

Data Visualization

CentraleDigitalLab
@LaPlateforme_



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What is Data Science?

Data Analysis

Needs of **concrete questions**



Explains data to take a **future decision**



Guided by the data **analyst**



Detects **superficial patterns**

Data Science

Needs of a **problematic** in a domain

Aims to develop a **product based on data**

Guided by the **interpretation** of the data

Highlights **deep patterns**

Machine Learning

Needs of a **task** and a **dataset**.

Optimizes a metric that measures **performance**

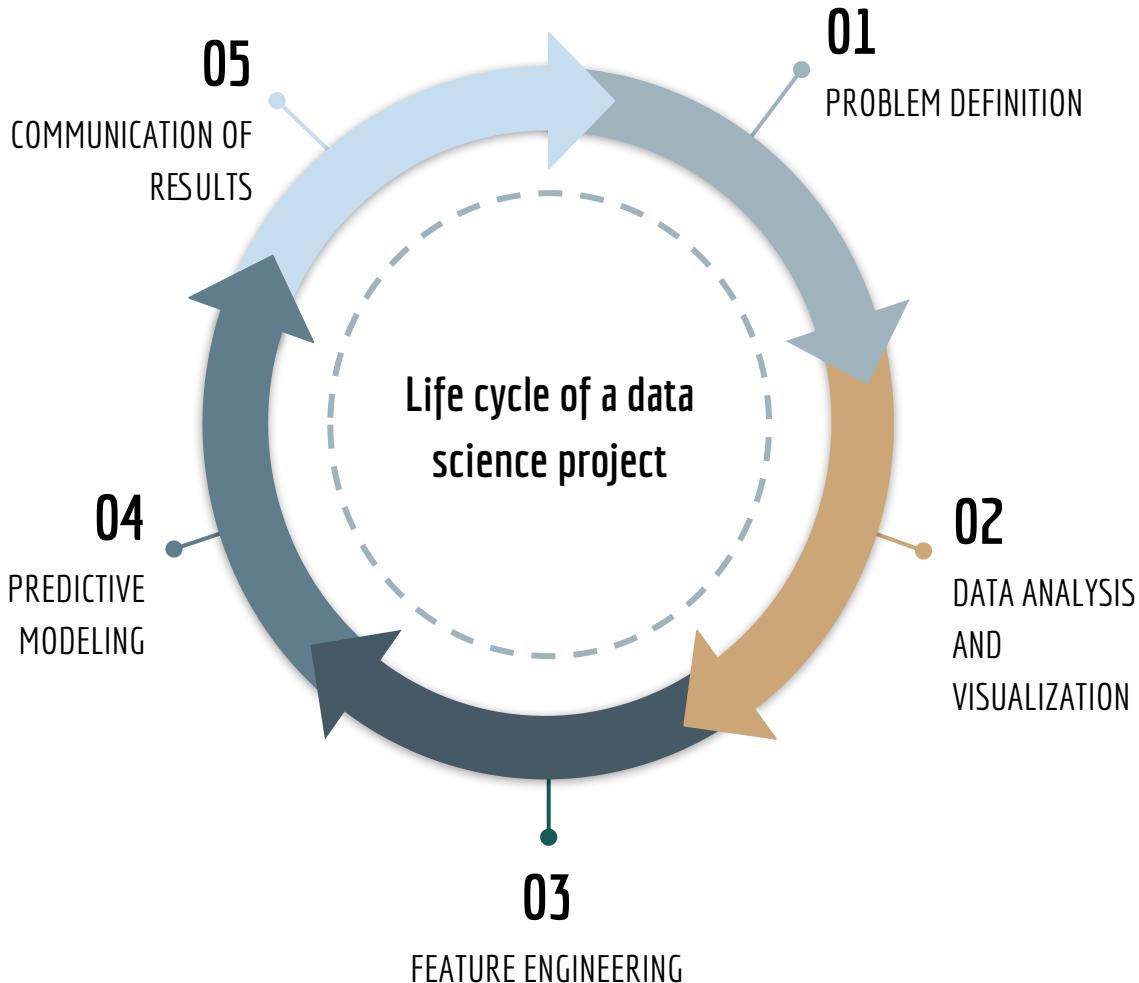
Guided by the **model theory**

Detects **deep patterns**

Endless lifecycle

In this course we'll see concepts related to:

1. Statistical and visualization tools for the **step 02**.
2. Statistical methods to understand results for the **step 04**.
3. Visualization and effective communication for the **step 05**.



What if we learn Machine Learning without data analysis and visualization?

- We **don't know what to model** unless we are told to.
- We **can't understand** the **impact** of our results
 - Long term impact usually given by **bias, unfairness**, or **information filtering**.
 - Impact given by **business metrics**.
- We waste so much time and effort developing **models that don't answer our questions**.

What if we learn Data Science without Machine Learning?

- We are **limited** to **simple analysis**. Or we use models without understanding them.
- Use of machine learning **models that are inappropriate for our dataset**. For example models that don't work well on categorical data.
- We **spend so much time optimizing a model** since we don't know how to properly do it.
- We can **only detect superficial patterns**.

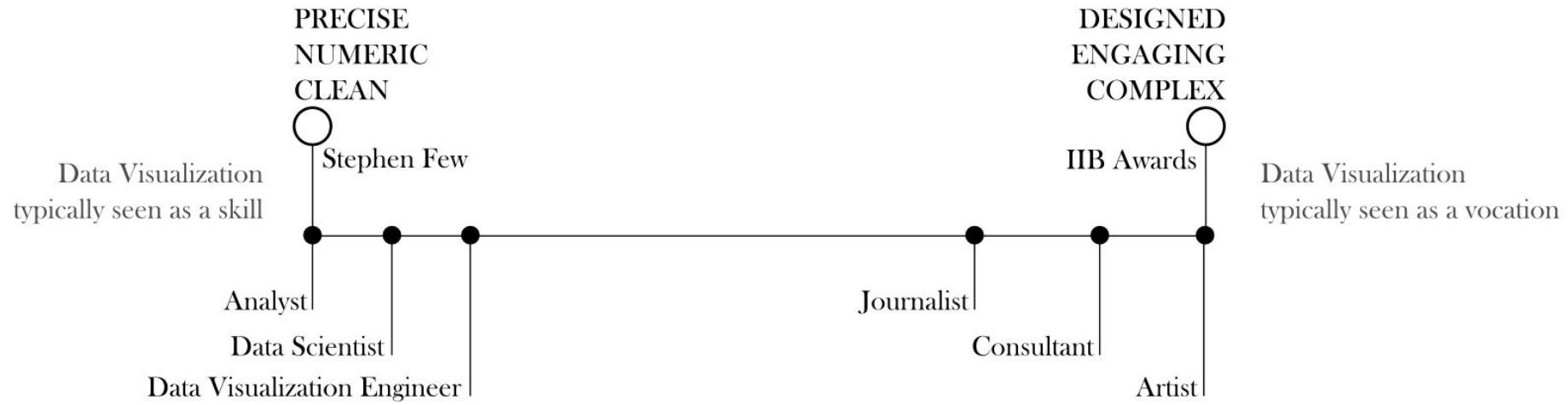
Visualization in Data Science

- Data visualization is for communication!
- There's a sender, receiver, a message, and a communication channel. All these factors affect the communication process.
- Data visualization helps to define our message and determine how the receiver will interpret it.
- Depending on the visualization it might improve or complicate the communication.

	A	B	C	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL		
1						Optimizer																																	
2	Results	Log	Trucar	Diff	Optim	LR	Cell	batch_	dropc	epoch:	embedc	hider	max_s	Filter	Merge	Pretra	Fineti	AUC	R1	rmse	AUC	R1	rmse	Accur	R2	AUC	R1	rmse	Accur	R2	AUC	R1	rmse	Accur	R2	Eval all			
3																																							
4	LSTM																																						
5/results/kddcup/lstm/pre	14648	N					100	0.3	500	-	100	50	> 5	Y	-	-				0.787	0.388	0.795	0.278															
6	/home/mteruel/edm/resul	14662	N					100	0.3	500	-	100	50	> 5	Y	-	-				0.879	0.359	0.831	0.439	0.794	0.345	0.850	0.275	0.605	0.533	0.672	-0.308	0.498	0.456	0.770	-0.431			
7	/home/mteruel/edm/resul	14663	N					100	0.3	500	-	50	50	> 5	Y	-	-				0.880	0.359	0.827	0.438	0.802	0.339	0.858	0.296	0.656	0.511	0.685	-0.183	0.597	0.414	0.800	-0.199			
8	/home/mteruel/edm/resul	14664	N					100	0.3	500	-	50	100	> 5	Y	-	-				0.814	0.374	0.881	0.361	0.822	0.431	0.804	0.336	0.864	0.315	0.666	0.490	0.713	-0.108	0.626	0.405	0.795	-0.094	
9/results/kddcup/lstn/pre	14735	Y					50	0.3	500	-	50	50	> 5	Y	-	-				0.759	0.467	0.617	0.050	0.657	0.415	0.784	-0.053	0.611	0.500	0.613	-0.164	0.634	0.398	0.783	-0.074			
10/results/kddcup/lstn/pre	14885	N					50	0.3	500	-	50	50	N	Y	-	-				0.837	0.335	0.871	0.341	0.855	0.450	0.842	0.290	0.895	0.369	0.741	0.386	0.796	0.153	0.662	0.418	0.771	-0.195	14939 ..
11								N												100	0.3	500	-	50	100	N	Y	-	-										
12																																							
▲ 13	Embeddings																																						
▼ 19	/home/mteruel/edm/resul	14661	N					100	0.3	500	50	50	100	> 5	N	N					0.885	0.352	0.836	0.457	0.814	0.335	0.856	0.326	0.703	0.466	0.723	0.006	0.724	0.393	0.797	-0.047			
20	/home/mteruel/edm/resul	14667	N					100	0.3	500	50	50	50	> 5	N	N					0.880	0.359	0.829	0.439	0.813	0.332	0.867	0.330	0.687	0.478	0.705	-0.053	0.688	0.405	0.810	-0.142			
21/results/kddcup/embedc	14706	Y					50	0.2	500	50	50	20	> 5	N	Y	Y				0.728	0.481	0.614	-0.010	0.683	0.390	0.798	0.069	0.641	0.467	0.687	0.004	0.599	0.404	0.773	-0.113			
22/results/kddcup/embedc	14716	Y					100	0.3	500	50	50	50	> 5	Y	N					0.756	0.459	0.645	0.079	0.674	0.430	0.746	-0.153	0.649	0.462	0.673	0.036	0.534	0.422	0.770	-0.207			
23/results/kddcup/embedc	14821	N					100	0.3	500	50	50	100	> 5	N	N				0.830	0.363	0.884	0.357	0.830	0.443	0.810	0.334	0.868	0.319	0.740	0.455	0.727	0.050	0.685	0.379	0.815	0.029		
24/results/kddcup/embedc	14823	N					100	0.3	500	50	50	100	> 5	Y	N				0.834	0.361	0.884	0.358	0.825	0.442	0.813	0.333	0.865	0.322	0.731	0.456	0.715	0.043	0.688	0.375	0.831	0.051		
25/results/kddcup/embedc	14828	N					50	0.2	500	50	50	100	20	> 5	Y	Y	Y			0.808	0.378	0.871	0.365	0.816	0.417	0.801	0.344	0.846	0.279	0.701	0.479	0.711	-0.053	0.575	0.407	0.813	-0.122	
26/results/kddcup/embedc	14832	N					50	0.3	500	50	50	100	200	> 5	Y	Y	Y			0.818	0.370	0.879	0.359	0.825	0.436	0.788	0.340	0.861	0.296	0.707	0.471	0.711	-0.018	0.672	0.388	0.811	-0.021	
27/results/kddcup/embedc	14858	N					50	0.3	500	50	50	100	200	> 5	Y	N	N			0.825	0.365	0.875	0.365	0.827	0.420	0.806	0.338	0.854	0.302	0.714	0.449	0.739	0.076	0.650	0.383	0.824	0.007	
28/results/kddcup/embedc	14873	N					50	0.3	500	20	100	200	> 5	Y	Y	Y			0.831	0.363	0.879	0.361	0.827	0.433	0.815	0.335	0.857	0.316	0.733	0.438	0.742	0.122	0.675	0.381	0.826	0.020		
29/results/kddcup/embedc	14875	N					50	0.3	500	20	100	200	> 5	Y	Y	N			0.835	0.362	0.880	0.361	0.822	0.432	0.815	0.340	0.846	0.293	0.722	0.445	0.736	0.089	0.712	0.371	0.823	0.069		
30/results/kddcup/embedc	14877	N					50	0.3	500	20	50	200	> 5	Y	Y	N			0.841	0.360	0.880	0.364	0.818	0.423	0.819	0.334	0.859	0.320	0.753	0.432	0.735	0.145	0.715	0.372	0.826	0.065	14941 ..	
31/results/kddcup/embedc	14886	N					100	0.3	500	50	50	100	N	Y	N				0.850	0.330	0.887	0.338	0.853	0.461	0.850	0.291	0.895	0.366	0.783	0.379	0.807	0.184	0.699	0.396	0.813	-0.069	14922+12 ..	
32/results/kddcup/embedc	14887	N					50	0.3	500	20	100	200	N	Y	Y	Y			0.846	0.328	0.879	0.339	0.852	0.458	0.843	0.289	0.896	0.373	0.788	0.371	0.820	0.219	0.652	0.399	0.804	-0.089	x	
▲ 33								N												0.881	0.339	0.851	0.456	0.843	0.290	0.892	0.366	0.804	0.362	0.831	0.258	0.737	0.379	0.814	0.020	14940 ..			
▼ 41/results/kddcup/embedc	15167	N	adam	0.01	gru	100	0.3	500	20	50	200	N	Y	Y	Y	0.818	0.343	0.890	0.334	0.854	0.472	0.839	0.294	0.896	0.349	0.732	0.391	0.807	0.130	0.576	0.437	0.787	-0.305					
42/results/kddcup/embedc	15177	N	adam	??	gru	100	0.3	500	20	50	200	N	Y	Y	Y	0.811	0.345	0.886	0.336	0.858	0.466	0.823	0.304	0.890	0.307	0.683	0.438	0.773	-0.088	0.627	0.419	0.801	-0.199					
43/results/kddcup/embedc	15235	N	adam	0.01	lstm	100	0.3	500	50	50	100	N	Y	N		0.811	0.347	0.882	0.345	0.841	0.439	0.814	0.304	0.892	0.305	0.684	0.425	0.799	-0.026	0.621	0.411	0.810	-0.153					
44/results/kddcup/embedc	15236	N	adam	0.01	lstm	50	0.3	500	20	100	200	N	Y	Y	Y	0.812	0.345	0.884	0.340	0.850	0.452	0.826	0.300	0.892	0.325	0.700	0.405	0.800	0.071	0.589	0.431	0.786	-0.265					
45/results/kddcup/embedc	26285	N					100	0.3	500	20	20	300	N	Y	N				0.853	0.325	0.881	0.335	0.854	0.469	0.841	0.291	0.895	0.362	0.790	0.369	0.814	0.228	0.675	0.397	0.796	-0.076		
46/results/kddcup/embedc	26286	N					100	0.3	500	20	20	300	N	Y	Y	Y	0.857	0.322	0.883	0.334	0.857	0.474	0.845	0.288	0.895	0.375	0.783	0.364	0.826	0.250	0.757	0.371	0.820	0.062				

enrollment_id,username,course_id

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30,JPkczY0xyoDZBjwZAAQHmjpsvnPQzwV0,DPnLzkJJqOOPRJfBxIHbQEERiYHu5ila



Credit: [Medium Article](#)

Can you identify your roll in this line? Where would you like to be?

Bias in perception

What do we think when we don't stop to analyze?

Patternicity bug!

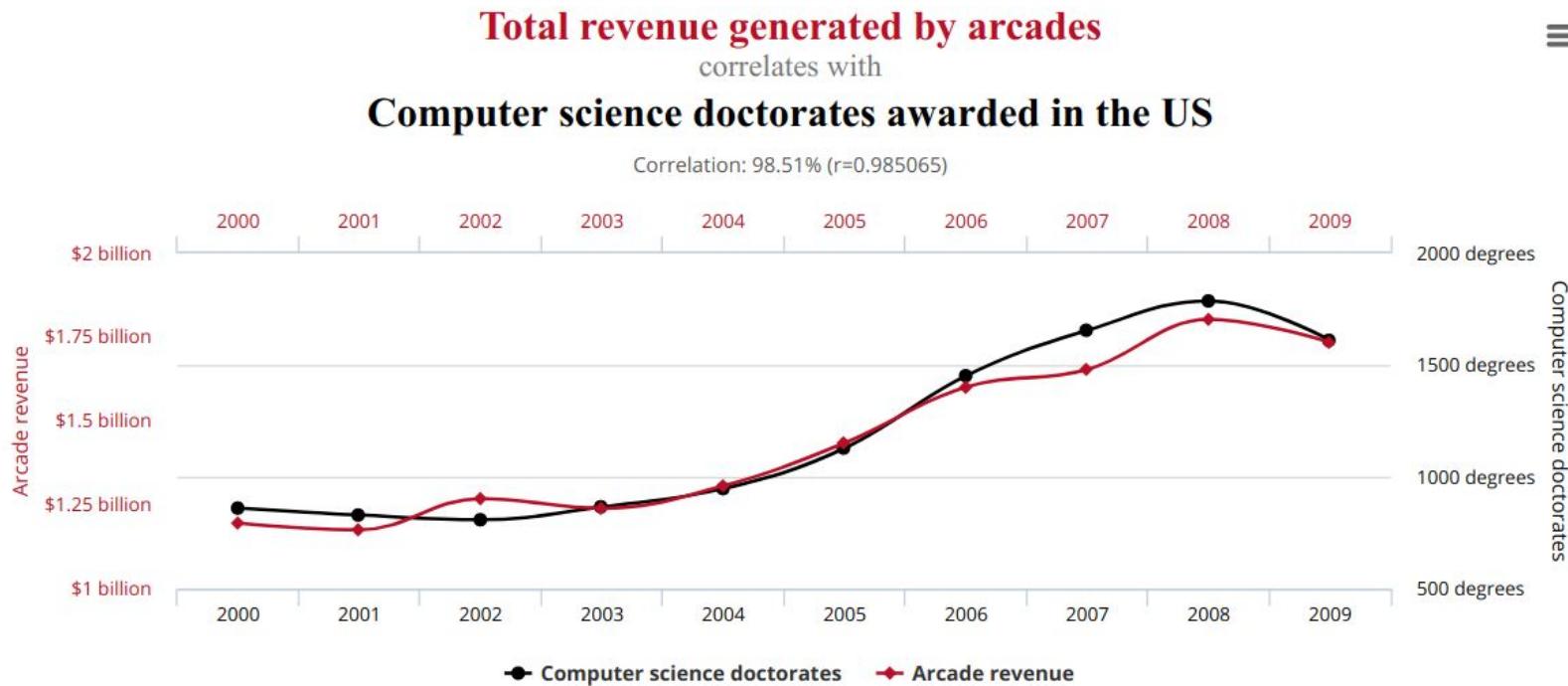
Tendency to find patterns in objects and to perceive the whole as more than the sum of its parts.



The face of mars



Correlation is not causation



Data sources: U.S. Census Bureau and National Science Foundation

tylervigen.com

<https://www.tylervigen.com/spurious-correlations>

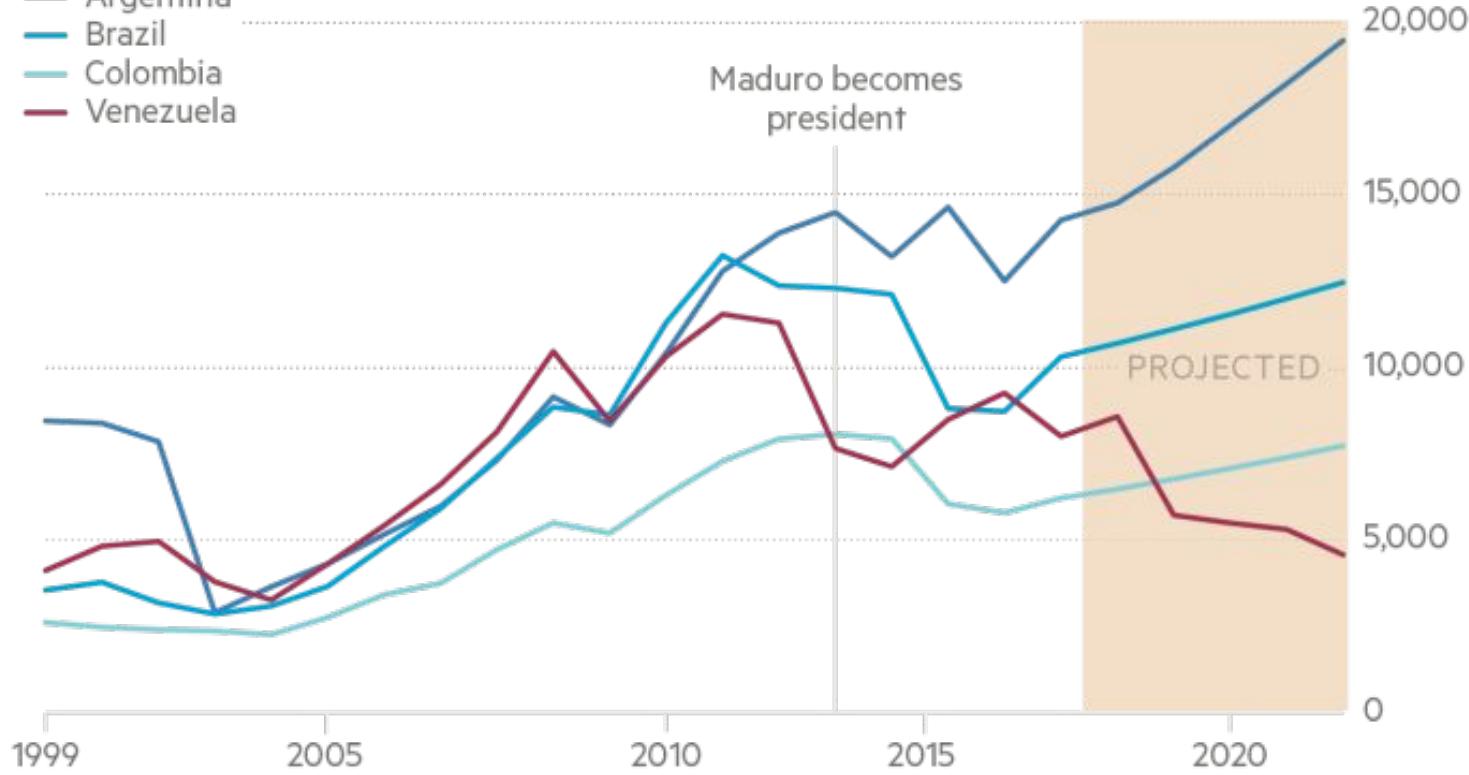
Storytelling bug!

Tendency to find reasons that explain the
presence of patterns in objects

Oil-rich Venezuela will have a lower per-capita GDP than its peers

GDP per capita in current US dollars

- Argentina
- Brazil
- Colombia
- Venezuela



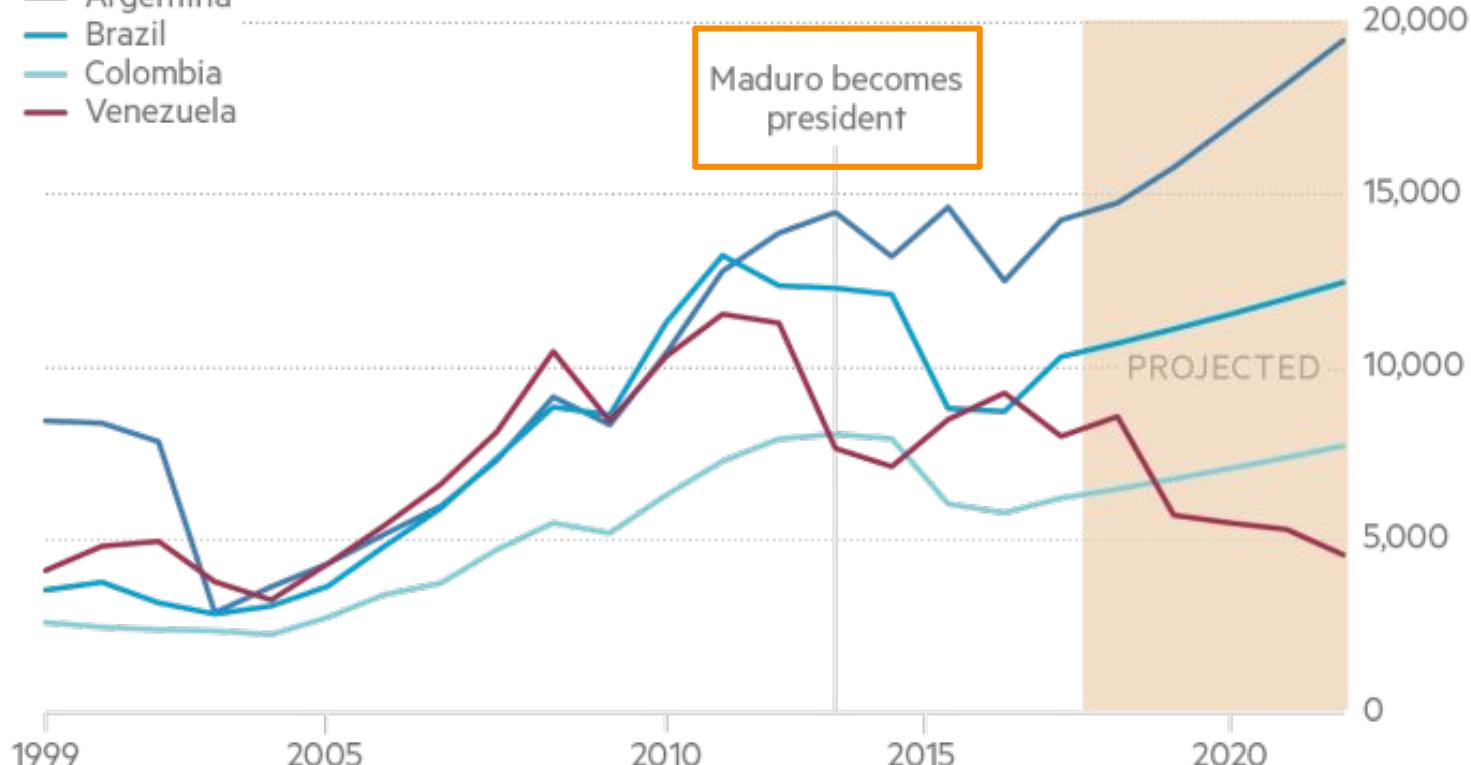
Source: IMF World Economic Outlook Database

FT

Oil-rich Venezuela will have a lower per-capita GDP than its peers

GDP per capita in current US dollars

- Argentina
- Brazil
- Colombia
- Venezuela



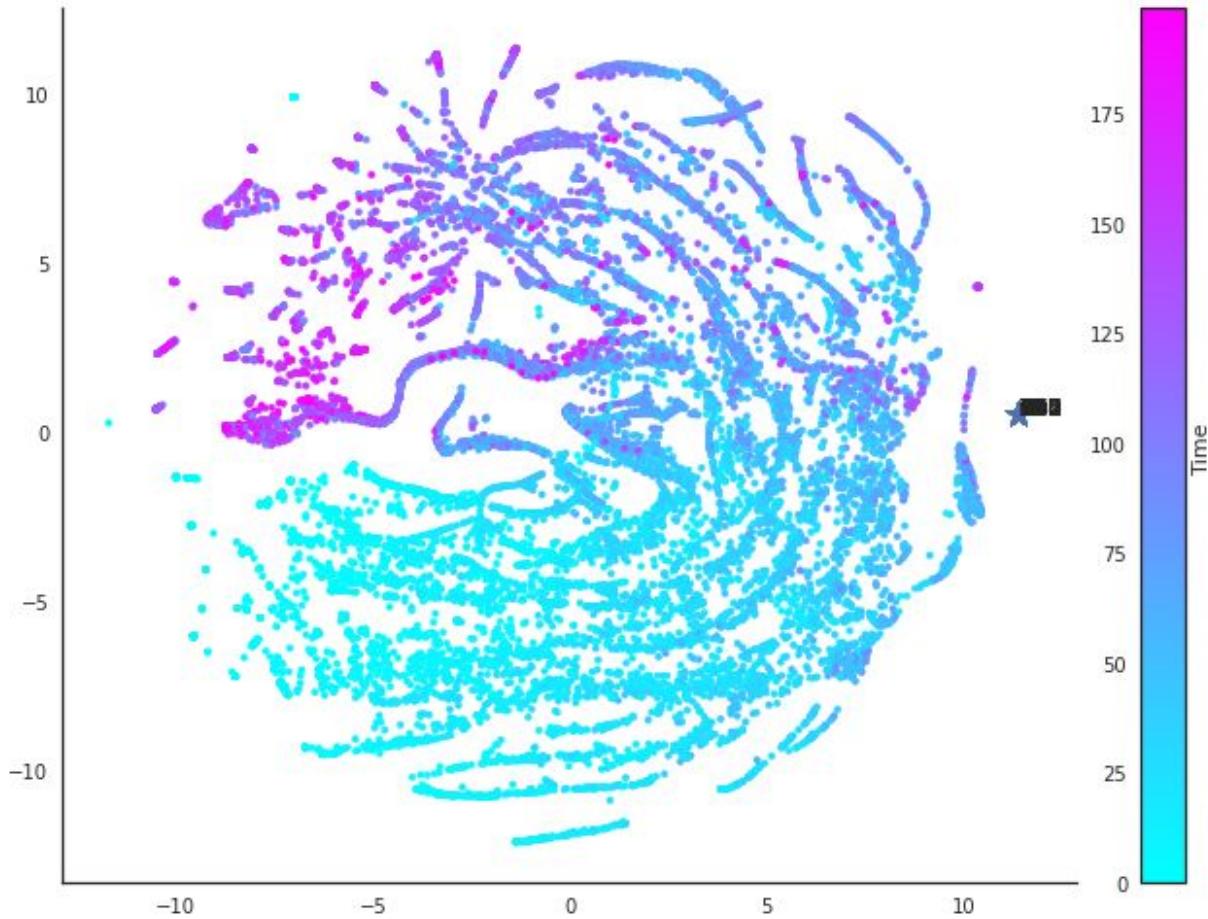
Source: IMF World Economic Outlook Database

Confirmation bug!

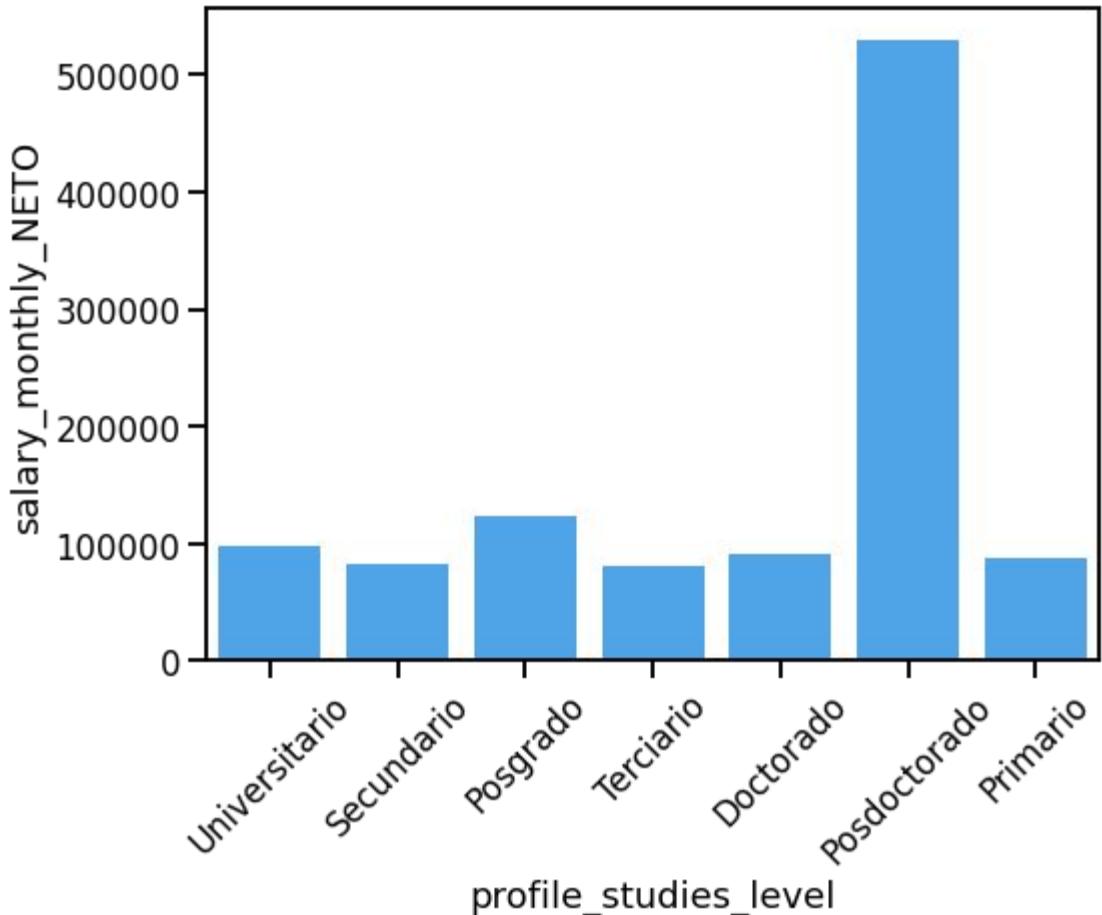
Tendency to believe (more) true the information that
supports our existing beliefs.

Are the patterns real?

- Color patterns
- "Worm" patterns



**Do we doubt
the data or
not?**



Presentation

Visualization for others

Optimize the
communication
process



Generate a message
that is quickly and
faithfully decoded

Characteristics of a good visualization

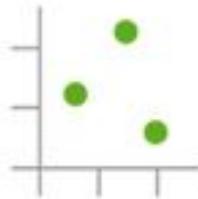
- Honest: represents data that is correct.
- Functional: represents data so that they can be properly interpreted.
- Enlightening: It must show patterns that would not be easily perceived using other media.
- Esthetic
- Informative

Visual Encodings

Data mapping → visual elements



Visual elements



Position



Length



Angle/Slope



Area



Volume



Difference



Color hue



Color Saturation



Contrast



Texture

How to choose the visual elements?

Principle of **consistency**: the properties of the image must correspond to the properties of the data.

- The lie factor

Principle of **ordering by importance**: the most important information must be coded in the most efficient way possible.

- What is the most important information?
- What are the most effective encodings?

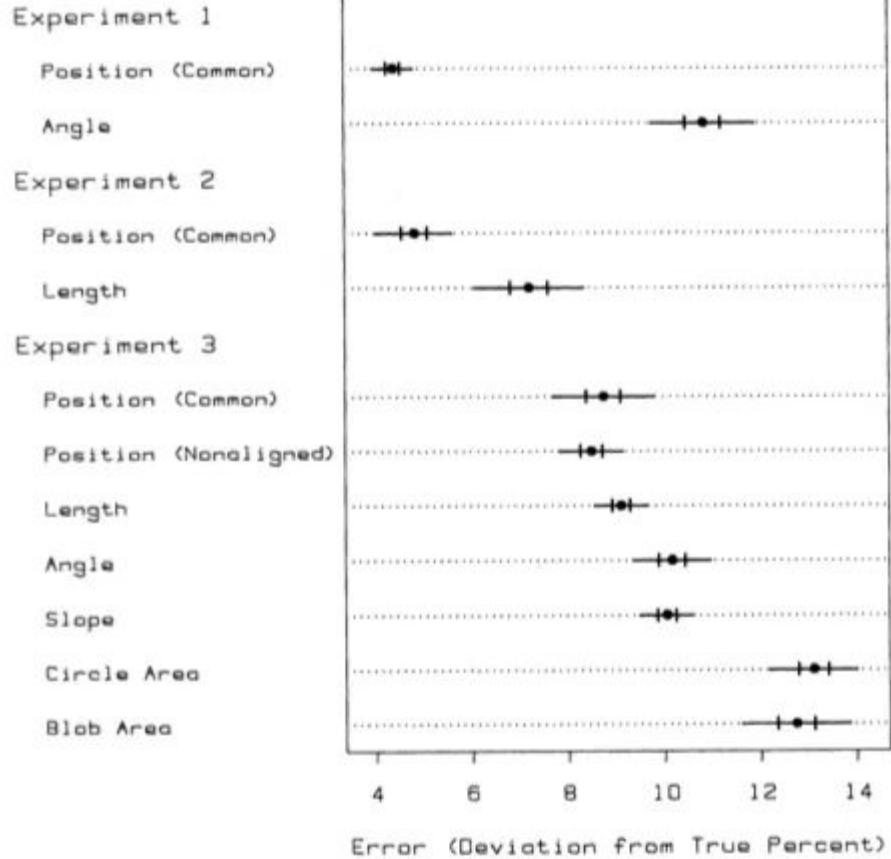
—

Not all visual elements are equally effective

How do we measure the error?

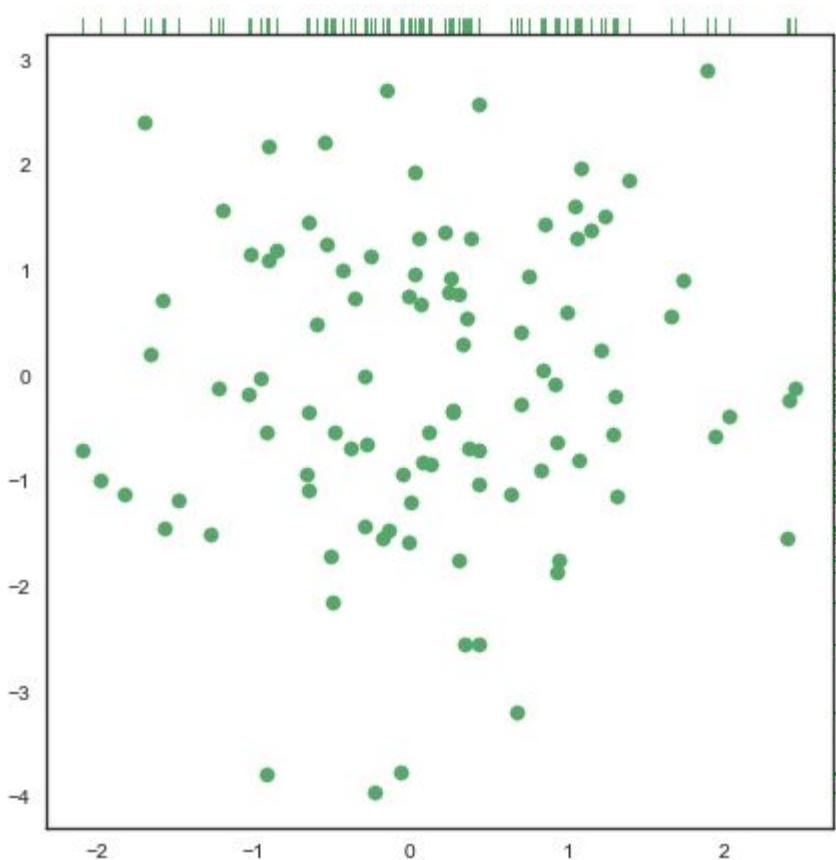
Different encodings allow us to better or worse estimate the difference between two quantities

William S. Cleveland and Robert McGill,
Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods, 1984



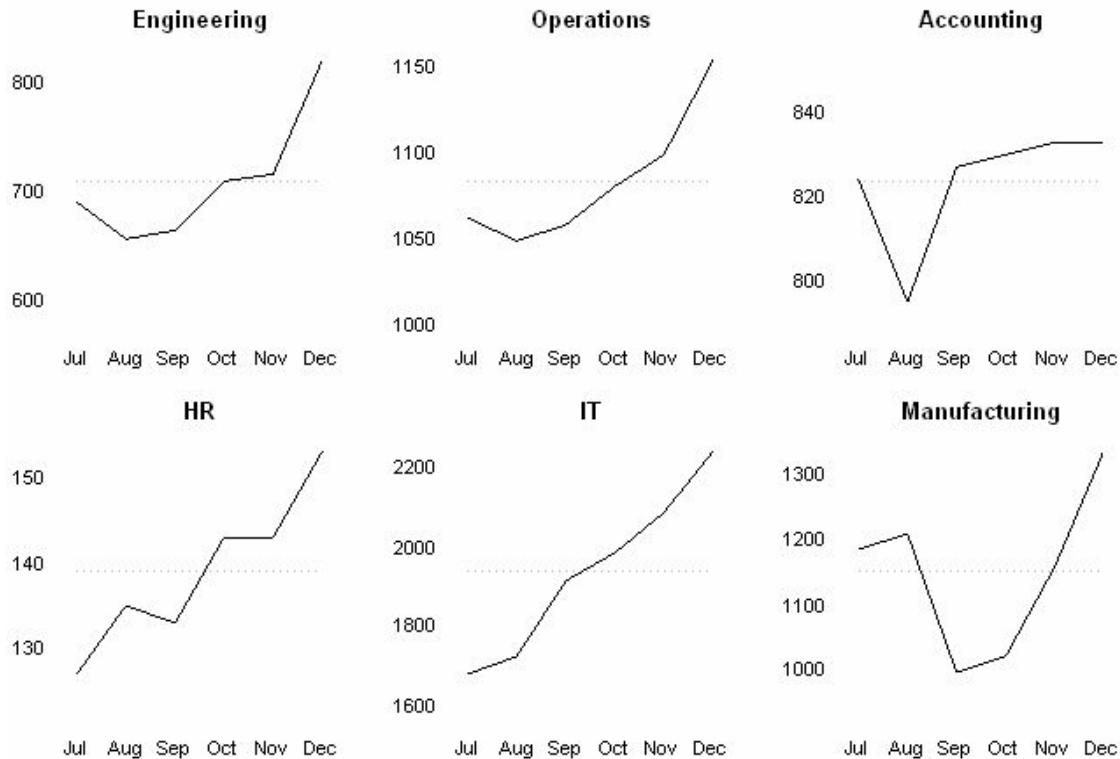
How do we measure the error?

1. Position on a common scale
2. Position on unaligned scales
3. Long
4. Angle and tilt (draw)
5. Area
6. Volume, density and color saturation
(tie)
7. chromatic hue



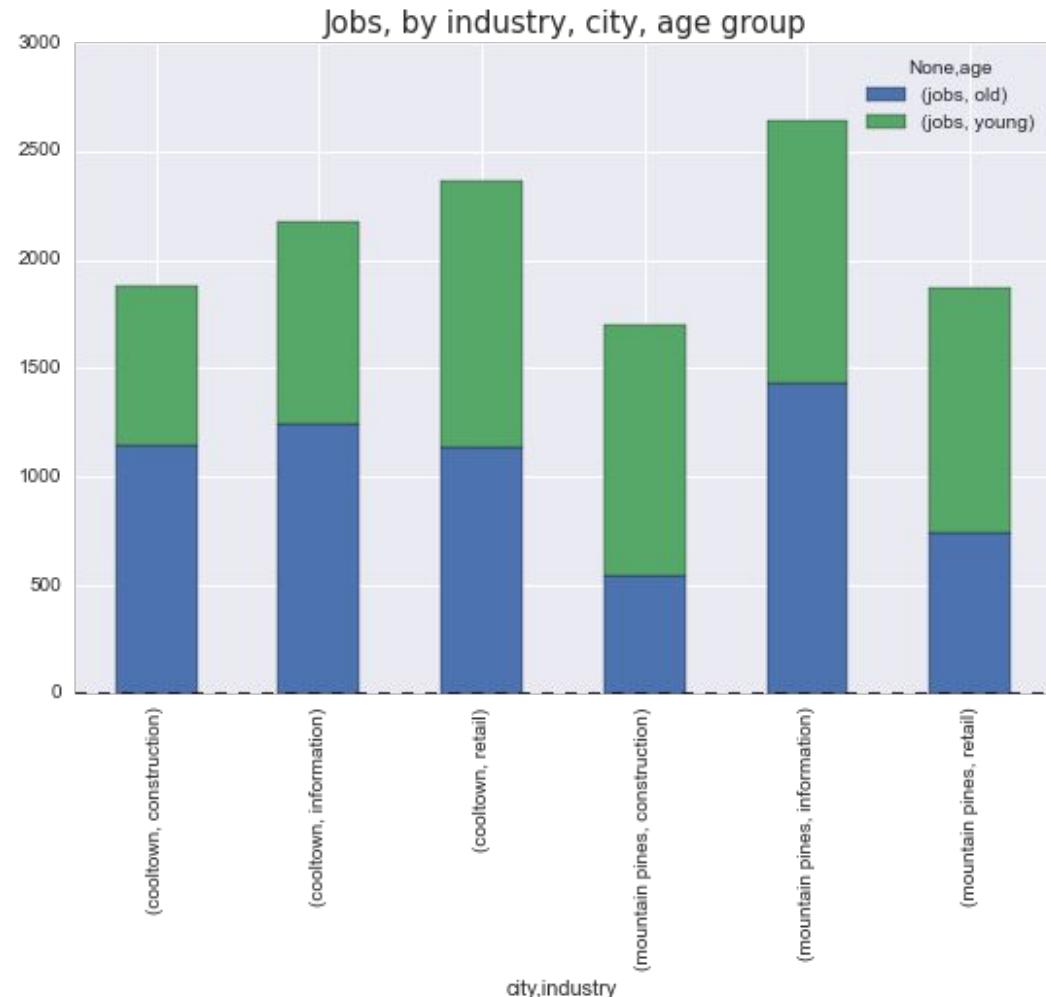
How do we measure the error?

1. Position on a common scale
2. **Position on unaligned scales**
3. Long
4. Angle and tilt (draw)
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6. Volume, density and color saturation
(tie)
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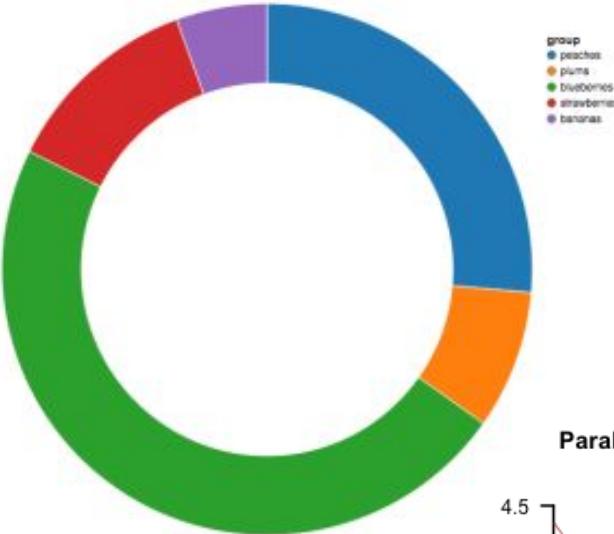


How do we measure the error?

1. Position on a common scale
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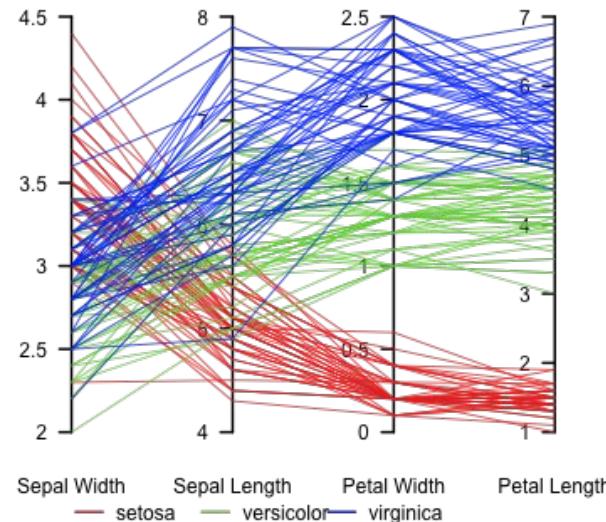


How do we measure the error?



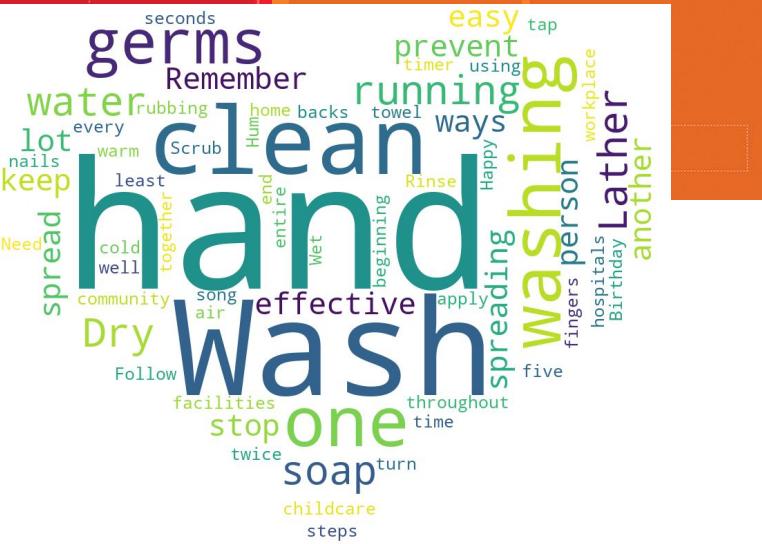
1. Position on a common scale
2. Position on unaligned scales
3. Long
4. Angle and tilt (draw)
5. Area
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(tie)
7. chromatic hue

Parallel coordinate plot, Fisher's Iris data



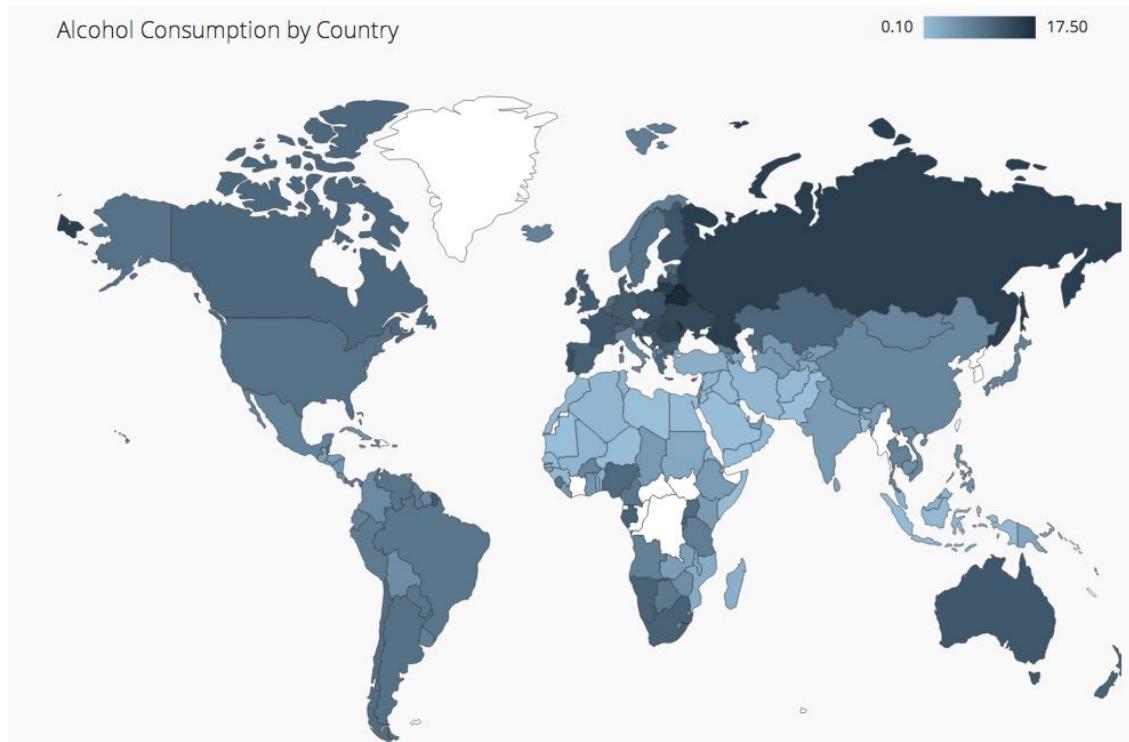
How do we measure the error?

1. Position on a common scale
 2. Position on unaligned scales
 3. Long
 4. Angle and tilt (draw)
 5. Area
 6. Volume, density and color saturation
(tie)
 7. chromatic hue



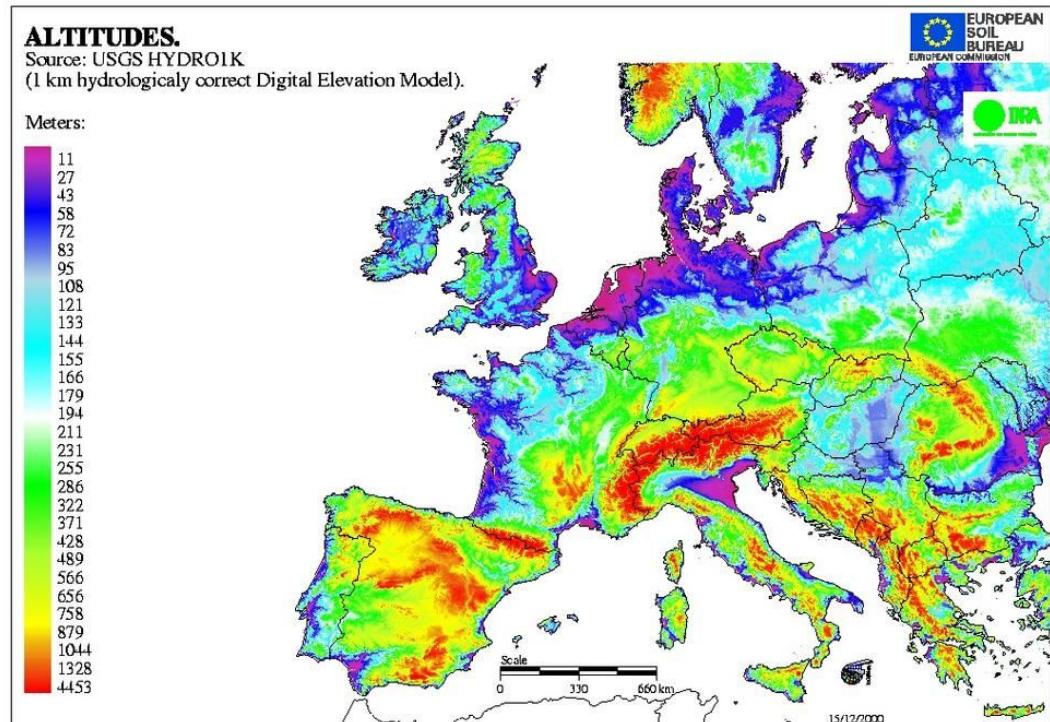
How do we measure the error?

1. Position on a common scale
2. Position on unaligned scales
3. Long
4. Angle and tilt (draw)
5. Area
6. **Volume, density and color saturation (tie)**
7. chromatic hue



How do we measure the error?

1. Position on a common scale
2. Position on unaligned scales
3. Long
4. Angle and tilt (draw)
5. Area
6. Volume, density and color saturation
(tie)
7. chromatic hue



Encodings according to data type

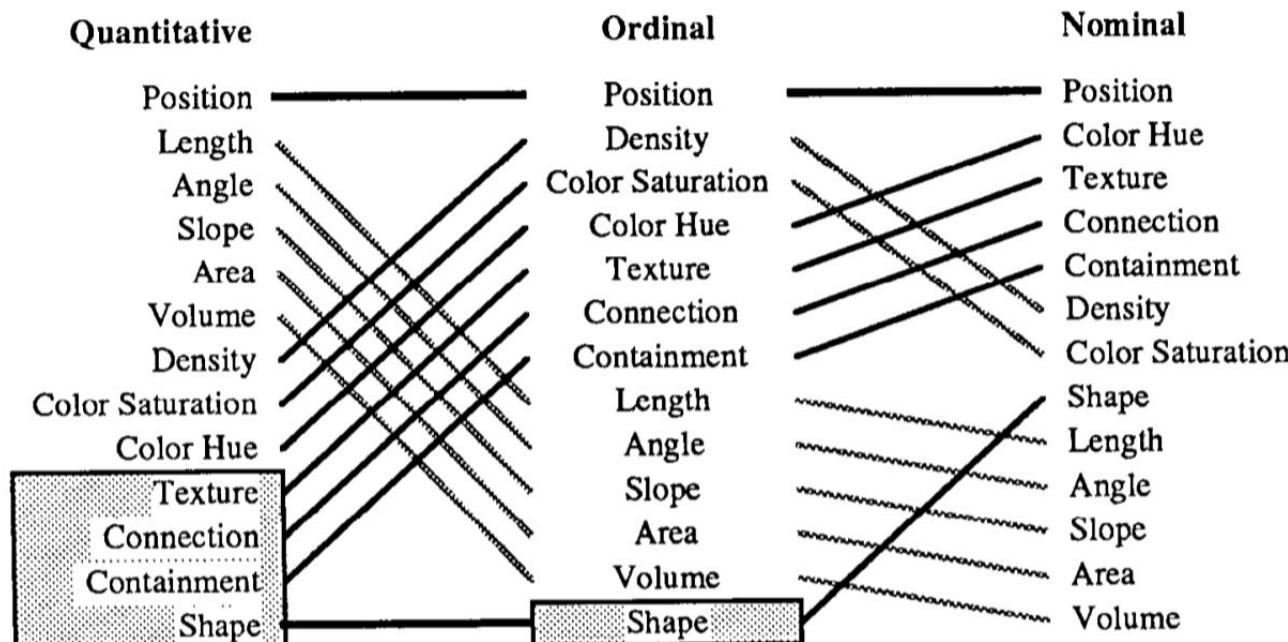


Fig. 15. Ranking of perceptual tasks. The tasks shown in the gray boxes are not relevant to these types of data.

Encodings according to data type

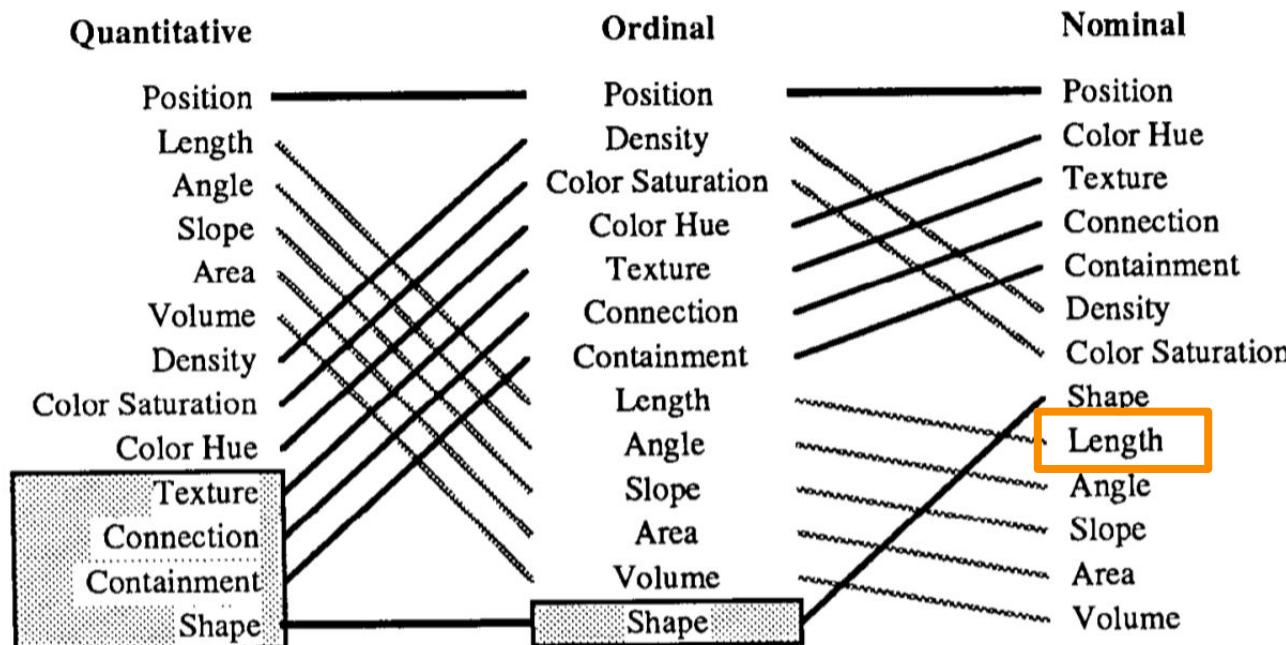


Fig. 15. Ranking of perceptual tasks. The tasks shown in the gray boxes are not relevant to these types of data.

Encodings according to data type

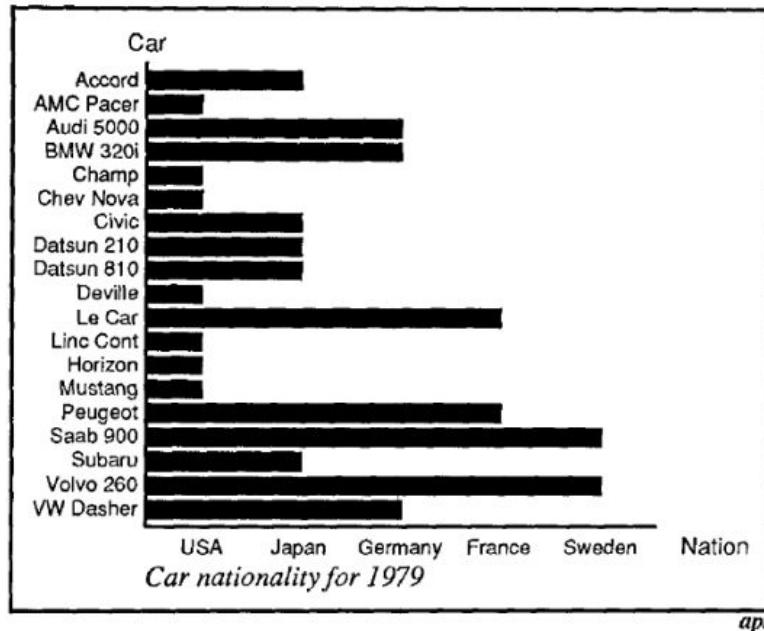
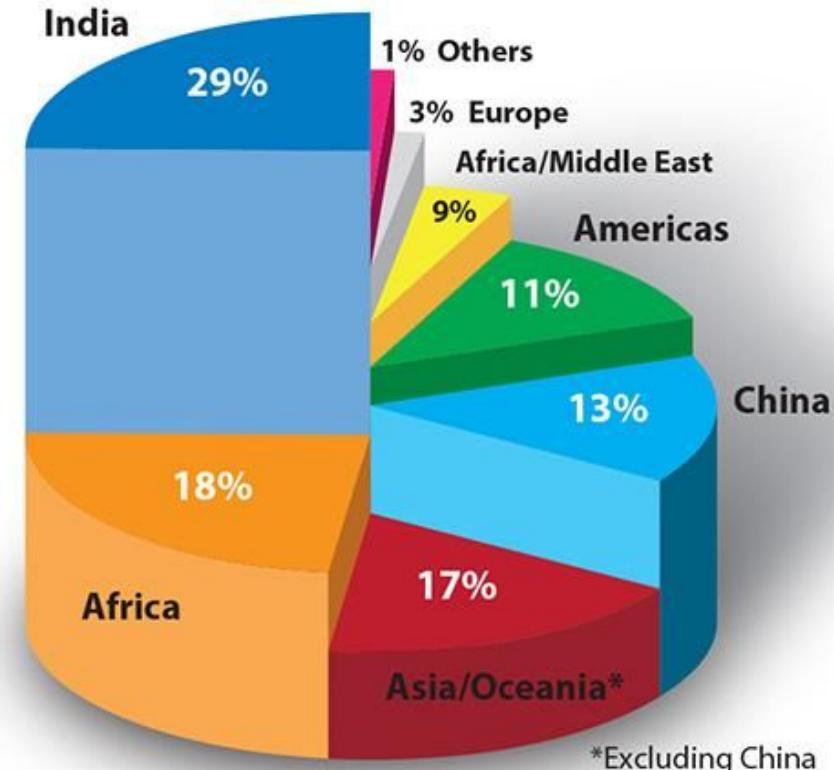


Fig. 11. Incorrect use of a bar chart for the *Nation* relation. The lengths of the bars suggest an ordering on the vertical axis, as if the USA cars were longer or better than the other cars, which is not true for the *Nation* relation.

The length of the bars is used to encode a categorical variable, which suggests a hierarchy of values. In addition, it is difficult to compare the different countries with each other.

The horror of pie charts

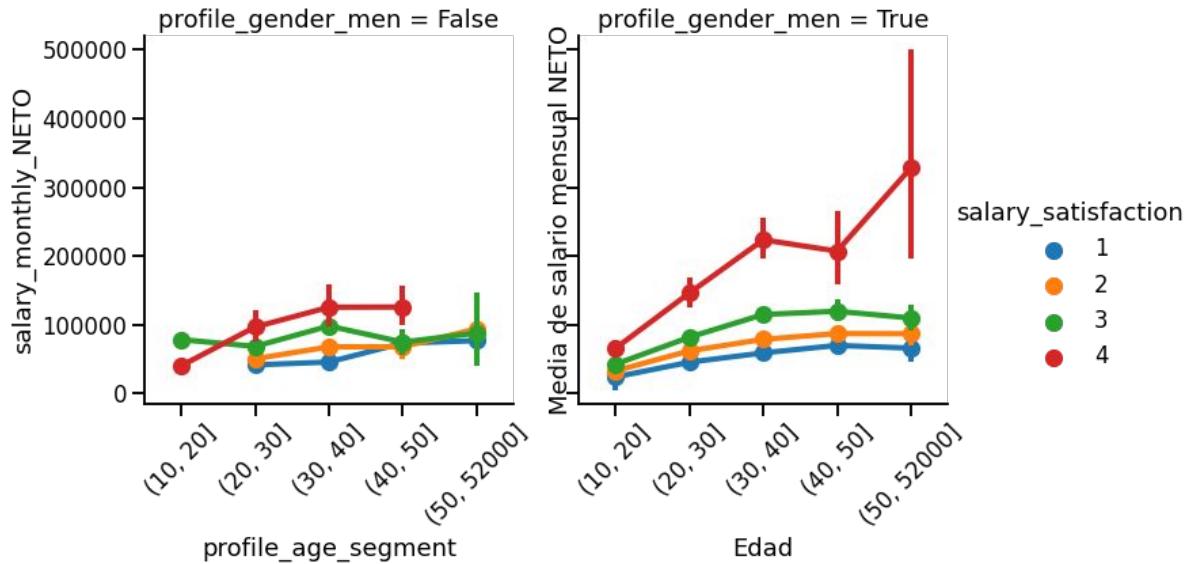
Share of worldwide urban population growth 2010-2050



Complex Graphics

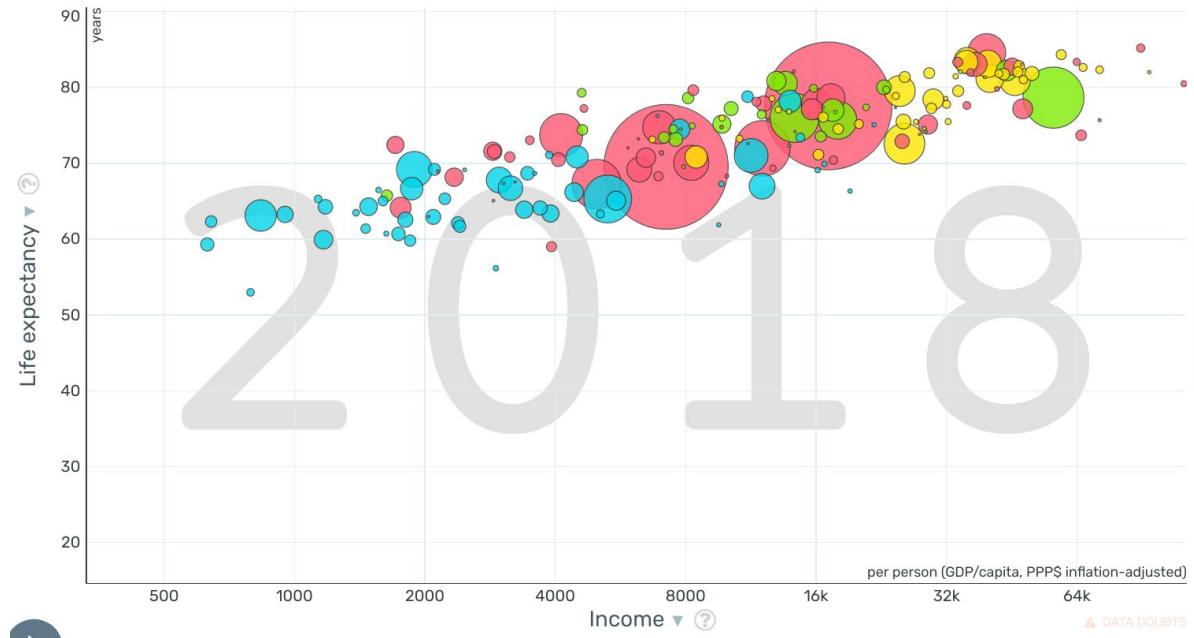
Adding more variables

- Every new variable we add needs a new encoding.
- In seaborn the structure is slightly different
- Other libraries like Plotly allow more complex and interactive graphs



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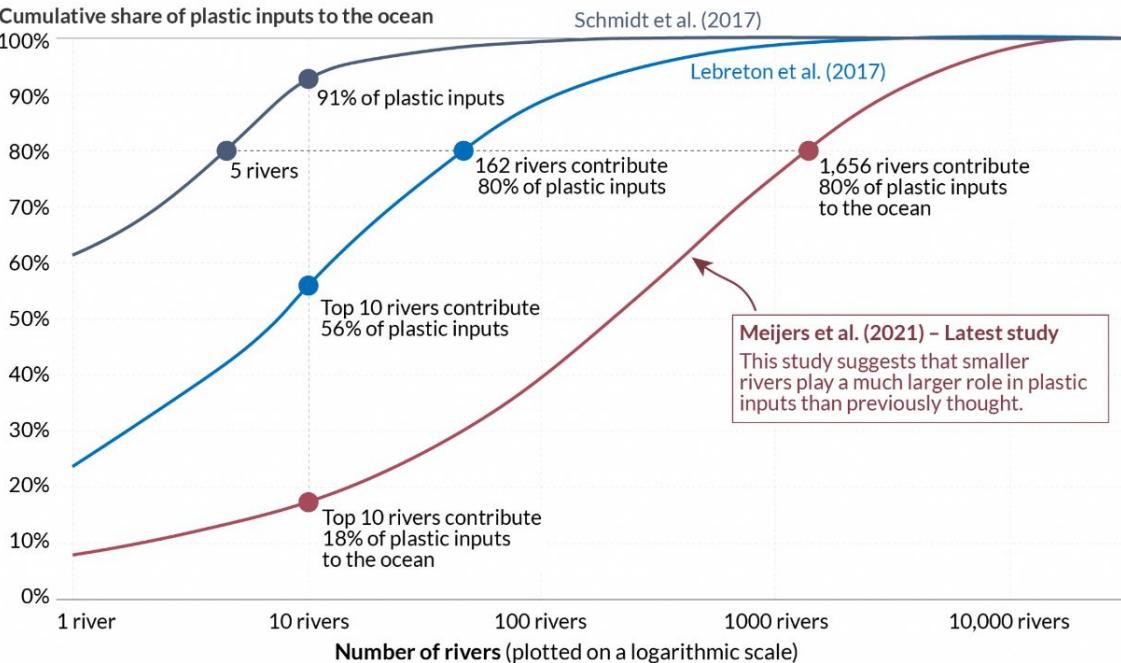
Harder to read graphics

- Less intuitive but more informative visualizations
- Complex transformations to data

How many rivers are responsible for what share of plastic input into the world's oceans?

Our World
in Data

Two earlier studies (in blue) compared with the latest study that uses higher-resolution data (in red).



Source: Lourens Meijer et al. (2021). Over 1,000 rivers account for 80% of global riverine plastic emissions into the ocean. *Science Advances*.

OurWorldinData.org – Research and data to make progress against the world's largest problems.

Licensed under CC-BY by the author Hannah Ritchie (2021).

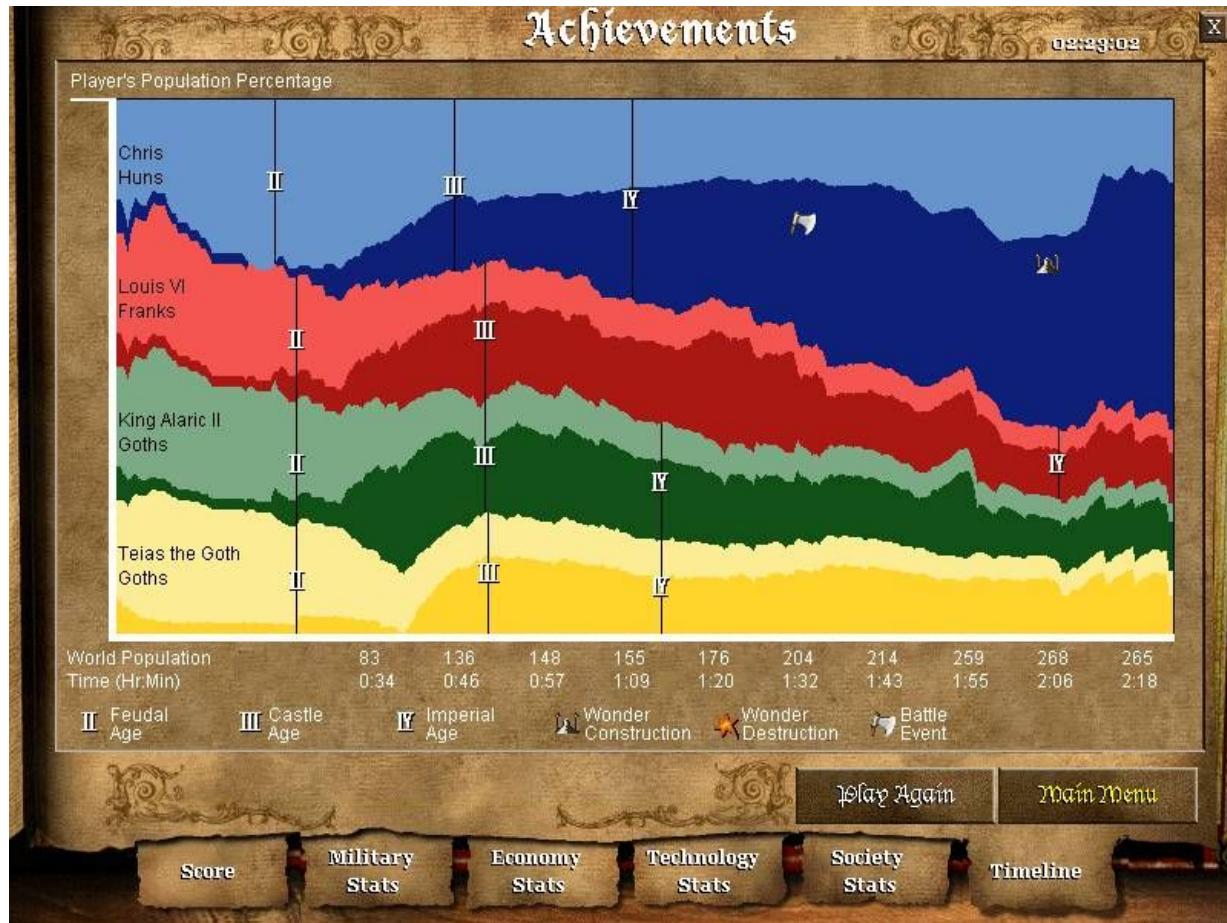
Harder to read graphics

- Less intuitive but more informative visualizations
- Complex transformations to data
- Uncommon Chart Types



Harder to read graphics

- Less intuitive but more informative visualizations
- Complex transformations to data
- Uncommon Chart Types
- Only for domain experts



Good data visualization practices

to maximize the effectiveness of communication

Basics to keep in mind

- Text size
- Visibility of elements against the background
- Visualization approaches
 - Projector: It has low resolution. Use bright colors (not dark or pastel).
 - Paper: color or black and white? There is no zoom possibility.
 - Digital screen: different resolutions and devices. Different methods of interaction.

—

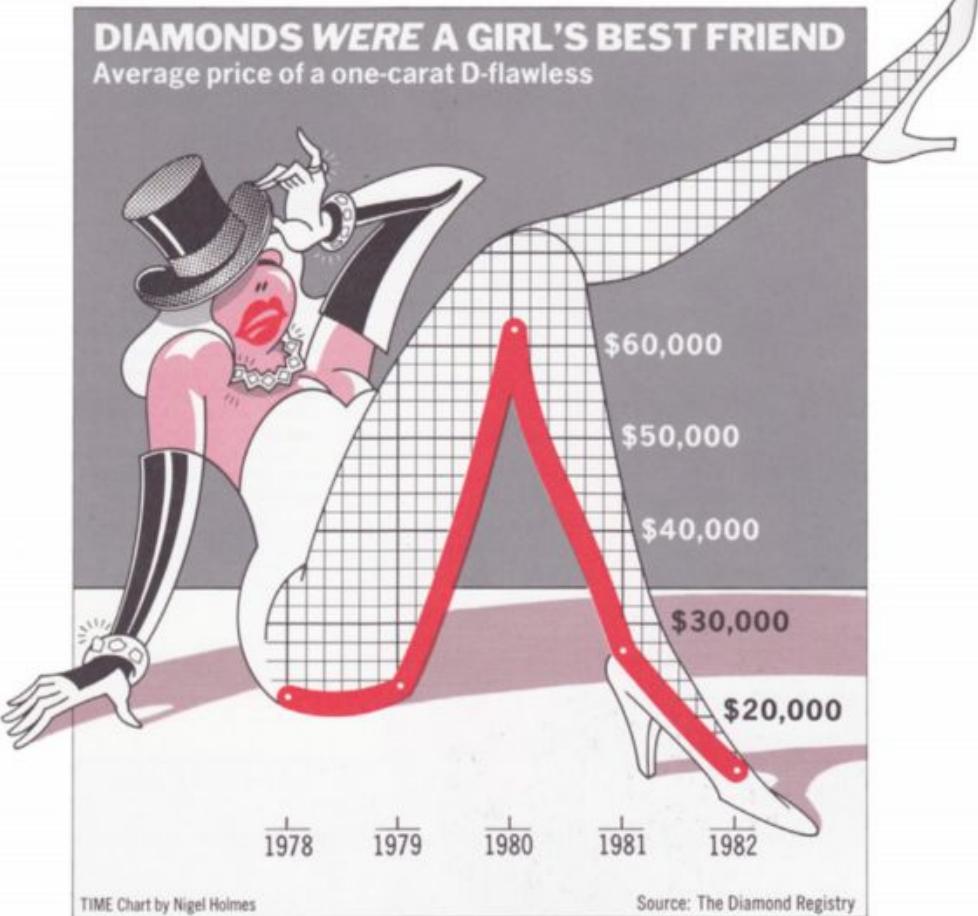
Chartjunk - Less is more

Edward Tufte: maximizar proporción tinta-datos

1. The priority is to show the data
2. Maximize data to ink ratio (all “ink” is used for data)
3. Remove non-data ink
4. Remove redundant ink
5. Review and edit

Example

Only a small number of visual elements are relevant!

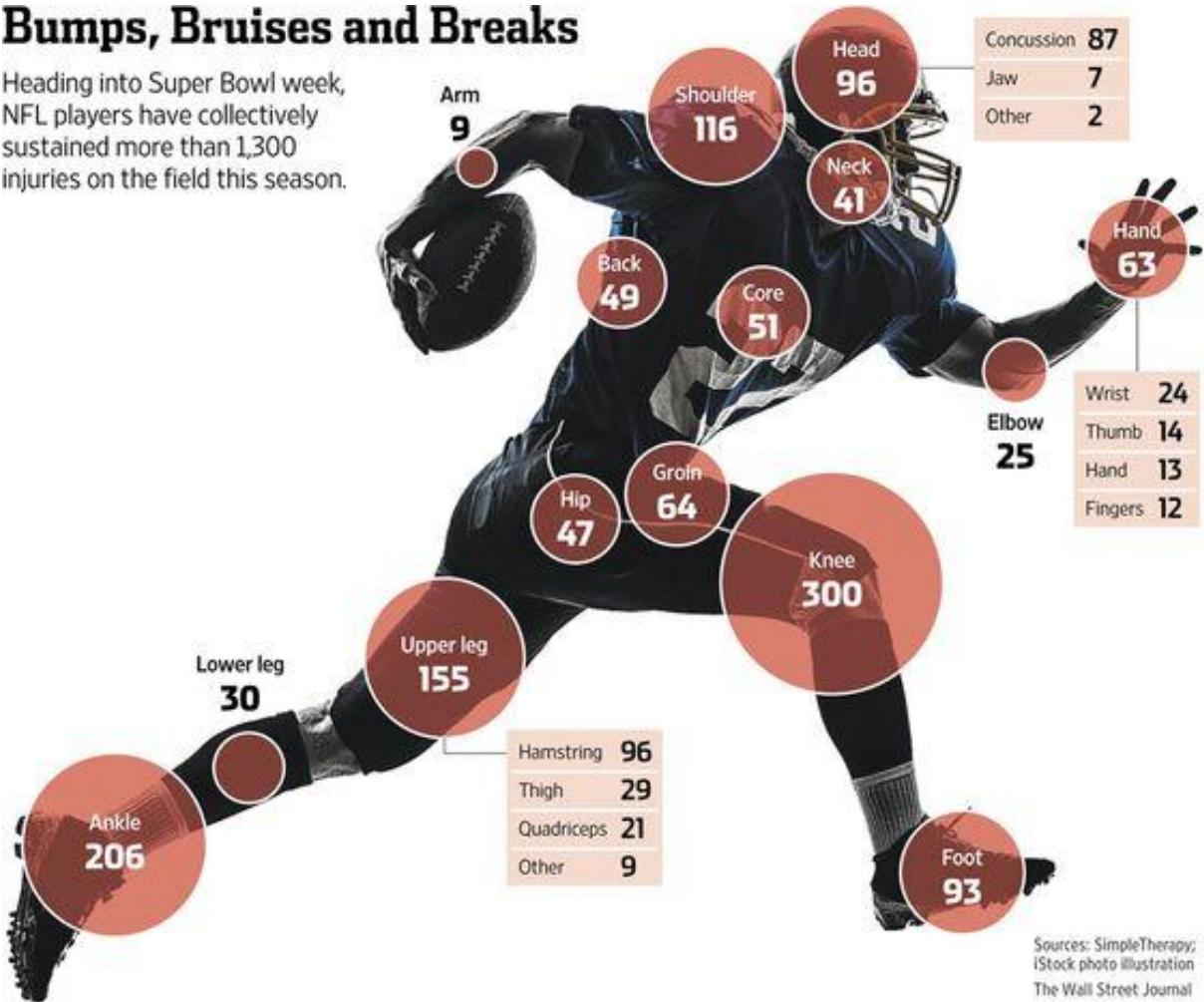


Bumps, Bruises and Breaks

Heading into Super Bowl week, NFL players have collectively sustained more than 1,300 injuries on the field this season.

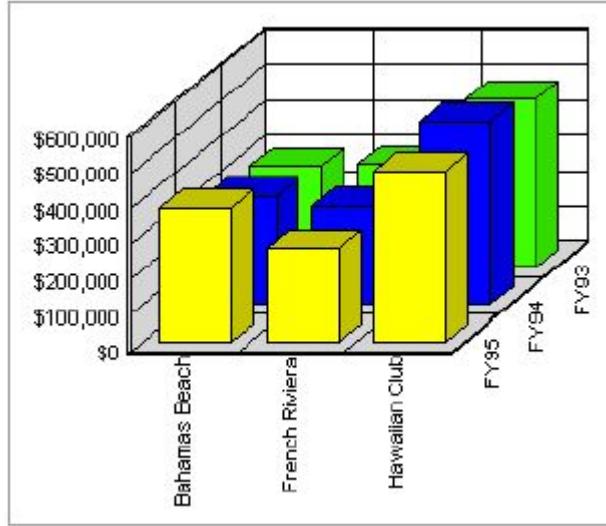
Example

All visual elements are
relevant to the information
conveyed



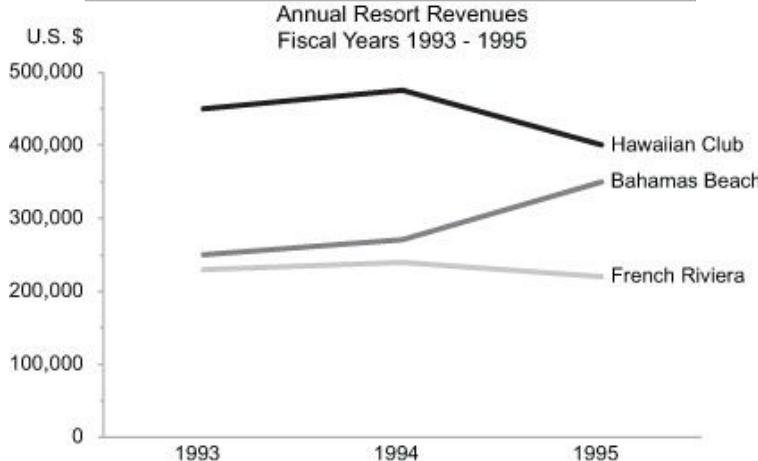
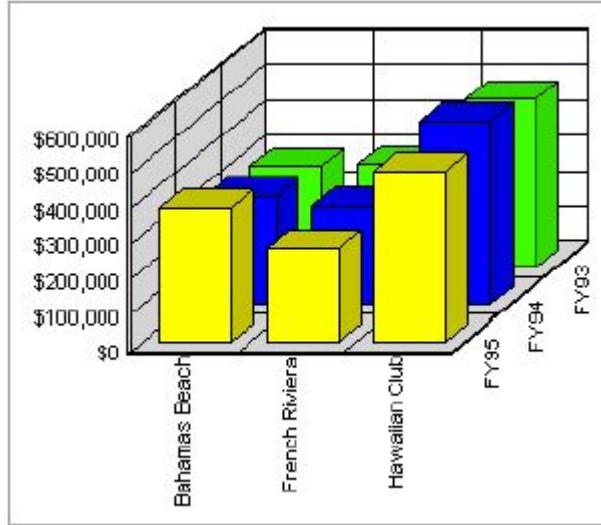
Example

- The bars are impossible to read
- Grids are useless
- Vertical labels are difficult to read
- The z axis, which represents years, goes backwards.



Example

- The bars are impossible to read
- Grids are useless
- Vertical labels are difficult to read
- The z axis, which represents years, goes backwards.



A design problem - perceptual edge

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First, make sure it
looks good in black
and white.

Properties of color encodings

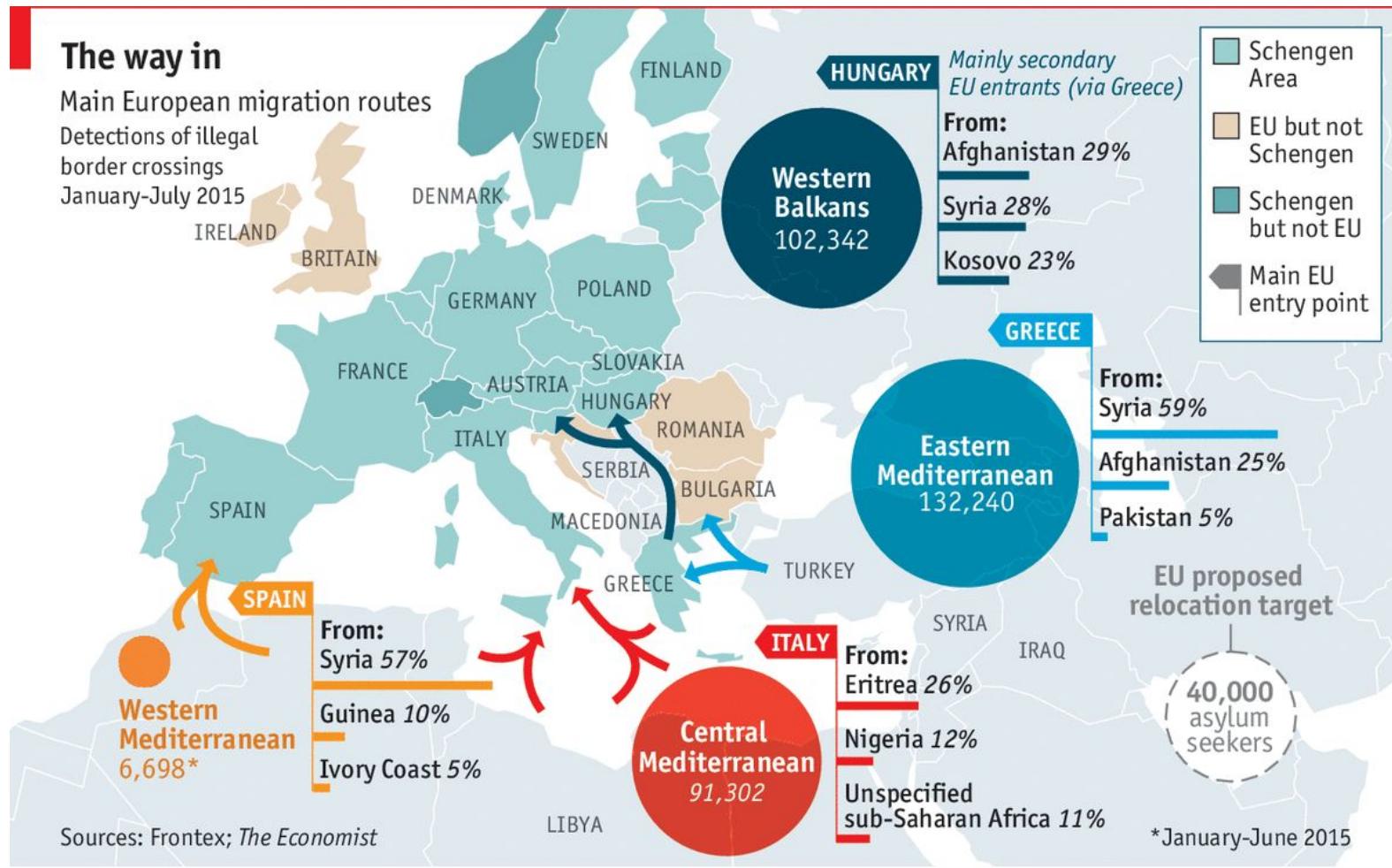
- There's no order
- We rely on conventions that may not be reproduced:
 - Red-blue, pink-light blue for male and female
 - Light blue for the ocean, green for the prairie, brown for the mountain
- We do not all perceive them the same (color blindness)
- Evoke unconscious (or subconscious) emotions

The way in

Main European migration routes

Detections of illegal border crossings

January-July 2015



The color and the message

SPRUCE UP FOR SPRING

Apartment guide

LEARNVEST WHERE LIFE GETS RICHER

Spring is the ideal time to freshen up the look of your home, and accessorizing is a simple way to reinvent any space. Add a burst of energy to your home by incorporating these decorating trends.

CHERRY BLOSSOM DISPLAY

Cherry blossoms only stay in bloom for a short time, so skip the real flowers & get creative.

Gather your craft supplies & create a display of paper flowers that will bring you joy all season.

BRIGHT TABLE LINENS

Brighten up your table linens by using fabric markers & stencils in your favorite spring colors.

YELLOW ACCENTS

Introduce this sunny pop of color by adding small accent pieces to each room.

MILK PAIL GARDEN POTS

Check out a local flea market to find some old-fashioned milk pails for plants. Adding a rustic charm is perfect for any outdoor space.

<http://www.natashamiller.com/2015/03/spring-decorating-trends.html>

Un mano a mano para decidir el futuro del país

En la recta final del año electoral, los candidatos desafían, se critican y se responden ejes prioritarios, sobre educación, Derechos Humanos, Inseguridad, narcotráfico, economía y calidad democrática. Hubo poco diálogo y varias fases fuertes de cara al voto propio y abierto.

Las palabras más utilizadas

14 Trabajador

- Argentinos 7
- Tecnología 7
- Estado 6
- Universidades 6
- Provincia de Buenos Aires 6
- Derechos Humanos 5
- Educación 5

Daniel Scioli 58 años // Gobernador

Mauro Macri 56 años // Gobernador

TIEMPO TOTAL: 265

No respetan los tiempos establecidos, tanto en las preguntas como en las respuestas.

Las palabras más utilizadas

7 Argentina 7

- Democracia 7
- Trabajar 6
- Estado 6
- Economía 6
- Compromiso 6
- Ajustar 5
- Policía 5

Electrochemistry at nanoelectrodes

Nanoelectrodes have several advantages for electrochemical sensing. Transport to microelectrodes proceeds through a relatively uniform linear-diffusion profile. They are also highly affected by convection and IR drop.

Ag/AgCl as a combined electrode

The combined reference/electrode electrode is created by electrolytically depositing a thin film of Ag onto the microband. Potentiostatic plating causes Ag to grow preferentially at the corners, creating dendrites. A galvanostatic plating protocol has been developed to provide the required smooth, shiny Ag deposit.

Characterisation

Cyclic voltammetry and electrochemical impedance spectroscopy will be used to verify that the system is behaving as predicted. The nanoband should have a similar response to the current nanoelectrode array.

Combined nanoelectrode system

This design consists of a microarray at the bottom of each cavity in the array, with the nanoband around the perimeter.

Fabrication

This design has been fabricated at the Scottish Microelectronics Centre using photolithography. In this technique layers of resist and insulator are deposited and patterned to produce the desired arrangement.

- Si wafer with oxide surface
- Metals are deposited and contact in a nitride passivation layer
- Photocresylate is deposited and exposed to UV light through a patterned mask
- Nitride is removed and patterned to form a metal layer

Each layer is deposited and patterned sequentially. This approach reliably produces uniform electrodes cheaply and easily.

Application

By coating the surface of the working electrode in a nucleic acid, the corresponding DNA sequence can be detected using electrochemical impedance spectroscopy (EIS). Before the target is added, the baseline resistance is measured for the redox couple is small. When the correct target is hybridized the resistance and the baseline rises at the electrode.

Objectives

Having made the initial measurements, the next steps will include:

- complete fabrication of the combined system, including optimisation of nanoband and cavity dimensions
- further investigation of the sensitivity of nanoelectrodes for use in DNA sensing and the relationship between the response and concentration of the target
- optimization of a galvanostatic sler plating protocol

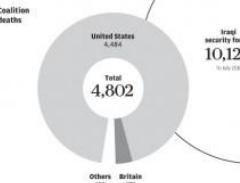
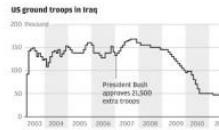
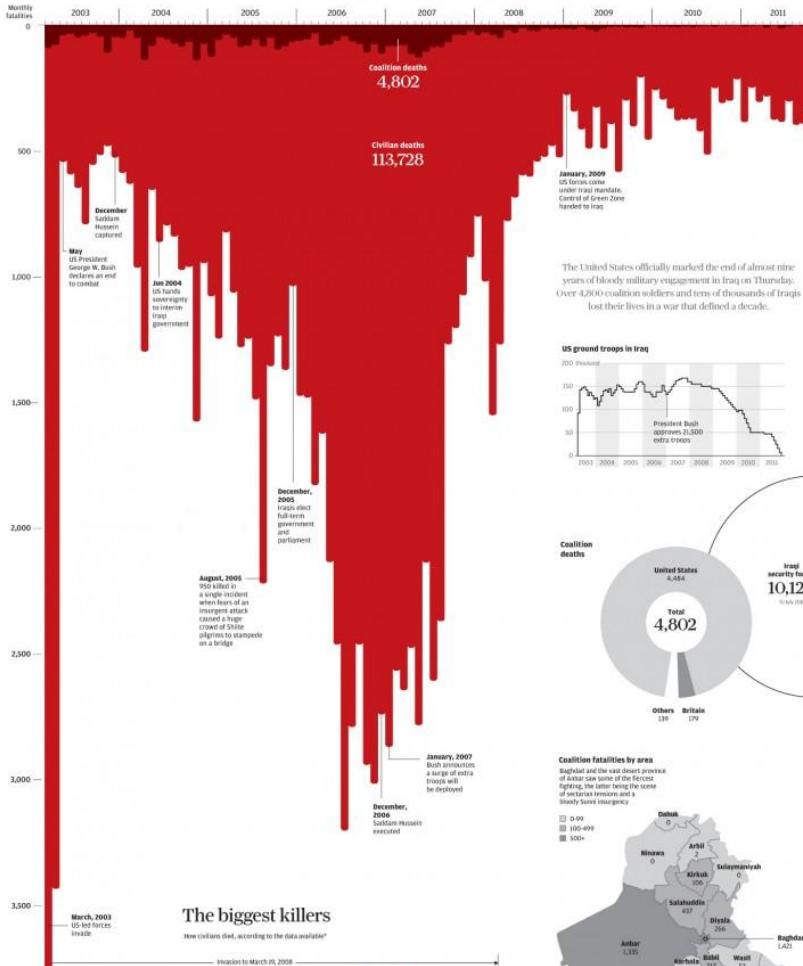
Many thanks to Dr Damon Compton, Dr Emily McLean, Professor Andy Mount, the Mount group and the EPSRC for their continuing support and expertise.

Developing and characterising a novel combined nanoelectrode system

L. P. Robinson, A. Mount

THE UNIVERSITY OF EDINBURGH

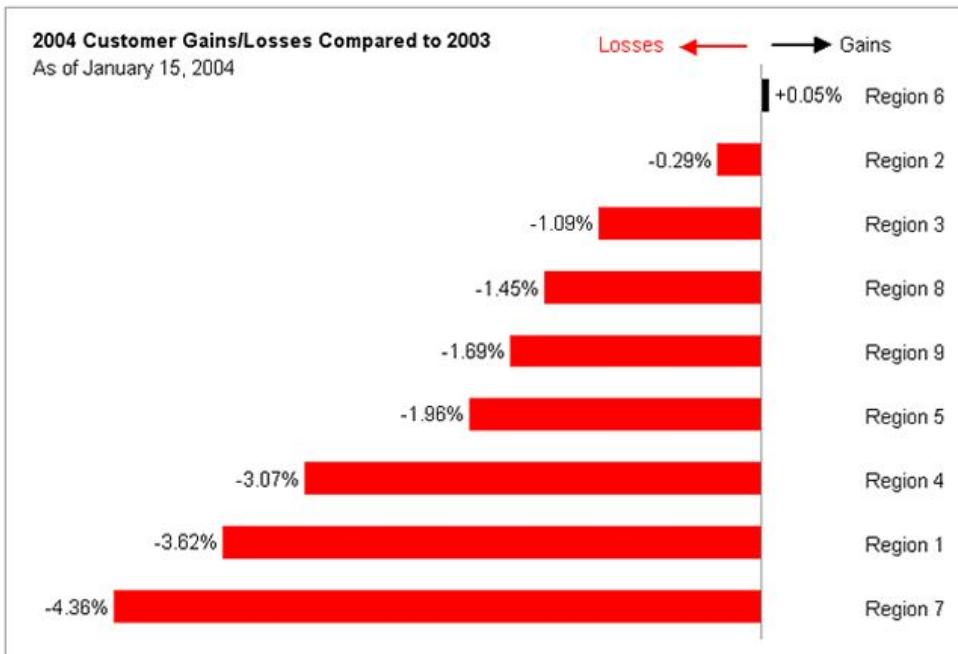
Iraq's bloody toll



Color palettes and color blindness

- Daltonism:
 - Coblis: You can upload an image and see how a colorblind person would see it.
 - Use colorblind safe palettes that come in visualization libraries
- Esthetic:
 - Coolors: Easy to use for quick combinations.
 - Paletton: More complete but requires a little more knowledge of colors.

Reinforcement through double encodings



In this example, the color encoding reinforces the losses without unbalancing the graph.

Do you swear to tell the
truth, the whole truth
and nothing but the
truth?

Questions?