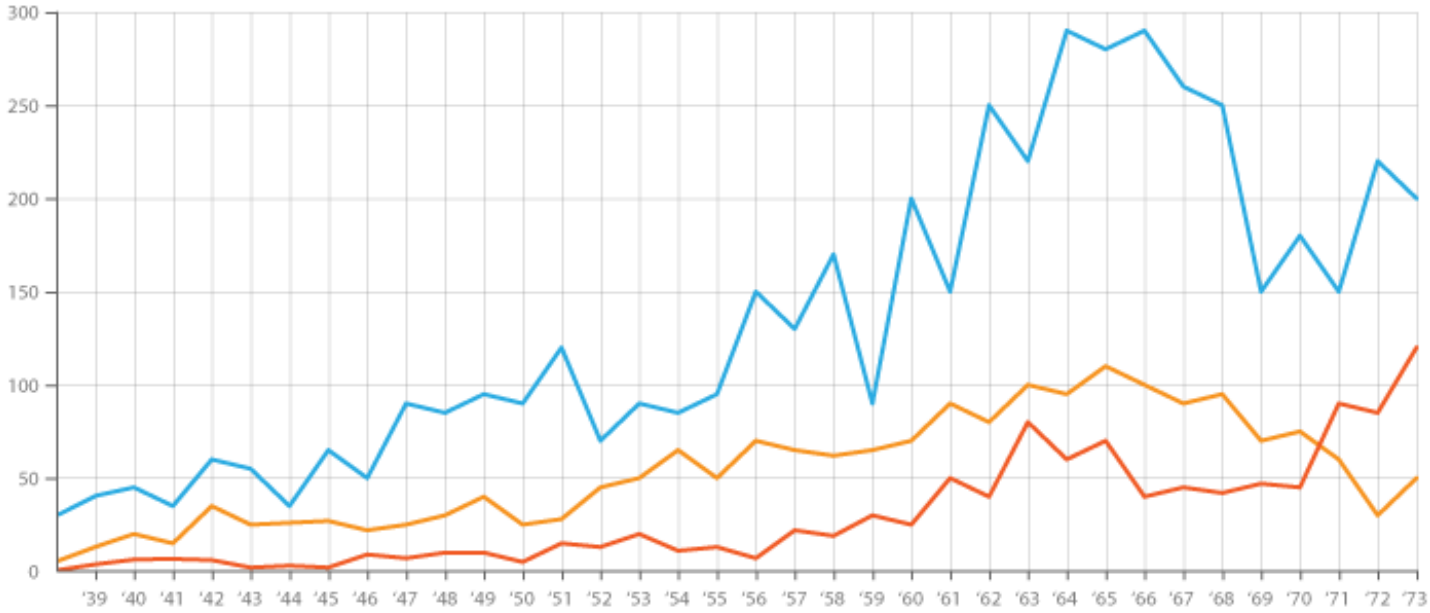


Figure from *Data Visualization Catalogue (http://datavizcatalogue.com)*

Line Charts/Line Graphs

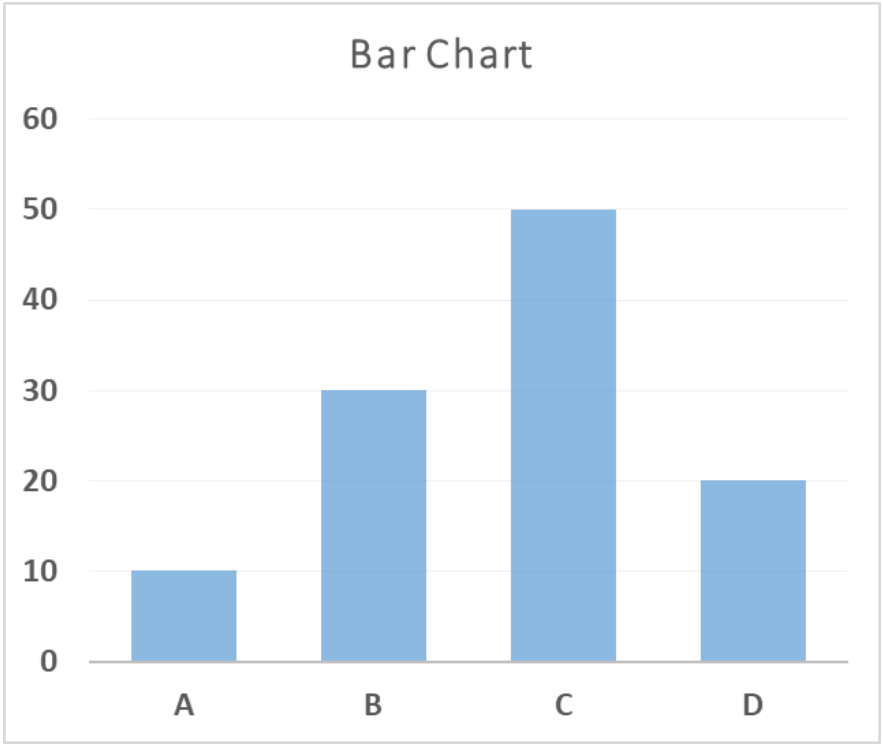


- Invented by the Scottish engineer and statistician William Playfair (1759-1823)
- Two quantitative variables, typically:
  - X → time or intervals , Y any
- Line indicates that there are also intermediate values

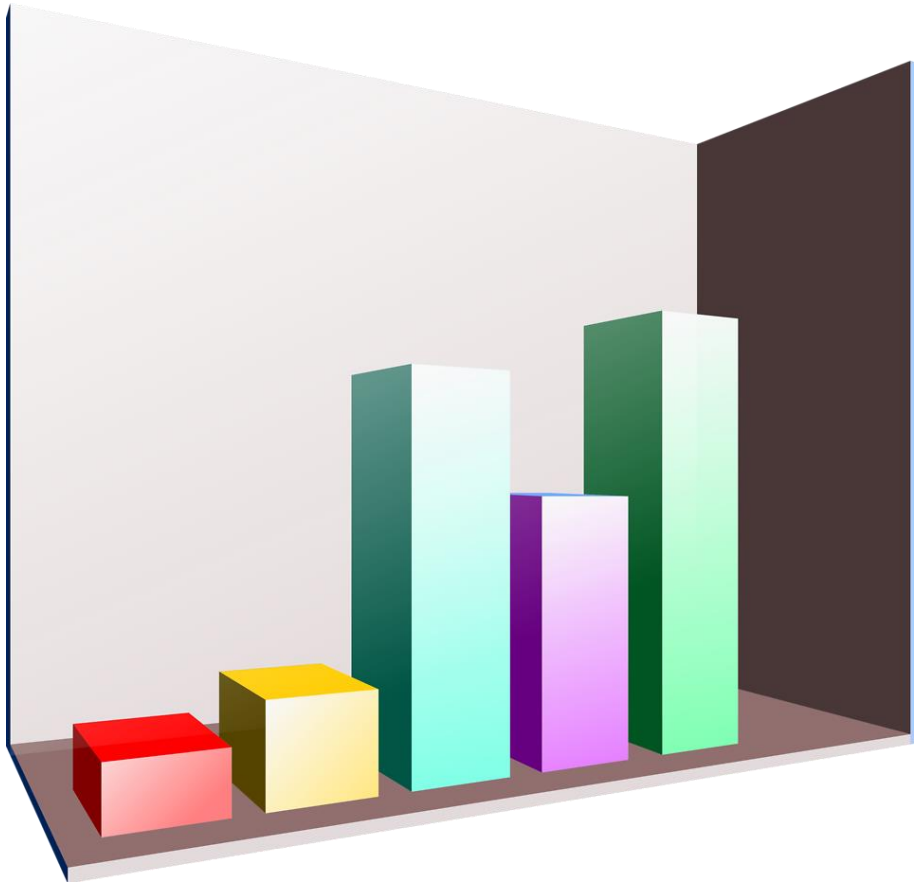
Figure from *Data Visualization Catalogue (http://datavizcatalogue.com)*

Bar Charts

- Bivariate Data
  - One nominal variable (typically independent)
  - One quantitative variable (typically dependent variable)
- Horizontal/Vertical bars
- Do not confuse with *histograms*.



Bar Charts



3D?!

Not a very good idea..

Histograms

- Bivariate Data
  - One independent and one dependent variable
  - The first variable is quantized in intervals (bins)

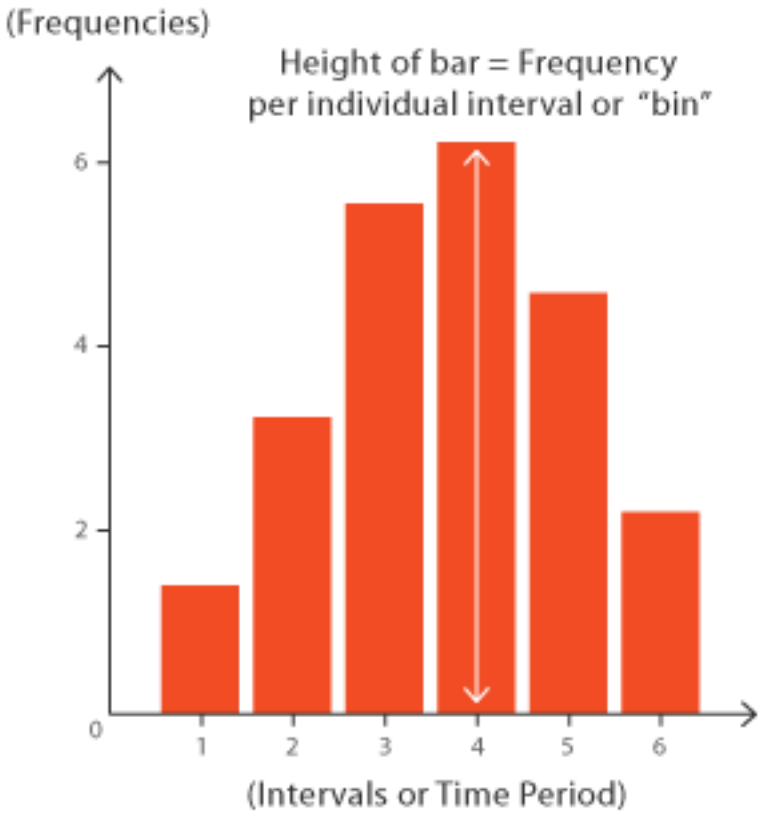
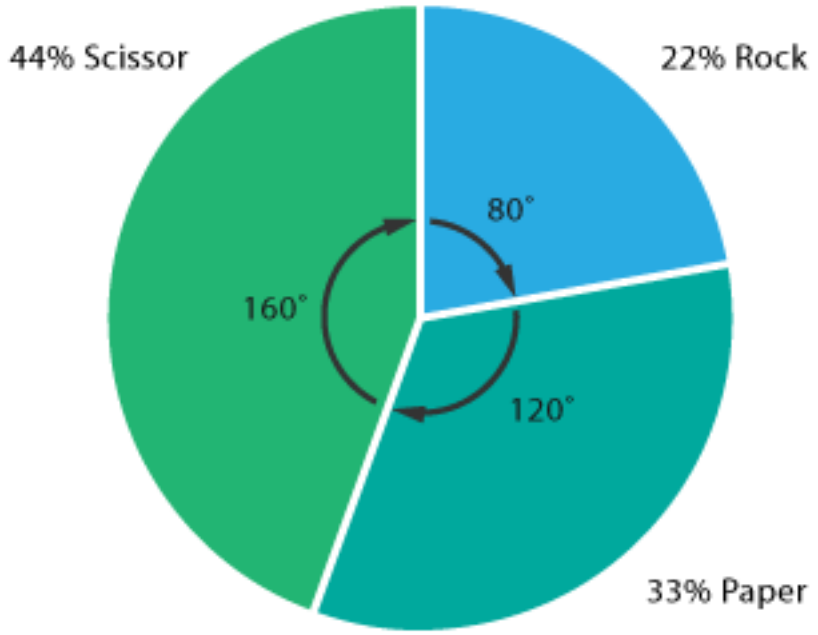


Figure from *Data Visualization Catalogue (http://datavizcatalogue.com)*

Pie Charts

- Bivariate Data
  - One independent and one dependent variable
- Good for a quick visual check.
- Not good for:
  - Many values.
  - Accurate comparisons.

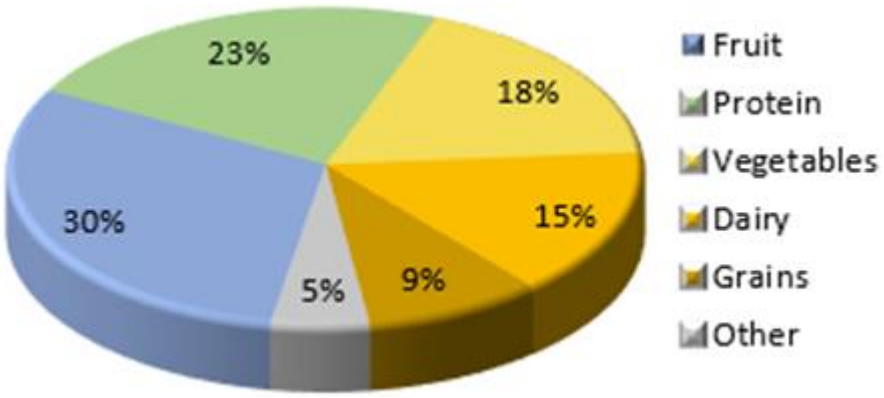
Figure from *Data Visualization Catalogue (http://datavizcatalogue.com)*



Data			
Rock	Paper	Scissor	TOTAL
2	3	4	9
To calculate percentages			
2/9=22%	3/9=33%	4/9=44%	100%
Degrees for each "pie slice"			
(2/9) x 360 = 80°	(3/9) x 360 = 120°	(4/9) x 360 = 160°	360°

Figure from *Data Visualization Catalogue (http://datavizcatalogue.com)*

Pie Charts



3D?!

Not more readable.

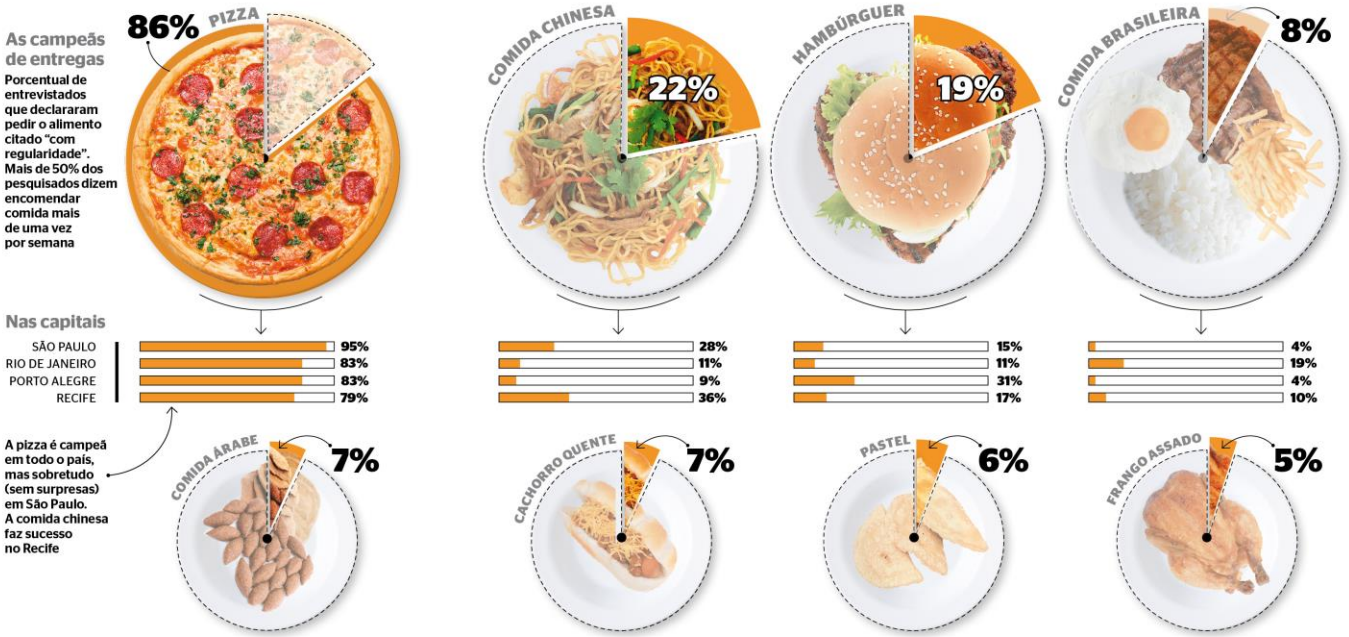
Diagrama
A NOTÍCIA EM PERSPECTIVA

Quando o brasileiro come fora

O crescimento da economia muda os hábitos alimentares e estimula o mercado de comida pronta

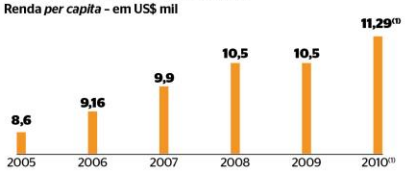
Luiz Salomão e **Alberto Cairo**

O BRASILEIRO vai cada vez menos à cozinha – e nisso já se aproxima dos países desenvolvidos. Segundo o estudo *Alimentação fora do lar na visão do consumidor brasileiro*, da GS&MD, consultoria de consumo especializada em varejo, **mais de 30% do gasto dos brasileiros com alimentação é feito com serviços de entrega ou refeições fora de casa**. Só Estados Unidos, Portugal, Reino Unido e Espanha estão à frente. Esse porcentual era de 24% em 2002. Oitenta e quatro por cento dos 1.224 entrevistados em grandes capitais disseram que costumam comprar alimentos prontos para consumo, seja em supermercados, padarias ou restaurantes. A pesquisa atribui essa mudança, em primeiro lugar, ao crescimento econômico: o Brasil cresceu três vezes mais que a média das economias mais desenvolvidas nos últimos cinco anos, e a classe C já representa quase metade da população. Em segundo lugar, as mulheres já são 43% do total de trabalhadores. Por fim, os "domicílios unipessoais" passaram de 3,4 milhões em 1996 para 6,3 milhões em 2006.



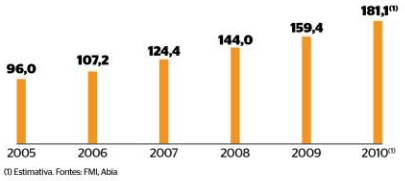
O aumento da renda no país...

Renda *per capita* – em US$ mil



...acompanha o crescimento das empresas de comida pronta e restaurantes

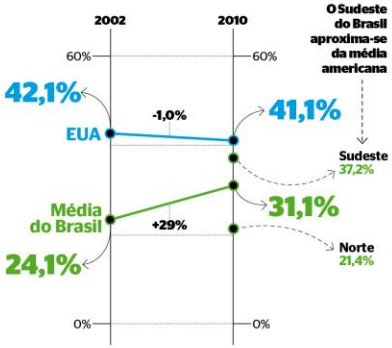
Faturamento anual total – em R$ bilhões



(1) Estimativa. Fontes: FMI, Abia

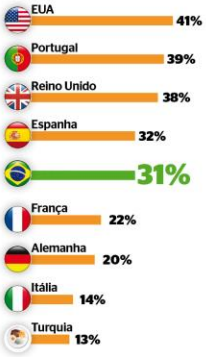
Porcentual do orçamento familiar para alimentação gasto em refeições fora de casa

Média no Brasil e nos EUA e em algumas regiões brasileiras



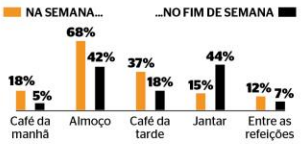
Quem gasta mais fora de casa

% sobre o total das despesas das famílias com alimentação



Em dias úteis, almoço fora; no fim de semana, jantar fora

Entrevistados que declaram comer habitualmente fora de casa



O brasileiro valoriza o sabor, a higiene e a aparência

Atributos que definem a qualidade da refeição (mais de uma resposta possível)

Fatores que determinam o gasto fora de casa

Por classe

Figure by Luiz Salomão.

Donut Charts

- Essentially, a pie chart with the center area cut out.
- Allows to focus more on arc length instead of comparing the proportion between slices.
- More space efficient.

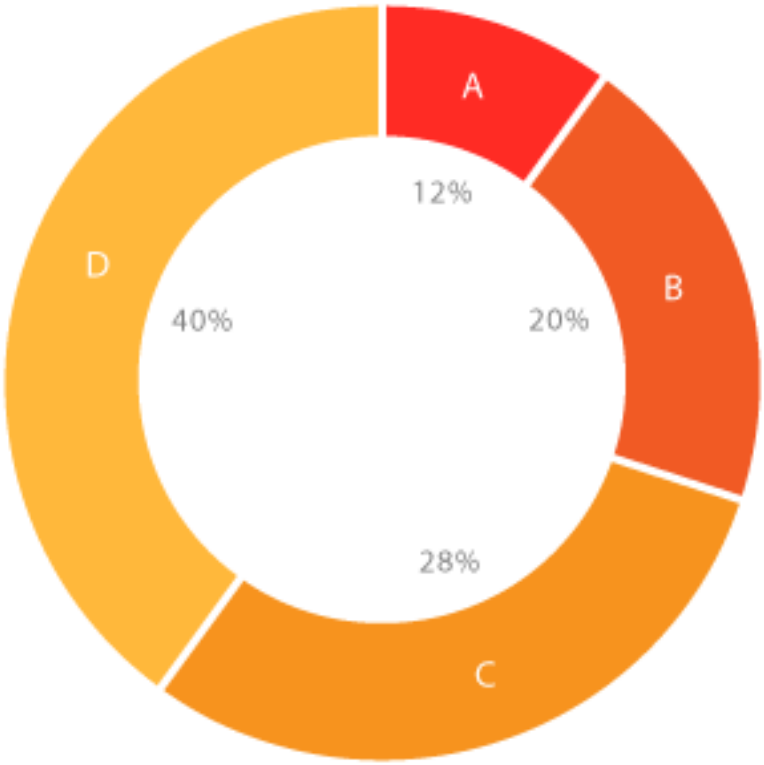
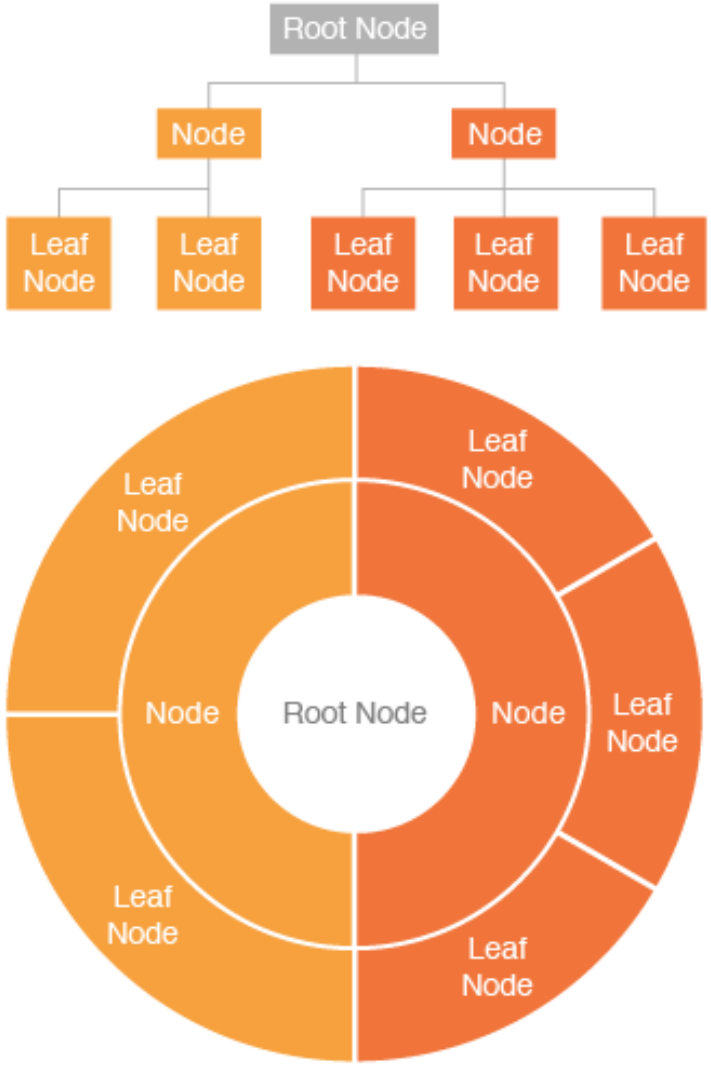


Figure from *Data Visualization Catalogue (http://datavizcatalogue.com)*

Sunburst Charts

- To shows *hierarchy* through a series of rings. Each ring corresponds to a level in the hierarchy.
- Hierarchy moving outwards from the center.
- Colour can be used to highlight hierarchal groupings or specific categories.



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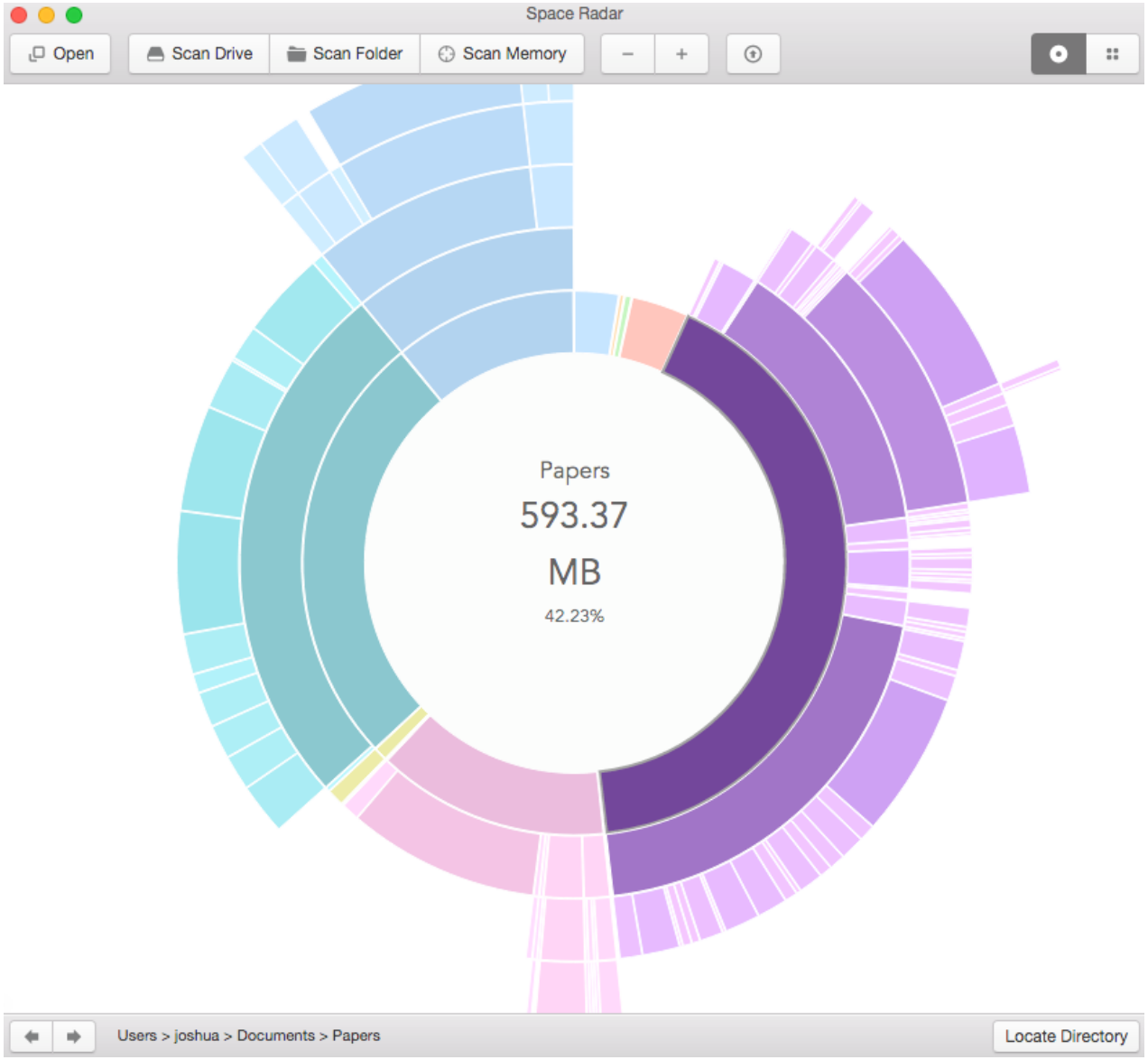
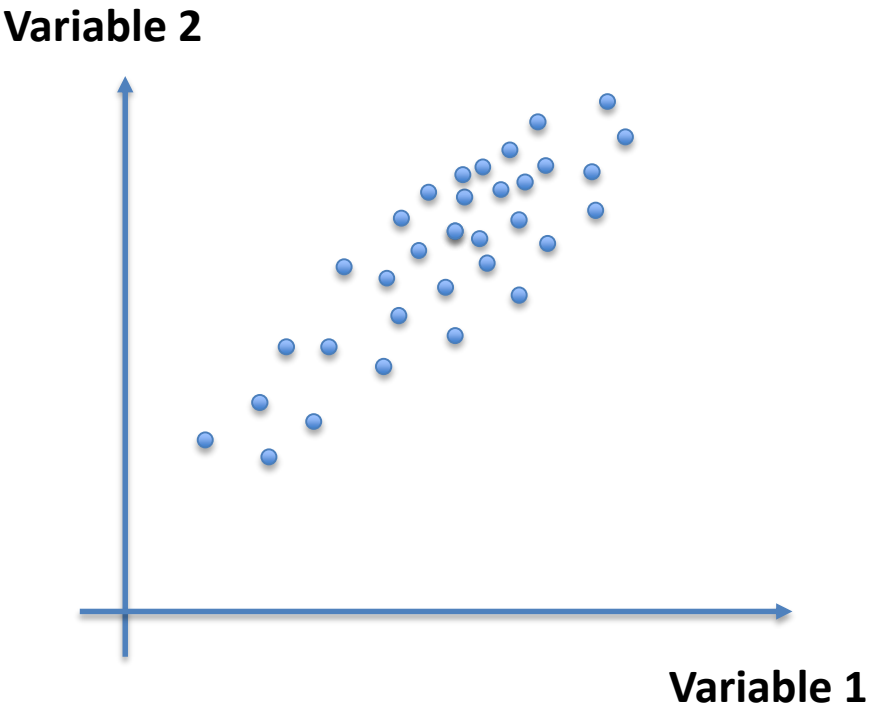
Sunburst Charts



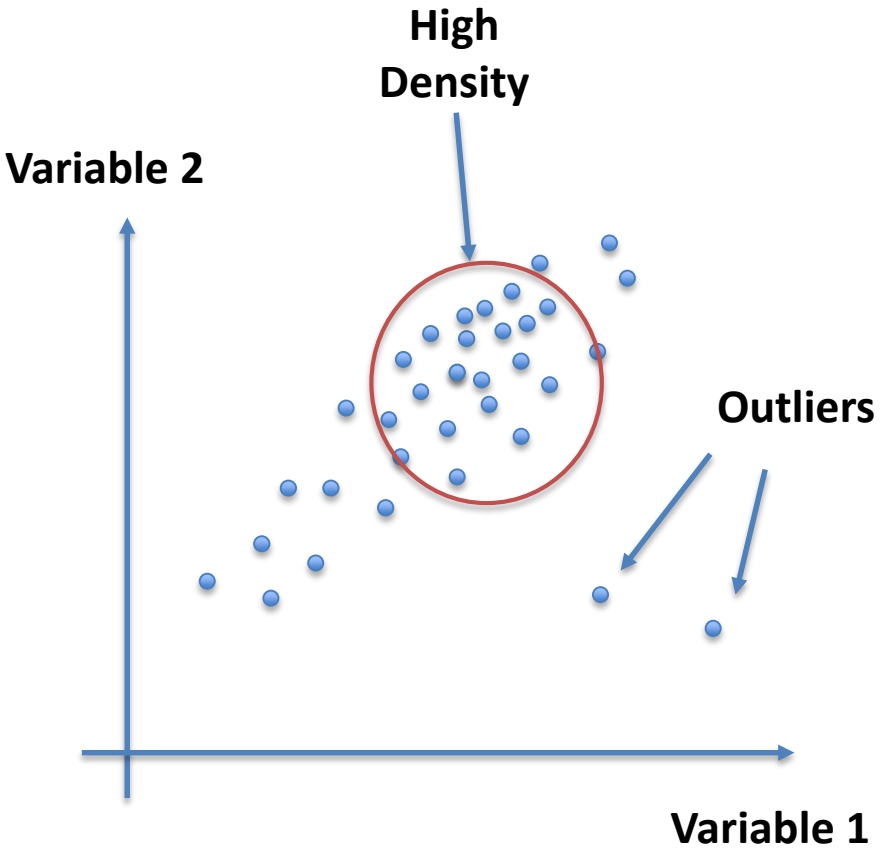
Produces by *Space Radar* app *(https://github.com/zz85/space-radar)*

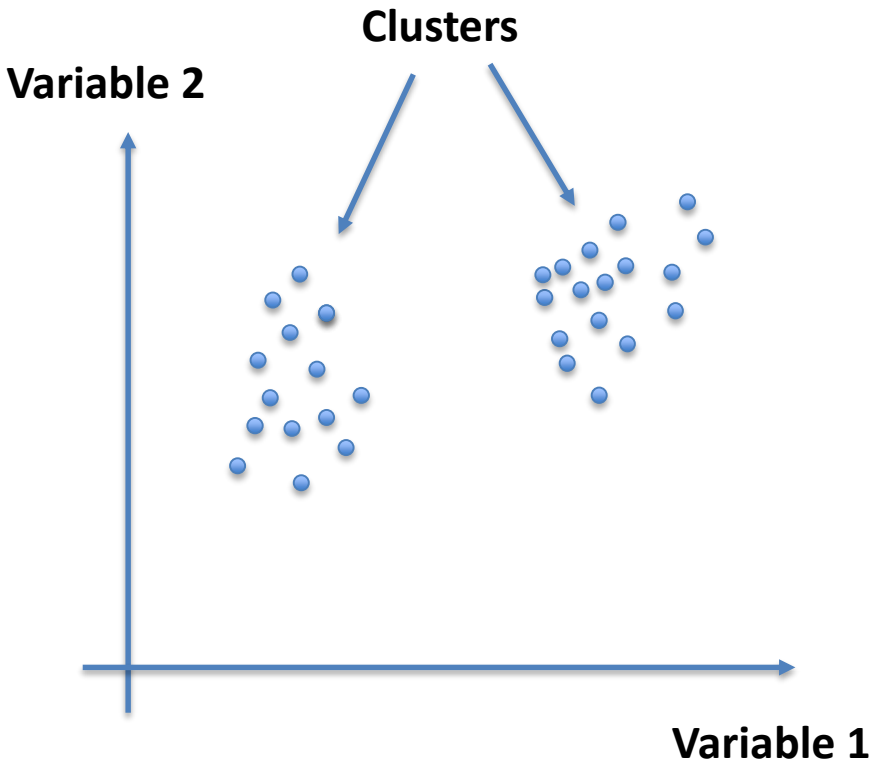
Scatter Plots

- Bivariate Data
  - Two independent variables
- Good to identify relationships, outliers and clusters.



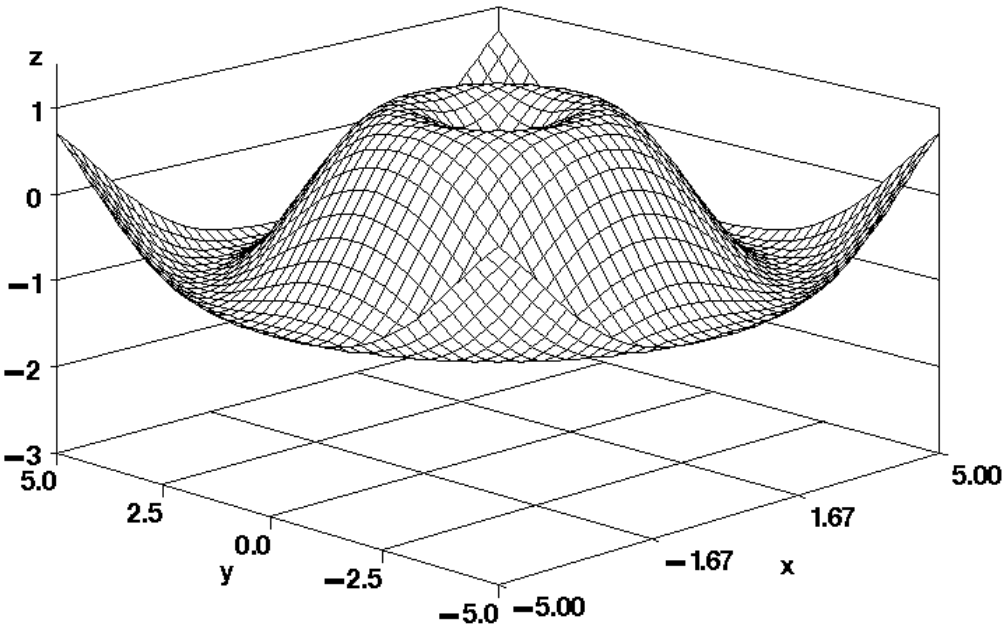
Scatter Plots





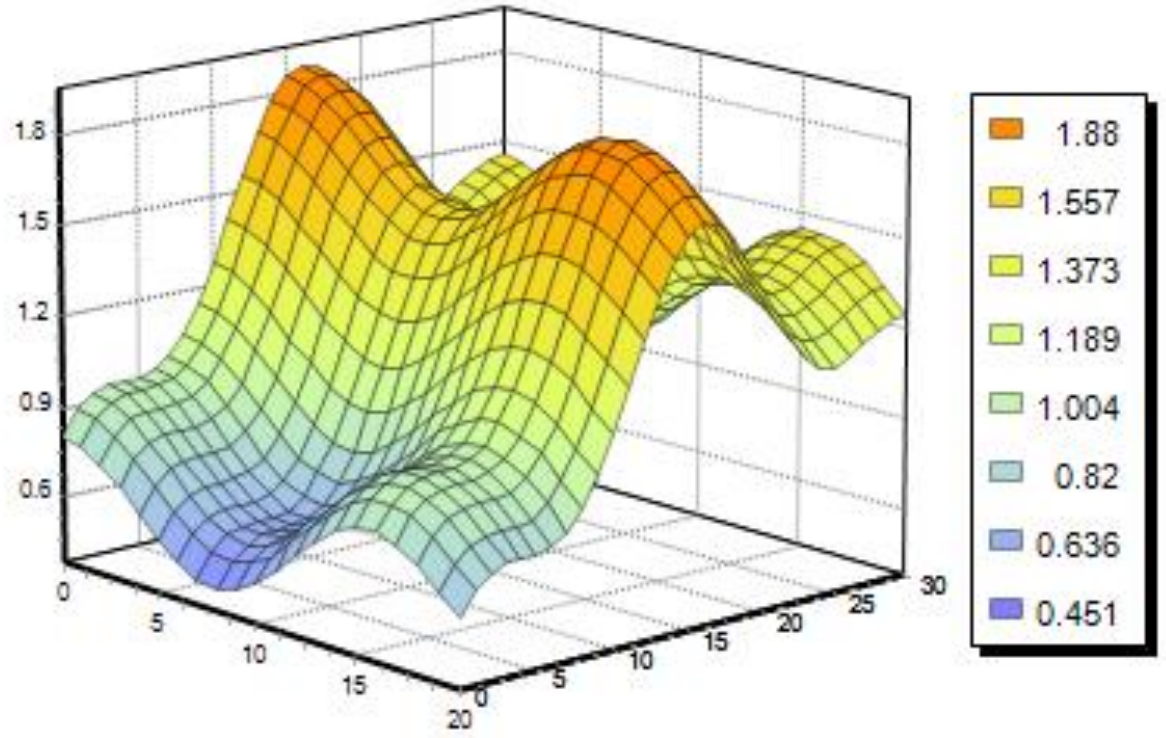
Surface Graphs

- Trivariate Data
  - Three continuous variables
  - Two independent and one dependent



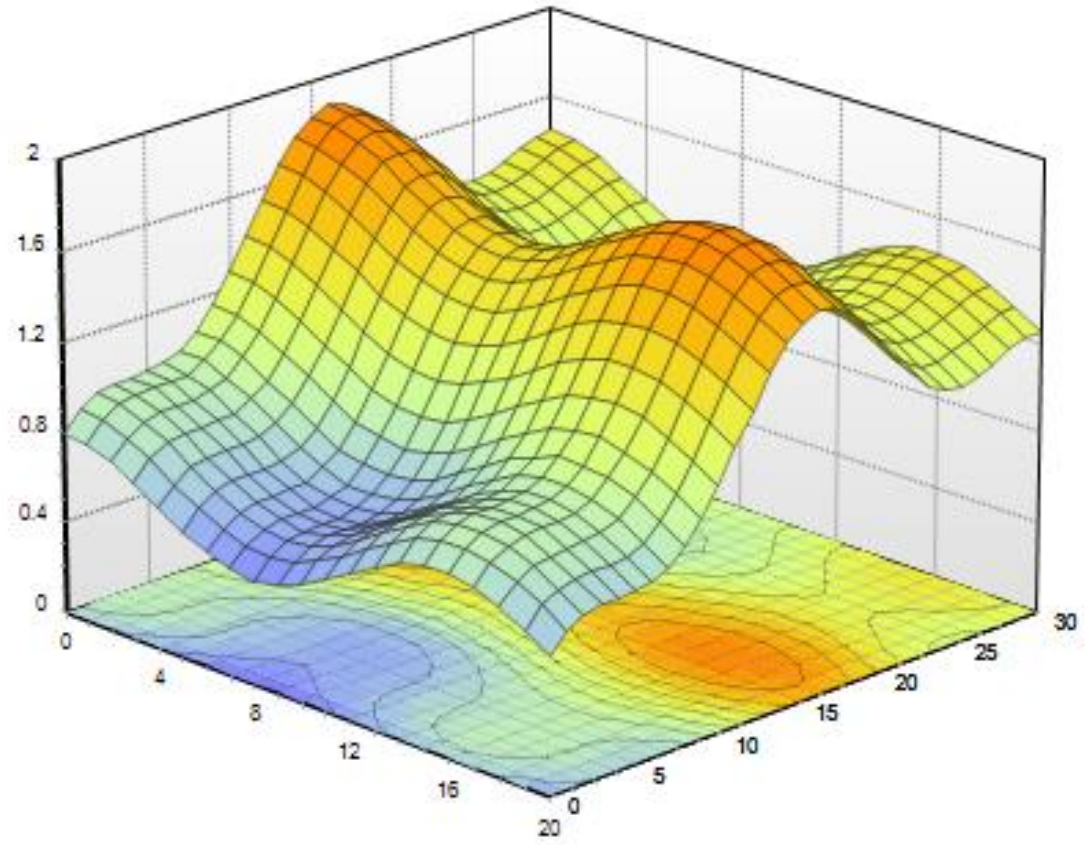
Surface Graphs

- Color may be associated to the dependent variable.



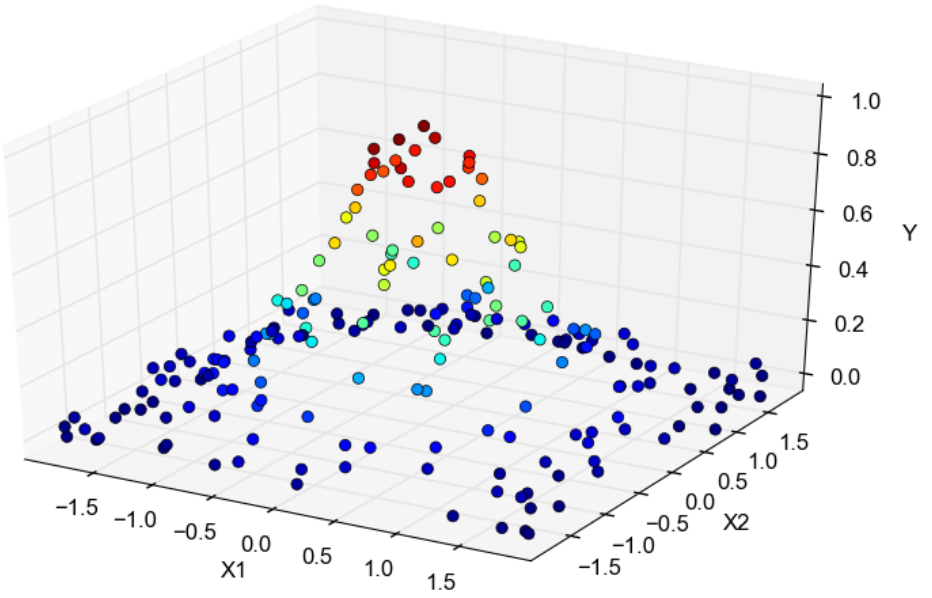
Surface Graphs

- Level curves can be also used.



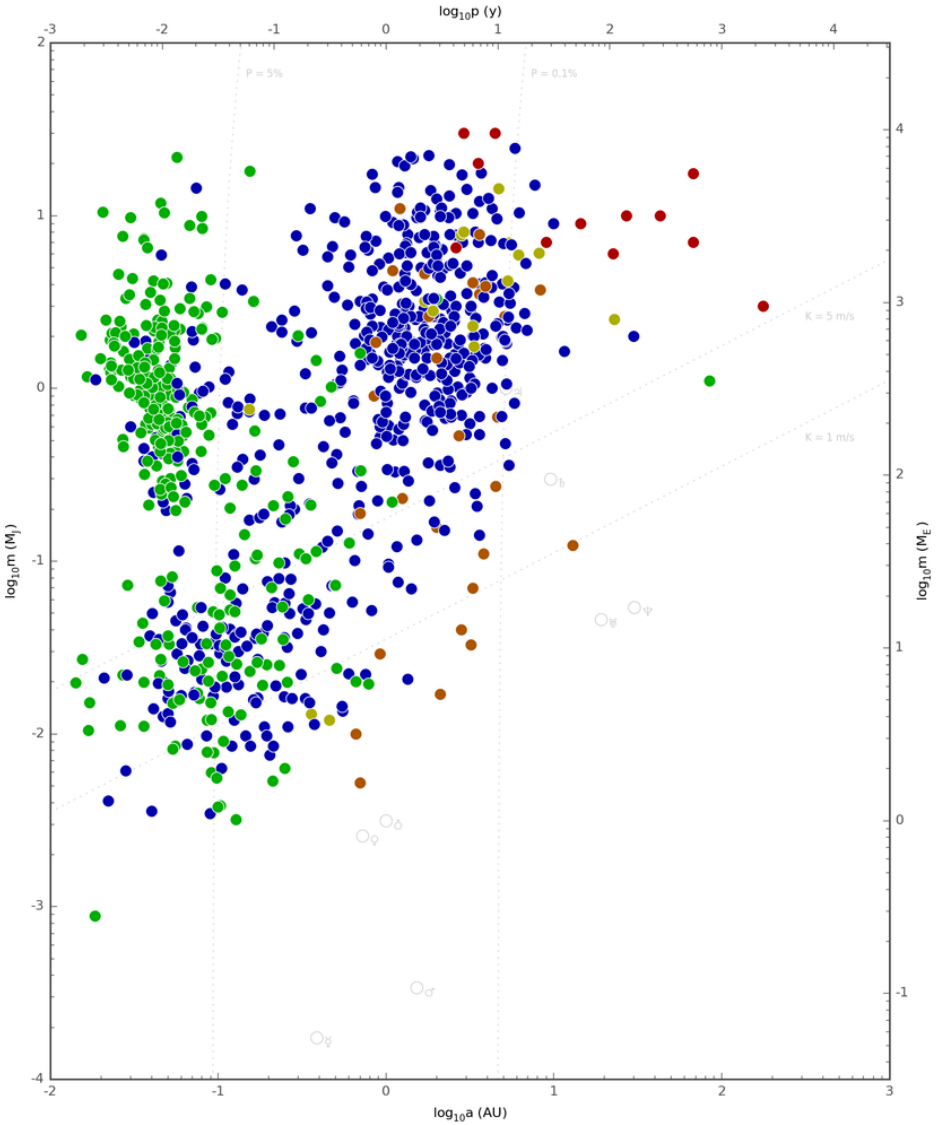
3D Scatter Plots

- Trivariate Data
  - Three quantitative variables
- Same concept of 2D Scatter Plot



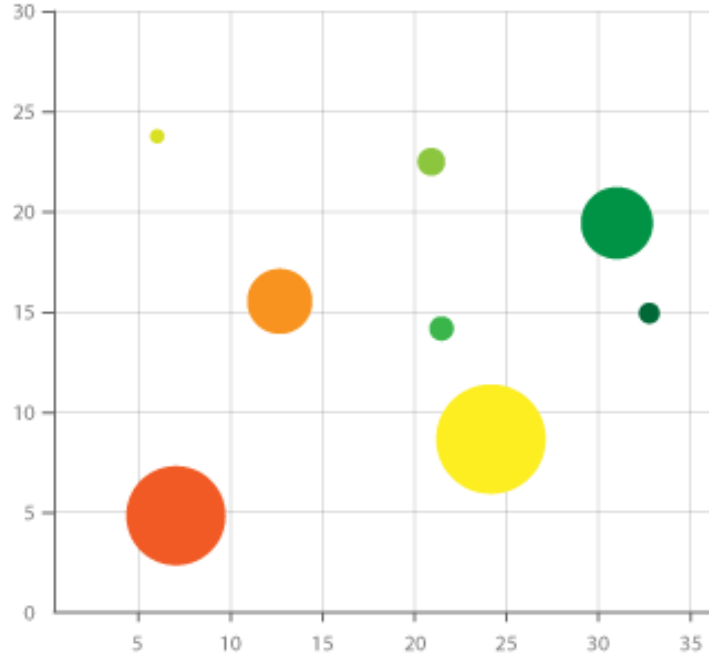
Colored Scatter Plots

- Trivariate Data
- Color can encode a variable or a category



Bubble Charts

- Trivariate Data
  - Three quantitative variables
- Do not allow for accurate comparison.
- Colors can be used to show different categories.



Bubble Charts

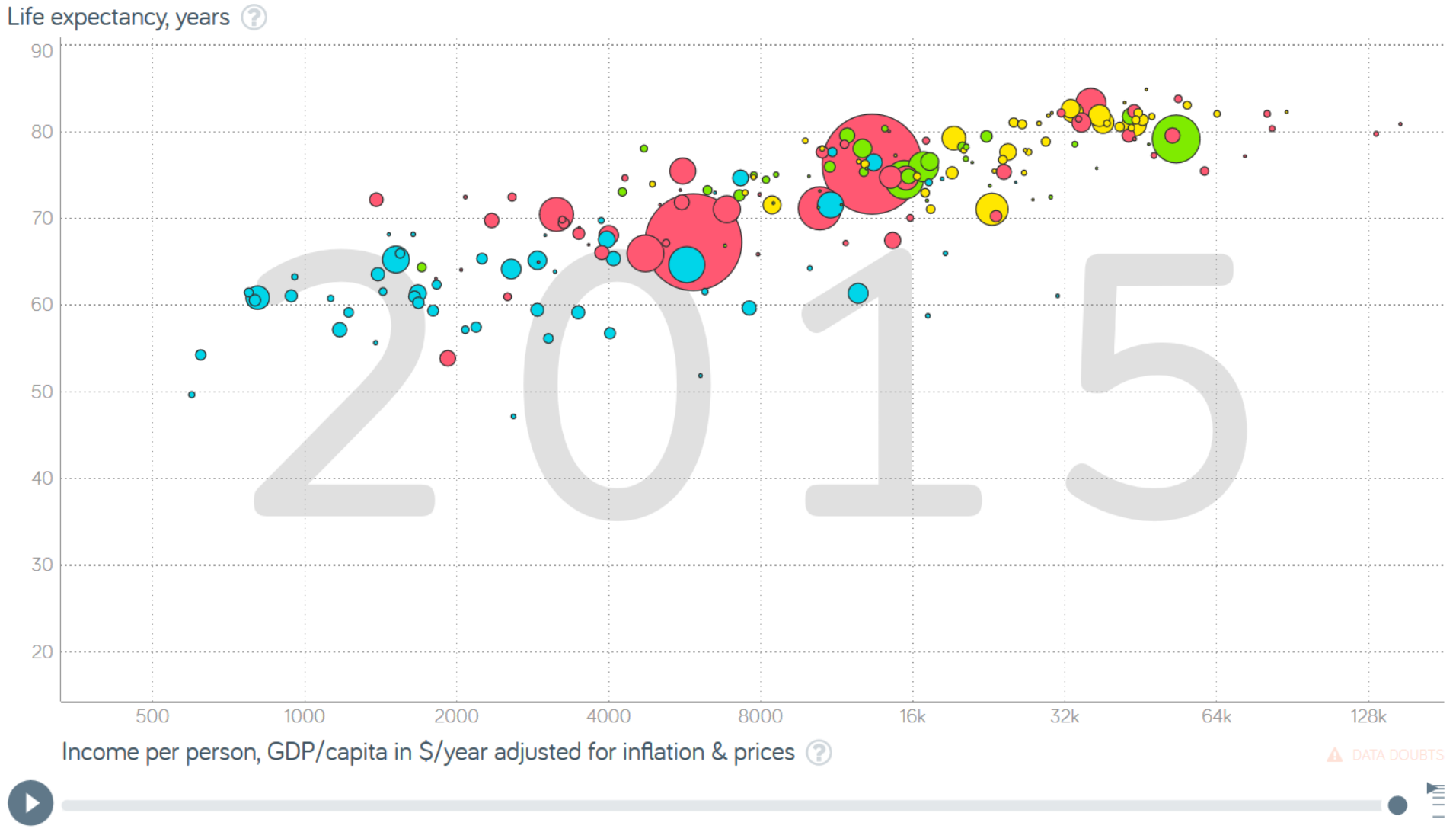
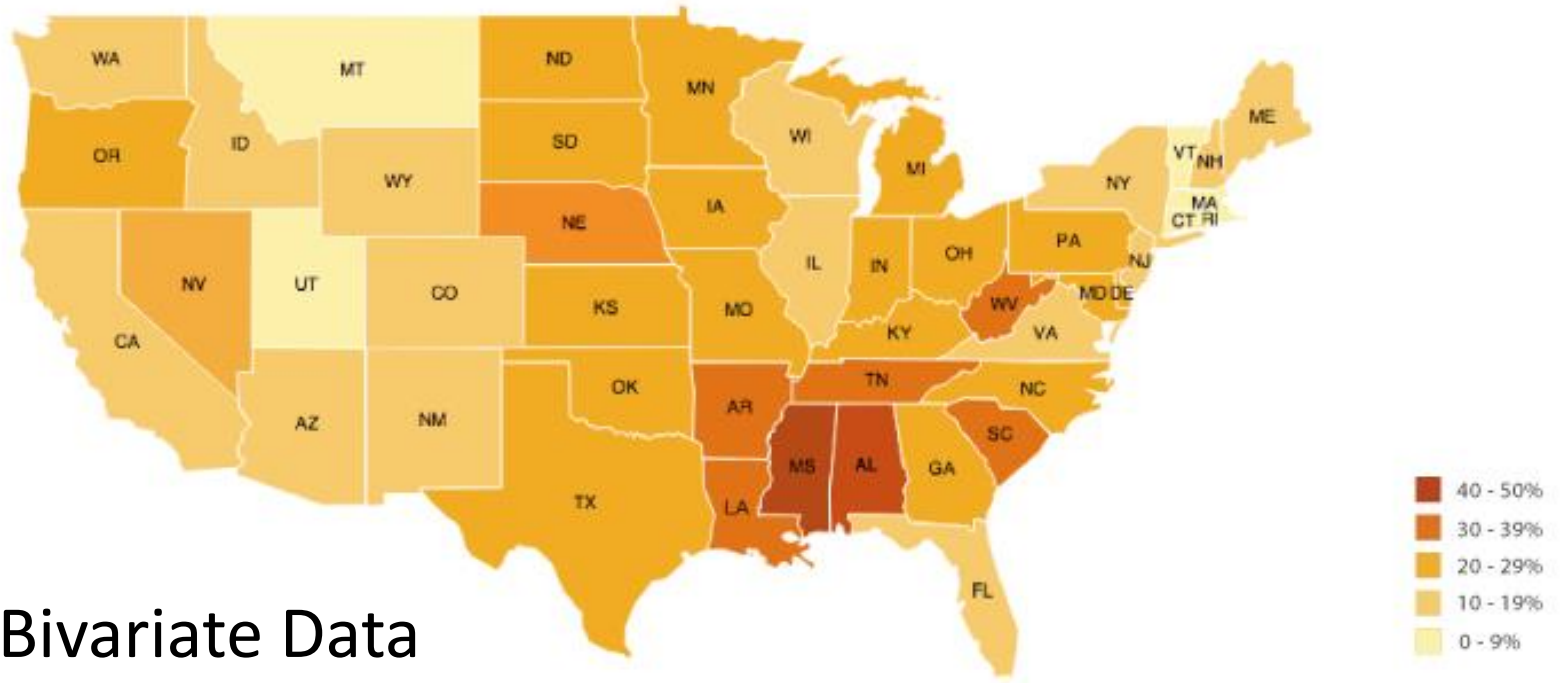


Figure from *http://gapminder.com*

Chloropleth Map



- Bivariate Data
  - Quantitative value over a geographical areas/regions
- Data are coloured, shaded or patterned in different ways.
- Good for an overview, not for accurate comparison.
- Small areas can be underemphasized.

Word Cloud

- Word Clouds displays how frequently words appear in a given body of text, by making the *size of each word proportional to its frequency*.
- Arrangement and color can vary a lot.
- Word Clouds can be used to compare two bodies of text or to give a quick idea of repeating keywords (e.g. used by researchers to summarize the content of their papers).

Word Clouds

- Disadvantages:
  - Long words are emphasized over short words.
  - Words whose letters contain many ascenders and descenders may receive more attention.
  - No accuracy comparison, mainly used for aesthetic reasons.

Word Clouds (example)

Produces by *www.jasondavies.com/wordcloud*.

Word Clouds (example)

Produces by *www.jasondavies.com/wordcloud*.

Word Clouds (example)

From www.wordclouds.com .

Summary

- Visualization plays a fundamental role in data analysis.
- Information coming from data. Data should be collected and processed properly.
- Depending on goal and data type, the use of certain graphs is more effective than others.

Questions ?