

# Describing Data

## *A Visual Survival Kit*

IX International Physics Conference in honor of F.Pianca  
December 22, 2021

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Based on a talk given January 6, 2021

# Overview

1. Personal background & motivation
2. Tools: data, sources, software
3. Visual elements
4. Critisizing

\*through examples

# Personal

## Career path

- University of Waterloo
- University of Illinois at Chicago
- University of Aberdeen
- Riga Technical University

## Outside of academia

- Family
- Sports
- Social service



2009 - 2014  
BMath, MMath



2014 - 2019  
PhD in Mathematics



2019 - 2020  
Postdoctoral fellow



2020 -  
Assistant Professor  
BITL Program Academic Advisor

# Motivation

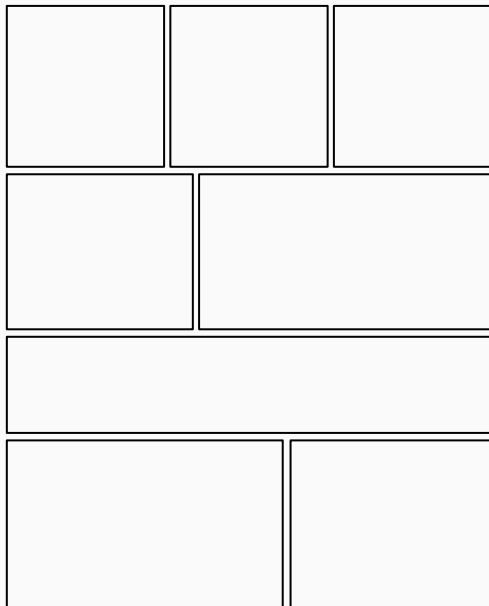
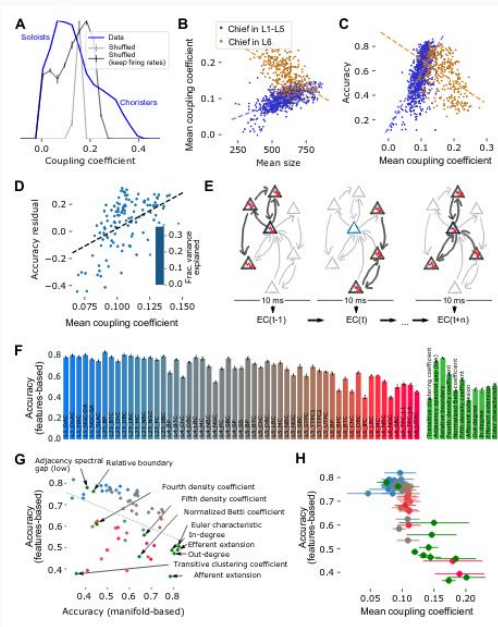
## The first look

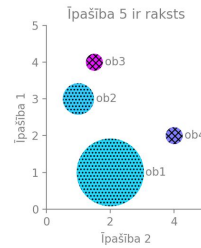
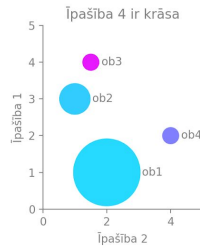
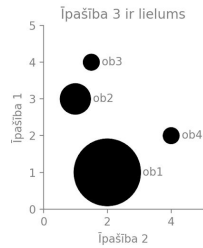
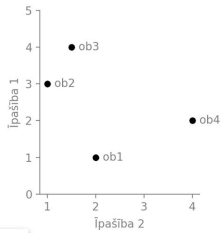
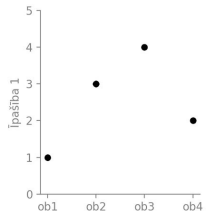
Seeing data:

- What is going on?
- What should I be seeing?

Presenting data:

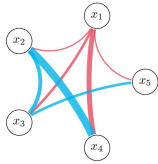
- What do I want to say?
- What does the reader expect?
- What is unnecessary?



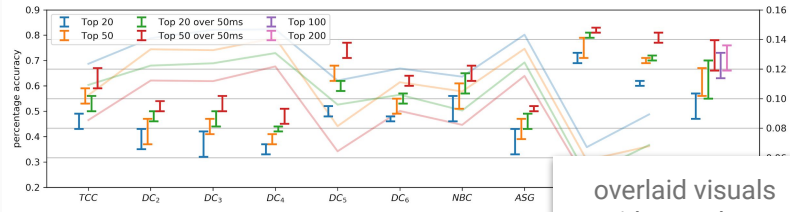


visualizing properties

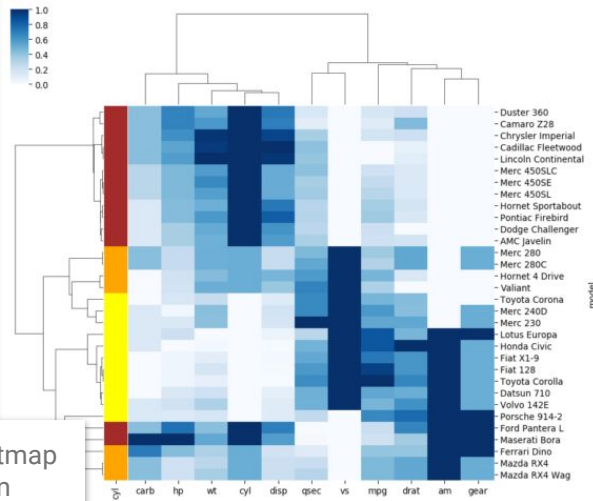
	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$
$x_1$	0	1	2	3	1
$x_2$	1	0	-2	-6	0
$x_3$	2	-2	0	0	-1
$x_4$	3	-6	0	0	0
$x_5$	1	0	-1	0	0



relationships as a graph



overlaid visuals with error bars



properties as a heatmap and dendrogram

# Motivation

Data relationships

What is the first thing you notice?

- Color
- Contrast
- Text / whitespace

# Tools: data types

Different requirements = different uses

## Objects and their properties

- Measurements, surveys
- parameters

## Dynamically changing properties

- Repeated measurements
- Change of parameters

## Relationships among objects

- Multiple dependencies
- Directional data

	A	B	C	D	E	F	
1	song_name	danceability	energy	key	loudness	mode	spe
2	Mercury: Retrograde	0.831	0.814	2	-7.364	1	
3	Pathology	0.719	0.493	8	-7.23	1	
4	Symbiote	0.85	0.893	5	-4.783	1	
5	ProductOfDrugs (Prod. The Virus and Antidote)	0.476	0.781	0	-4.71	1	
6	Venom	0.798	0.624	2	-7.668	1	
7	Gatetka	0.721	0.568	0	-11.295	1	
8	kamikaze (+ pulse)	0.718	0.668	8	-4.162	1	
9	T.R.U. (Totally Rotten Underground)	0.694	0.711	8	-5.525	1	
10	I Put My Dick in Your Mental	0.774	0.751	1	-2.445	1	
11	Andromeda	0.893	0.907	11	-10.406	1	
12	BRAINFOOD	0.864	0.365	8	-10.219	1	
13	Troll Under the Bridge	0.736	0.932	1	-3.726	1	
14	1000 Rounds	0.825	0.761	8	-5.389	1	
15	Sacrifice	0.767	0.576	10	-9.683	0	
16	Backpack	0.765	0.726	5	-5.58	1	
17	D(R)Own	0.617	0.541	6	-4.113	1	
18	Okay, But This Is The Last Time	0.755	0.298	1	-15.032	1	
				11	-9.635	1	

table

unordered objects with properties

weighted adjacency matrix

objects and pairwise properties

0	-4	1	0	0	-2	1	-1
-2	1	0	-1	-3	1	1	0
-2	0	-1	0	-2	-3	-1	-2
-1	0	-3	-2	0	-3	-1	-2
-3	-2	1	-3	-3	0	-3	-1
-2	1	1	-1	-1	-3	0	-3
1	-1	0	-2	-2	-1	-3	0

time series

unordered objects with ordered properties

date	2017-01-01	2017-01-02	2017-01-03	2017-01-04	2017-01-05	2017-01-06	2017-01-07	2017-01-08	2017-01-09	2017-01-10	2017-01-11	2017-01-12	2017-01-13	2017-01-14
meantemp	15.91	18.5	17.11	18.7	18.39	19.32	14.71	15.68	14.57	12.11	11	11.79	13.24	
humidity	85.87	77.22	81.89	70.05	74.94	79.32	95.83	83.53	80.81	71.94	72.11	74.58	67.06	
wind_speed	2.74	2.89	4.02	4.55	3.3	8.68	10.04	1.95	6.54	9.36	9.77	6.63	6.44	
meanpressure	50	1018.28	1018.33	1015.7	1014.33	1011.77	1011.38	1015.55	1015.95	1016.89	1016.78	1016.37	1017.53	

```
2 {
3   "particles": {
4     "number": {
5       "value": 80,
6       "density": {
7         "enable": true,
8         "value_area": 800
9       }
10    },
11    "color": {
12      "value": "#01b6ed"
13    },
14    "shape": {
15      "type": "circle",
16      "stroke": {
17        "width": 0,
18        "color": "#01b6ed"
19      },
20      "polygon": {
21        "nb_sides": 10
22      },
23      "image": {
24        "src": "img/github.svg",
25        "width": 100,
26        "height": 100
27      }
28    },
29    "opacity": {
30      "value": 0.5,
31      "random": false,
32      "anim": {
33        "enable": false,
34        "speed": 1000
35      }
36    }
37  }
38 }
```

dictionary

hieraeachal properties

# Tools: data sources

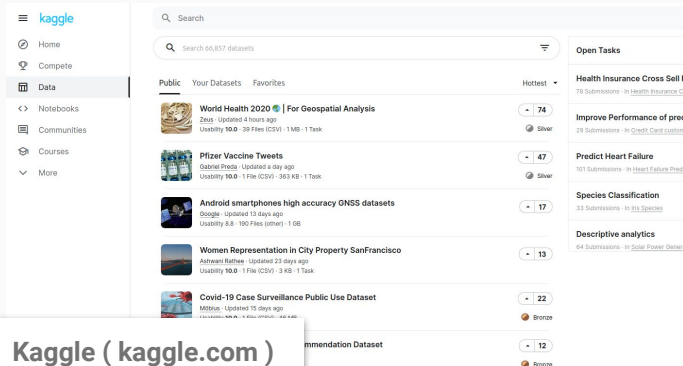
## Examples of data banks

### General

- Kaggle
- Atvērto Datu Portāls
- EU Open Data Portal

### Specific

- Allen Brain Map  
portal.brain-map.org
- Blue Brain Nexus  
bluebrainnexus.io
- Janelia  
neuprint.janelia.org



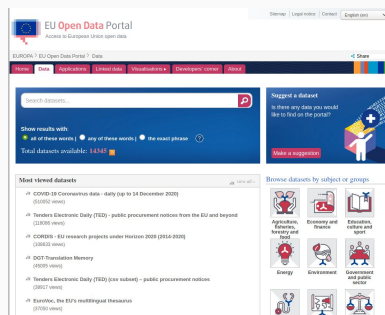
The screenshot shows the Kaggle website interface. On the left is a navigation menu with options like Home, Complete, Data, Notebooks, Communities, Courses, and More. The main content area displays a search bar and a list of public datasets. The datasets listed include 'World Health 2020 For Geospatial Analysis', 'Pfizer Vaccine Tweets', 'Android smartphones high accuracy GNS5 datasets', 'Women Representation in City Property San Francisco', and 'Covid-19 Case Surveillance Public Use Dataset'. Each dataset entry shows its name, a small thumbnail, and some statistics like the number of files and size. On the right side, there are 'Open Tasks' and 'Recommendation Dataset' sections.

Kaggle ( kaggle.com )



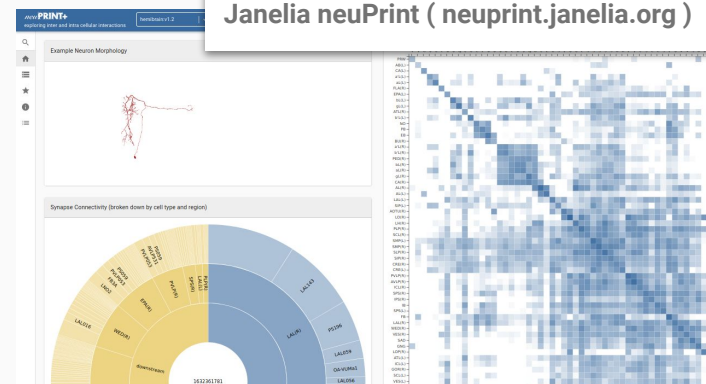
The screenshot shows the Latvian Open Data Portal (data.gov.lv). The header includes the logo and navigation links for 'Datu katalogs', 'Apgūsti datu prasmes!', 'Vadlīnijas', and 'Jautājumi un atbildes'. Below the header is a search bar and a 'Meklēt' button. The main content area features a large banner with the text 'Laipni lūdzam Latvijas Atvērto datu portālā!' and statistics showing '433 DATU KOPAS' and '83 PUBLICĪTAJI'. Below the banner is a section titled 'DATU KATALOGA KATEGORIJS' with four categories: 'Ārlietas', 'Ekonomika un uzņēmējdarbība', 'Enerģija', and 'Iedzīvotāju sabiedrība'. Each category has a sub-section with a title and a count.

Atvērto Datu Portāls ( data.gov.lv )



The screenshot shows the EU Open Data Portal. The header includes the logo and navigation links for 'Home', 'Log in/Sign up', and 'Contact'. Below the header is a search bar and a 'Meklēt' button. The main content area features a large banner with the text 'EU Open Data Portal' and a list of datasets. The datasets listed include 'COVID-19 Coronavirus data - daily (up to 14 December 2020)', 'Tendencijas Elektroniskā Dienā (TED) - publiskie dokumenti izņemti no ESU un tālruni', 'CORONAS - ESU pētījumi par koronavīrusu 2020 (2020-2020)', 'DOT Translācijas teorija', 'Tendencijas Elektroniskā Dienā (TED) (bez noteikumiem) - publiskie dokumenti izņemti', and 'EuroVoc, the EU's multilingual thesaurus'. Below the list is a section titled 'Browse datasets by subject or groups' with icons for various subjects like Agriculture, Economy and Finance, Education, Health, Law, Life Sciences, Medicine, and Society.

EU Open Data Portal ( data.europa.eu )



The screenshot shows the Janelia neuPrint website. The header includes the logo and navigation links for 'Home', 'Log in/Sign up', and 'Contact'. Below the header is a search bar and a 'Meklēt' button. The main content area features a large banner with the text 'Janelia neuPrint' and a visualization of a neuron morphology. The visualization shows a 3D model of a neuron and a corresponding heatmap of its connectivity. The heatmap is a square grid with a color scale from yellow to blue, representing the strength of connections between different parts of the neuron. The text 'Synapse Connectivity (broken down by cell type and region)' is visible above the heatmap.

Janelia neuPrint ( neuprint.janelia.org )

**matplotlib**  
Version 3.3.3

Installation Documentation Examples Tutorials Contributing

home | contents | **Matplotlib: Python plotting**

**Matplotlib: Visualization with Python**

Matplotlib is a comprehensive library for creating static, animated, and interactive visualizations in Python.

Matplotlib makes easy things easy and hard things possible.

Create Customize

- Develop publication quality plots with just
- Use
- Take full control of line styles, font
- Explore

matplotlib ( matplotlib.org )

**Plotly ( dash-gallery.plotly.host )**

**Image Processing**

AI | ML | Image Processing | Semiconductor | (+1)

**Support Vector Machine**

ML | AI | scikit-learn | SVM

**Drug Discovery**

Pharma | 3d | Biotechnology

**DISTRIBUTION**

Violin Density Boxplot Histogram

**CORRELATION**

Scatterplot Connected Scatter plot Bubble plot Heatmap 2D density plot Correlation

**RANKING**

Barplot Boxplot Parallel plot Lollipop plot Wordcloud Spider

**PART OF A WHOLE**

Stacked barplot Tree plot Venn diagram Diagram plot Pie plot Tree diagram

**Python Graph Gallery**  
( python-graph-gallery.com )

**PGFPlots gallery ( pgfplots.sourceforge.net )**

# Tools: inspiration

## Collections of different examples

### Ready-made templates

- Plotly
- Chart.js, D3.js

### Fine detail control

- The Python Graph Gallery
- matplotlib

### Extreme detail control

- TeXample.net
- PGFPlots Gallery

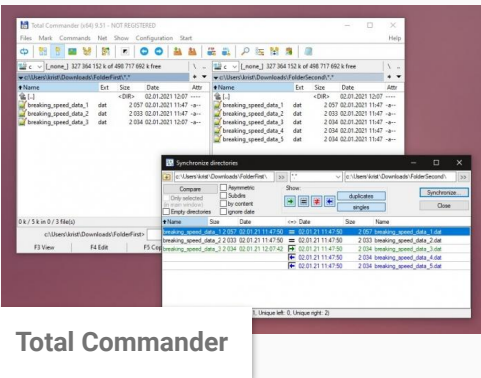


# Tools: software

## Data management and exploration

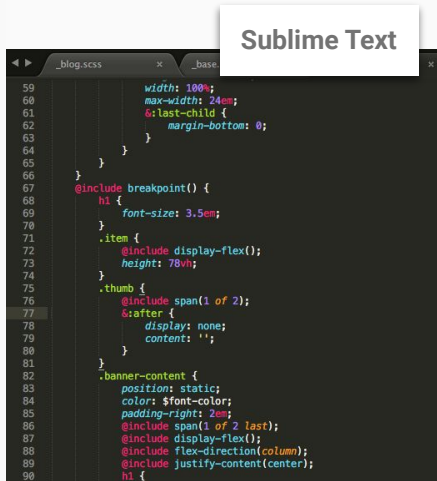
### Managing files

- Total Commander



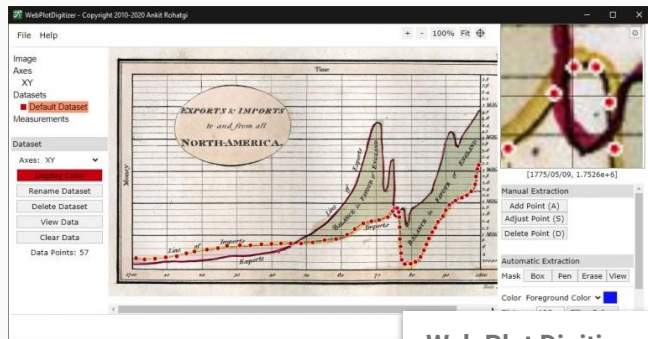
### Reading text and numbers

- Excel, Google Sheets
- Sublime Text, Notepad++

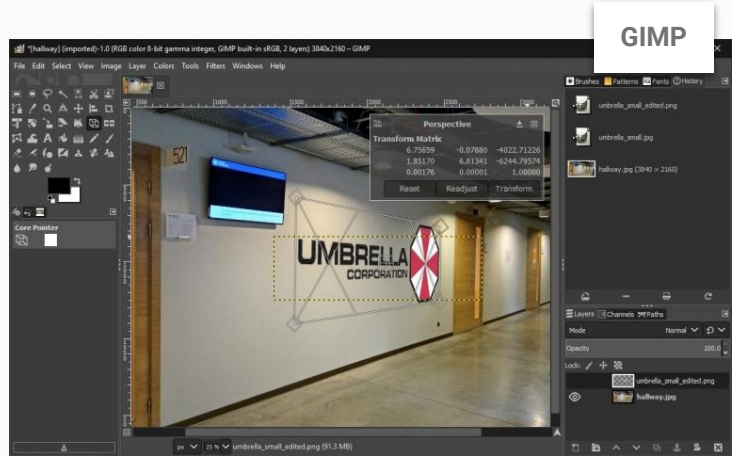


### Reading data from images

- Web Plot Digitizer
- GIMP (Gnu Image Manipulation Program)



**Web Plot Digitizer**



# Tools: software

Some coding required

## Plug and chug

- MS Excel, Google Sheets
- MS Word
- Canva
- Plotly, Chart.js

## Unlimited control

- Python: CSV, JSON, pandas
- LaTeX: TikZ, PGFPlots

```
>>> import pandas as pd
>>> df = pd.read_pickle('mc2_newparams2.pkl')
>>> df
   tpsg_strong_low  tpsg_strong_high  tpsg_low  tpsg_high  reciprocal_pairs  zero_outdeg  zero_indeg
0      0.456522      0.456522      0.266667      0.266667           1           15           3
1      0.100756      0.100756      0.094926      0.094926           44           22          11
2      0.119700      0.119700      0.111111      0.111111           25           20           7
3      0.000000      0.000000      0.333333      0.333333           0            9           1
4      0.133989      0.133989      0.114300      0.114300           20           23           3
...
31341      0.068787      0.068787      0.068950      0.068950           162           4           16
31342      0.140519      0.140519      0.139227      0.139227           40           3           3
31343      0.030780      0.030780      0.030934      0.030934           803           3           6
31344      0.174490      0.174490      0.168207      0.168207           17           9           10
...
          0.037836      0.038262      0.038262           590           2           20
```

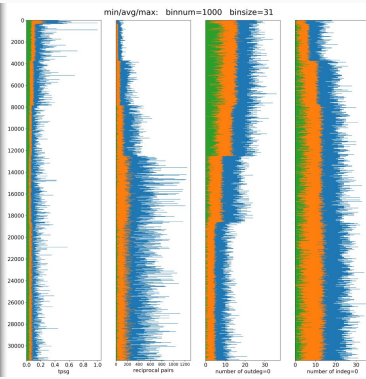
Python + pandas

```
def plot_surfs():
    # load dataframe and initiate figure
    print('loading dataframe, flush=True')
    df = pd.read_pickle(database_dir+'mc2_newparams.pkl')
    df_strong = pd.read_pickle(database_dir+'mc2_tpsg.pkl')
    fig = plt.figure(figsize=(10,10)) # default is (8,6)

    # tpsg
    print('computing and plotting: tpsg, flush=True')
    ax1 = fig.add_subplot(4,1,1); plt.rc('text', 'log');
    data_tpsg = df[['tpsg_high']]
    data_tpsg_low = df[['tpsg_low']]
    ax1.plot(data_tpsg[0:1], lw=3, label='tpsg', alpha=0.8)
    data_tpsg_strong = df_strong[['tpsg_strong_high']]
    data_tpsg_strong_low = df_strong[['tpsg_strong_low']]
    ax1.plot(data_tpsg_strong[0:1], lw=3, label='tpsg_strong', alpha=0.8)
    data_tpsg_low = df[['tpsg_low']]
    ax1.plot(data_tpsg_low[0:1], lw=3, label='difference', alpha=0.8)
    ax1.set_xlabel('tpsg, fontsize=30'); plt.yticks(fontsize=10)
    ax1.set_ylabel('number of tpsg')

    # reciprocal edges
    print('computing and plotting: reciprocal edges, flush=True')
    ax2 = fig.add_subplot(4,1,2); plt.rc('text', 'log');
    data_rec = df[['reciprocal_pairs']]
    data_rec = df[['reciprocal_pairs']]
    ax2.plot(data_rec[0:1], lw=3)
    ax2.set_xlabel('reciprocal pairs, fontsize=30'); plt.yticks(fontsize=10)
    ax2.set_ylabel('number of reciprocal pairs')

    # outdegree
    print('computing and plotting: out degree, flush=True')
    ax3 = fig.add_subplot(4,1,3); plt.rc('text', 'log');
    data_out = df[['zero_outdeg']]
    data_out = df[['zero_outdeg']]
    ax3.plot(data_out[0:1], lw=3)
    ax3.set_xlabel('number of outdeg=0, fontsize=10'); plt.yticks(fontsize=10)
    ax3.set_ylabel('number of outdeg=0, fontsize=10'); plt.yticks(fontsize=10)
```



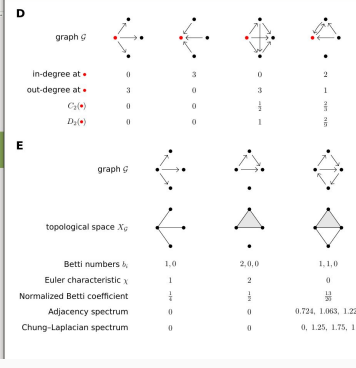
Python + matplotlib

```

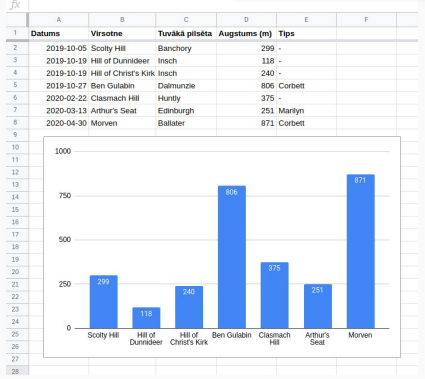
132 | \draw[blue] (v) to [bend right=90] (v);
133 |
134 | \draw[red] (c) to [bend right=45] (d);
135 | \draw[red] (a) to [bend right=45] (b);
136 | \draw[red] (a) to [bend right=45] (c);
137 | \draw[red] (a) to [bend right=45] (d);
138 | \draw[red] (b) to [bend right=45] (c);
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140 | \draw[red] (c) to [bend right=45] (d);
141 | \draw[red] (c) to [bend right=45] (a);
142 | \draw[red] (d) to [bend right=45] (a);
143 | \draw[red] (d) to [bend right=45] (b);
144 | \draw[red] (d) to [bend right=45] (c);
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148 | \draw[red] (d) to [bend right=45] (a);
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150 | \draw[red] (d) to [bend right=45] (c);
151 | \draw[red] (d) to [bend right=45] (a);
152 | \draw[red] (d) to [bend right=45] (b);
153 | \draw[red] (d) to [bend right=45] (c);
154 | \draw[red] (d) to [bend right=45] (a);
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156 | \draw[red] (d) to [bend right=45] (c);
157 | \draw[red] (d) to [bend right=45] (a);
158 | \draw[red] (d) to [bend right=45] (b);
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160 | \draw[red] (d) to [bend right=45] (a);
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194 | \draw[red] (d) to [bend right=45] (b);
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204 | \draw[red] (d) to [bend right=45] (c);
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206 | \draw[red] (d) to [bend right=45] (b);
207 | \draw[red] (d) to [bend right=45] (c);
208 | \draw[red] (d) to [bend right=45] (a);
209 | \draw[red] (d) to [bend right=45] (b);
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LaTeX + TikZ

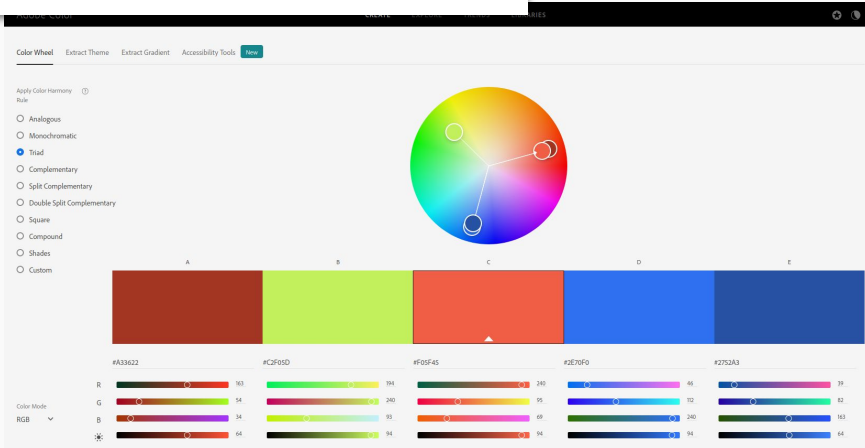


Virsnotes File Edit View Insert Format Data Tools **Google Sheets**



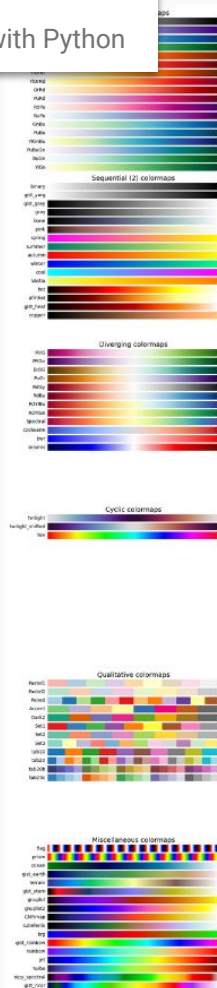
## Adobe Color Wheel ( [color.adobe.com](https://color.adobe.com) )

- similar color choices
- accessibility tools for color impairment



## matplotlib colormap

- color palettes for use with Python



# Elements

## Color choices

## Emphasize

- Red, green
- Complementary colors

## Reduce importance

- Light
- Similar to background

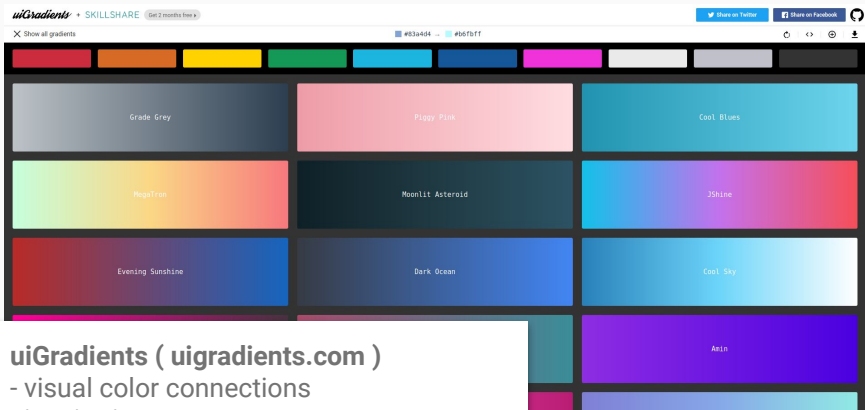
## Enrich

- Pattern overlay

\*\* Organizations have style guides

## uiGradients ( [uigradients.com](https://uigradients.com) )

- visual color connections
- inspiration



### Differentials

The ideas behind linear approximations are sometimes formulated in the terminology and notation of *differentials*. If  $y = f(x)$ , where  $f$  is a differentiable function, then the **differential**  $dx$  is an independent variable; that is,  $dx$  can be given the value of any real number. The **differential**  $dy$  is then defined in terms of  $dx$  by the equation

$$dy = f'(x) dx$$

If  $dx \neq 0$ , we can divide both sides of Equation 3 by  $dx$  to obtain

$$\frac{dy}{dx} = f'(x)$$

We have seen similar equations before, but now the left side can genuinely be interpreted as a ratio of differentials.

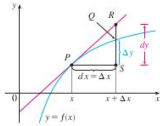


FIGURE 5

So  $dy$  is a dependent variable; it depends on the values of  $x$  and  $dx$ . If  $dx$  is given a specific value and  $x$  is taken to be some specific number in the domain of  $f$ , then the numerical value of  $dy$  is determined.

The geometric meaning of differentials is shown in Figure 5. Let  $P(x, f(x))$  and  $Q(x + \Delta x, f(x + \Delta x))$  be points on the graph of  $f$  and let  $dx = \Delta x$ . The corresponding change in  $y$  is

$$\Delta y = f(x + \Delta x) - f(x)$$

The slope of the tangent line  $PR$  is the derivative  $f'(x)$ . Thus the directed distance  $SR$  to  $R$  is  $f'(x) dx = dy$ . Therefore  $dy$  represents the amount that the tangent line falls (the change in the linearization), whereas  $\Delta y$  represents the amount that the  $y = f(x)$  rises or falls when  $x$  changes by an amount  $dx$ .

**EXAMPLE 3** Compare the values of  $\Delta y$  and  $dy$  if  $y = f(x) = x^3 + x^2 - 2x + 1$  and  $x$  changes (a) from 2 to 2.05 and (b) from 2 to 2.01.

consistency across all visuals  
Jame Stewart, "Calculus"

# Elements

## Scheme consistency

Often overlooked

- Done well: adds to the story being told
- Done poorly: distracts from the main ideas

\*\* The data **does not** speak for itself

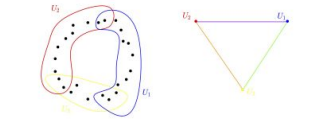


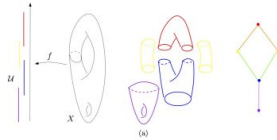
Figure 3: The nerve of a cover of a set of sampled points in the plane.

of continuous spaces into abstract combinatorial structures that are well-suited for the design of effective data structures and algorithms.

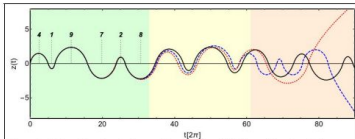
### 3 Using covers and nerves for exploratory data analysis and visualization: the Mapper algorithm

Using the nerve of covers as a way to summarize, visualize and explore data is a natural idea that was first proposed for TDA in Singh et al. (2007), giving rise to the so-called Mapper algorithm.

**Definition 2.** Let  $f: X \rightarrow \mathbb{R}^k$ ,  $k \geq 1$ , be a continuous real valued function and let  $\{U_i\}_{i \in I}$  be a cover of  $\mathbb{R}^k$ . The *soft link cover* of  $X$  induced by  $(f, U)$  is the collection of sets



consistency in some visual types  
interdisciplinary articles



**Figure 2:** Motion of the planet above and beyond the orbital plane of the stars in the Sitnikov problem.  $x$ -axis shows time in units of revolution of the primaries,  $y$ -axis gives distance from planet above and beyond the orbital plane. The plot shows motion of the planet for three different initial conditions. In the beginning, the motion is very similar, but after about 33 revolutions of the primaries, first differences appear and after 60 revolutions the three initial conditions develop into totally different types of motion. The red line shows a planet moving very far away from the stars in one direction; the blue line shows the same behaviour with a planet moving away in the other direction. In both cases a very long and possible endless winter would begin. The black line shows a planet that continues to have a more or less regular sequence of seasons.

### 3.2. Non-mathematical explanation

For those who - like the masters of Westeros - refuse to indulge in the wonders of celestial mechanics, let us explain the main point in simpler words. Let's define the time the two stars need for one revolution around the barycenter as one "year". We can then define any infinitely long and arbitrary sequence of whole numbers. The theorem of Mosers stated



**Figure 3:** Visualization of how a Sitnikov system could look like. The planet oscillates between a star and a black hole. (Created with Universe Sandbox! <http://universe.sandbox.com/>)

### 4. A universal mechanism for every

Close to the orbital plane of the stars in large amount of stellar energy, if the planet's flux will be reduced. In other words: the warmer it will be. A planet that oscillates regular seasons like on Earth. But as it oscillates with any sequence of duration longer the cold season will be. To reproduce a seemingly chaotic sequence of summers and

inconsistency  
most technical articles

# Analysis: color

Ryan Best, Shom Mazumder, FiveThirtyEight

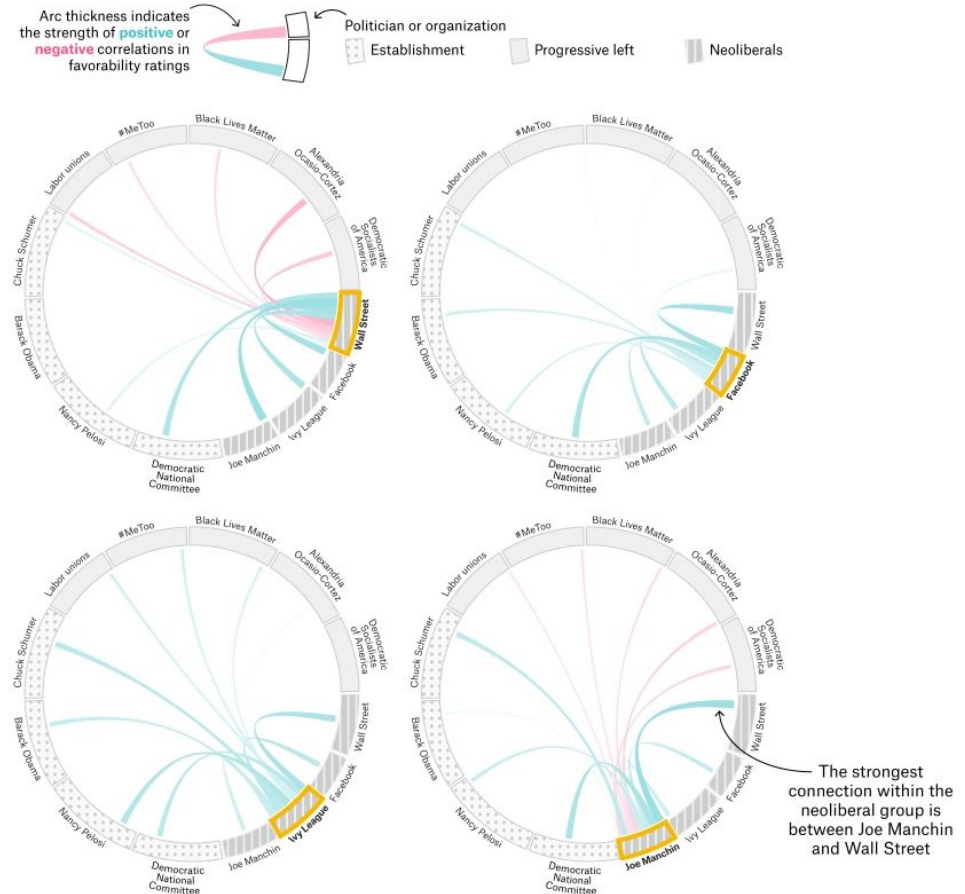
- Main idea in title
- Soft color scheme



- Small value = light color
- Extra information = patterns

## Neoliberals seem at odds with the progressive left

How favorability ratings of 13 politicians and organizations are related, focusing on figures associated with "neoliberals," from a poll of 2,900 likely Democratic primary voters



# Analysis: overload

Graphic Detail blog, The Economist

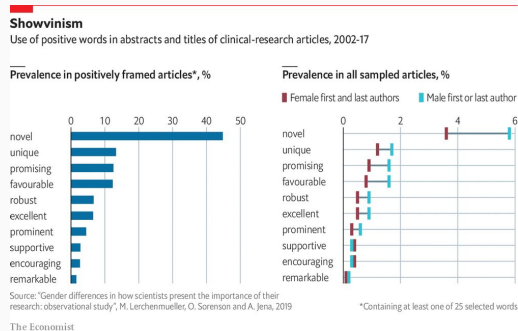
High volume of information

- Is it worth showing?
- What does it add to message?
- What are the common ideas?
- How to best combine it?

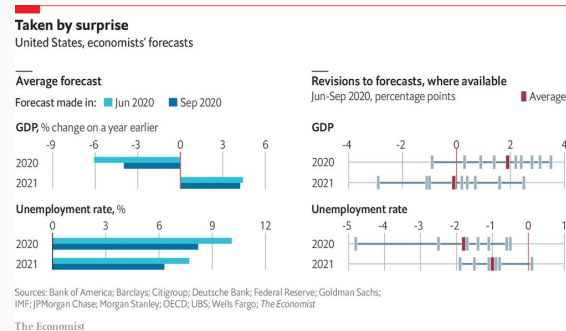
Interactive information

- Plotly
- D3.js

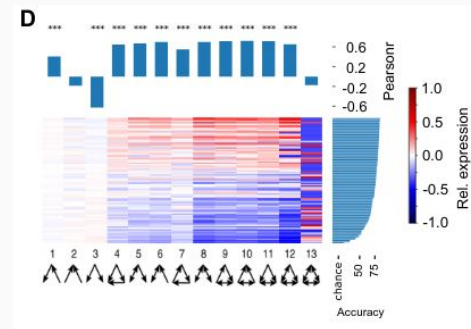
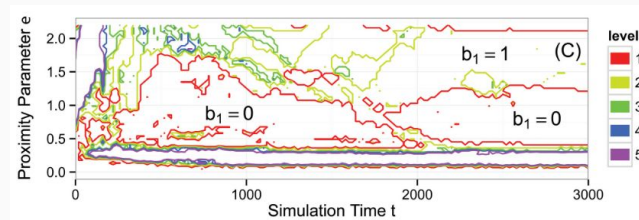
separate visuals: good



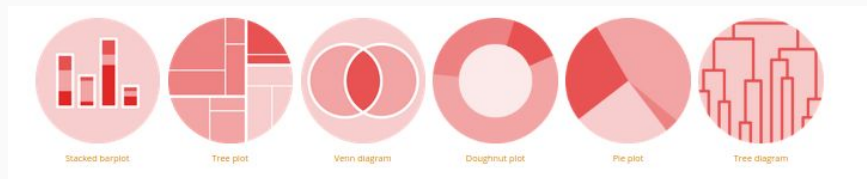
separate visuals: bad



academic visuals: need knowledge to evaluate



1. Background / Motivation
2. Tools / Elements / Analysis



### Sources:

- The Economist Graphic Detail blog [economist.com/graphic-detail](https://economist.com/graphic-detail)
- FiveThirtyEight [fivethirtyeight.com](https://fivethirtyeight.com)
- Adobe Color Wheel [color.adobe.com/create/color-wheel](https://color.adobe.com/create/color-wheel)
- The Python Graph Gallery [python-graph-gallery.com](https://python-graph-gallery.com)
- PGFPlots Gallery [pgfplots.sourceforge.net/gallery.html](https://pgfplots.sourceforge.net/gallery.html)
- TikZ and PGF examples [texample.net/tikz/examples](https://texample.net/tikz/examples)
- Lisa Charlotte Rost [github.com/lisacharlotterost/talk-slides](https://github.com/lisacharlotterost/talk-slides)
- James Gleick “The Information: A History, A Theory, A Flood”
- Topaz et al “Topological Data Analysis of Biological Aggregation Models”
- Reimann et al “Topology of synaptic connectivity constrains neuronal stimulus representation”