LECTURE 8

Visualization I

Visualizing distributions and KDEs

Data Science, Fall 2023 @ Knowledge Stream

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Goals for this Lecture

Lecture 9

Reviewing and concluding regex

Understand the theories behind effective visualizations and start to generate plots of our own

- The necessary "pre-thinking" before creating a plot
- Python libraries for visualizing data

Agenda

Lecture 9

- Regex
  - Regex review and regex functions
- Visualization
  - Goals of visualization
  - Visualizing distributions
  - Kernel density estimation

Regex Review and regex Functions

Lecture 9

- **Regex**
  - **Regex review and regex functions**
- Visualization
  - Goals of visualization
  - Visualizing distributions
  - Kernel density estimation

Review: regex

Operation	Order	Example	Matches	Doesn't match
concatenation (consecutive chars)	3	`AABAAB`	`AABAAB`	every other string
or, |	4	`AA|BAAB`	`AA` `BAAB`	every other string
***** (zero or more)	2	`AB*A`	`AA` `ABBBBBBA`	`AB` `ABABA`
group (parenthesis)	1	`A(A|B)AAB`	`AAAAB` `ABAAB`	every other string
		`(AB)*A`	`A` `ABABABABA`	`AA` `ABBA`

The regex order of operations. Grouping is evaluated first.

Review: regex

Operation	Example	Matches	Doesn't match
any character (except newline)	`.U.U.U.`	CUMULUS JUGULUM	SUCCUBUS TUMULTUOUS
character class	`[A-Za-z][a-z]*`	word Capitalized	camelCase 4illegal
repeated exactly a times: {a}	`j[aeiou]{3}hn`	jaoehn jooohn	jhn jaeiouhn
repeated from a to b times: {a,b}	`j[ou]{1,2}hn`	john juohn	jhn jooohn
at least one	`jo+hn`	john jooooooohn	jhn jjohn

Review: regex

Operation	Example	Matches	Doesn't match
beginning of line	`^ark`	`ark two` `ark o ark`	`dark`
end of line	`ark$`	`dark` `ark o ark`	`ark two`
escape character	`cow\.com`	`cow.com`	`cowscom`

Extraction

`re.findall(pattern, text)`

Return a list of all matches to `pattern`.

```
text = "My social security number is 123-45-6789 bro, or actually maybe it's 321-45-6789.";
```

```
pattern = r"[0-9]{3}-[0-9]{2}-[0-9]{4}"
re.findall(pattern, text)
```

```
['123-45-6789', '321-45-6789']
```

A **match** is a substring that matches the provided regex.

Extraction

`re.findall(pattern, text)`

Return a list of all matches to `pattern`.

```
text = "My social security number is 123-45-6789 bro, or actually maybe it's 321-45-6789.";
pattern = r"[0-9]{3}-[0-9]{2}-[0-9]{4}"
re.findall(pattern, text)
```

```
['123-45-6789', '321-45-6789']
```

A **match** is a substring that matches the provided regex.

`ser.str.findall(pattern)`

Returns a Series of lists

```
df["SSN"].str.findall(pattern)
```

	SSN
0	987-65-4321
1	forty
2	123-45-6789 bro or 321-45-6789
3	999-99-9999

```
0                  [987-65-4321]
1                             []
2  [123-45-6789, 321-45-6789]
3                  [999-99-9999]
Name: SSN, dtype: object
```

Extraction with Capture Groups

`ser.str.extract(pattern)`

Returns a DataFrame of each capture group's **first** match in the string

```
pattern_cg = r"([0-9]{3})-([0-9]{2})-([0-9]{4})"
df["SSN"].str.extract(pattern_cg)
```

	SSN
0	987-65-4321
1	forty
2	123-45-6789 bro or 321-45-6789
3	999-99-9999

	0	1	2
0	987	65	4321
1	NaN	NaN	NaN
2	123	45	6789
3	999	99	9999

Extraction with Capture Groups

`ser.str.extract(pattern)`

Returns a DataFrame of each capture group's **first** match in the string

```
pattern_cg = r"([0-9]{3})-([0-9]{2})-([0-9]{4})"
df["SSN"].str.extract(pattern_cg)
```

	SSN
0	987-65-4321
1	forty
2	123-45-6789 bro or 321-45-6789
3	999-99-9999

	0	1	2
0	987	65	4321
1	NaN	NaN	NaN
2	123	45	6789
3	999	99	9999

`ser.str.extractall(pattern)`

Returns a multi-indexed DataFrame of **all** matches for each capture group

```
df["SSN"].str.extractall(pattern_cg)
```

	SSN
0	987-65-4321
1	forty
2	123-45-6789 bro or 321-45-6789
3	999-99-9999

	match	0	1	2
0	0	987	65	4321
2	0	123	45	6789
	1	321	45	6789
3	0	999	99	9999

Substitution

`re.sub(pattern, repl, text)`

Returns text with all instances of **`pattern`** replaced by **`repl`**.

```
text = '<div><tdvalign="top">Moo</td></div>'
pattern = r"<[^>]+>"
re.sub(pattern, '', text) # returns Moo
```


`Moo`

How it works:

- **`pattern`** matches HTML tags
- Then, sub/replace HTML tags with **`repl=''`** (i.e., empty string)

Substitution

`re.sub(pattern, repl, text)`

Returns text with all instances of `pattern` replaced by `repl`.

```
text = '<div><td
valign="top">Moo</td></div>'
pattern = r"<[^>]+>"
re.sub(pattern, '', text) # returns Moo
```

```
Moo
```

How it works:

- **`pattern`** matches HTML tags
- Then, sub/replace HTML tags with **`repl=''`** (i.e., empty string)

`ser.str.replace(pattern, repl, regex=True )`

Returns Series with all instances of the `pattern` in Series `ser` replaced by `repl`.

```
df["Html"].str.replace(pattern, '')
```

	Html
0	<td valign="top">Moo</td>
1	Link
2	Bold text

```
0           Moo
1          Link
2     Bold text
Name: Html, dtype: object
```

String Function Summary

Base Python	re	pandas str
`s.lower()` `s.upper()`		`ser.str.lower()` `ser.str.upper()`
`s.replace(…)`	`re.sub(…)`	`ser.str.replace(…)`
`s.split(…)`	`re.split(…)`	`ser.str.split(…)`
`s[1:4]`		`ser.str[1:4]`

	`re.findall(…)`	`ser.str.findall(…)`
		`ser.str.extractall(…)`
		`ser.str.extract(…)`

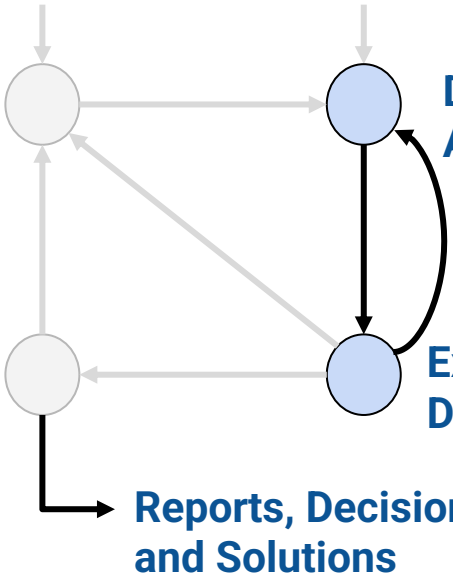
`'ab' in s`	`re.search(…)`	`ser.str.contains(…)`
`len(s)`		`ser.str.len()`
`s.strip()`		`ser.str.strip()`

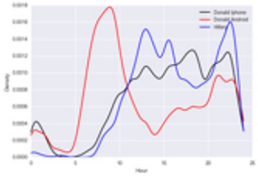
Goals of Visualization

Lecture 8, Spring 2024

- Regex
  - Regex review and regex functions
- **Visualization**
  - **Goals of visualization**
  - Visualizing distributions
  - Kernel density estimation

Where are we?





(today)

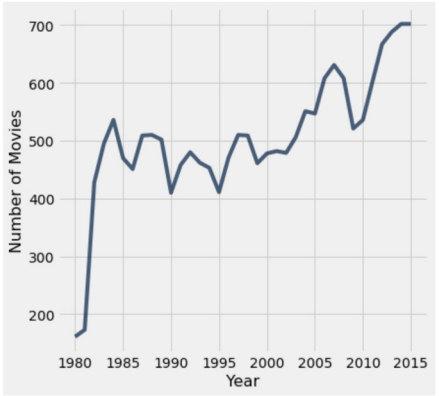
Data Wrangling Intro to EDA	→ Working with Text Data Regular Expressions	Plots and variables Seaborn	Viz principles KDE/Transformations

(Part I: Processing Data) (Part II: Visualizing and Reporting Data)

Visualizations in BS (and in Data Science, so far)

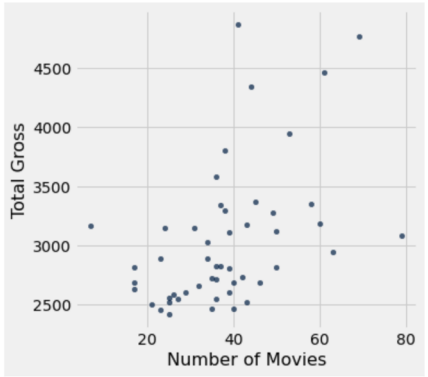
You worked with many types of visualizations throughout.

```
# The call is
# t.plot(x_label, y_label)

movies.plot('Year', 'Number of Movies')
```

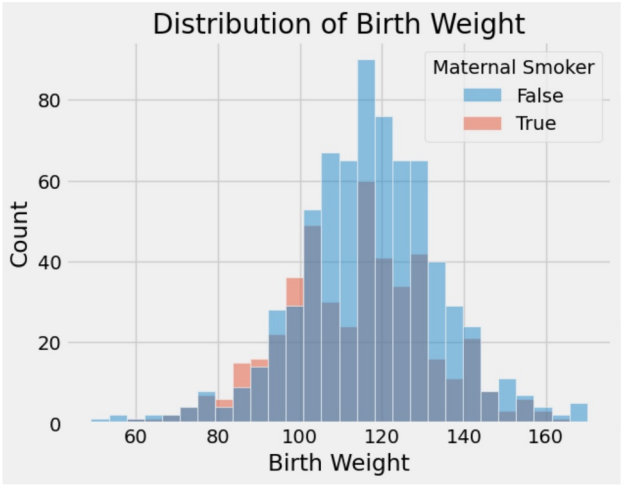


Line plot

```
# The call is
# t.scatter(x_label, y_label)

actors.scatter('Number of Movies', 'Total Gross')
```



Scatter plot



Histogram

What did these achieve?

- Provide a high-level overview of a complex dataset.
- Communicated trends to viewers.

Goals of Data Visualization

Goal 1: To **help your own understanding** of your data/results.

- Key part of exploratory data analysis.
- Summarize trends visually before in-depth analysis.
- Lightweight, iterative and flexible.

Goal 2: To **communicate results/conclusions to others**.

- Highly editorial and selective.
- Be thoughtful and careful!
- Fine-tuned to achieve a communications goal.
- Considerations: clarity, accessibility, and necessary context.

What do these goals imply?

Visualizations aren't a matter of making "pretty" pictures.

We need to do a lot of thinking about what stylistic choices communicate ideas most effectively.

Goals of Data Visualization

What do these goals imply?

Visualizations aren't a matter of making "pretty" pictures.

We need to do a lot of thinking about what stylistic choices communicate ideas most effectively.

First half of visualization topics in Data Science: Choosing the "right" plot for

- Introducing plots for different variable types
- Generating these plots through code

Second half of visualization topics in Data Science: Stylizing plots appropriately

- Smoothing and transforming visual data
- Providing context through labeling and color

Visualizing Distributions

Lecture 9

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- **Visualization**
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  - Kernel density estimation

Distributions

A distribution describes…

- The set of values that a variable can possibly take.
- The frequency with which each value occurs for a **single** variable

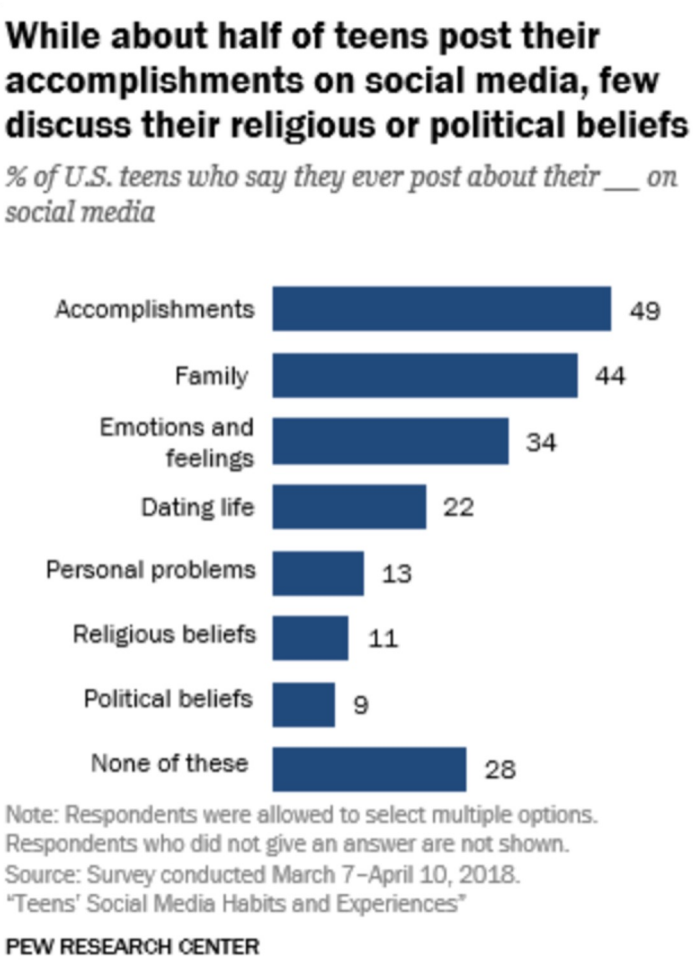
Example: Distribution of students across discussion sections in Data Science.

- The list of discussion sections (09-12 pm, 02-05 pm, etc.)
- The number of students enrolled in each section

In other words: How is the variable distributed across all of its possible values?

This means that percentages **should sum to 100%** (if using proportions) and counts should **sum to the total number of datapoints** (if using raw counts).

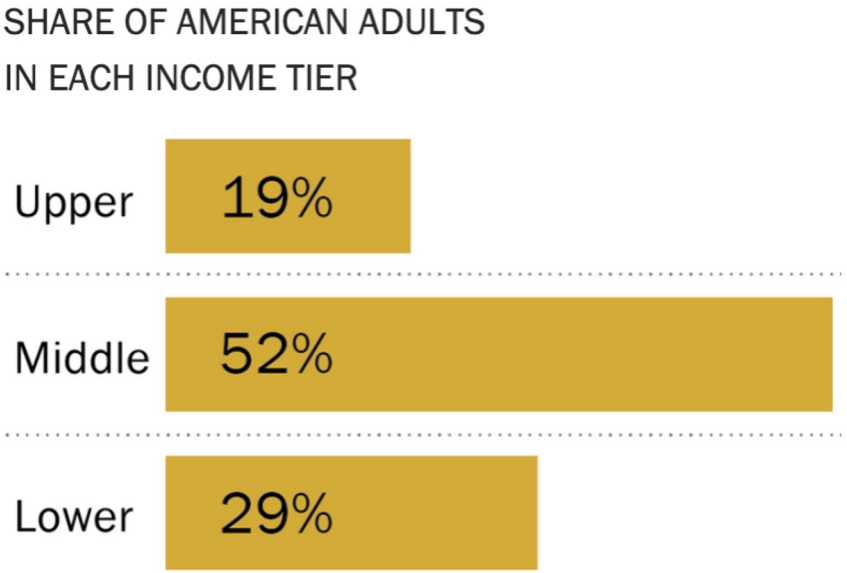
Let's see some examples.



Does this chart show a distribution?

No.

- The chart does show percents of individuals in different categories!
- But, this is not a distribution because individuals can be in more than one category (see the fine print).



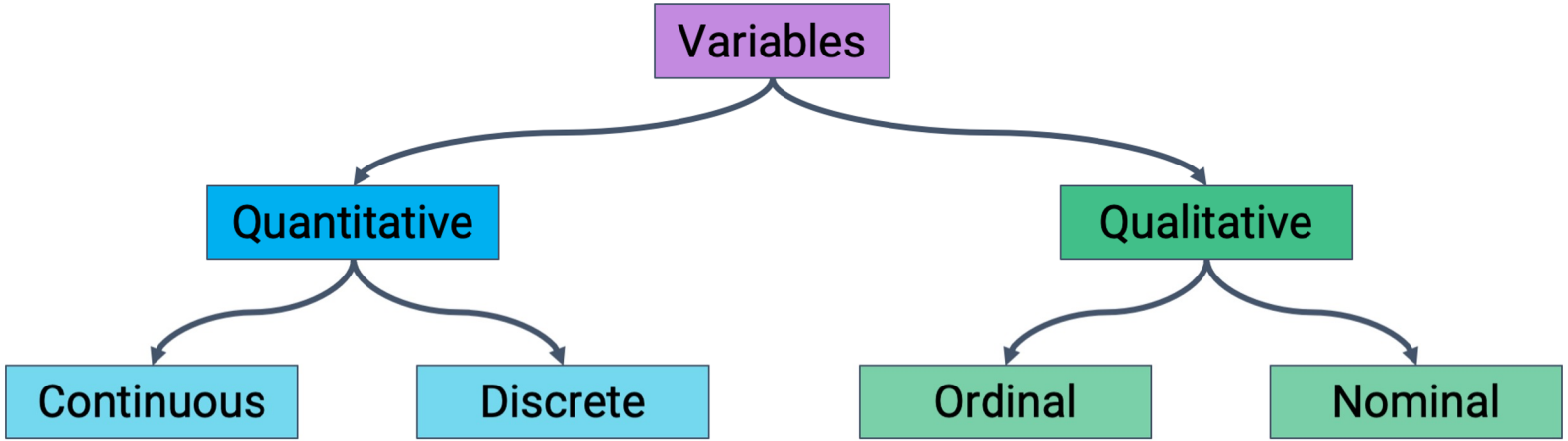
Does this chart show a distribution?

Yes!

- This chart shows the distribution of the qualitative ordinal variable "income tier."
- Each individual is in exactly one category.
- The values we see are the proportions of individuals in that category.
- Everyone is represented, as the total percentage is 100%.

Variable Types Should Inform Plot Choice

Different plots are more or less suited for displaying particular types of variables.

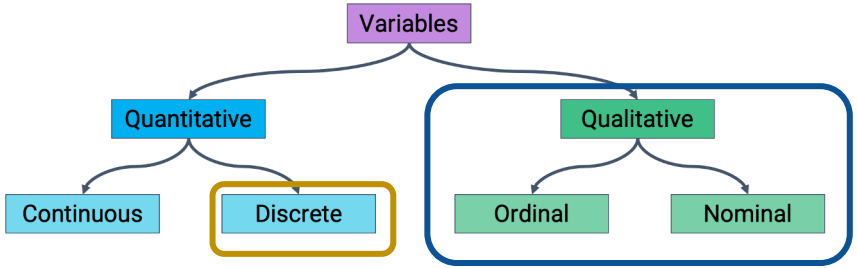


First step of visualization: Identify the variables being visualized. Then, select a plot type accordingly.

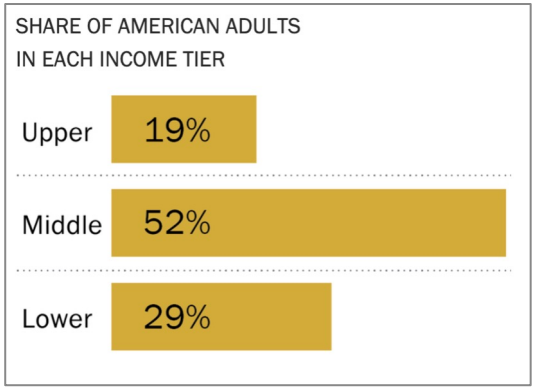
Bar Plots: Distributions of Qualitative Variables

Bar plots are the most common way of displaying the **distribution** of a **qualitative** variable.

*Sometimes quantitative discrete data too, if there are few unique values.



- For example, the proportion of adults in the upper, middle, and lower classes.
- Lengths encode values.
  - *Widths* encode *nothing*!
  - *Color* could indicate a sub-category (but not necessarily).



World Bank Dataset

We will be using the `wb` dataset about world countries for most of our work today.

	Continent	Country	Primary completion rate: Male: % of relevant age group: 2015	Primary completion rate: Female: % of relevant age group: 2015	Lower secondary completion rate: Male: % of relevant age group: 2015	Lower secondary completion rate: Female: % of relevant age group: 2015	Youth literacy rate: Male: % of ages 15-24: 2005-14	Youth literacy rate: Female: % of ages 15-24: 2005-14	Adult literacy rate: Male: % ages 15 and older: 2005-14	Adult literacy rate: Female: % ages 15 and older: 2005-14
0	Africa	Algeria	106.0	105.0	68.0	85.0	96.0	92.0	83.0	68.0
1	Africa	Angola	NaN	NaN	NaN	NaN	79.0	67.0	82.0	60.0
2	Africa	Benin	83.0	73.0	50.0	37.0	55.0	31.0	41.0	18.0
3	Africa	Botswana	98.0	101.0	86.0	87.0	96.0	99.0	87.0	89.0
5	Africa	Burundi	58.0	66.0	35.0	30.0	90.0	88.0	89.0	85.0

Generating Bar Plots: Matplotlib

We will mainly use two libraries for generating plots: Matplotlib and Seaborn.

Most Matplotlib plotting functions follow the same structure: We pass in a sequence (`list`, `array`, or `Series`) of values to be plotted on the x-axis, and a second sequence of values to be plotted on the y-axis.

```
import matplotlib.pyplot as plt
plt.plotting_function(x_values, y_values)
```

Matplotlib is typically given the alias `plt`

To add labels and a title:

```
plt.xlabel("x axis label")
plt.ylabel("y axis label")
plt.title("Title of the plot");
```

Generating Bar Plots: Matplotlib

To create a bar plot in Matplotlib: `plt.bar( )`

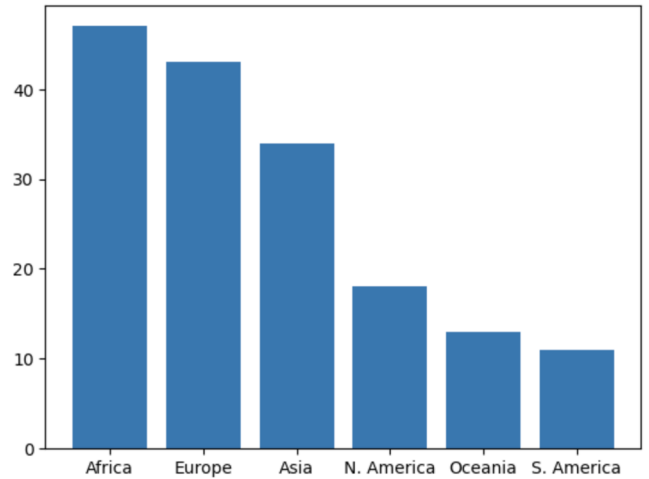
```
continents = wb["Continent"].value_counts()
```

```
Africa          47
Europe          43
Asia            34
N. America      18
Oceania         13
S. America      11
Name: Continent, dtype: int64
```

```
plt.bar(continents.index, continents.values);
```

x values

y values

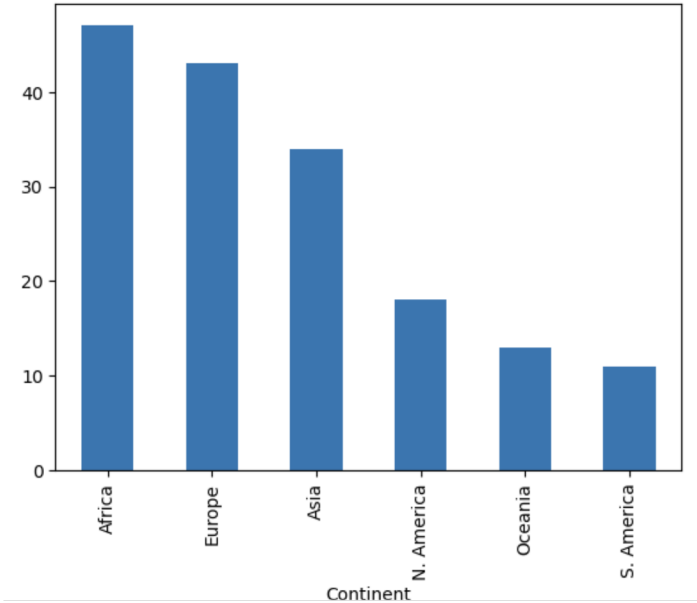


Generating Bar Plots: pandas Native Plotting

To create a bar plot in native `pandas`: `.plot(kind='bar')`

```
Africa          47
Europe          43
Asia            34
N. America      18
Oceania         13
S. America      11
Name: Continent, dtype: int64
```

```
wb["Continent"].value_counts().plot(kind='bar')
```



Generating Bar Plots: Seaborn

Seaborn plotting functions use a different structure: Pass in an entire `DataFrame`, then specify what column(s) to plot.

Seaborn is typically given the alias `sns`

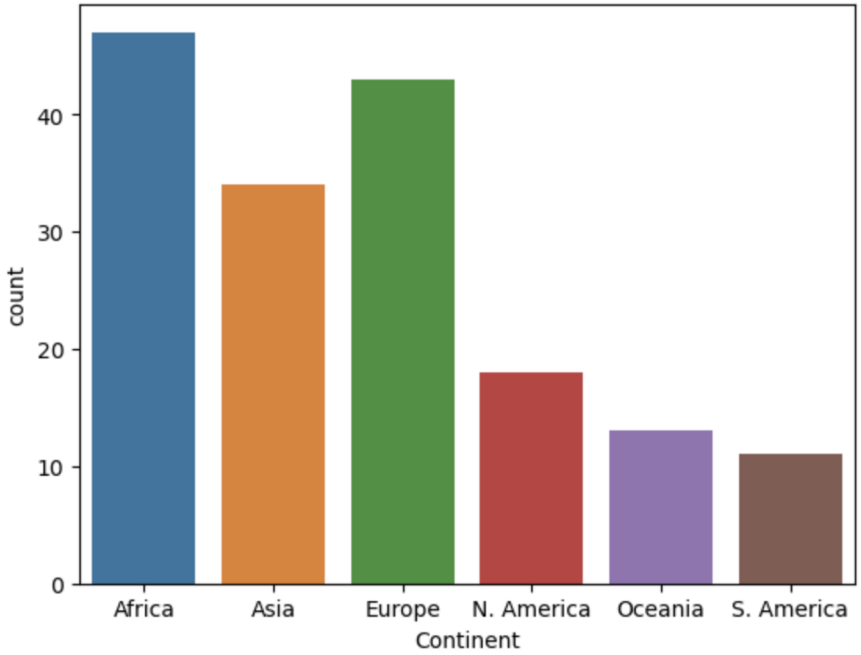
```
import seaborn as sns
sns.plotting_function(data=df, x="x_col", y="y_col")
```

To add labels and a title, use the same syntax as before:

```
plt.xlabel("x axis label")
plt.ylabel("y axis label")
plt.title("Title of the plot");
```

Generating Bar Plots: Seaborn

To create a bar plot in Seaborn: `sns.countplot( )`



`countplot` operates at a higher level of abstraction!

You give it the entire `DataFrame` and it does the counting for you.

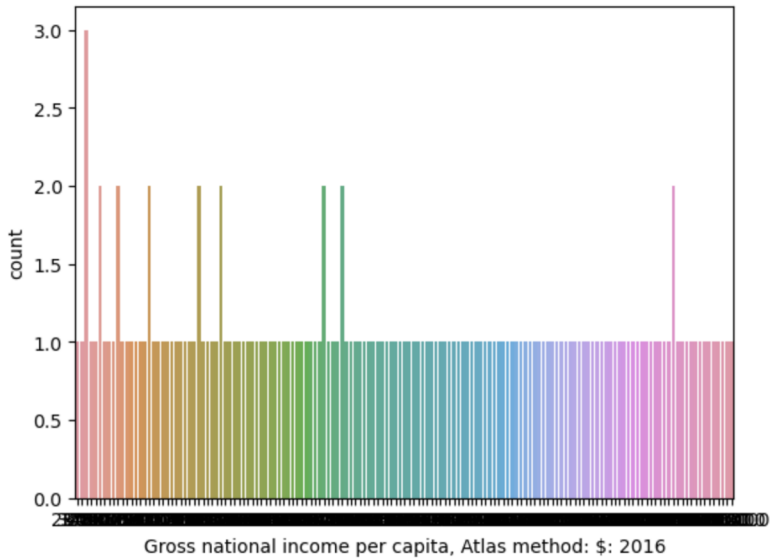
```
import seaborn as sns

sns.countplot(data=wb, x="Continent");
```

Distributions of Quantitative Variables

Earlier, we said that bar plots are appropriate for distributions of qualitative variables.

Why only qualitative? Why not quantitative as well?

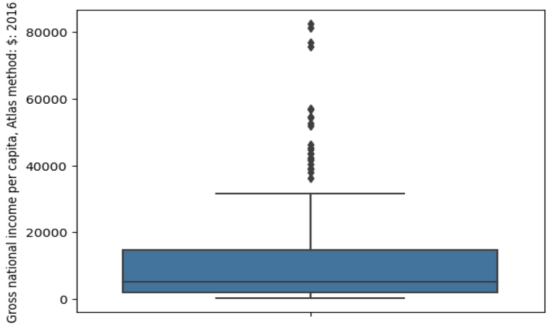
- For example: The distribution of gross national income per capita.



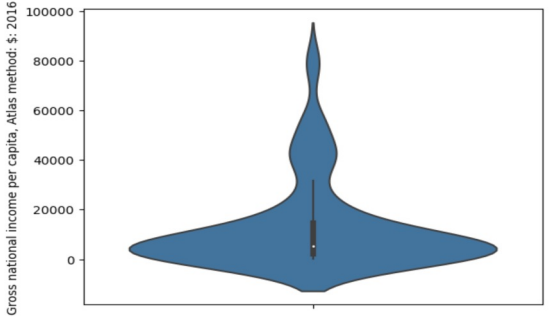
A bar plot will create a separate bar for each unique value. This leads to too many bars for continuous data!

Distributions of Quantitative Variables

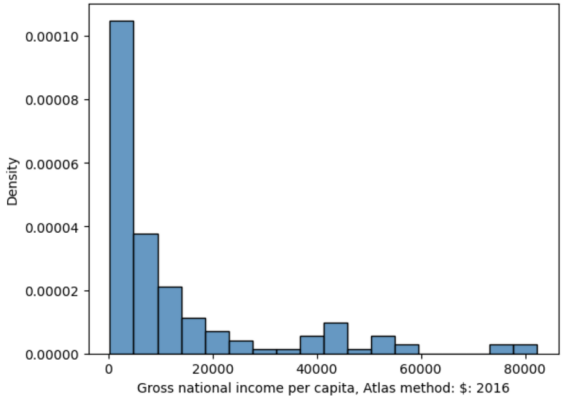
To visualize the distribution of a continuous quantitative variable:



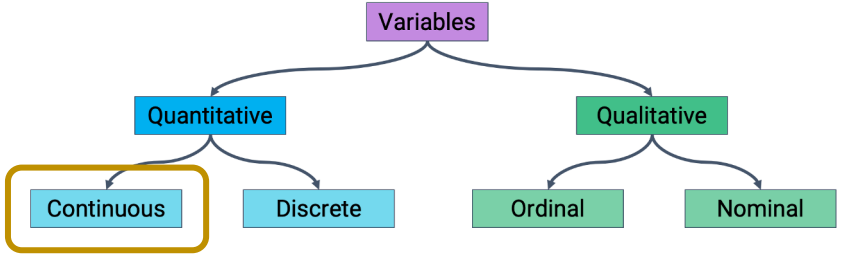
Box plot



Violin plot



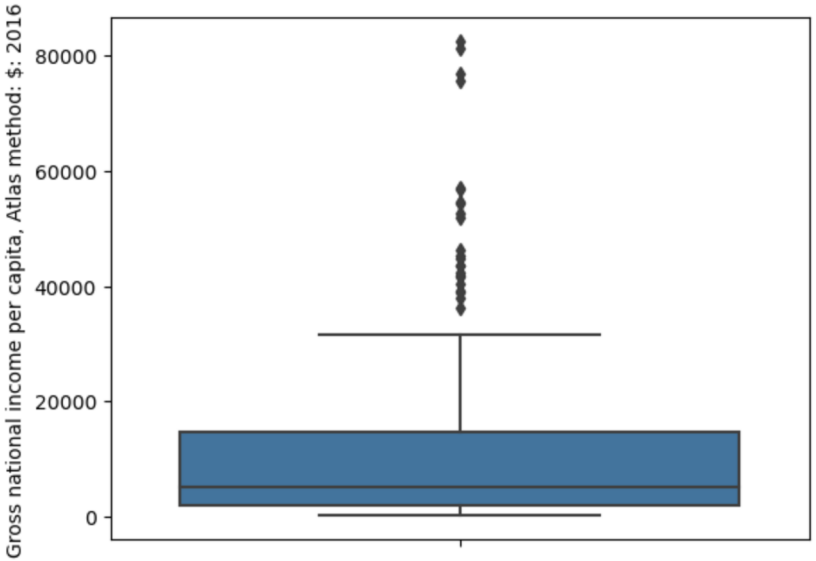
Histogram

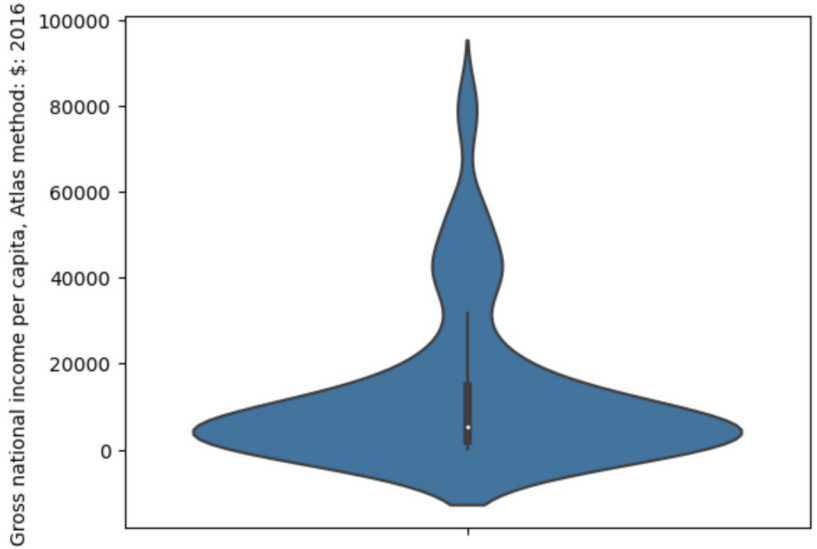


Box plots and Violin Plots

Box plots and violin plots display distributions using information about **quartiles**.

- In a box plot, the width of the box encodes no meaning.
- In a violin plot, the width of the "violin" indicates the density of datapoints at each value.

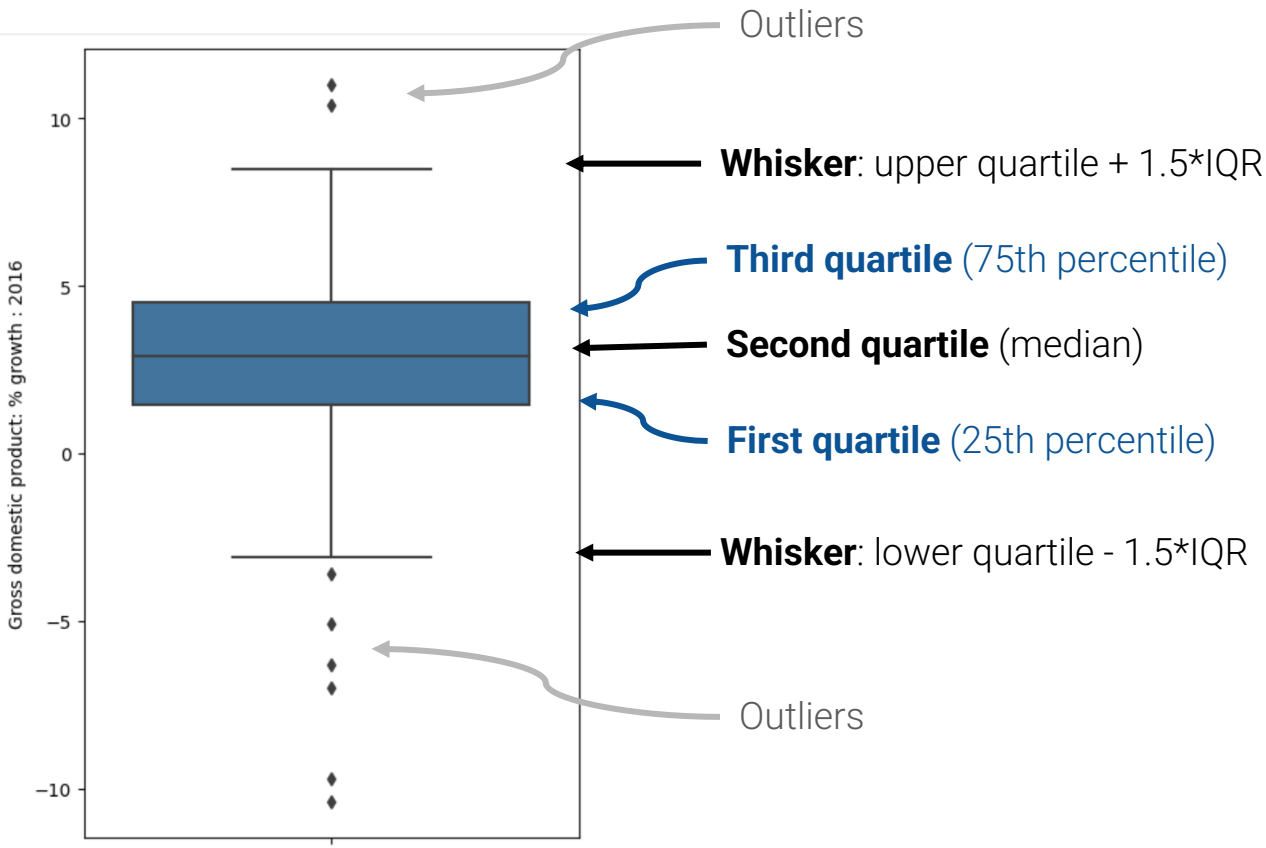





```
sns.boxplot(data=df, y="y_variable");
```

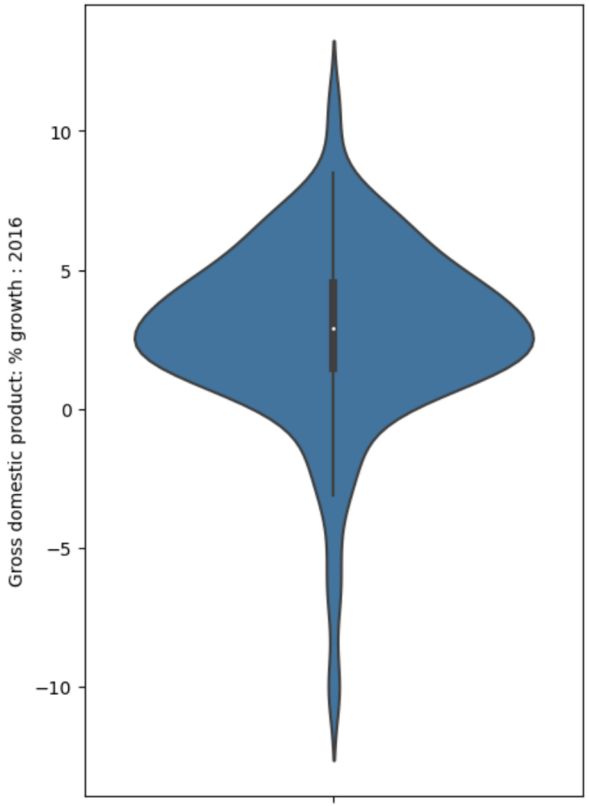
```
sns.violinplot(data=df, y ="y_variable");
```

Box Plots




```
sns.boxplot(data=wb, y="Gross domestic product: % growth : 2016")
```

Violin Plots



Violin plots are similar to box plots, but also show smoothed density curves.

- The "width" of our "box" now has meaning!
- The three quartiles and "whiskers" are still present – look closely.

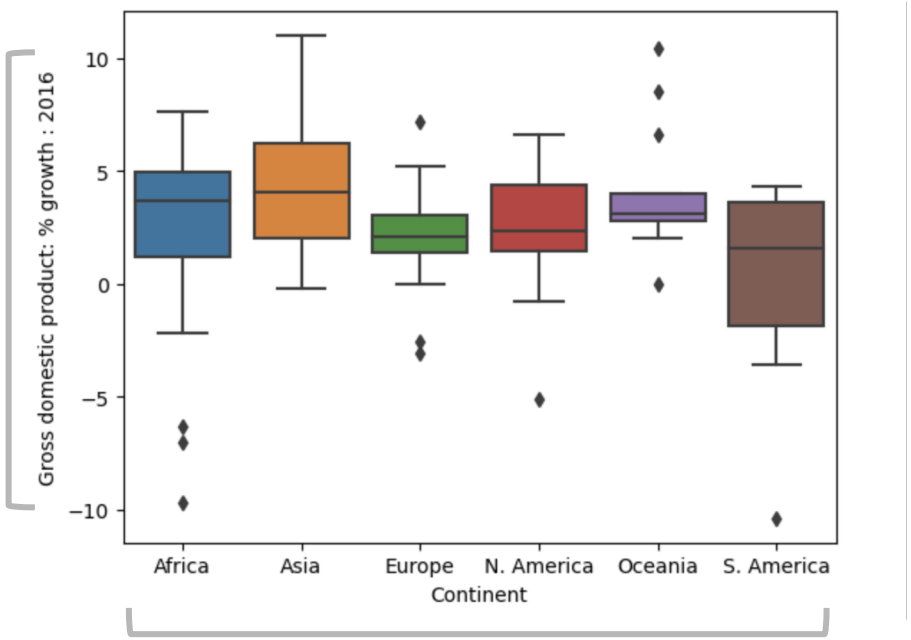
```
sns.violinplot(data=wb, y="Gross domestic product: % growth : 2016")
```

Side-by-side Box and Violin Plots

What if we wanted to incorporate a *qualitative* variable as well? For example, compare the distribution of a quantitative continuous variable *across* different qualitative categories.

```
sns.boxplot(data=wb, x="Continent", y="Gross domestic product: % growth : 2016");
```

GDP growth:
quantitative continuous



Continent: qualitative nominal

Quartiles

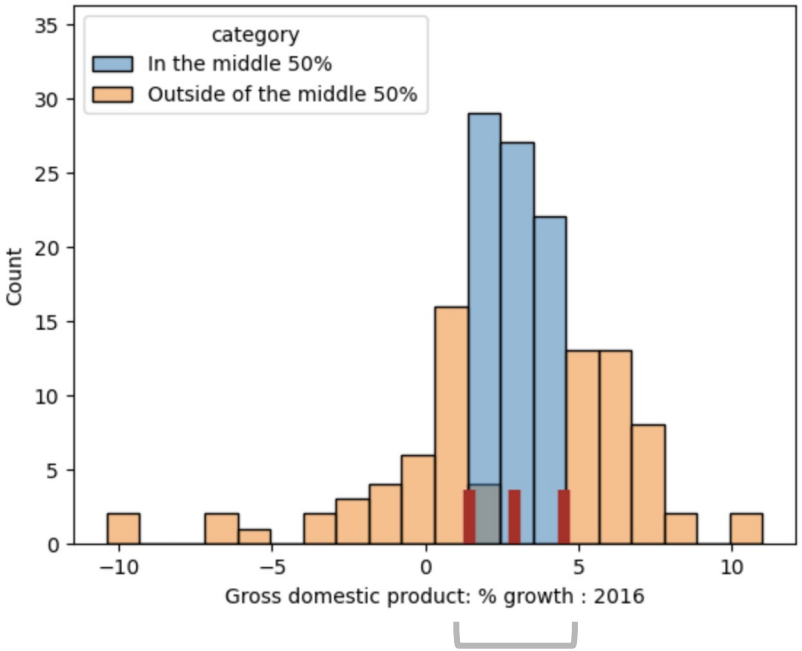
For a quantitative variable:

- First or lower quartile: 25th percentile.
- Second quartile: 50th percentile (median).
- Third or upper quartile: 75th percentile.

The interval [first quartile, third quartile] contains the "middle 50%" of the data.

Interquartile range (IQR) measures spread.

- IQR = third quartile – first quartile.



The length of this region is the IQR

LECTURE 8

Visualization

Start Working on Notebooks