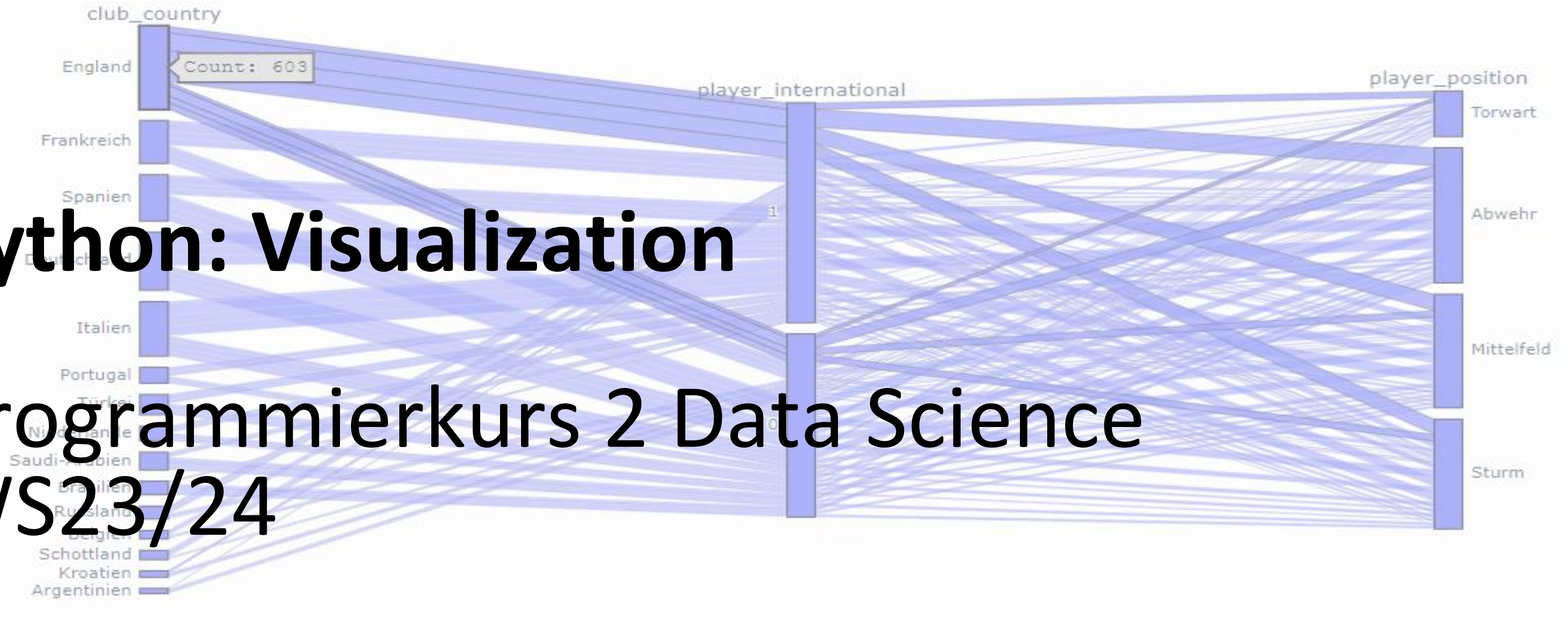

# Python: Visualization

Programmierkurs 2 Data Science
WS23/24

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# Learning Goals Python: Visualization

- **Paraphrase** the two actors, key elements, and processes of the Data Design Guide.
- **Explain** the advantages of the Matplotlib library and list a few extensions.
- Conceptually **design** Line, Scatter, Bar, Histogram, and Pie charts when given an example with multiple attributes.
- **Compare** the impact of Data Transformation processes on visualizations, and how they may affect the decoder interpretation.
- **Dicuss** the value and **draw conclusions** of Boxplot, Heatmap, and Pair-Plots (matrix).
- **Give example** on static plots and a potential extention to an interactive usage.

# The Data Design Guide

*https://www.designation.eu/en/2019/01/31/why-does-no-one-understand-my-data-visualization/*

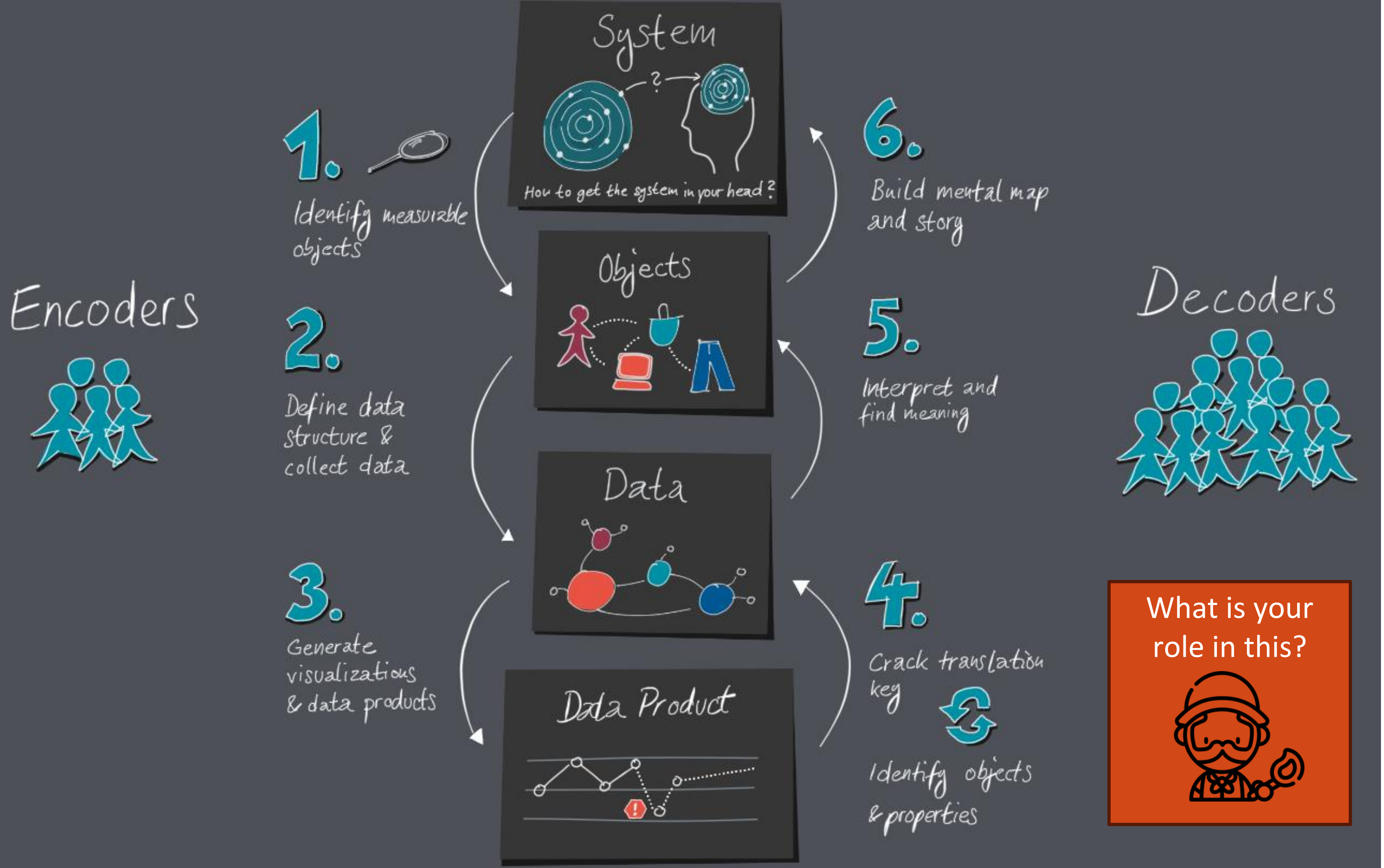
→ Part of Data-Literacy ☺

*"You can see a lot by looking." – Mason and Wiggins (OSEMN)*

*But data is abstract and often difficult to understand.*

*As Data Scientists, we want to enable others to read and interpret information.*

1. **System**
   *Understand the system (mental map) behind all data including believes and questions.*
2. **Objects**
   *Identify measurable objects, not every detail of the real-world can be captured.*
3. **Data**
   *Create the data model and prioritize simplicity rather inflated data sets.*
4. **Data Product**
   *Graphs do not visualize all the complexity of the system.*


System
How to get the system in your head?
Objects
Data
Data Product
Encoders
1. Identify measurable objects
2. Define data structure & collect data
3. Generate visualizations & data products
Decoders
4. Crack translation key
Identify objects & properties
5. Interpret and find meaning
6. Build mental map and story

What is your role in this?

# Hints for Data Visualizations

**Reverse Engineering**

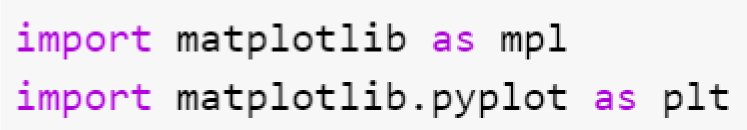
- Most extended libraries built on top of Matplotlib automate labeling, annotation, customization, grid arrangement, and many more and help **encoders** for initial mass exploration.
- Go into detail for visualisations, annotation, and styling that help the **decoder** interpret the data and deliver your key message.

**Learning Process**

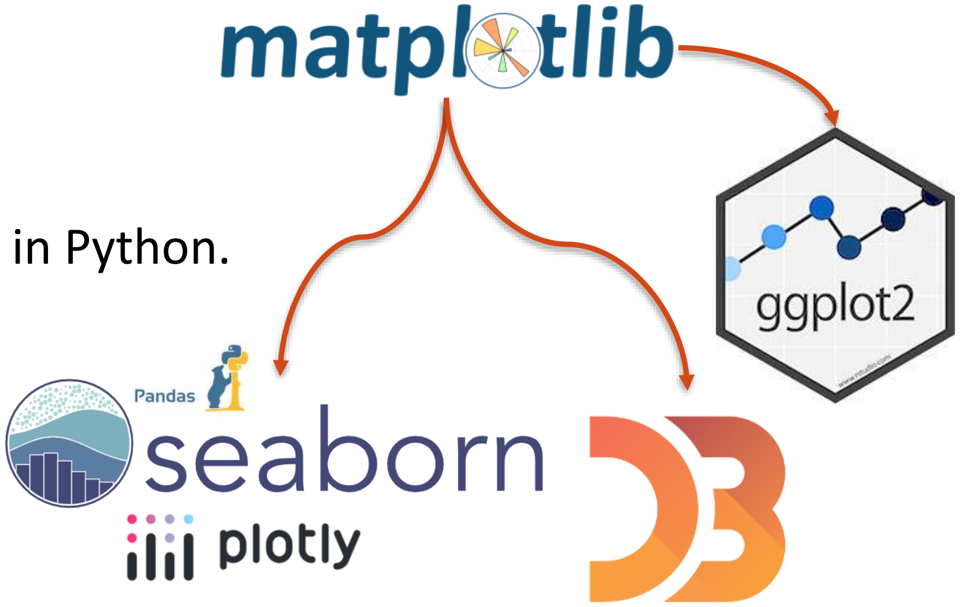
- Learn from examples and focus practicing with real data (your project).
- Some libraries work better for one type of visualization than others.
- Do not underestimate data transformation steps!
- Demand early feedback on your plots and stay updated with developments.
- Explore interactivity (e.g., plotly).

# Matplotlib

- Released in 2003 by John Hunter.
- Multi-platform data visualization library.
- Works with containers, NumPy arrays, and Pandas Series in Python.
- Designed to work with the broader SciPy stack.

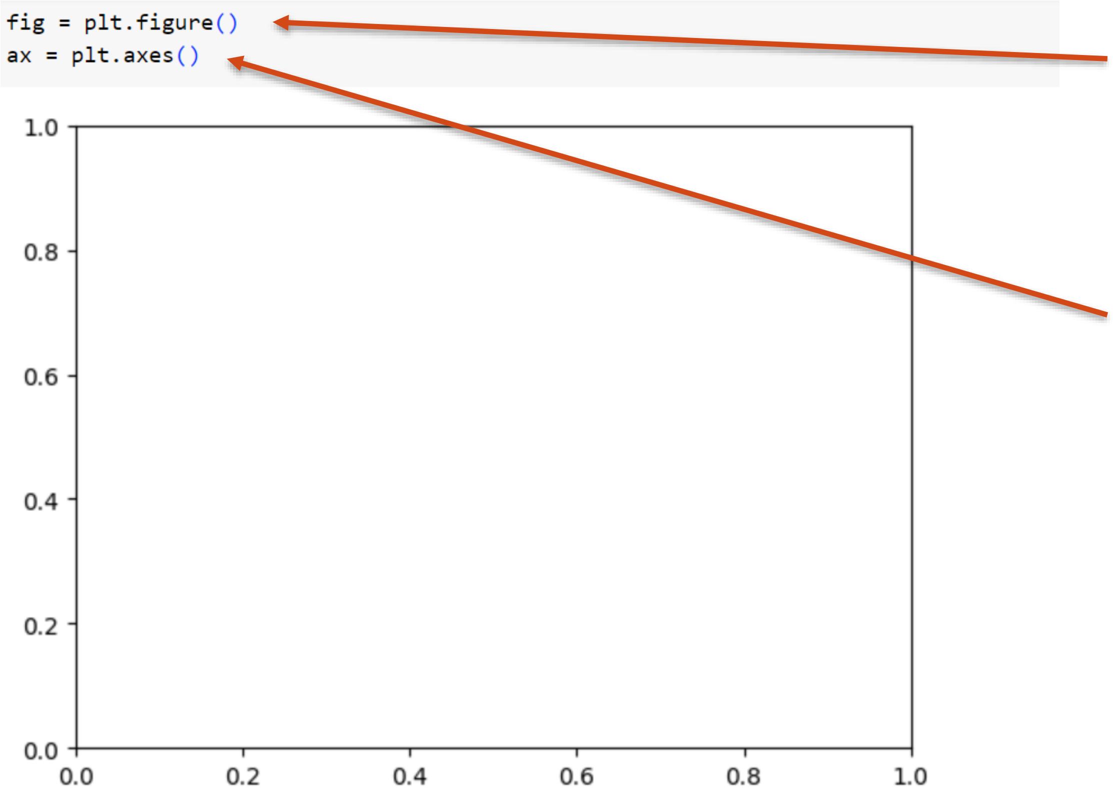


```
import matplotlib as mpl
import matplotlib.pyplot as plt
```



- Powerful extensions such as plotly, seaborn, ggplot, HoloViews, Altair, and Pandas use Matplotlib’s API.
- Matplotlib’s syntax mostly helpful for final plot creation or adjustments.

# Matplotlib

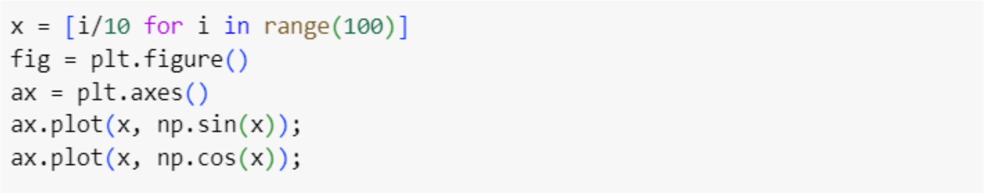


```
fig = plt.figure()
ax = plt.axes()
```

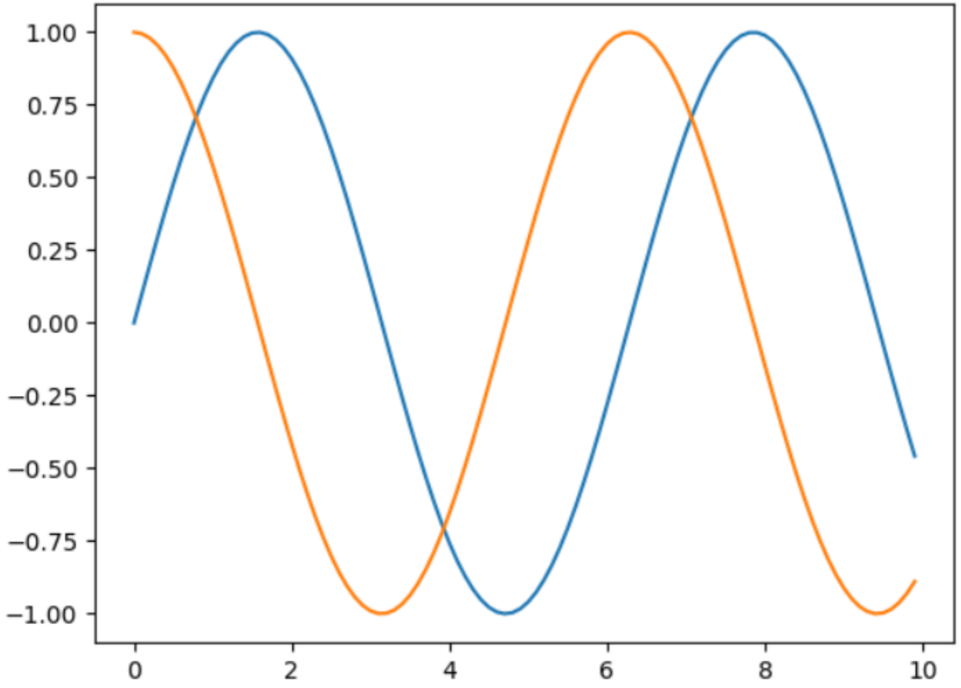
- **Figure instance**
  A single container that contains all the objects representing axes, graphics, text, and labels.
- **Axes instance** (or group)
  A bounding box with ticks and labels containing plot elements for visualization.

# Matplotlib Plot

*https://matplotlib.org/stable/api/_as_gen/matplotlib.axes.Axes.plot.html#matplotlib.axes.Axes.plot*



```
x = [i/10 for i in range(100)]
fig = plt.figure()
ax = plt.axes()
ax.plot(x, np.sin(x));
ax.plot(x, np.cos(x));
```



Plot y versus x as lines and/or markers.

```
ax.plot([x], y, [fmt], *,
  data=None, **kwargs)
```

- Coordinates of points or line nodes given by x, y.
- Each plot colored differently per default.

# Matplotlib Plot (fmt)

```
fmt = '[marker][line][color]'
```

| character | description |
|---|---|
| '.' | point marker |
| ',' | pixel marker |
| 'o' | circle marker |
| 'v' | triangle_down marker |
| '^' | triangle_up marker |
| '<' | triangle_left marker |
| '>' | triangle_right marker |
| 's' | square marker |
| 'p' | pentagon marker |
| 'P' | plus (filled) marker |
| '*' | star marker |
| 'h' | hexagon1 marker |
| 'H' | hexagon2 marker |
| '+' | plus marker |
| 'x' | x marker |
| 'X' | x (filled) marker |
| 'D' | diamond marker |
| 'd' | thin_diamond marker |

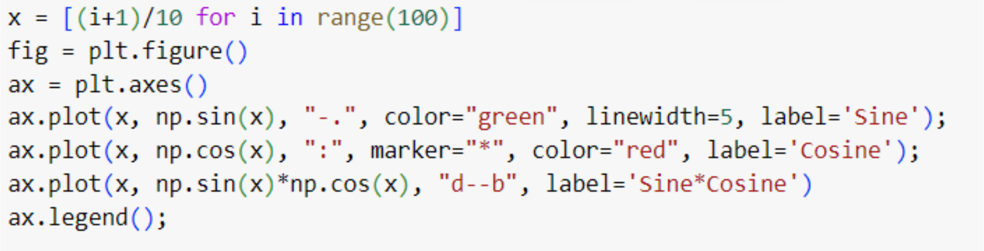
| character | description |
|---|---|
| '-' | solid line style |
| '--' | dashed line style |
| '-.' | dash-dot line style |
| ':' | dotted line style |

| character | color |
|---|---|
| 'b' | blue |
| 'g' | green |
| 'r' | red |
| 'c' | cyan |
| 'm' | magenta |
| 'y' | yellow |
| 'k' | black |
| 'w' | white |

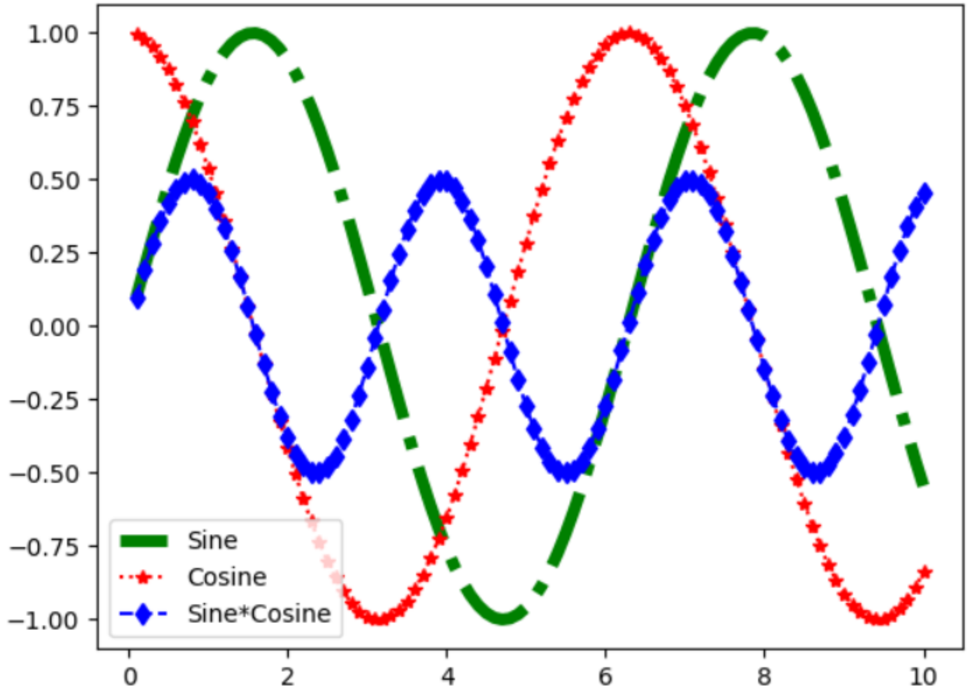
or full names ('green’)
or hex strings ('#008000')

# Matplotlib Plot (cont.)

*https://matplotlib.org/stable/api/_as_gen/matplotlib.lines.Line2D.html#matplotlib.lines.Line2D*



```
x = [(i+1)/10 for i in range(100)]
fig = plt.figure()
ax = plt.axes()
ax.plot(x, np.sin(x), "-.", color="green", linewidth=5, label='Sine');
ax.plot(x, np.cos(x), ":", marker="*", color="red", label='Cosine');
ax.plot(x, np.sin(x)*np.cos(x), "d--b", label='Sine*Cosine')
ax.legend();
```



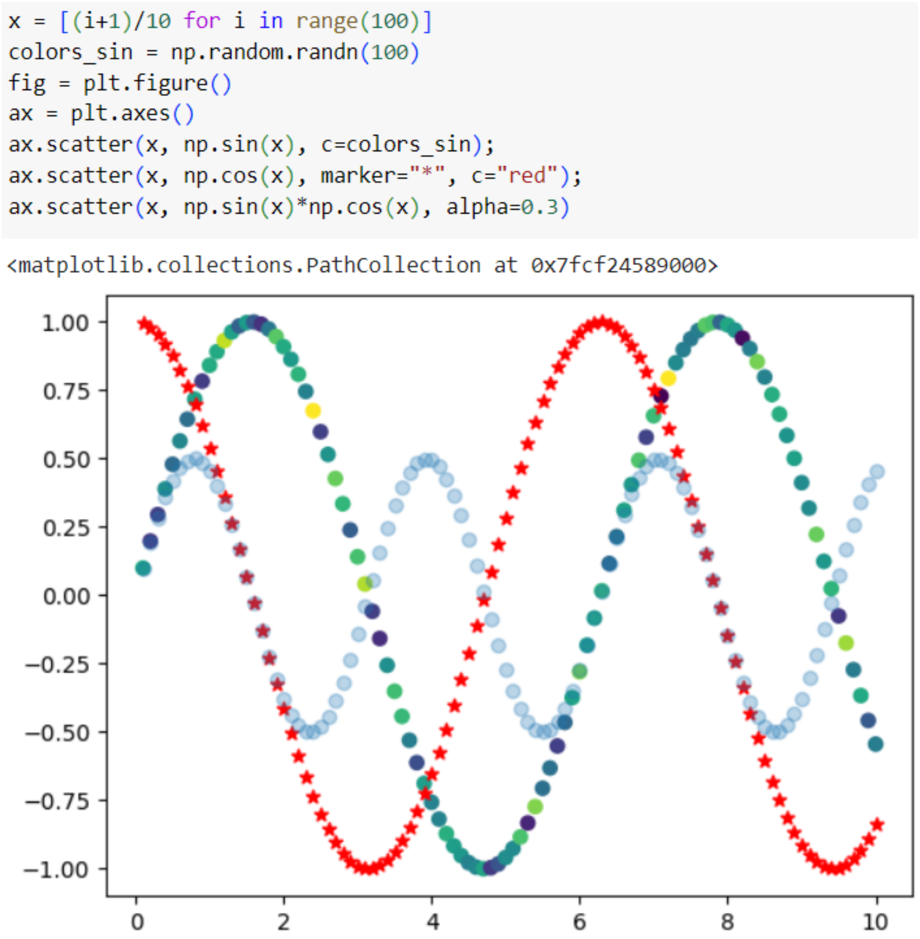
Plot y versus x as lines and/or markers.

```
ax.plot([x], y, [fmt], *,
  data=None, **kwargs)
```

- Coordinates of points or line nodes given by x, y.
- Each plot colored differently per default.
- **fmt** is a convenient color, marker and linestyle formatter.
- **Line2D** provides more parameters such as marker, markersize, linewidth, and many more.
- Add **labels** to plots and display **ax.legend.**

# Matplotlib Scatter

*https://matplotlib.org/stable/api/_as_gen/matplotlib.axes.Axes.scatter.html*



```
x = [(i+1)/10 for i in range(100)]
colors_sin = np.random.randn(100)
fig = plt.figure()
ax = plt.axes()
ax.scatter(x, np.sin(x), c=colors_sin);
ax.scatter(x, np.cos(x), marker="*", c="red");
ax.scatter(x, np.sin(x)*np.cos(x), alpha=0.3)
```

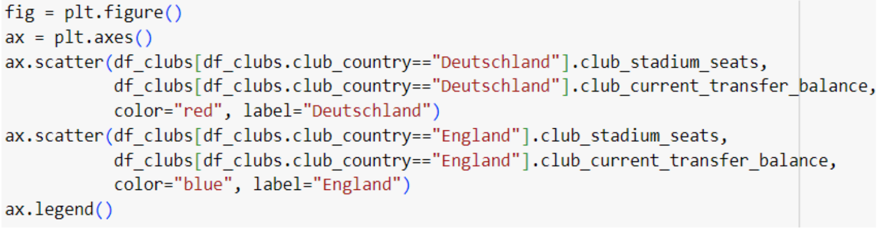
```
<matplotlib.collections.PathCollection at 0x7fcf24589000>
```

Plot y versus x as markers (close plot cousin)

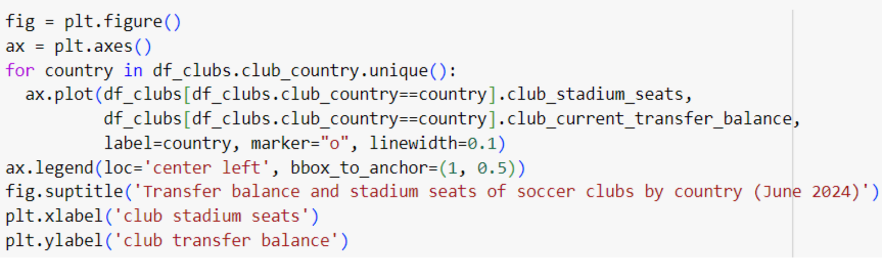
- Allows you to control and configure **points individually** (size, face color, edge color, etc.) mapped to data.
- `plt.plot` should be preferred over `plt.scatter` if extra work for each point does not pay off.

# Matplotlib Plot and Scatter (cont.)

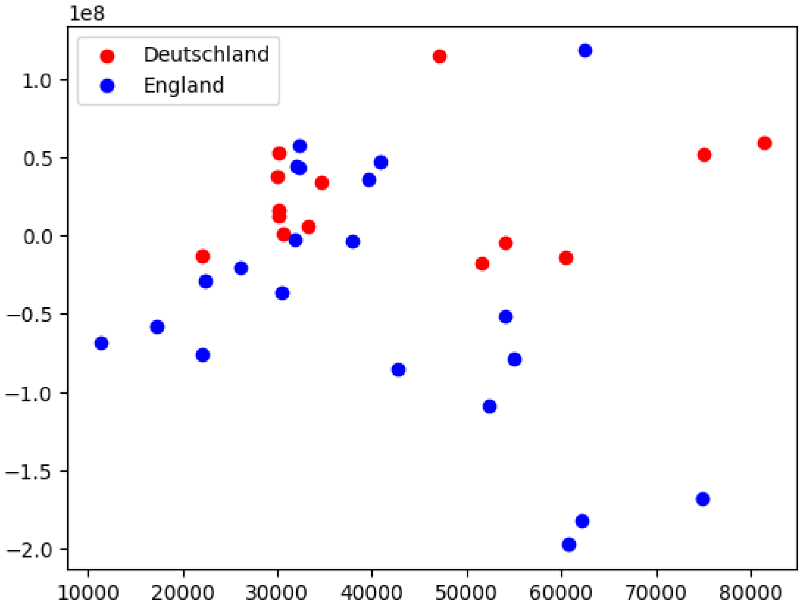
What information can the Encoder interpret?

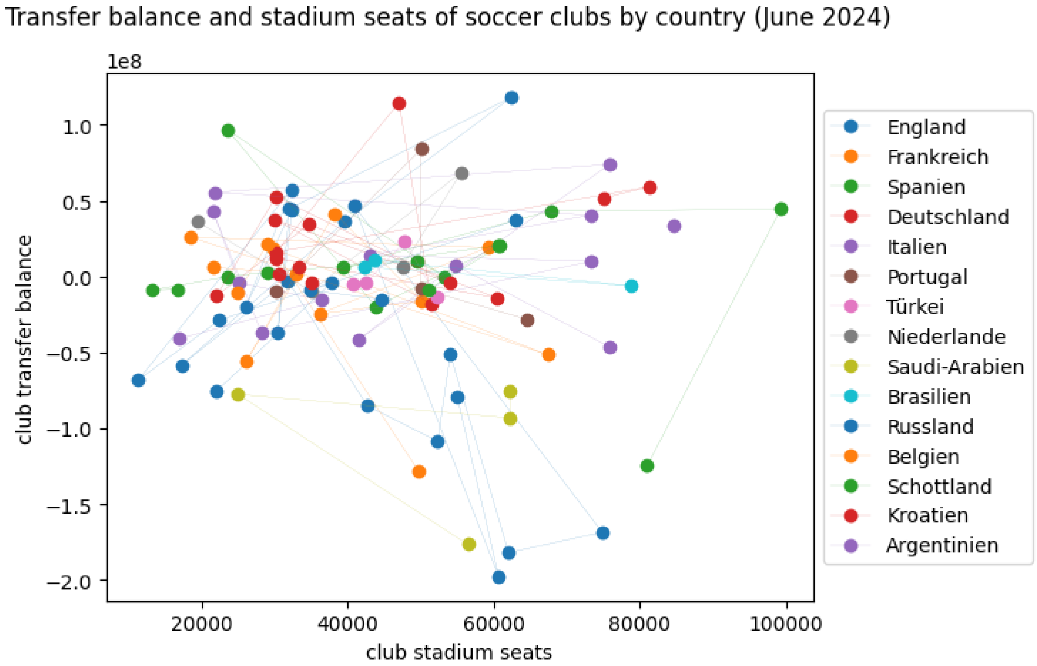


```
fig = plt.figure()
ax = plt.axes()
ax.scatter(df_clubs[df_clubs.club_country=="Deutschland"].club_stadium_seats,
           df_clubs[df_clubs.club_country=="Deutschland"].club_current_transfer_balance,
           color="red", label="Deutschland")
ax.scatter(df_clubs[df_clubs.club_country=="England"].club_stadium_seats,
           df_clubs[df_clubs.club_country=="England"].club_current_transfer_balance,
           color="blue", label="England")
ax.legend()
```



```
fig = plt.figure()
ax = plt.axes()
for country in df_clubs.club_country.unique():
  ax.plot(df_clubs[df_clubs.club_country==country].club_stadium_seats,
          df_clubs[df_clubs.club_country==country].club_current_transfer_balance,
          label=country, marker="o", linewidth=0.1)
ax.legend(loc='center left', bbox_to_anchor=(1, 0.5))
fig.suptitle('Transfer balance and stadium seats of soccer clubs by country (June 2024)')
plt.xlabel('club stadium seats')
plt.ylabel('club transfer balance')
```

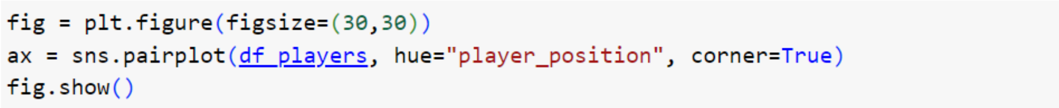




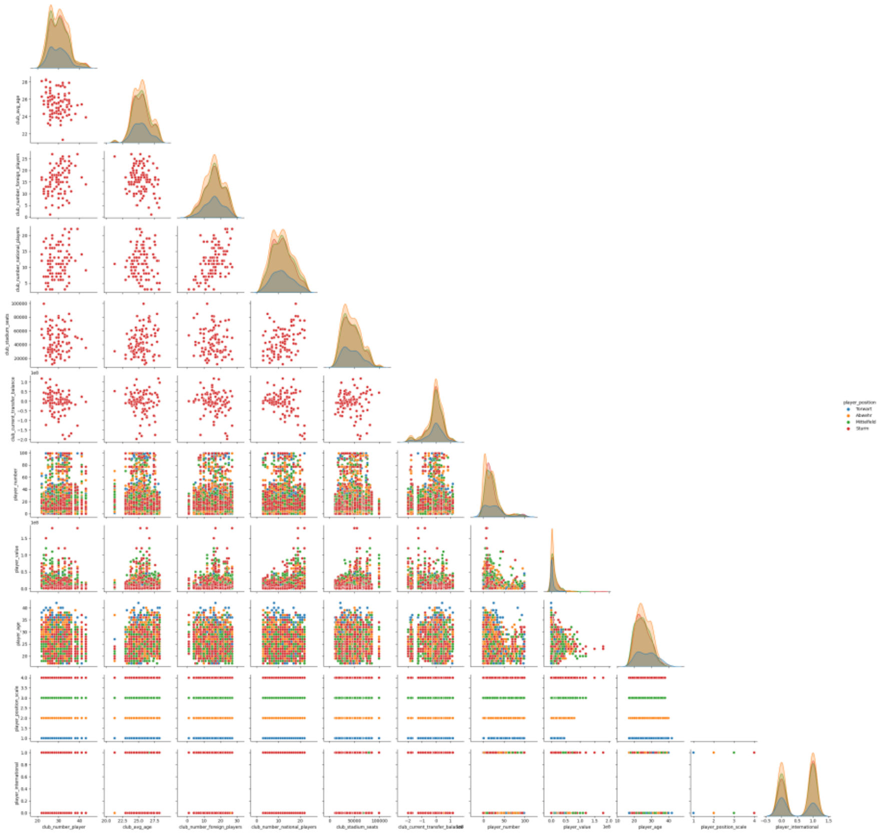
```
import seaborn as sns
```

# Matplotlib Scatter-Matrix

*https://seaborn.pydata.org/generated/seaborn.pairplot.html*



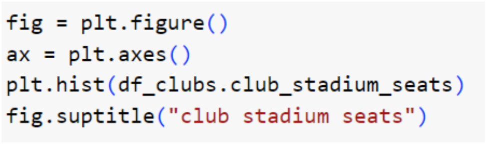
```
fig = plt.figure(figsize=(30,30))
ax = sns.pairplot(df_players, hue="player_position", corner=True)
fig.show()
```



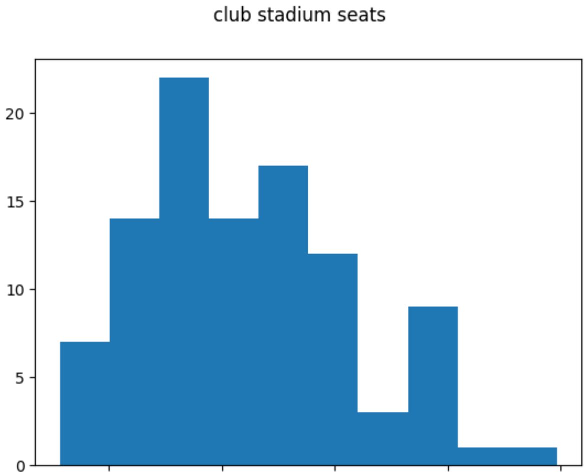
```
sns.pairplot(df,hue,…)
```

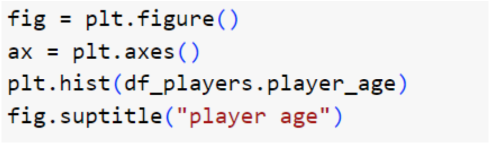
- Plot several pairs of variables and their joint distributions.
- Can be displayed individually and in more detail and examined in more detail by the data scientist.
- **hue** and **marker** can visualize additional dimensions.

# Matplotlib Histogram

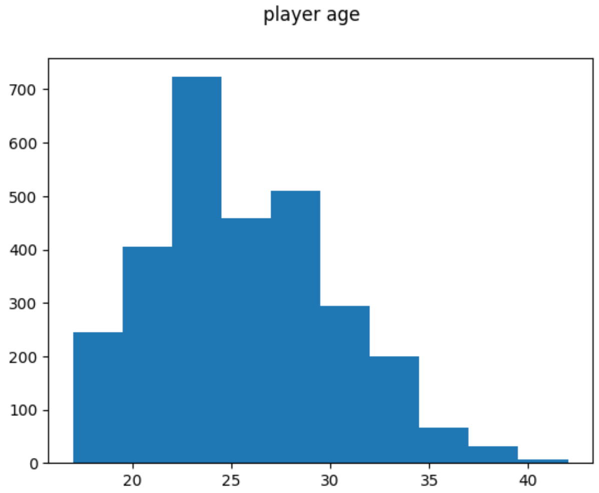


```
fig = plt.figure()
ax = plt.axes()
plt.hist(df_clubs.club_stadium_seats)
fig.suptitle("club stadium seats")
```





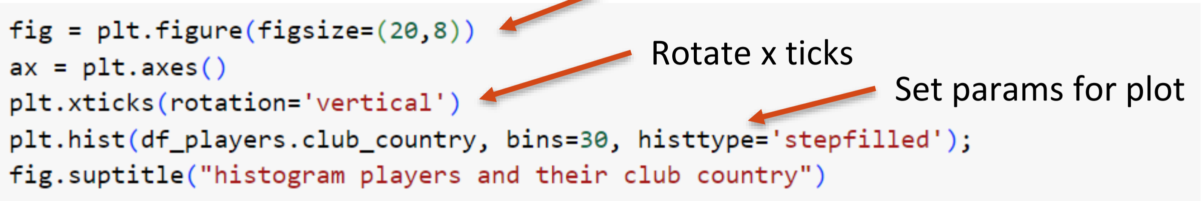
```
fig = plt.figure()
ax = plt.axes()
plt.hist(df_players.player_age)
fig.suptitle("player age")
```



`plt.hist(data, bin, ...)`

- Data can be any iterable container (e.g., list, NumPy array, Series).
- Representation of the distribution of data and frequencies.
- Bin the data in x and count the number of values in each bin.
- Great to get a sense of location, spread and skewness of the data (e.g., unimodal, bimodal or multimodal).

# Matplotlib Histogram (cont.)

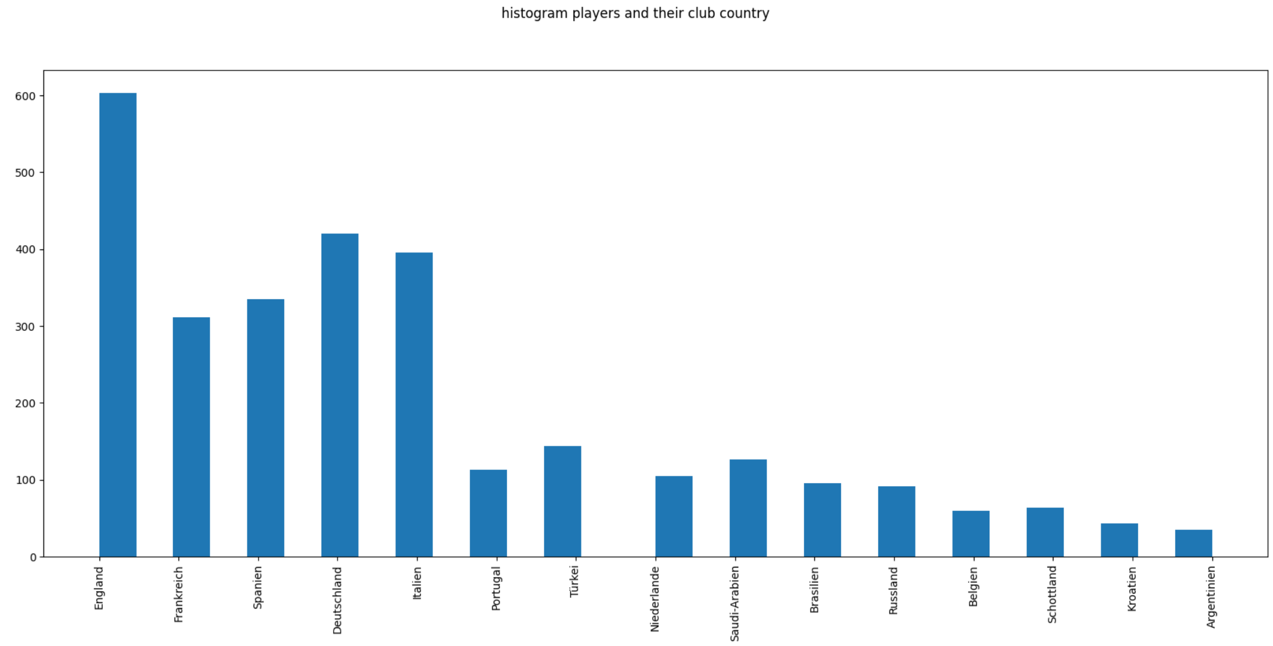


```
fig = plt.figure(figsize=(20,8))
ax = plt.axes()
plt.xticks(rotation='vertical')
plt.hist(df_players.club_country, bins=30, histtype='stepfilled');
fig.suptitle("histogram players and their club country")
```

Set figure size (width, height)

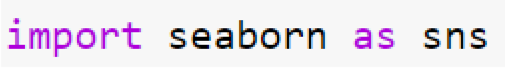
Rotate x ticks

Set params for plot



`plt.hist(data, bin, ...)`

- Data can be any iterable container (e.g., list, NumPy array, Series)
- Representation of the distribution of data and frequencies.
- Bin the data in x and count the number of values in each bin.
- Great to get a sense of location, spread and skewness of the data (e.g., unimodal, bimodal or multimodal).

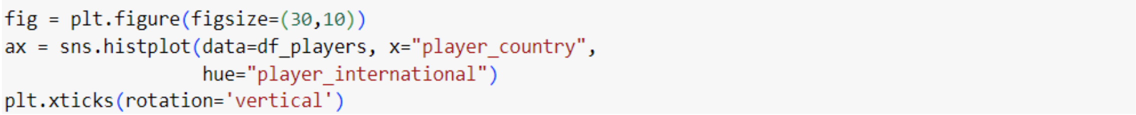


```
import seaborn as sns
```

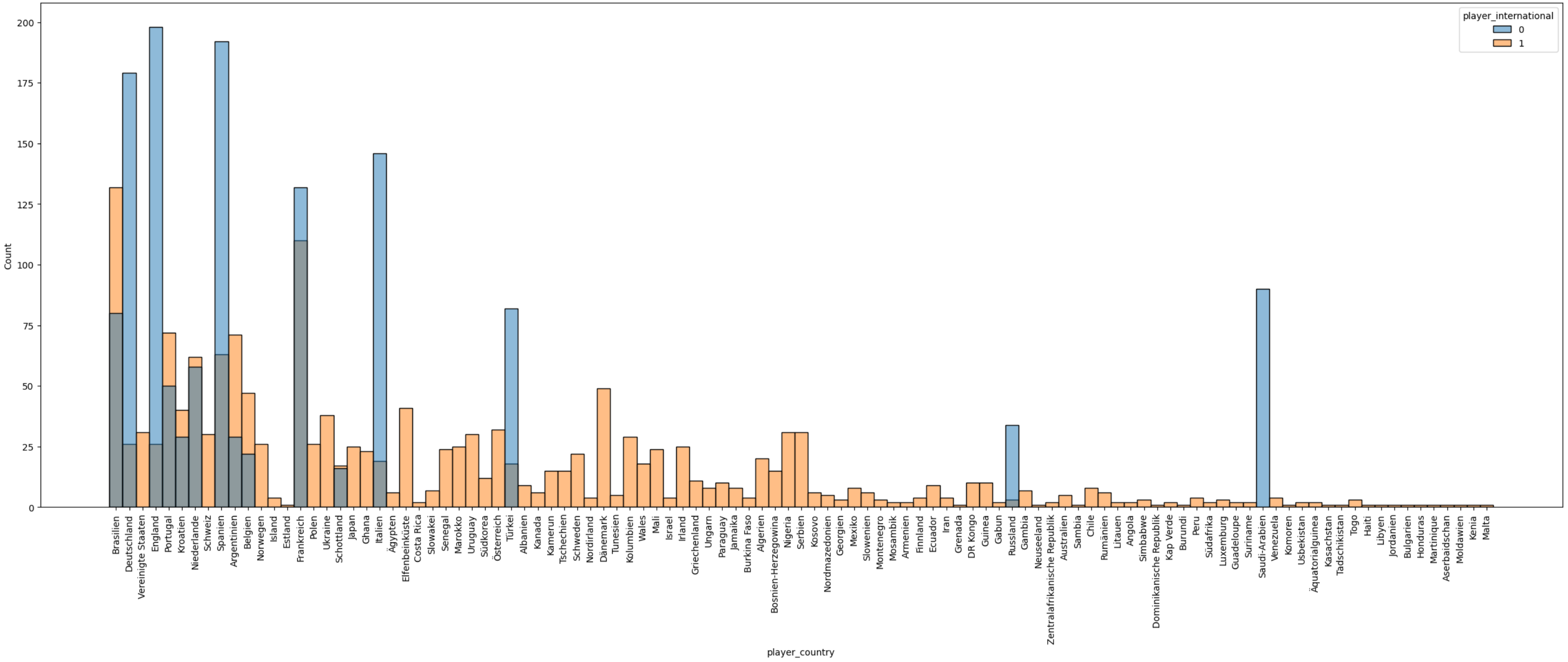
# Seaborn Histogram

*https://seaborn.pydata.org/generated/seaborn.histplot.html*

Draw histograms with **hue** mapping and **transparent overlapping** layers.



```
fig = plt.figure(figsize=(30,10))
ax = sns.histplot(data=df_players, x="player_country",
                  hue="player_international")
plt.xticks(rotation='vertical')
```



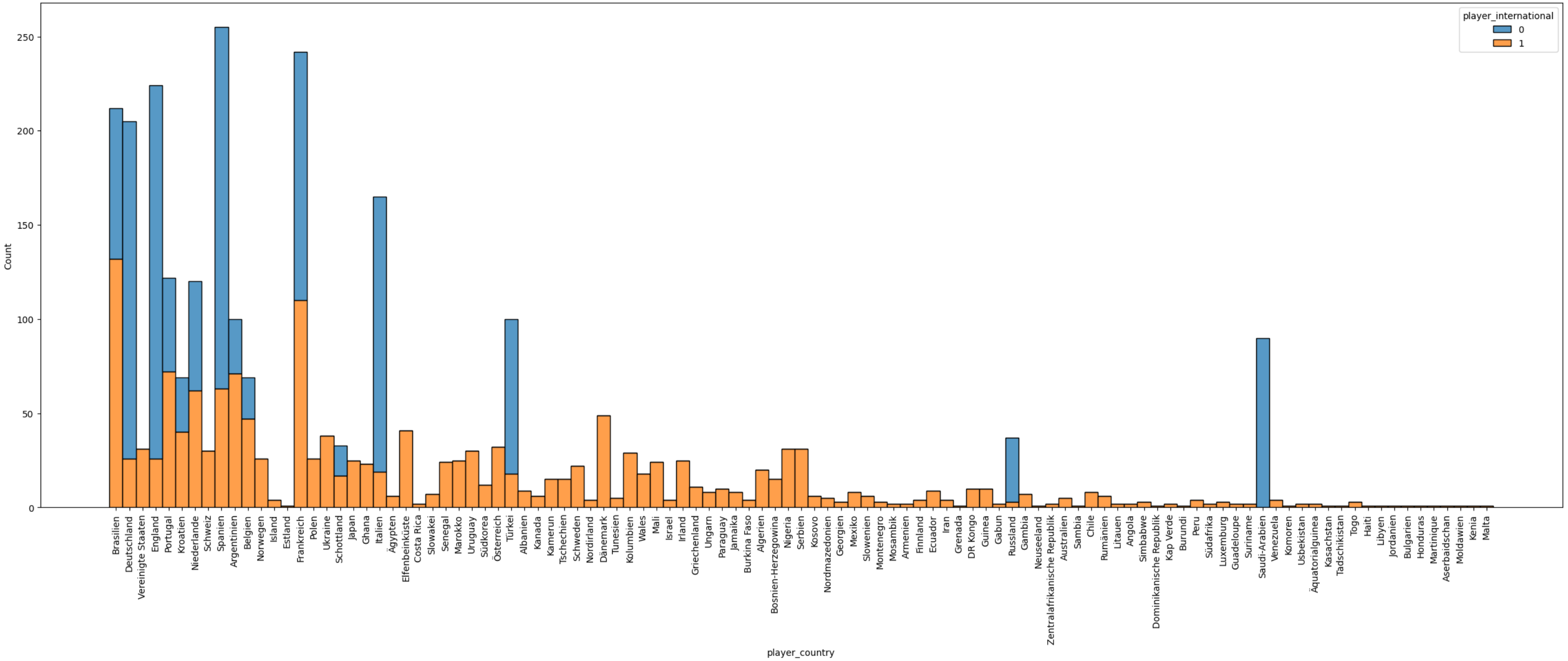
```
import seaborn as sns
```

# Seaborn Histogram (cont.)

*https://seaborn.pydata.org/generated/seaborn.histplot.html*

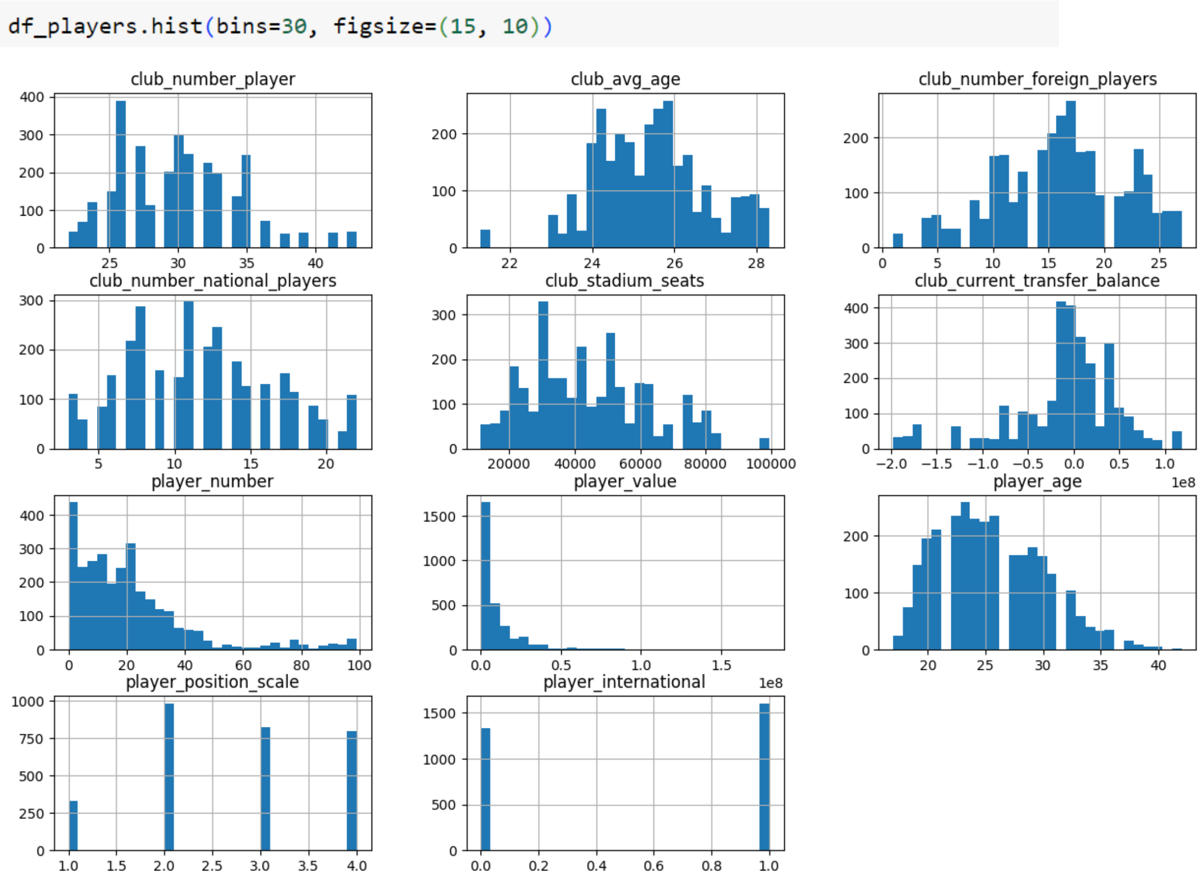
Draw histograms with **stacked hue** mapping.

```
fig = plt.figure(figsize=(30,10))
ax = sns.histplot(data=df_players, x="player_country",
                  hue="player_international", multiple="stack")
plt.xticks(rotation='vertical')
```



# Pandas Histogram

*https://pandas.pydata.org/docs/reference/api/pandas.DataFrame.hist.html*



```
df_players.hist(bins=30, figsize=(15, 10))
```

```
DataFrame.hist()
```

- Calls matplotlib.pyplot.hist() on each series in the DataFrame.

# Data Transformation (Recap)

*A function that **maps** the entire **set** of values of a given attribute **to** a **new set** of **replacement values**.*

Do not underestimate Data Transformation within your dataset!

**Attribute Construction**:

- Unary function definition `f(A)` → `A`, where A is a set or
- Binary function definition `f(A, B)` → `A*B`, whera A.index ≡ B.index, and * some operation

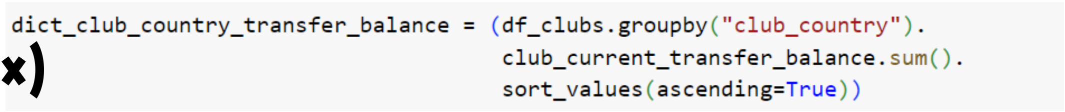
**Aggregation**: involves grouping and computations such as sum(), mean(), median(), min(), and max(), to generate insights into the nature of numeric values.

**Generalization**: concept hierarchy climbing.

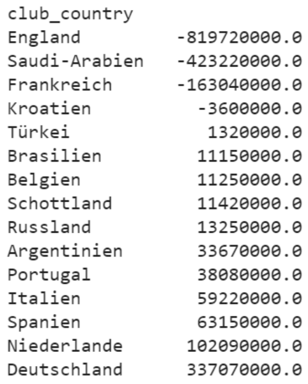
**Normalization**: series transformation to a scale so values lie within a specified range (usually smaller and positive).

# Matplotlib Horizontal Bar

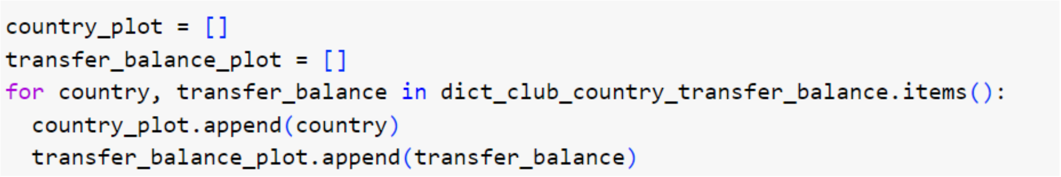
*https://matplotlib.org/stable/gallery/lines_bars_and_markers/barh.html*



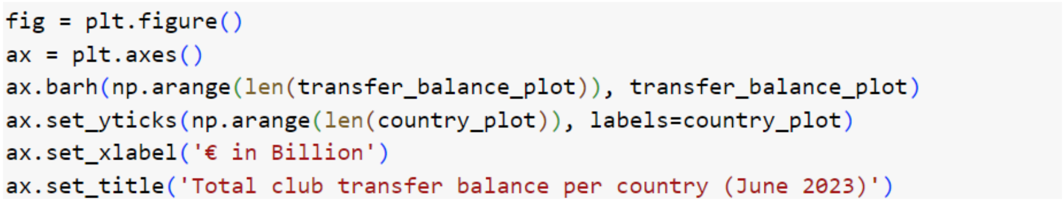
```
dict_club_country_transfer_balance = (df_clubs.groupby("club_country").
                                      club_current_transfer_balance.sum().
                                      sort_values(ascending=True))
```



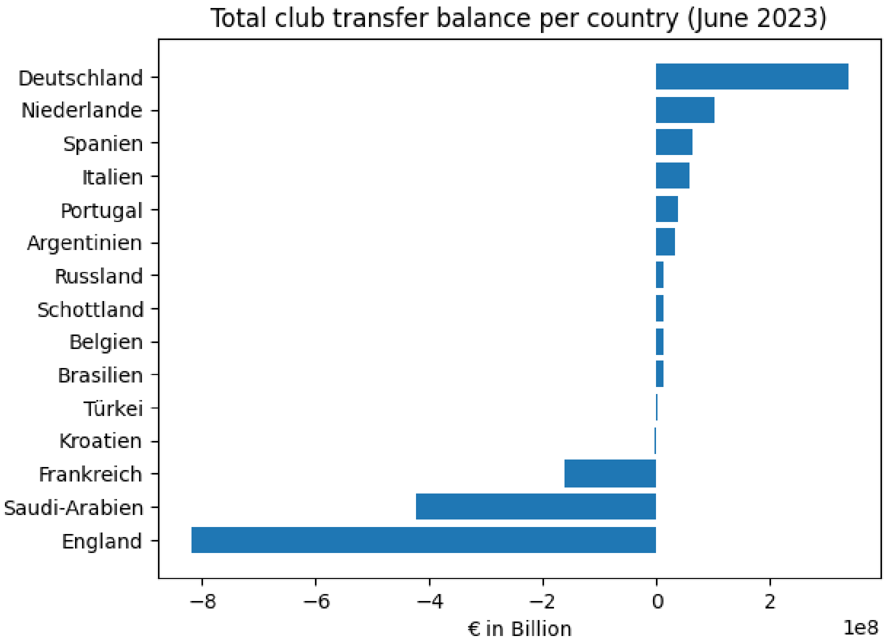
```
club_country
England          -819720000.0
Saudi-Arabien    -423220000.0
Frankreich       -163040000.0
Kroatien           -3600000.0
Türkei              1320000.0
Brasilien          11150000.0
Belgien            11250000.0
Schottland         11420000.0
Russland           13250000.0
Argentinien        33670000.0
Portugal           38080000.0
Italien            59220000.0
Spanien            63150000.0
Niederlande       102090000.0
Deutschland       337070000.0
```



```
country_plot = []
transfer_balance_plot = []
for country, transfer_balance in dict_club_country_transfer_balance.items():
  country_plot.append(country)
  transfer_balance_plot.append(transfer_balance)
```

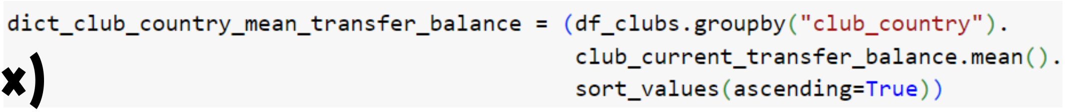


```
fig = plt.figure()
ax = plt.axes()
ax.barh(np.arange(len(transfer_balance_plot)), transfer_balance_plot)
ax.set_yticks(np.arange(len(country_plot)), labels=country_plot)
ax.set_xlabel('€ in Billion')
ax.set_title('Total club transfer balance per country (June 2023)')
```

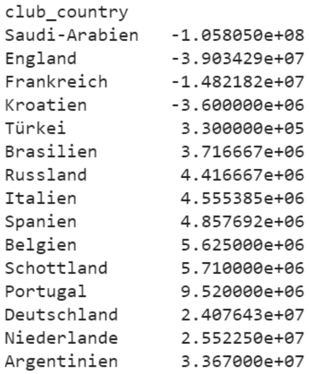


# Matplotlib Horizontal Bar (cont.)

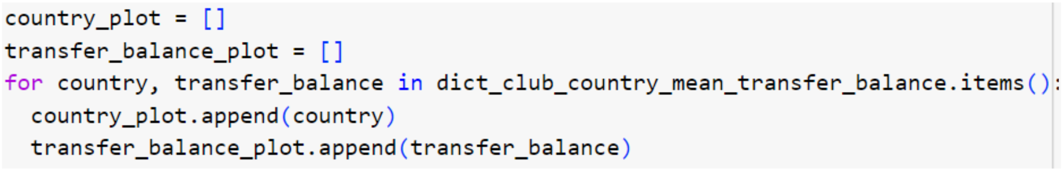
*https://matplotlib.org/stable/gallery/lines_bars_and_markers/barh.html*



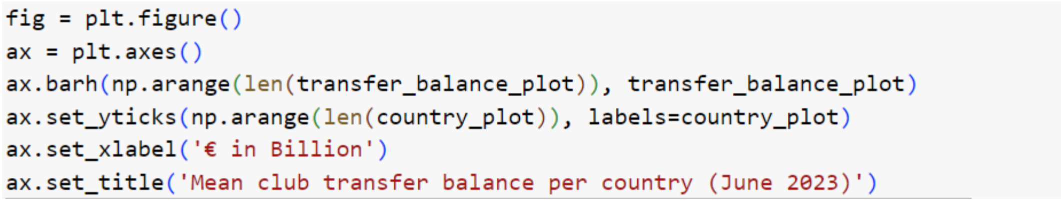
```
dict_club_country_mean_transfer_balance = (df_clubs.groupby("club_country").
                                           club_current_transfer_balance.mean().
                                           sort_values(ascending=True))
```



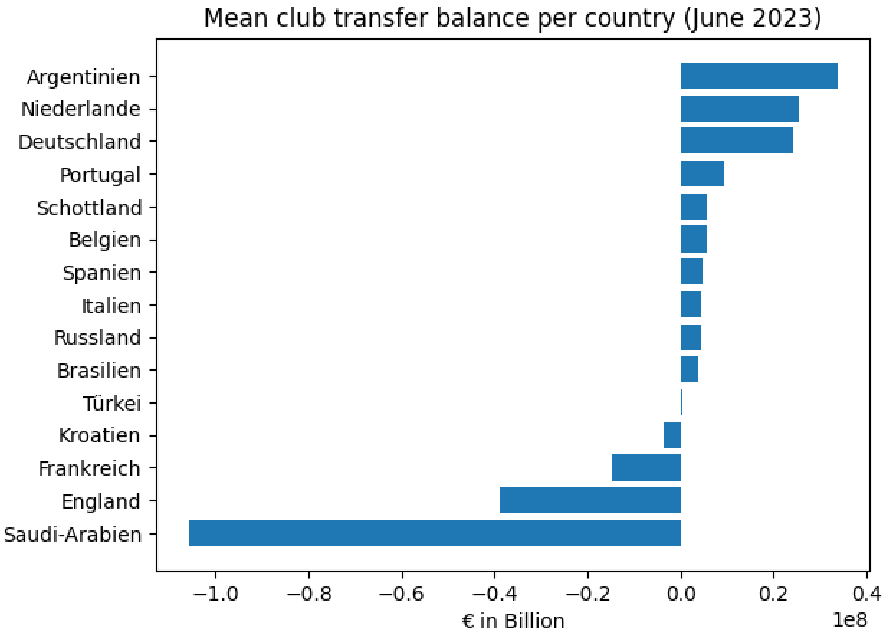
```
club_country
Saudi-Arabien    -1.058050e+08
England          -3.903429e+07
Frankreich       -1.482182e+07
Kroatien         -3.600000e+06
Türkei            3.300000e+05
Brasilien         3.716667e+06
Russland          4.416667e+06
Italien           4.555385e+06
Spanien           4.857692e+06
Belgien           5.625000e+06
Schottland        5.710000e+06
Portugal          9.520000e+06
Deutschland       2.407643e+07
Niederlande       2.552250e+07
Argentinien       3.367000e+07
```



```
country_plot = []
transfer_balance_plot = []
for country, transfer_balance in dict_club_country_mean_transfer_balance.items():
  country_plot.append(country)
  transfer_balance_plot.append(transfer_balance)
```



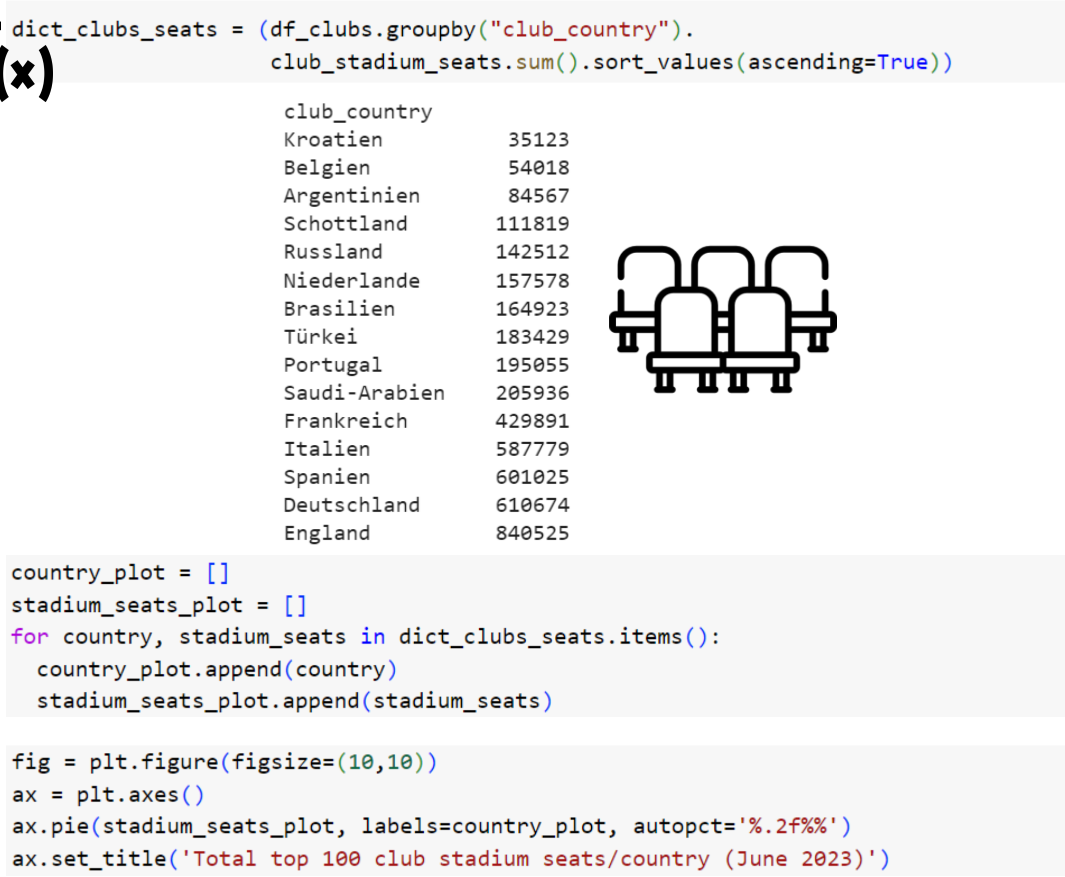
```
fig = plt.figure()
ax = plt.axes()
ax.barh(np.arange(len(transfer_balance_plot)), transfer_balance_plot)
ax.set_yticks(np.arange(len(country_plot)), labels=country_plot)
ax.set_xlabel('€ in Billion')
ax.set_title('Mean club transfer balance per country (June 2023)')
```



Two different messages!

# Matplotlib Pie

*https://matplotlib.org/stable/gallery/pie_and_polar_charts/pie_features.html*

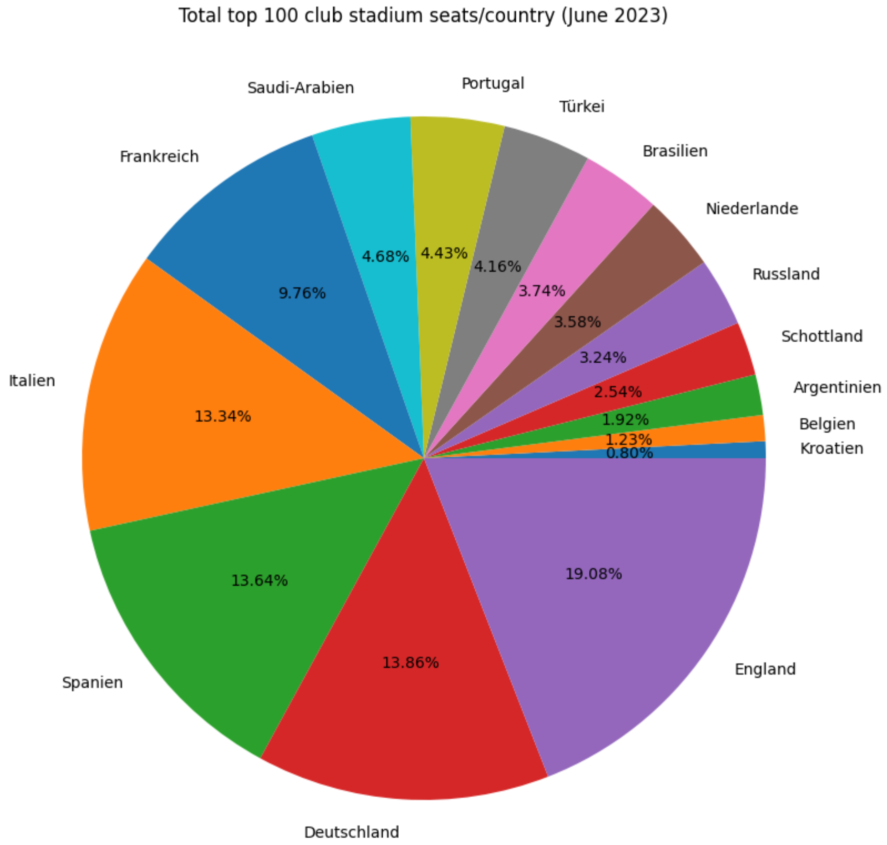


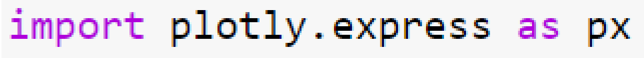
```
dict_clubs_seats = (df_clubs.groupby("club_country").
                    club_stadium_seats.sum().sort_values(ascending=True))
```

```
club_country
Kroatien          35123
Belgien           54018
Argentinien       84567
Schottland       111819
Russland         142512
Niederlande      157578
Brasilien        164923
Türkei           183429
Portugal         195055
Saudi-Arabien    205936
Frankreich       429891
Italien          587779
Spanien          601025
Deutschland      610674
England          840525
```

```
country_plot = []
stadium_seats_plot = []
for country, stadium_seats in dict_clubs_seats.items():
  country_plot.append(country)
  stadium_seats_plot.append(stadium_seats)
```

```
fig = plt.figure(figsize=(10,10))
ax = plt.axes()
ax.pie(stadium_seats_plot, labels=country_plot, autopct='%.2f%%')
ax.set_title('Total top 100 club stadium seats/country (June 2023)')
```

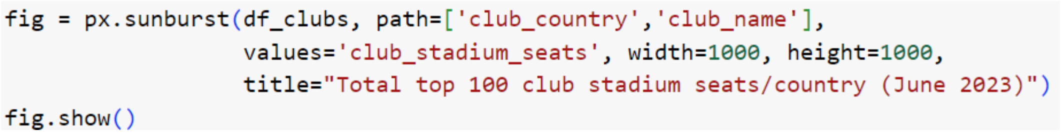




```
import plotly.express as px
```

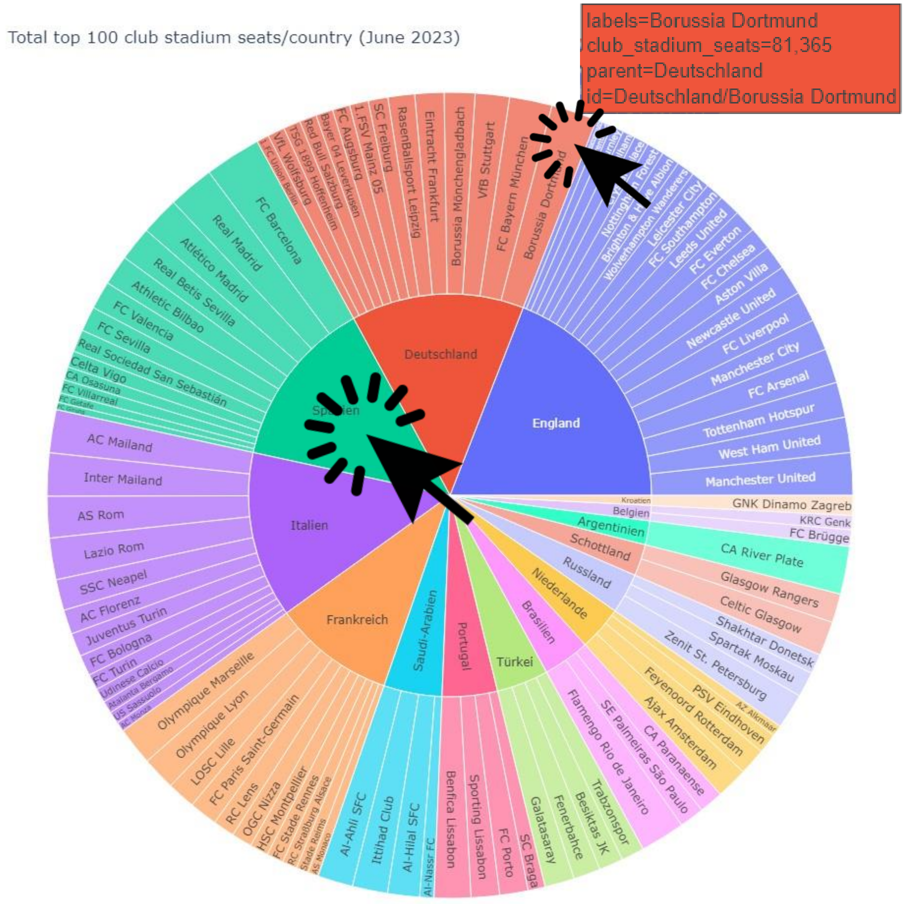
# Plotly Sunburst-Pie

*https://plotly.com/python/sunburst-charts/*



```
fig = px.sunburst(df_clubs, path=['club_country','club_name'],
                  values='club_stadium_seats', width=1000, height=1000,
                  title="Total top 100 club stadium seats/country (June 2023)")
fig.show()
```

- Sunbursts visualize hierarchical data spanning outwards radially from root to leaves (like treemaps).
- Each row of the DataFrame is represented as a sector of the sunburst.
- Path parameter corresponding to a list of series in outward order.



Total top 100 club stadium seats/country (June 2023)

labels=Borussia Dortmund
club_stadium_seats=81,365
parent=Deutschland
id=Deutschland/Borussia Dortmund

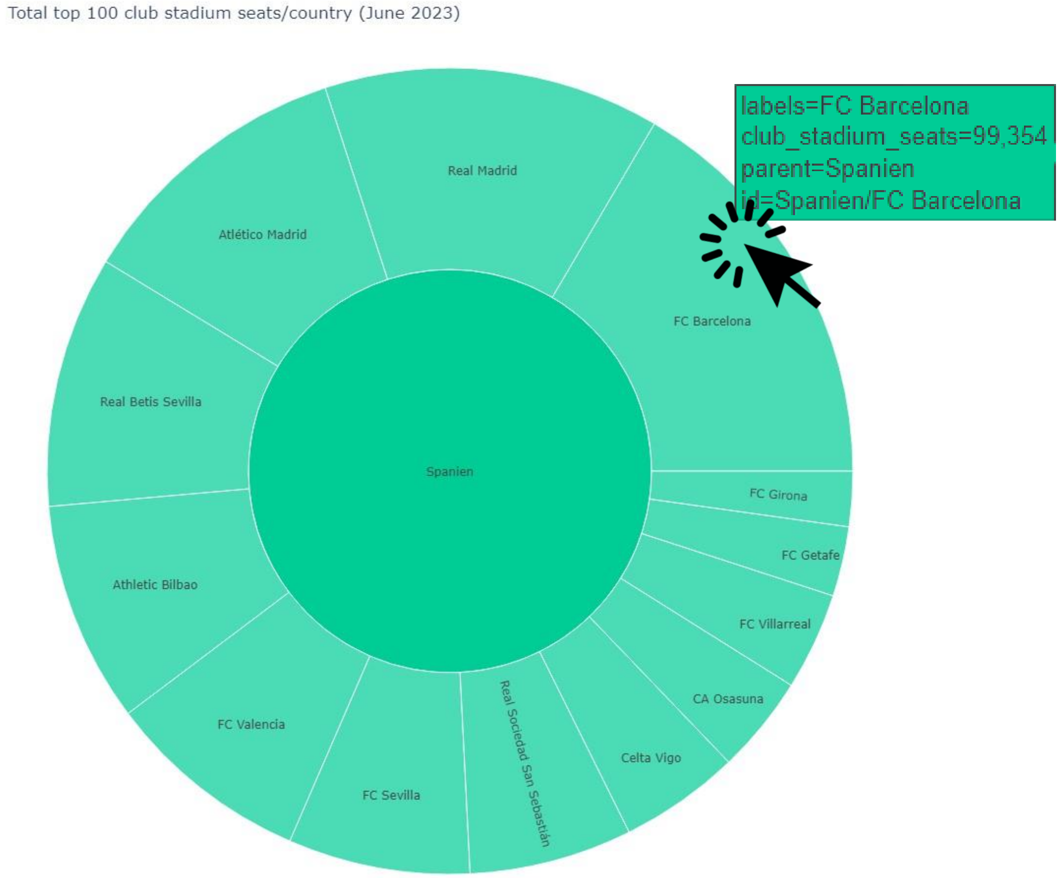
```
import plotly.express as px
```

# Plotly Sunburst-Pie (cont.)

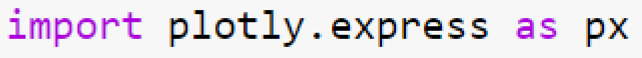
*https://plotly.com/python/sunburst-charts/*

```
fig = px.sunburst(df_clubs, path=['club_country','club_name'],
                  values='club_stadium_seats', width=1000, height=1000,
                  title="Total top 100 club stadium seats/country (June 2023)")
fig.show()
```

- Sunbursts visualize hierarchical data spanning outwards radially from root to leaves (like treemaps).
- Each row of the DataFrame is represented as a sector of the sunburst.
- Path parameter corresponding to a list of series in outward order.
- Plotly charts are interactive and provide settings for hover animations and custom controls.



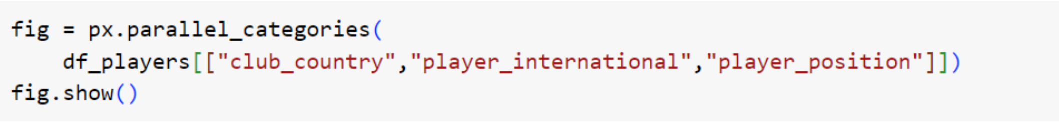
labels=FC Barcelona
club_stadium_seats=99,354
parent=Spanien
id=Spanien/FC Barcelona



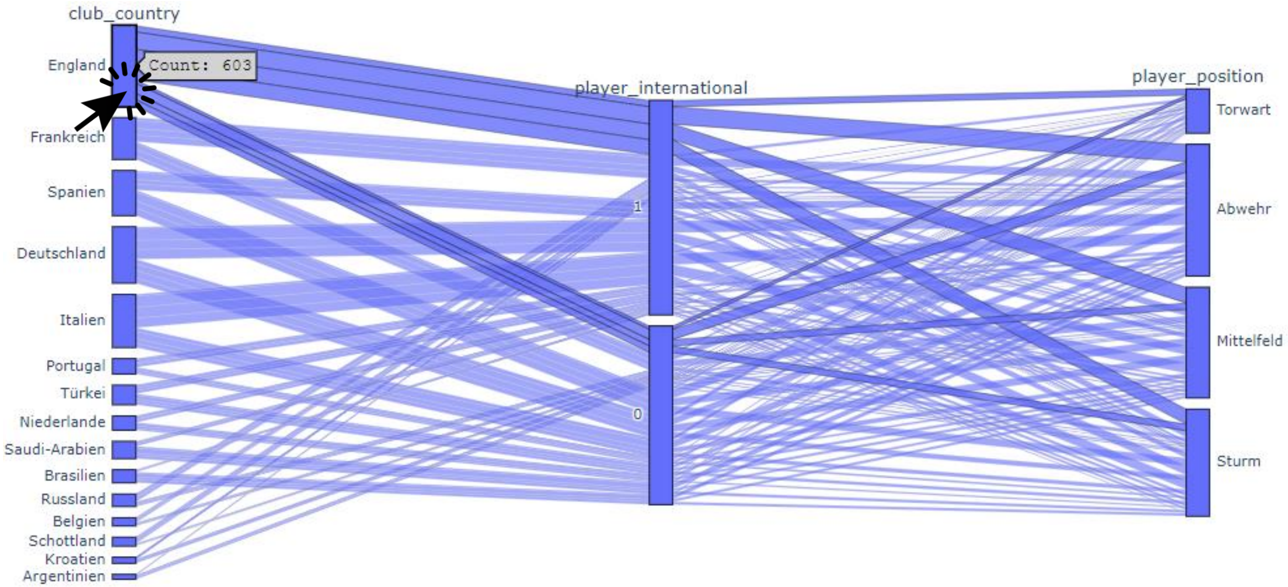
```
import plotly.express as px
```

# Plotly Parallel-Sets

*https://plotly.com/python/parallel-categories-diagram/*



```
fig = px.parallel_categories(
    df_players[["club_country","player_international","player_position"]])
fig.show()
```



Visualization of **multi-dimensional categorical** data sets.

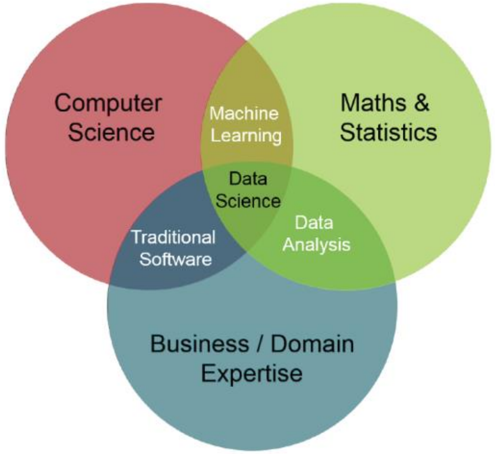
- Each variable represented by a column of rectangles.
- Relative heights of the rectangles reflect the relative frequency of occurrence.
- Ribbons connect rectangles corresponding to the relative frequency of occurrence of the combination given by the order of the DataFrame columns.

# Let us recap the past slides...

As Data Scientists, we encode

- A system into objects *(e.g., DFB: increase transparency of soccer player).*
- Objects into data *(e.g., soccer players and clubs).*
- Data into data products *(e.g., Line, Scatter, Histograms, Bar, Pie, and many others).*

To help the decoder interpret data and deliver some message.



*The role of a Data Scientists may be a lot, but we can use some statistics and visualizations to guide and help ourselves.*

# Preprocessing Considerations (Recap)

Think about likely **causes of noise** and errors when **correcting and transforming data**, e.g.,

- Do two extremely similar attributes really represent the same?
- Does a missing value have more meaning in the data context than np.NaN?
- Is this “outlier“ really an outlier, or is there a reasonable explanation for it?
- Does removing an outlier harm or help interpreting the whole data context?

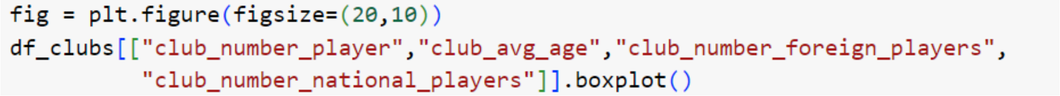
Consider **ethics** when applying Data Integration and Transformations:

- Limit harmful uses
- Reflect diversity / inclusion
- Uphold human rights and values

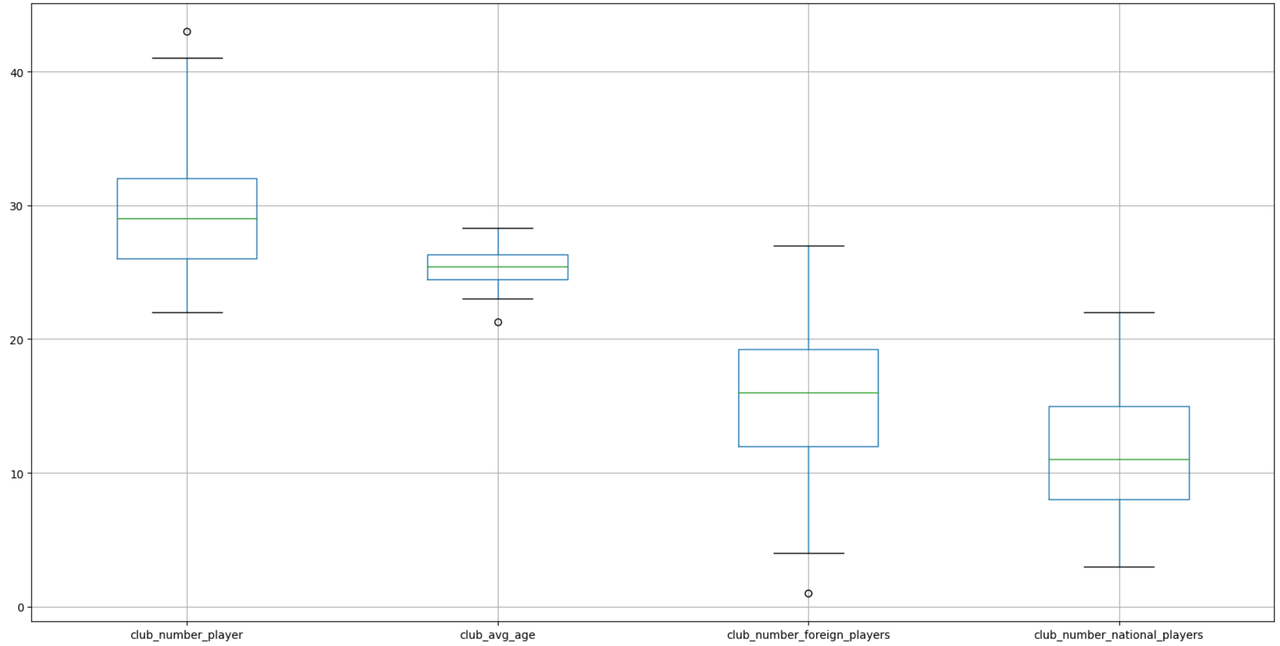
**…preprocessing changes the data and introduces new bias.**

# Matplotlib Boxplot

*https://pandas.pydata.org/docs/reference/api/pandas.DataFrame.boxplot.html*

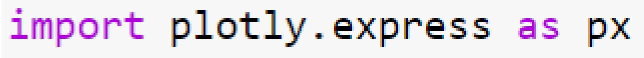


```
fig = plt.figure(figsize=(20,10))
df_clubs[["club_number_player","club_avg_age","club_number_foreign_players",
          "club_number_national_players"]].boxplot()
```



Boxplot graphically depicts groups of **numerical** data:

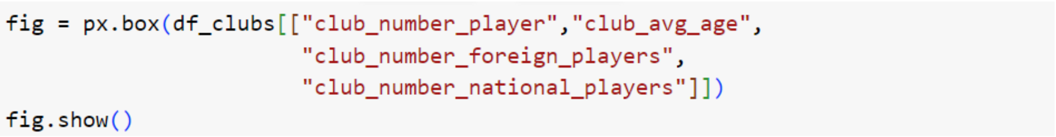
- Median
- Q1 and Q3 quartiles
- 1.5 * IQR (IQR = Q3 - Q1)
- Dots represent outliers



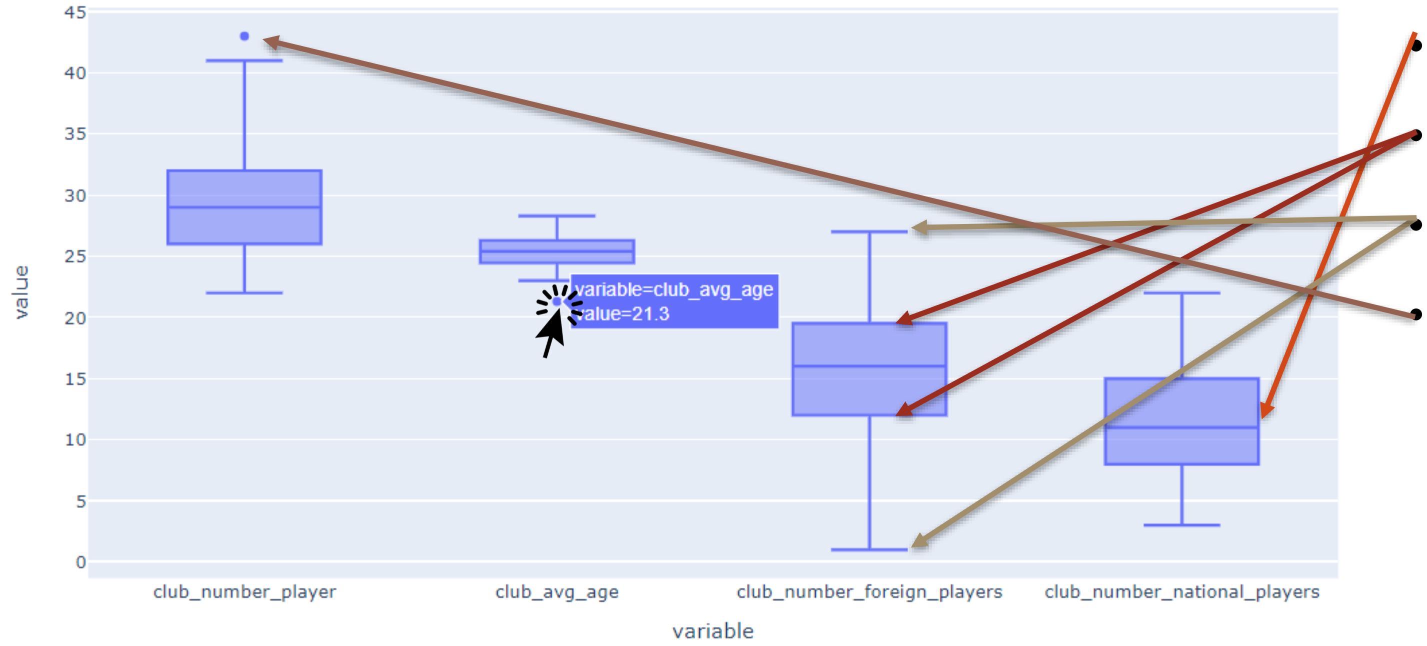
```
import plotly.express as px
```

# Plotly Boxplot

*https://plotly.com/python/box-plots/*



```
fig = px.box(df_clubs[["club_number_player","club_avg_age",
                       "club_number_foreign_players",
                       "club_number_national_players"]])
fig.show()
```



Boxplot graphically depicts groups of **numerical** data:

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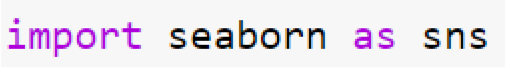
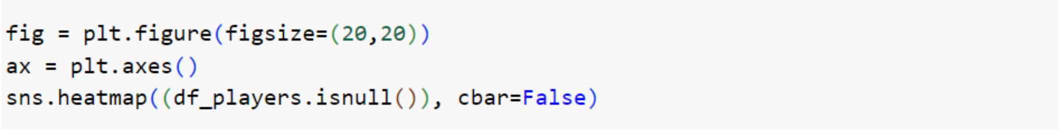


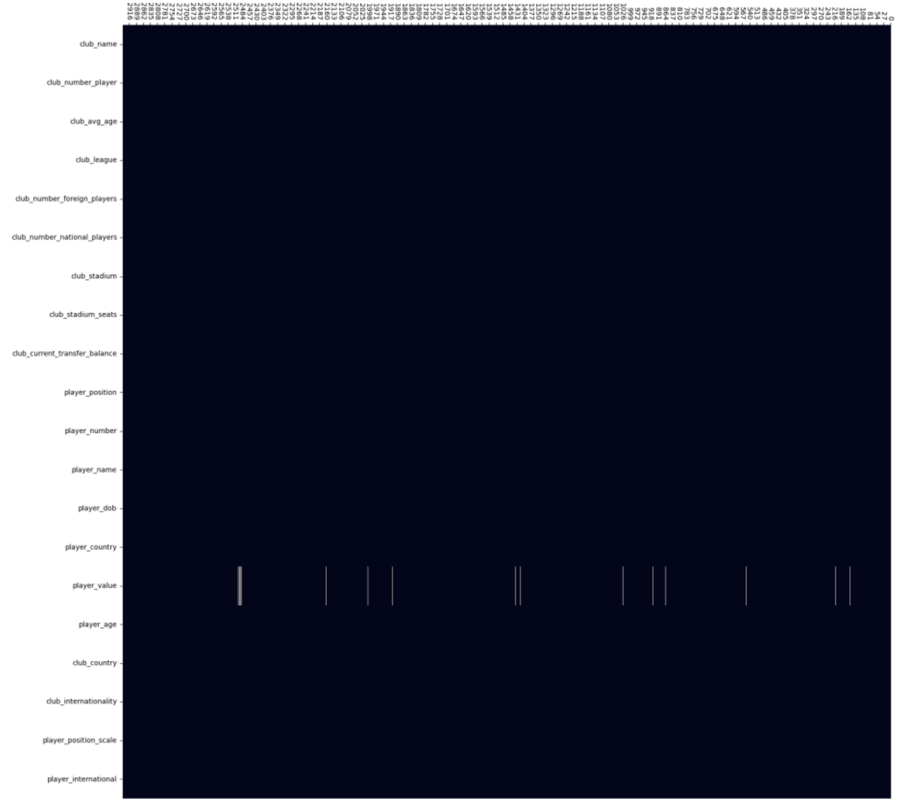
```
import seaborn as sns
```

# NaN Heatmap

*https://seaborn.pydata.org/generated/seaborn.heatmap.html*



```
fig = plt.figure(figsize=(20,20))
ax = plt.axes()
sns.heatmap((df_players.isnull()), cbar=False)
```



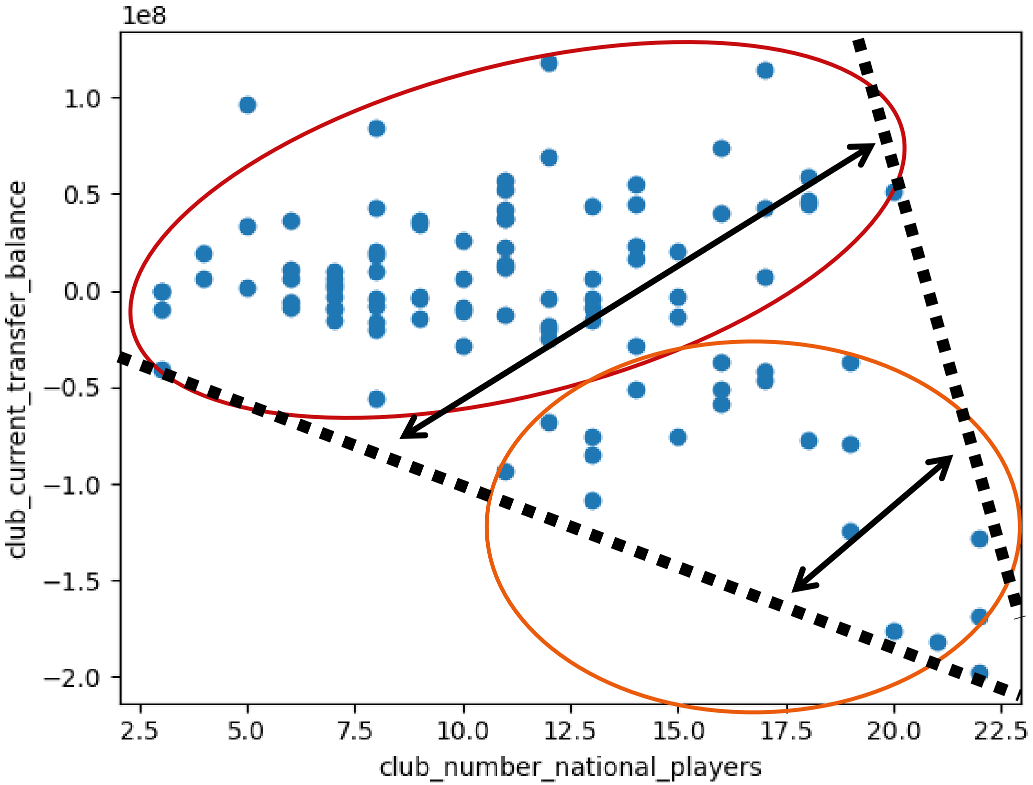
Graphical representation of data that uses a system of color coding to represent different values.

- Values can be **boolean** or **numeric**.
- **cbar** plots a colormap next to the graph.

# Correlation

*In reference of statistics slides by Yibi Huang (University of Chicago)*

How would you interpret this scatter plot? Do you see a tendency or groups between the two variables?



*r* = -0.38
(negative weak association)

Correlation *r* is a **numerical measure** ranging between [-1 (strong), 0(nothing), 1 (strong)].

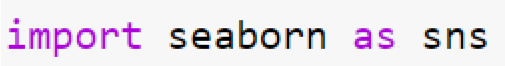
It describes the **direction** and **strength** of the **linear relationship** between two numerical variables.

Various methods exist, but most are based on the sum of standard deviations and mean between X and Y.

- Weak Association
  large spread of Y when X is known.
- Strong Association
  small spread of Y when X is known.

Important notes:

- Correlation is very sensitive to outliers!
- Causation indicates association – not causation!

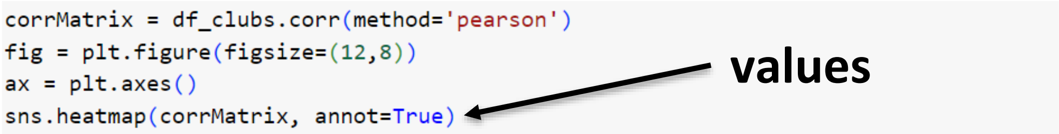


```python
import seaborn as sns
```

# Correlation Heatmap

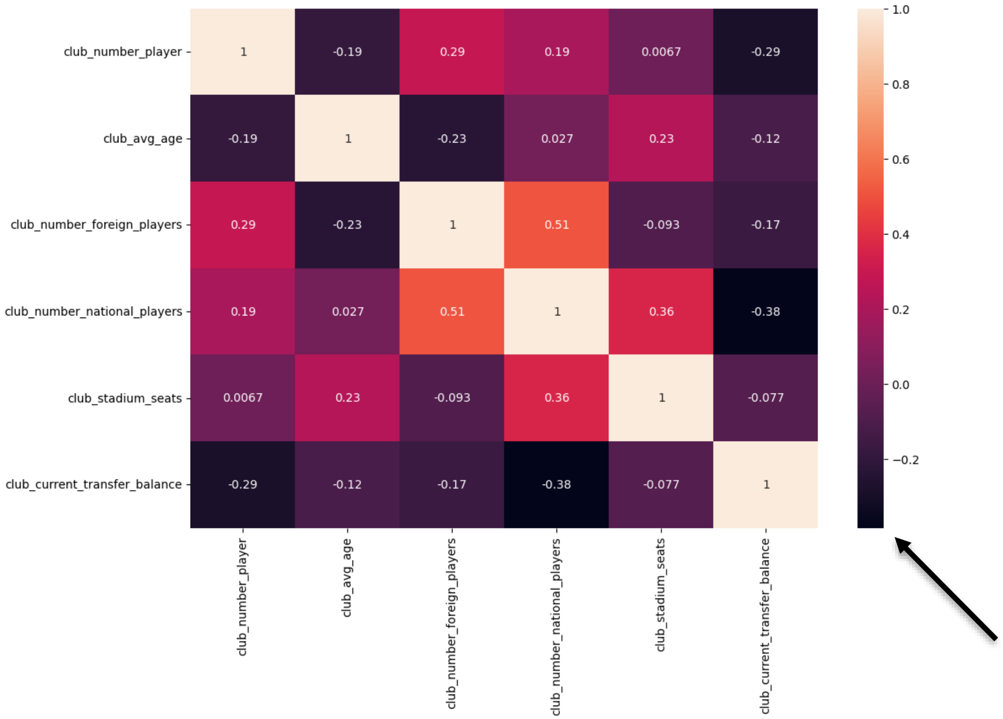
*https://pandas.pydata.org/docs/reference/api/pandas.DataFrame.corr.html*

*https://seaborn.pydata.org/generated/seaborn.heatmap.html*



```python
corrMatrix = df_clubs.corr(method='pearson')
fig = plt.figure(figsize=(12,8))
ax = plt.axes()
sns.heatmap(corrMatrix, annot=True)
```

**values**



**cbar**

One famous correlation factor implemented into Pandas DataFrame is the **Pearson coefficient**.

Linear ratio between the covariance of two variables and the product of their standard deviations.

$$cov_{x,y} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{N - 1}$$

- **Bar** mean of elements
- **N** number of values

# Please take these considerations with a little grain of salt ☺

| Scenario | Data Preprocessing | Data Transformation | Data Visualization |
|---|---|---|---|
| Few attributes | Attribute Integration | Attribute Generalization | Detailed & Interactive |
| Few instances | Instance Integration | | Detailed & Interactive |
| Many attributes | Attribute Reduction | Normalization for Analysis<br>Attribute Summarization | Radar, Heatmaps, Matrix-Plots, XYZ-axis with hue and markers |
| Many instances | Sampling<br>Outlier Analysis<br>NaN Strategy | Grouping and Aggregation | Box-Plot, Scatter, Heatmaps, Histograms, Bubble |
| Numerical Data | Homogenous Formatting | Aggregation (Grouping with categorical data)<br>Normalization | Scatter, Line, Waterfall, Violin, Correlation(!) |
| Categorical Data | Scaling | Attribute Generalization<br>Aggregation (Counting) | Stacked Bar, Pie, Donut, Sunburst, Parallel Sets |

# Takeaways

- **Matplotlib** is the cross-platform **basis** for **most library extensions** in other statistical softwares.
- If your **data set** is **large**, make use of **heatmaps** and **pair plots** (matrix) to preprocess, transform, and find interesting patterns.
- Do not underestimate **data transformation** steps (use them), as they change your dataset and **help you deliver** a **message**.
- Learn from **examples**, ask for early **feedback** from your peers, **explore** other (interactive) **libraries**.

# Outlook

- In the next weeks, we will see how things work in R.

- After Christmas holidays, we will have our project poster day and recap what we have learned.
- Doodle (in January) to schedule the oral exams in the week 5.-10. February 2024.

# See you again next week!

Questions?