

# Applied Data Analysis (CS401)



A PICTURE  
IS WORTH  
A THOUSAND  
WORDS

## Lecture 3 Visualizing data 24 Sep 2025

EPFL

Maria Brbić

## Announcements

- You must find 4 team mates and [register](#) by **this Fri Sep 26th 23:59**
  - Every student must register individually
  - Still looking for a team or for team members? Use Ed! If need be, talk to Sevda & Pierre [TAs]
- Project milestone 1 was released last Sun; **due Fri 3 Oct 23:59**
- Friday's lab session:
  - 15:30–16:30: Project milestone P1 office hours ([Zoom](#))
  - In parallel: Exercise on data visualization and working with data from the Web ([Exercise 2](#))
  - Happening **only in GCC330, CE14 (not BCH2201!)**

2

## Feedback

Give us feedback on this lecture here:

<https://go.epfl.ch/ada2025-lec3-feedback>

- What did you (not) like about this lecture?
- What was (not) well explained?
- On what would you like more (fewer) details?
- ...

1

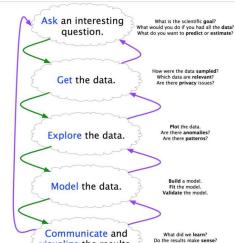
## Uses for data visualization

**Analysis:** Support reasoning about information

- Finding relationships
- Discover structure
- Quantifying values and influences
- Should be part of the data analysis cycle ➡

**Communication:** Inform and persuade others

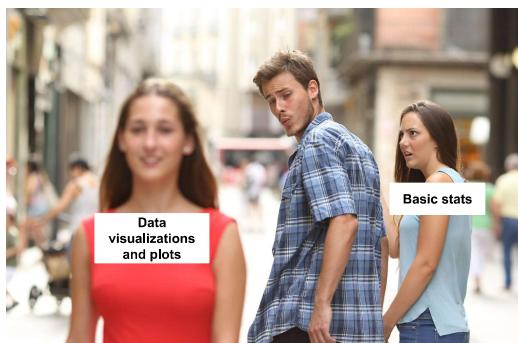
- Capture attention, engage
- Tell a story visually
- Can focus on certain aspects and omit others



**Decision making:** Make it easier to evaluate potential courses of action

4

3



5

## An unconventional example



"[Garden of Eden](#)": 8 lettuces, each of which is enclosed in its own airtight plexiglas box and represents a major city. The concentration of ozone in each box is controlled in real-time to reflect the current pollution level in the city.

6

## Static viz

Great for data exploration,  
developed throughout the last few  
centuries...

## Interactive viz

More and more common when  
delivering the results (and also during  
exploration). New frameworks are the  
key enabler.

7

## Want to learn more?

Dedicated course:

[COM-480: Data Visualization](#)

8

## Today's lecture

- Part 1: Navigating the chart landscape
- Part 2: Principles and best practices
- Part 3: A (small) selection of use cases for data visualization

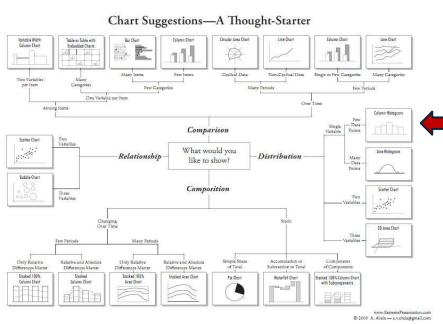
## Part 1

### Navigating the chart landscape

9

10

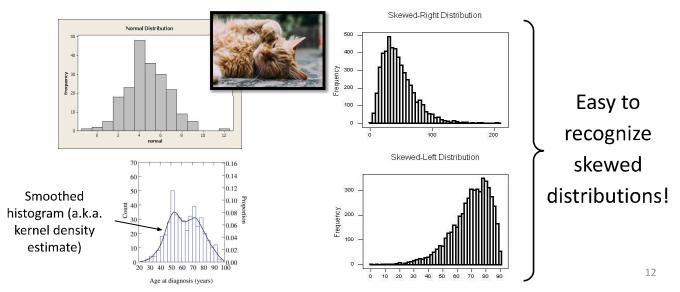
## Chart selection



11

## One variable: histograms

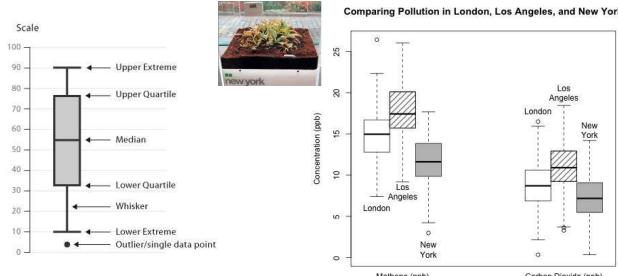
Histograms can tell you a lot about a single variable, discrete or continuous



12

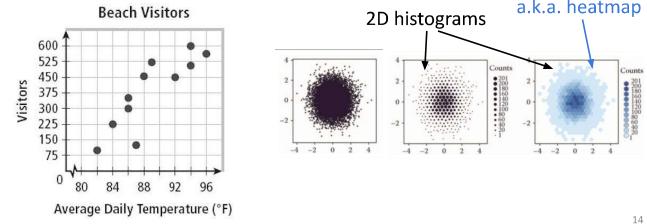
11

## One variable: box plots



## Two variables: scatter plots

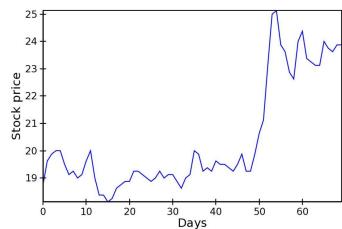
Scatter plots quickly expose the relationships between two variables



14

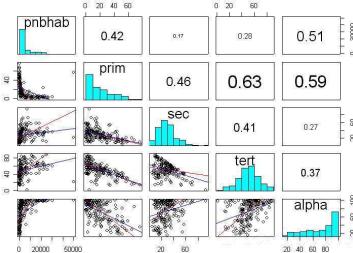
## Two variables: line plots

If relationship is functional (for instance, after binning and aggregating)



15

## > 2 variables: scatter plot matrix

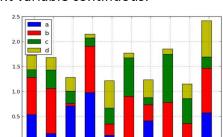


16

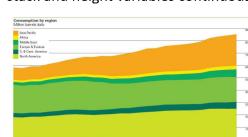
## > 2 variables: stacked plots

Here: 3 variables: stack index, height, color

Stack variable and color variables categorical, height variable continuous:



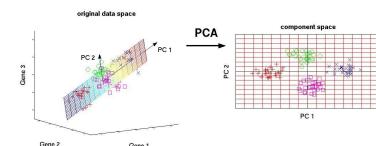
Color variable categorical, stack and height variables continuous:



17

## Dimensionality reduction

- For example, **PCA**: allows visualization of high-dimensional continuous data in 2D using principal components
- The principal components are the strongest (highest variation) dimensions in the dataset, and are orthogonal



18

## One dataset, visualized 25 ways



<http://flowingdata.com/2017/01/24/one-dataset-visualized-25-ways>

"You must help the data focus and get to the point. Otherwise, it just ends up rambling about what it had for breakfast this morning and how the coffee wasn't hot enough."

19

20

## Part 2

### Principles and best practices

## Instructive coffee table books by Edward Tufte



[\[another great coffee table book\]](#)

21

22

## Perception of magnitudes



(134, 134, 134)



(144, 144, 144)

Which is brighter?

## Just noticeable difference (JND)

- Weber's law:  $\frac{\Delta I}{I} = k$ ,
- $I$ : intensity;  $\Delta I$ : increase from  $I$  to notice a difference;  $k$ : constant
- Required increase  $\Delta I$  depends on original intensity  $I$
- Most continuous variations in stimuli are perceived in discrete (multiplicative) steps

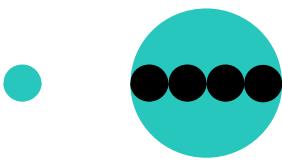


23



Compare area of circles

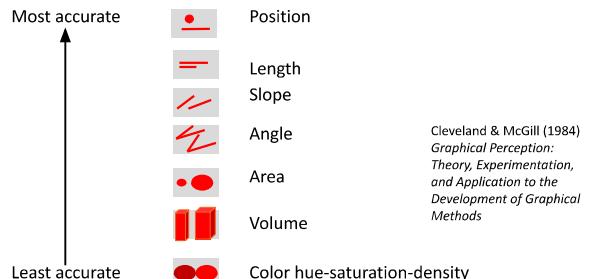
24



Compare area of circles

25

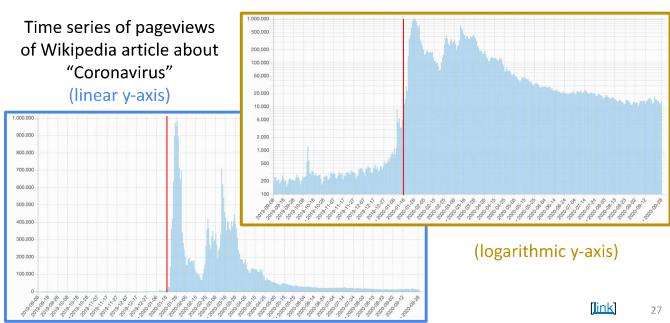
## Perception of magnitudes



26

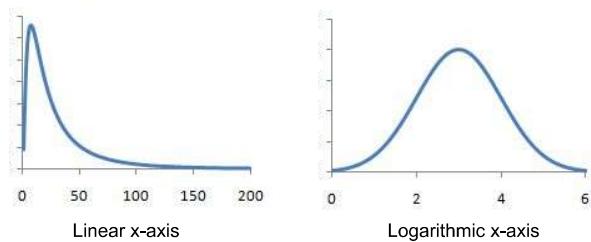
## Choose your axes wisely!

Time series of pageviews  
of Wikipedia article about  
“Coronavirus”  
(linear y-axis)



[\[Link\]](#) 27

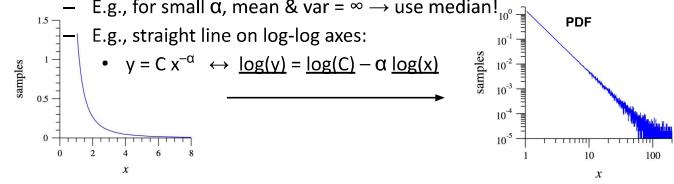
## Choose your axes wisely: Visualizing heavy-tailed distributions



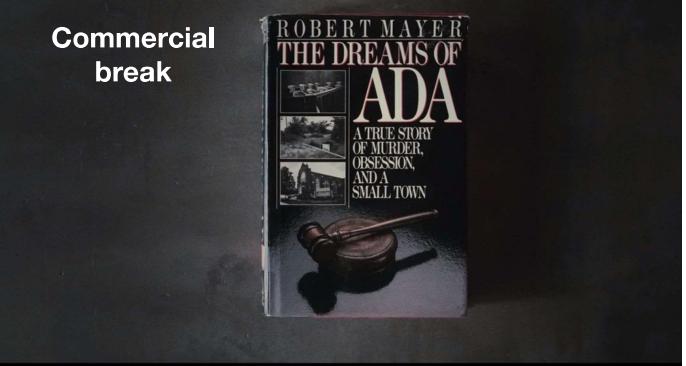
28

## Heavy-tailed data: power laws

- Probability of  $x$ :  $p(x) = Cx^{-\alpha}$ ,
- Very large values are rare, “but not very rare”
- Body size vs. city size
- Many natural phenomena are power laws (e.g., # of friends)
- For dealing with them, need to know some tricks
- E.g., for small  $\alpha$ , mean & var =  $\infty$  → use median!
- E.g., straight line on log-log axes:
  - $y = C x^{-\alpha} \leftrightarrow \log(y) = \log(C) - \alpha \log(x)$

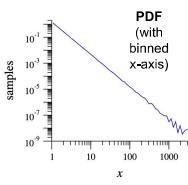


## Commercial break



## Heavy-tailed data: power laws

- Complementary cumulative distribution function (CCDF):  
 $P(x) := \Pr\{X \geq x\}$



### POLLING TIME

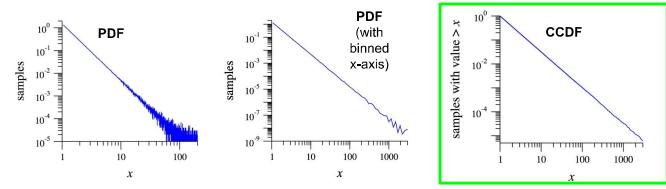
- Do you recall how is CDF defined?
- Scan QR code or go to <https://go.epfl.ch/ada2025-lec3-poll>



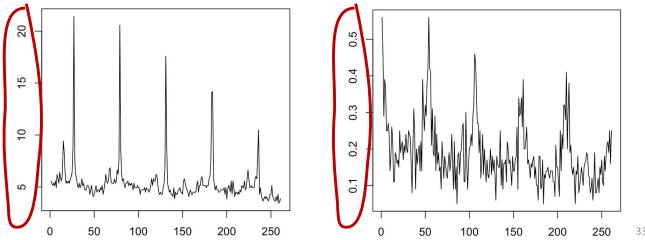
## Heavy-tailed data: power laws

- Complementary cumulative distribution function (CCDF):  
 $P(x) := \Pr\{X \geq x\}$
- CCDF of power law is also a power law (with exponent  $\alpha - 1$ )  

$$P(x) = C \int_x^{\infty} x'^{-\alpha} dx' = \frac{C}{\alpha - 1} x^{-(\alpha - 1)}$$
- CCDF plot is monotonically decreasing (even without binning)

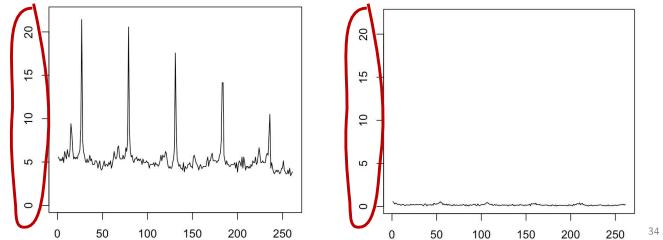


**Answer fast:** which time series has a higher mean value?



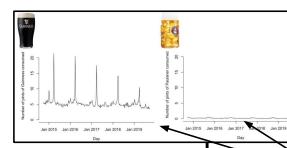
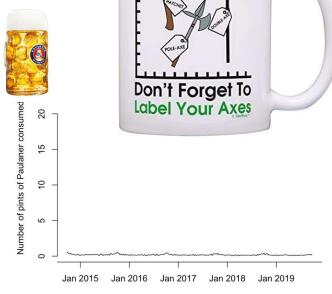
33

**Answer fast:** which time series has a higher mean value?



34

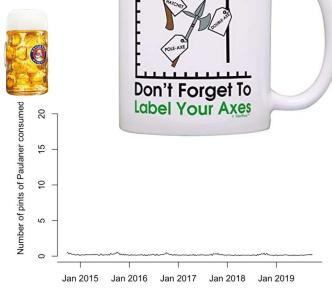
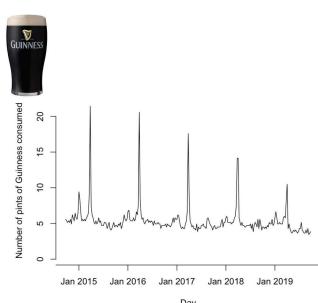
**Label your axes!**



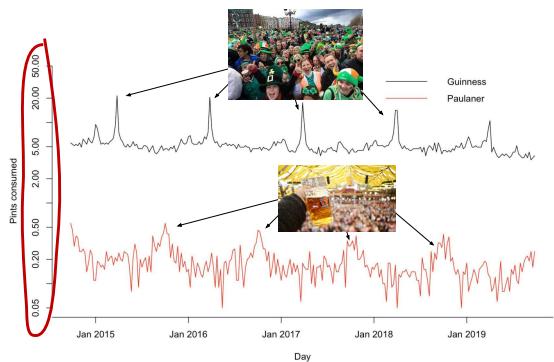
**THINK FOR A MINUTE:**

How could we show details of both time series without using different y-axes?

(Feel free to discuss with your neighbor.)



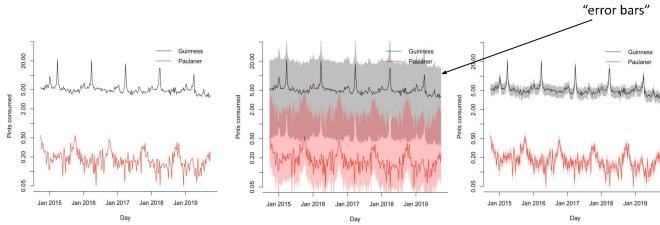
35



37

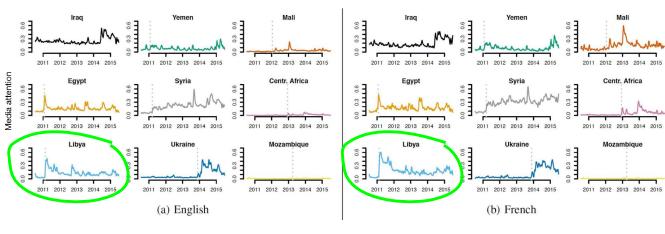
## Show data uncertainty!

Which beer is more popular, **Guinness** or **Paulaner**?



38

## Consider using small multiples!



(a) English

(b) French

## Use colors consistently!

[\[link\]](#)

## Use colors wisely!

Choose colors based on the information you want to convey

### Sequential

Colors can be ordered from low to high



### Diverging

Two sequential schemes extended out from a critical midpoint value

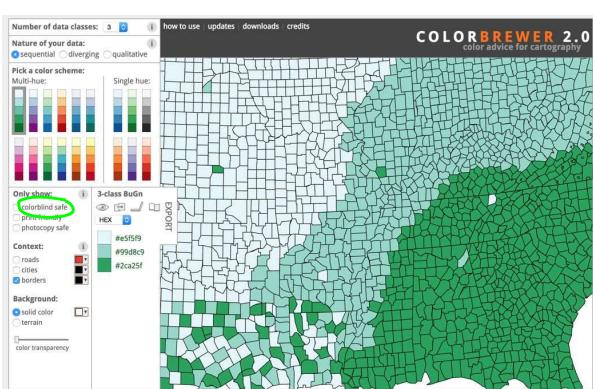


### Categorical

Lots of contrast between each adjacent color

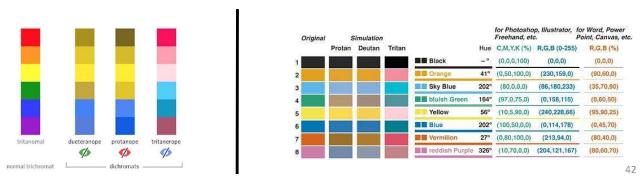
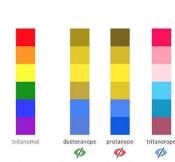


40



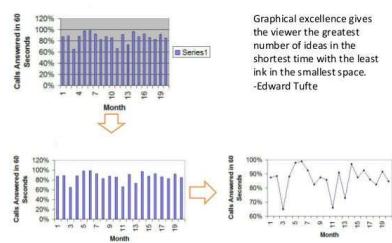
## Use colorblind-safe palettes!

- Remember: 10% of males have some form of colorblindness



42

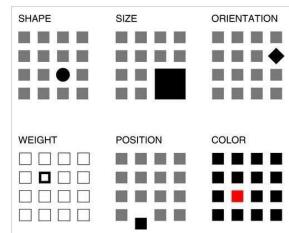
## Use data ink wisely! Avoid chart junk!



43

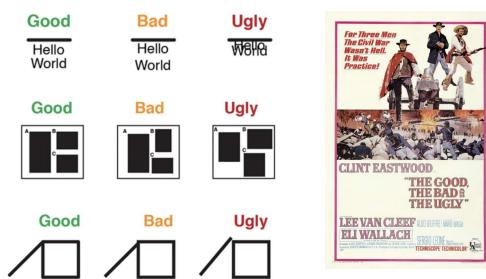
## Use visual contrast

- Use visual contrast to highlight the important information
- Vary the size, shape, position, orientation, or color of an element to make the key part of the figure the most visually prominent
- Avoid incorporating every form of visual contrast



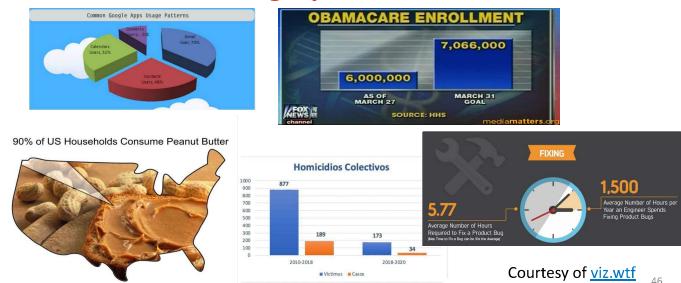
44

## The good, the bad and the ugly



45

## Which principles and best practices do these graphics violate?



46

## Part 3

### A (small) selection of use cases for data visualization

Use case:  
Presenting  
scientific results



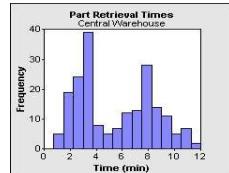
47

48

Use case:  
Data wrangling

## Multimodal data

- Two or more distinct peaks in a histogram often suggest **2 or more distinct populations** of samples.
- But don't guess! Explore further by using, e.g., color and a histogram of multiple populations (p.t.o.).

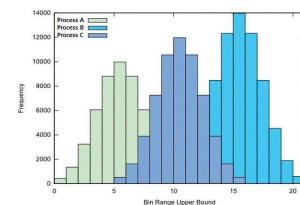


49

Use case:  
Data wrangling

## Multimodal data

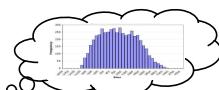
Explore further by using, e.g., color and a histogram of multiple populations



50

Use case:  
Data wrangling

## Weird data



- Maintain a **theory of what the data should look like**.
- Some data is **very hard to explain**.
- Never just blink it away!
- First, assume a bug. Try to fix it.
- If not a bug: you might have made an interesting discovery!
- Some of science's most important findings were made by not ignoring weird data, but dwelling on it!



51

Use case:  
Journalism

NY Times interactive visualizations (recession/recovery 2014)

<http://www.nytimes.com/interactive/2014/06/05/upshot/how-the-recession-reshaped-the-economy-in-255-charts.html>

And 2014 "the year in interactive storytelling"

[http://www.nytimes.com/interactive/2014/12/29/us/year-in-interactive-storytelling.html?\\_r=0](http://www.nytimes.com/interactive/2014/12/29/us/year-in-interactive-storytelling.html?_r=0)

NY Times graphics are a great source of best practices in viz (except for when they're not...)



52

Use case:  
Educating the public

Hans Rosling:

200 countries, 200 years, 4 minutes

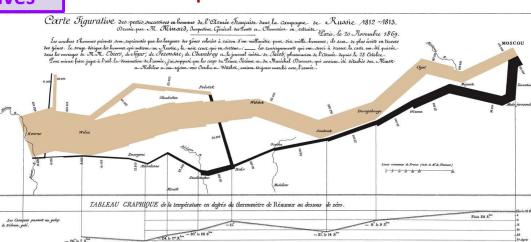
<https://www.youtube.com/watch?v=ibkSRlYSoio>



53

Use case:  
Give new perspectives

Charles Joseph Minard 1869  
Napoleon's march



According to Tufte: "It may well be the best statistical graphic ever drawn."  
5 variables: army size, location, dates, direction, temperature during retreat

54

## Interactive toolkits: D3

Without doubt, the most widely used interactive visualization framework is **D3**.

### Tools

(remaining slides for your personal perusal)

Note from the authors: *D3 is intentionally a low-level system. During the early design of D3, we even referred to it as a "visualization kernel" rather than a "toolkit" or "framework"*

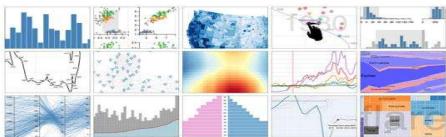
55

56

## Interactive toolkits: Vega

Vega is a “visualization grammar” developed on top of D3.js  
It specifies graphics in JSON format.

### vega

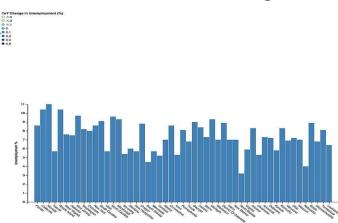


Vega is a *visualization grammar*, a declarative format for creating, saving, and sharing interactive visualization designs.

57

## Interactive toolkits: Vincent

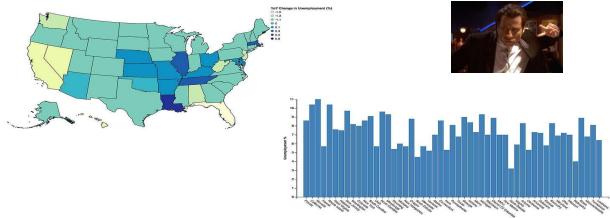
Vincent is a Python-to-Vega translator.  
Trivia question: why is it called Vincent? Hint: Vincent+Vega= ?



58

## Interactive toolkits: Vincent

Vincent is a Python-to-Vega translator.  
Trivia question: why is it called Vincent? Hint: Vincent+Vega= ?



59

## Bokeh: another interactive viz library

Bokeh is an independent Viz library focused more heavily on big data visualization. Has both Python and Scala bindings.



60

## Visualizing maps: Folium

More in tomorrow's lab session!



61

## Feedback

Give us feedback on this lecture here:

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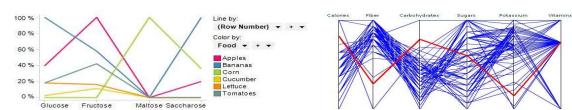
- What did you (not) like about this lecture?
- What was (not) well explained?
- On what would you like more (fewer) details?
- ...

62

## > 2 variables: parallel-coord. plots

Color, x, y

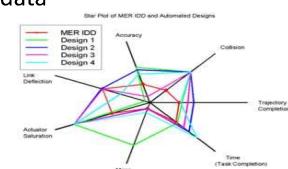
Color variable is categorical, others arbitrary



63

## > 2 variables: radar charts

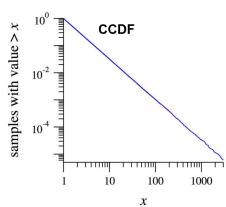
- Similar to parallel-coord. plots
- Doesn't pretend that x axis has meaningful order
- Also good for periodic data



64

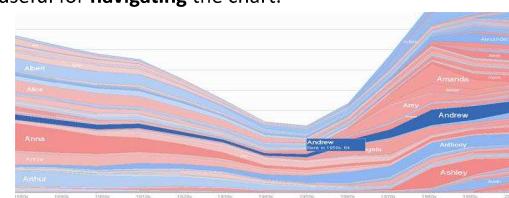
## Heavy-tailed data: power laws

- Smart trick for plotting CCDF of any distribution:
  - x-axis: data sorted in ascending order
  - y-axis:  $(n:1)/n$  (where n is number of data points)



## Interactive chart design: simplifying

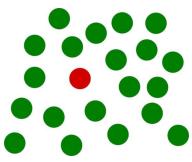
- With interactive charts you can keep things very simple by **hiding** and **dynamically revealing** important structure.
- On an interactive chart, you reveal the information most useful for **navigating** the chart.



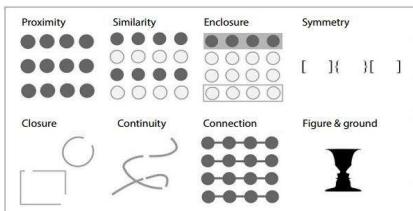
66

## Use structure!

Gestalt psychology principles (1912)



67

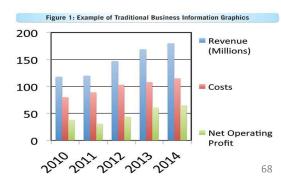


## A case for ugly visualizations

People instinctively gravitate to attractive visualizations, and they have a better chance of getting on the cover of a journal.

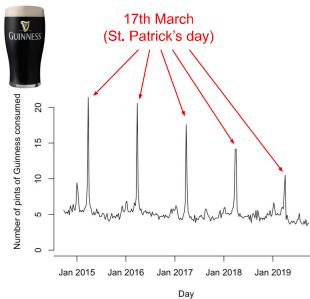
But does this **conflict with the goals of visualization?**

- Rapid exploration
- Focus on most important details
- Easy and fast to develop and customize



68

## Guide your audience!



69