



Transforming Excel Analysis into pandas

Bruno Gonçalves

www.data4sci.com/newsletter

<https://github.com/DataForScience/Excel>

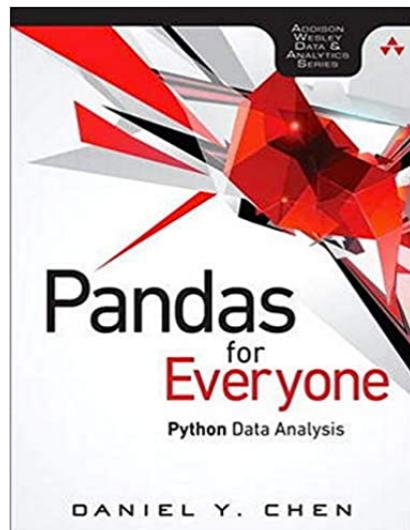


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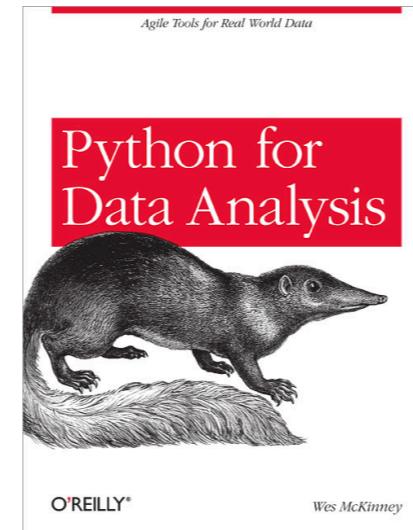
1. Excel Pitfalls
2. Pandas DataFrames
3. Simple Data Modeling
4. Manipulating Excel Spreadsheets
5. Advanced Spreadsheet Functionality

References

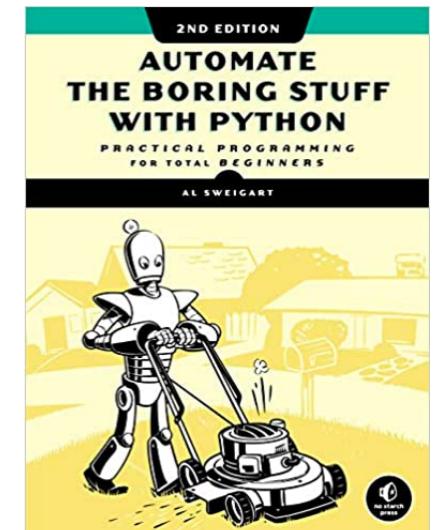
<https://github.com/DataForScience/Excel>



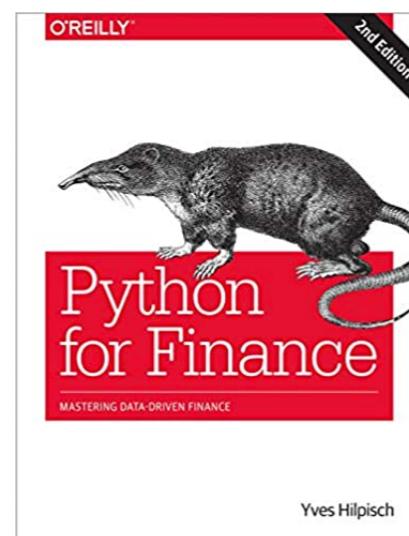
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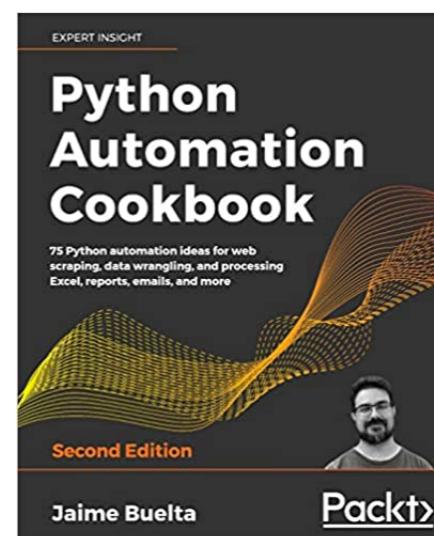
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<https://amzn.to/3gNQzPC>



Lesson I: Excel Pitfalls



Microsoft Excel

- Developed by Microsoft in 1983.
- Part of the Microsoft Office suite of software
- Currently available for Windows, macOS, Android and iOS.
- Allows for calculation, plotting, pivot tables, and a macro programming language called Visual Basic for Applications.
- Essentially a visual WYSIWYG tool
- Cell based computation



Microsoft Excel

<https://support.microsoft.com/en-us/office/excel-specifications-and-limits-1672b34d-7043-467e-8e27-269d656771c3>

**Total number of rows and columns
on a worksheet**

1,048,576 rows by 16,384 columns

Column width

255 characters

**Total number of characters that a
cell can contain**

32,767 characters

**Noncontiguous cells that can be
selected**

2,147,483,648 cells

Buggy Functionality

- Even for things as simple as linear regression

LINEST function

Excel for the web, Excel 2019, Excel 2016, Excel 2019 for Mac, Excel 2013, [More...](#)

This article describes the formula syntax and usage of the **LINEST** function in Microsoft Excel. Find links to more information about charting and performing a regression analysis in the **See Also** section.

Description

The **LINEST** function calculates the statistics for a line by using the "least squares" method to calculate a straight line that best fits your data, and then returns an array that describes the line. You can also combine **LINEST** with other functions to calculate the statistics for other types of models that are linear in the unknown parameters, including polynomial, logarithmic, exponential, and power series. Because this function returns an array of values, it must be entered as an array formula. Instructions follow the examples in this article.

The equation for the line is:

$$y = mx + b$$

-or-

$$y = m_1x_1 + m_2x_2 + \dots + b$$

if there are multiple ranges of x-values, where the dependent y-values are a function of the independent x-values. The m-values are coefficients corresponding to each x-value, and b is a constant value. Note that y, x, and m can be vectors. The array that the **LINEST** function returns is {mn,mn-1,...,m1,b}. **LINEST** can also return additional regression statistics.

Buggy Functionality

<https://support.microsoft.com/en-us/topic/incorrect-output-is-returned-when-you-use-the-linear-regression-linest-function-in-excel-626211cb-8ee7-aaac-aa1a-1e51f5a54e17>

- Even for things as simple as linear regression

LINEST function

Excel for the web, Excel 2019, Excel 2016, Excel 2019 for Mac, Excel 2013, [More...](#)

This article desc
more information

Descripti

The LINEST function returns the statistics for a straight line that you can use in your worksheet. You can use the LINEST function with other functions and formulas or use it on its own. The LINEST function returns the same results as the Regression tool in the Analysis ToolPak. You can find more information about the Regression tool in the Analysis ToolPak in this article.

The equation for

$y = mx + b$

-or-

$y = m_1x_1 + m_2x_2 + \dots + b$

Incorrect output is returned when you use the Linear Regression (LINEST) function in Excel

Symptoms

When you use the LINEST worksheet function in a worksheet in Microsoft Excel, the statistical output may return incorrect values. The Regression tool in the Analysis ToolPak may also return incorrect values.

If there are multiple ranges of x-values, where the dependent y-values are a function of the independent x-values. The m-values are coefficients corresponding to each x-value, and b is a constant value. Note that y, x, and m can be vectors. The array that the LINEST function returns is {mn,mn-1,...,m1,b}. LINEST can also return additional regression statistics.

Cell based computations

- Cells show only the **current value**.

The screenshot shows an Excel spreadsheet titled "Mortgage Calculator". The spreadsheet includes a "MORTGAGE AMORTIZATION SCHEDULE" table with columns for PMT NO, PAYMENT DATE, BEGINNING BALANCE, SCHEDULED PAYMENT, EXTRA PAYMENT, TOTAL PAYMENT, PRINCIPAL, INTEREST, ENDING BALANCE, and CUMULATIVE INTEREST. The table spans from row 16 to 29. Above the table, there is an "ENTER VALUES" section with input fields for Loan amount (\$200,000.00), Interest rate (5.00%), and other parameters like Loan term in years (30), Payments made per year (12), and Loan repayment start date (9/2/20). To the right of the table is a "LOAN SUMMARY" section with various financial metrics. The Excel ribbon at the top shows tabs for Home, Insert, Page Layout, Formulas, Data, Review, and View.

PMT NO	PAYMENT DATE	BEGINNING BALANCE	SCHEDULED PAYMENT	EXTRA PAYMENT	TOTAL PAYMENT	PRINCIPAL	INTEREST	ENDING BALANCE	CUMULATIVE INTEREST
1	9/2/20	\$200,000.00	\$1,073.64	\$100.00	\$1,173.64	\$340.31	\$833.33	\$199,659.69	\$833.33
2	10/2/20	\$199,659.69	\$1,073.64	\$100.00	\$1,173.64	\$341.73	\$831.92	\$199,317.96	\$1,665.25
3	11/2/20	\$199,317.96	\$1,073.64	\$100.00	\$1,173.64	\$343.15	\$830.49	\$198,974.81	\$2,495.74
4	12/2/20	\$198,974.81	\$1,073.64	\$100.00	\$1,173.64	\$344.58	\$829.06	\$198,630.23	\$3,324.80
5	1/2/21	\$198,630.23	\$1,073.64	\$100.00	\$1,173.64	\$346.02	\$827.63	\$198,284.21	\$4,152.43
6	2/2/21	\$198,284.21	\$1,073.64	\$100.00	\$1,173.64	\$347.46	\$826.18	\$197,936.75	\$4,978.61
7	3/2/21	\$197,936.75	\$1,073.64	\$100.00	\$1,173.64	\$348.91	\$824.74	\$197,587.85	\$5,803.35
8	4/2/21	\$197,587.85	\$1,073.64	\$100.00	\$1,173.64	\$350.36	\$823.28	\$197,237.49	\$6,626.63
9	5/2/21	\$197,237.49	\$1,073.64	\$100.00	\$1,173.64	\$351.82	\$821.82	\$196,885.66	\$7,448.45
10	6/2/21	\$196,885.66	\$1,073.64	\$100.00	\$1,173.64	\$353.29	\$820.36	\$196,532.38	\$8,268.81
11	7/2/21	\$196,532.38	\$1,073.64	\$100.00	\$1,173.64	\$354.76	\$818.88	\$196,177.62	\$9,087.70
12	8/2/21	\$196,177.62	\$1,073.64	\$100.00	\$1,173.64	\$356.24	\$817.41	\$195,821.38	\$9,905.10
13	9/2/21	\$195,821.38	\$1,073.64	\$100.00	\$1,173.64	\$357.72	\$815.92	\$195,463.66	\$10,721.03

Cell based computations

- Cells show only the **current value**.
- Underlying logic is **not clear**

G22 =IF([@PMT NO]<>"",IF([@SCHEDULED PAYMENT])+[@EXTRA PAYMENT]<=[@BEGINNING BALANCE],[@SCHEDULED PAYMENT]+[@EXTRA PAYMENT],[@BEGINNING BALANCE]),"")

- **Logic** bugs are hard or impossible to spot

The screenshot shows an Excel spreadsheet titled "Mortgage Calculator". The spreadsheet includes an "ENTER VALUES" section with input fields for Loan amount (\$200,000.00), Interest rate (5.00%), Loan term in years (30), Payments made per year (12), Loan repayment start date (9/2/20), and Optional extra payments (\$100.00). It also includes a "LOAN SUMMARY" section with results like Scheduled payment (\$1,073.64), Actual number of payments (360), and Total interest (\$149,442.54). The main part of the spreadsheet is a "MORTGAGE AMORTIZATION SCHEDULE" table with 29 rows. The columns are labeled: PMT NO, PAYMENT DATE, BEGINNING BALANCE, SCHEDULED PAYMENT, EXTRA PAYMENT, TOTAL PAYMENT, PRINCIPAL, INTEREST, ENDING BALANCE, and CUMULATIVE INTEREST. The table tracks the loan balance over time, showing how each payment is split between principal and interest.

	PMT NO	PAYMENT DATE	BEGINNING BALANCE	SCHEDULED PAYMENT	EXTRA PAYMENT	TOTAL PAYMENT	PRINCIPAL	INTEREST	ENDING BALANCE	CUMULATIVE INTEREST
17	1	9/2/20	\$200,000.00	\$1,073.64	\$100.00	\$1,173.64	\$340.31	\$833.33	\$199,659.69	\$833.33
18	2	10/2/20	\$199,659.69	\$1,073.64	\$100.00	\$1,173.64	\$341.73	\$831.92	\$199,317.96	\$1,665.25
19	3	11/2/20	\$199,317.96	\$1,073.64	\$100.00	\$1,173.64	\$343.15	\$830.49	\$198,974.81	\$2,495.74
20	4	12/2/20	\$198,974.81	\$1,073.64	\$100.00	\$1,173.64	\$344.58	\$829.06	\$198,630.23	\$3,324.80
21	5	1/2/21	\$198,630.23	\$1,073.64	\$100.00	\$1,173.64	\$346.02	\$827.63	\$198,284.21	\$4,152.43
22	6	2/2/21	\$198,284.21	\$1,073.64	\$100.00	\$1,173.64	\$347.46	\$826.18	\$197,936.75	\$4,978.61
23	7	3/2/21	\$197,936.75	\$1,073.64	\$100.00	\$1,173.64	\$348.91	\$824.74	\$197,587.85	\$5,803.35
24	8	4/2/21	\$197,587.85	\$1,073.64	\$100.00	\$1,173.64	\$350.36	\$823.28	\$197,237.49	\$6,626.63
25	9	5/2/21	\$197,237.49	\$1,073.64	\$100.00	\$1,173.64	\$351.82	\$821.82	\$196,885.66	\$7,448.45
26	10	6/2/21	\$196,885.66	\$1,073.64	\$100.00	\$1,173.64	\$353.29	\$820.36	\$196,532.38	\$8,268.81
27	11	7/2/21	\$196,532.38	\$1,073.64	\$100.00	\$1,173.64	\$354.76	\$818.88	\$196,177.62	\$9,087.70
28	12	8/2/21	\$196,177.62	\$1,073.64	\$100.00	\$1,173.64	\$356.24	\$817.41	\$195,821.38	\$9,905.10
29	13	9/2/21	\$195,821.38	\$1,073.64	\$100.00	\$1,173.64	\$357.72	\$815.92	\$195,463.66	\$10,721.03

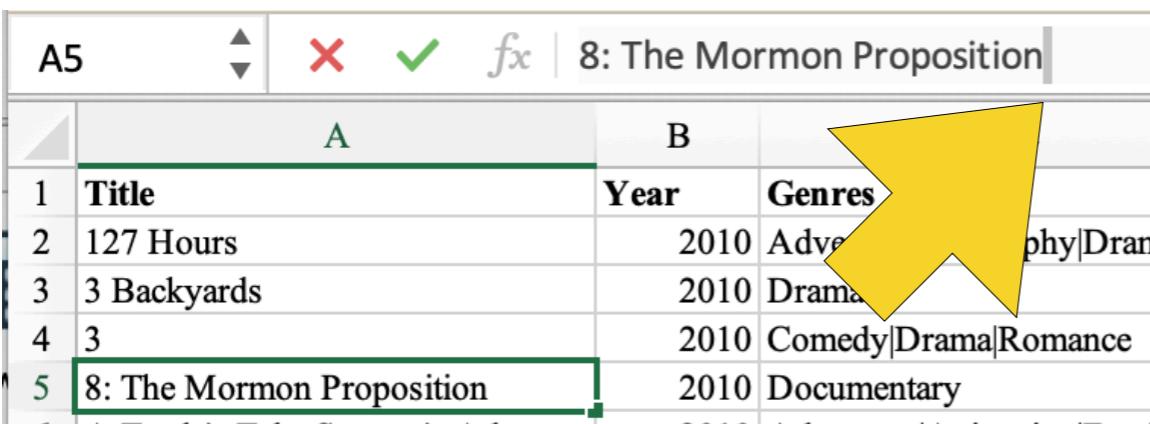
Cell based computations

- Cells show only the **current value**.
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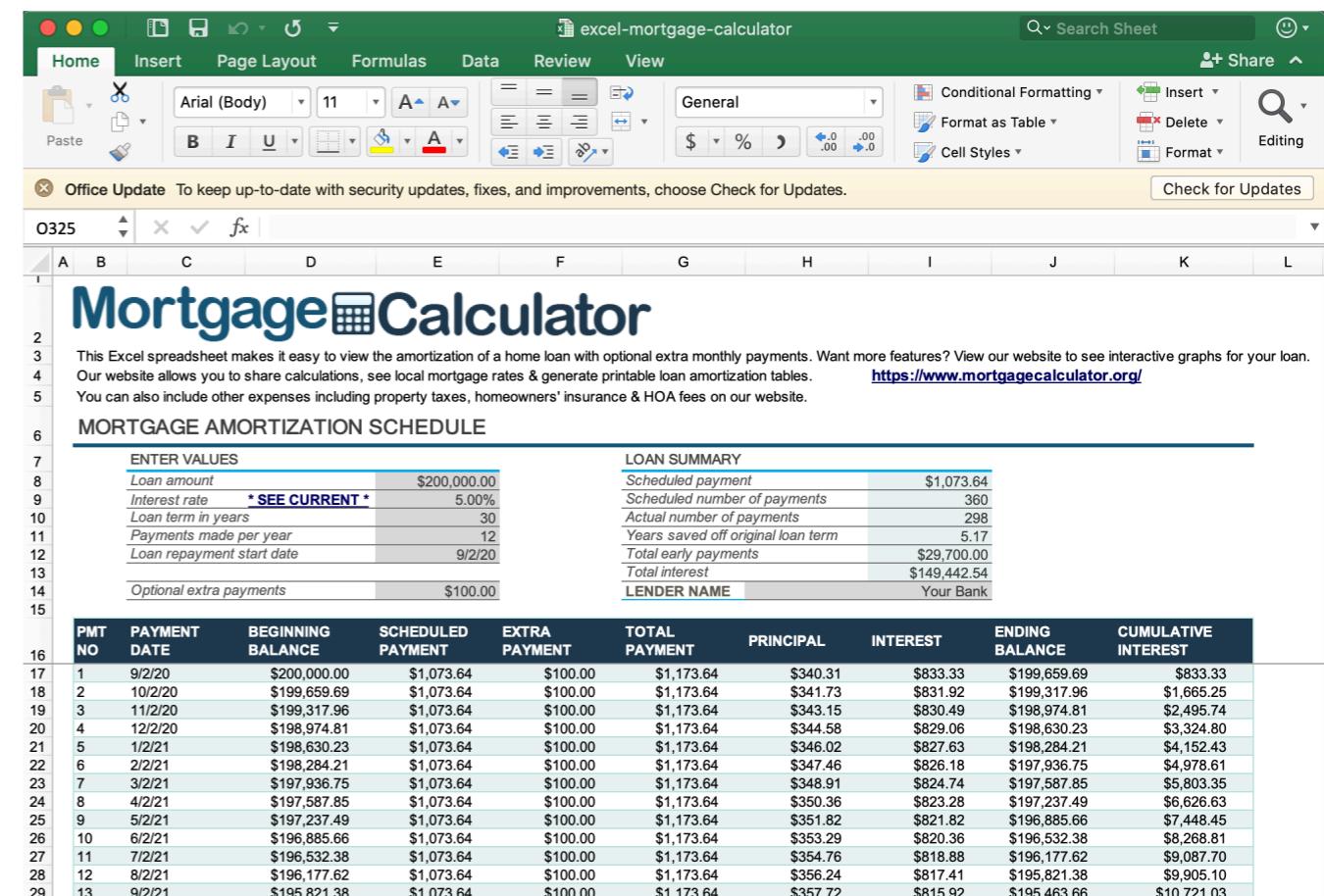


```
G22      ▾ ✕ ✓ fx | =IF([@PMT NO]<>"",IF([@SCHEDULED PAYMENT])+[@EXTRA PAYMENT]<=[@BEGINNING BALANCE],[@SCHEDULED PAYMENT])+[@EXTRA PAYMENT],[@BEGINNING BALANCE]),"")
```

- **Logic** bugs are hard or impossible to spot
- No way to standardize the data across the entire sheet (issues with white space and non-printing characters)



	A	B	
1	Title	Year	Genres
2	127 Hours	2010	Adventures Thriller Drama
3	3 Backyards	2010	Drama
4	3	2010	Comedy Drama Romance
5	8: The Mormon Proposition	2010	Documentary



This Excel spreadsheet makes it easy to view the amortization of a home loan with optional extra monthly payments. Want more features? View our website to see interactive graphs for your loan. Our website allows you to share calculations, see local mortgage rates & generate printable loan amortization tables. <https://www.mortgagecalculator.org/>

You can also include other expenses including property taxes, homeowners' insurance & HOA fees on our website.

MORTGAGE AMORTIZATION SCHEDULE

ENTER VALUES									LOAN SUMMARY									
ENTER VALUES				LOAN SUMMARY					Scheduled payment	\$1,073.64	Actual number of payments	360						
Loan amount	\$200,000.00	Interest rate	* SEE CURRENT *	5.00%	Payments made per year	12	Loan repayment start date	9/2/20	Years saved off original loan term	5.17	Total early payments	\$29,700.00						
Optional extra payments	\$100.00								Total interest	\$149,442.54	LENDER NAME	Your Bank						
MORTGAGE AMORTIZATION SCHEDULE									PMT NO	PAYMENT DATE	BEGINNING BALANCE	SCHEDULED PAYMENT	EXTRA PAYMENT	TOTAL PAYMENT	PRINCIPAL	INTEREST	ENDING BALANCE	CUMULATIVE INTEREST
1	9/2/20	\$200,000.00	\$1,073.64	\$100.00	\$1,173.64	\$340.31	\$833.33	\$199,659.69									\$833.33	
2	10/2/20	\$199,659.69	\$1,073.64	\$100.00	\$1,173.64	\$341.73	\$831.92	\$199,317.96									\$1,665.25	
3	11/2/20	\$199,317.96	\$1,073.64	\$100.00	\$1,173.64	\$343.15	\$830.49	\$198,974.81									\$2,495.74	
4	12/2/20	\$198,974.81	\$1,073.64	\$100.00	\$1,173.64	\$344.58	\$829.06	\$198,630.23									\$3,324.80	
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Can easily lead to lost data

<https://www.bbc.com/news/technology-54423988>



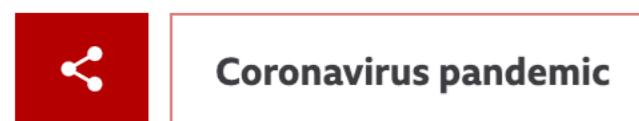
The BBC News navigation bar features the BBC logo, a sign-in button, and links to Home, News, Sport, Reel, Worklife, and Travel. Below the navigation bar is a large red 'NEWS' header. Underneath the header is a red navigation bar with links to Home, Coronavirus, Video, World, US & Canada, UK, Business, Tech (which is underlined), Science, Stories, and Entertainment & Arts.

Tech

Excel: Why using Microsoft's tool caused Covid-19 results to be lost

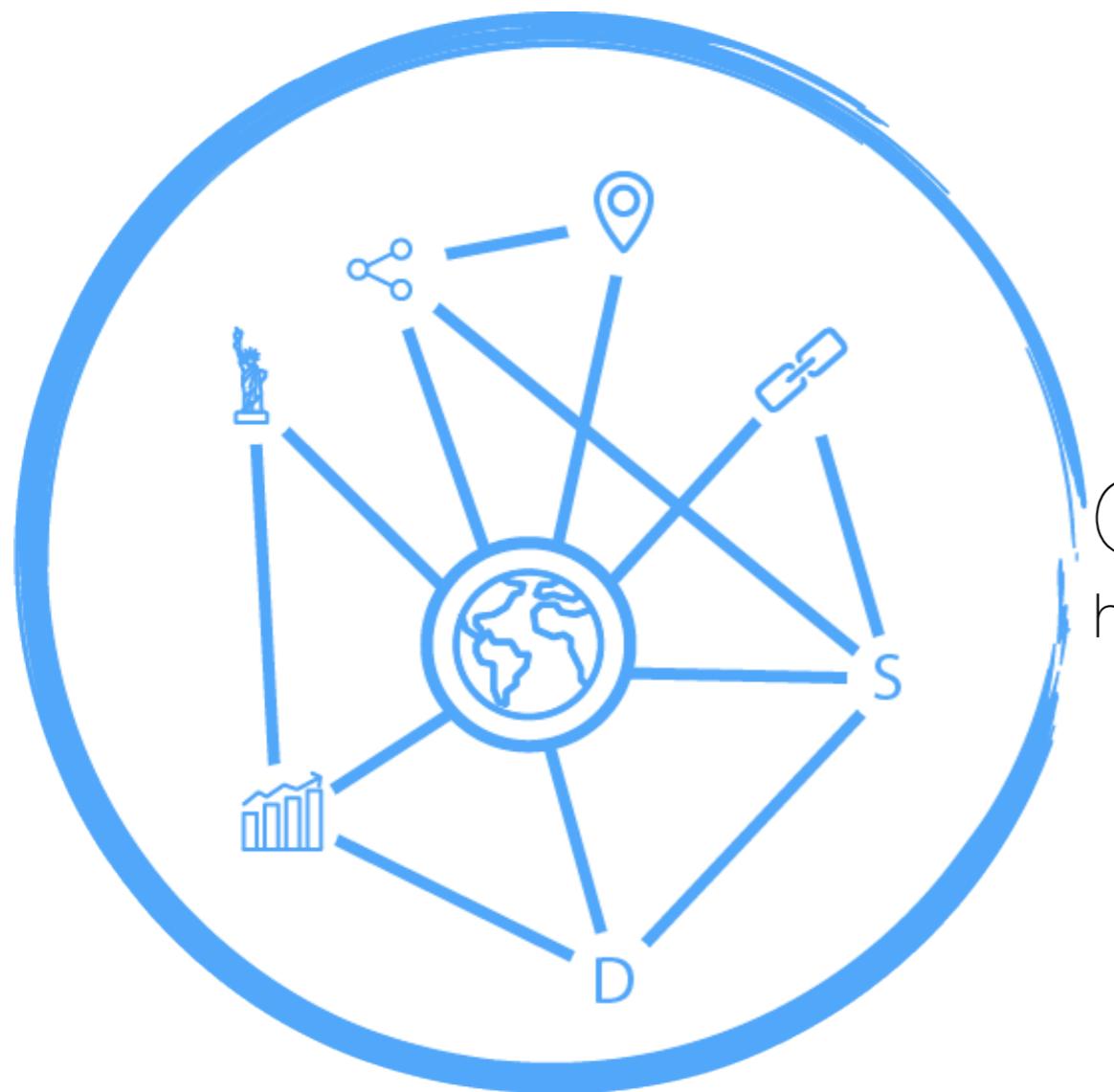
By Leo Kelion
Technology desk editor

① 5 October 2020



Hard to Automate

- The Graphical interface makes it easy to explore the functionality, but hard to automate it
- The only way to reproduce a computation is to redo each step, manually, a process that is error-prone
- Data is hard to validate
- Different worksheets in the same workbook can follow different conventions



Code - Pitfalls

<https://github.com/DataForScience/Excel>



Lesson II:

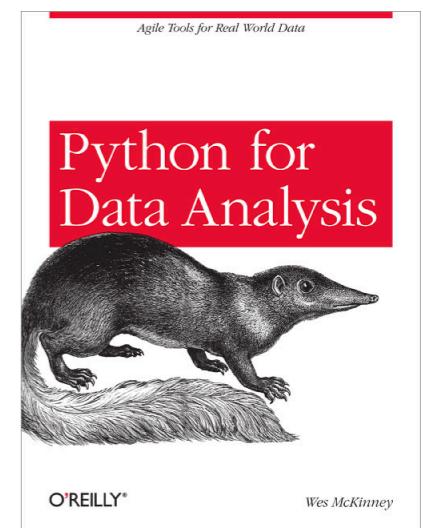
Pandas DataFrames

pandas

pandas.pydata.org

- Created by [Wes McKinney](#) in 2008 while working for [AQR Capital Management](#), currently working at [Two Sigma](#) and [Ursa Labs](#)
- Pandas is specifically designed to handle time series and data frames
- High performance, flexible tool for quantitative analysis on financial data
- The functionality is built on top [numpy](#) and [matplotlib](#) (see next lecture)
- The fundamental data structures are [Series](#) (1-dimensional) and [DataFrame](#) (2-dimensional).
- Each column of a [DataFrame](#) can have a different [dtype](#) but all the elements in a column (or [Series](#)) must be of the same [dtype](#)
- Conventionally imported as

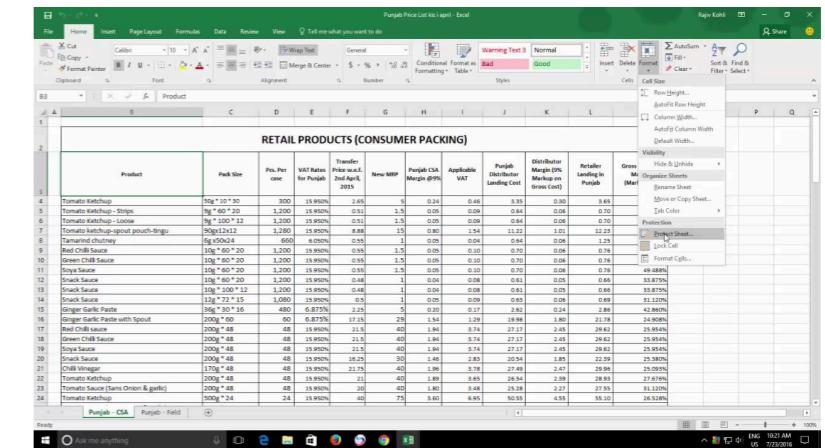
```
import pandas as pd
```



<https://amzn.to/2Pmg6UX>

Series and Data Frames

- A **Series** is conceptually equivalent to a **numpy** array with some extra information (column and row names, etc)
- A **DataFrame** can be thought of as the union of several **Series**, with names associated.
- Similarly, you can think of a **DataFrame** as an **Excel sheet** and of a **Series** as an individual **column**
- A minimal **DataFrame** implementation would be a dict where each element is a list



Series

	id
0	23
1	42
2	12
3	86

+

Series

	Name
0	“Bob”
1	“Karen”
2	“Kate”
3	“Bill”

=

DataFrame

	id	Name
0	23	“Bob”
1	42	“Karen”
2	12	“Kate”
3	86	“Bill”

DataFrame Fields

- **DataFrame**s contain a great deal of extra information in addition to just the data values. In particular, they include:
 - **columns** - column names
 - **index** - row names
 - **dtypes** - dtype associated with each column
 - **shape** - number of rows and columns
 - **ndim** - the number of dimensions
- **DataFrame**s make it easy to add new columns.
- **DataFrame** elements can be accessed and modified in various ways

DataFrame Exploration

- We get information about the contents of a **DataFrame** using several simple methods:
 - `head()` - display the top 5 rows
 - `tail()` - display the bottom 5 rows
 - `info()` - Print a concise summary of a DataFrame
 - `describe()` - Generate descriptive statistics that summarize the data

Indexing and Slicing

- pandas supports various ways of indexing the contents of a **DataFrame**
- [**<column name>**] - select a given column by it's name. column names can also be used as field names
- **.loc[<row name>]** - select a given row by it's (Index) name
- **.iloc[<position>]** - select a given row by it's position in the Index, starting at 0
- **.loc[<row name>, <column name>]** - select an individual element by row and column name
- **.iloc[<row position>, <row position>]** - select an individual element by row and column position (starting at 0)
- **.iloc** also supports ranges and slices similarly to **python** lists or **numpy** arrays

Importing and Exporting Data

- pandas has powerful methods to read and write data from multiple sources:
 - `pd.read_clipboard()` - Create DataFrame from the clipboard data
 - `pd.read_csv()` - Read a comma-separated values file
 - `pd.read_fwf()` - Read fixed width text file
 - `pd.read_excel()` - Read an Excel file
 - `pd.read_html()` - Read tabular data from a URL (or local html file)
 - `pd.read_pickle()` - Read a Pickle file
- Each of these functions accepts a large number of options and parameters controlling its behavior. Use `help(<function name>)` to explore further.
- Each `read_*`() function has a complementary `to_*`() function to write out a `DataFrame` to disk. The `to_*`() functions are members of the `DataFrame` object

Importing and Exporting Data

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Text-based formats

- `pd.read_csv()` - Read a **DataFrame** from a comma-separated values file. This is perhaps the most common and most robust read method and is able to process practically **any well-formed text-based format** (including **compressed files**)
 - `sep=' '` - Define the separator to use. `,` is the default (hence the name). `' '`, `'|'`, and `'\t'` are also common
 - `header=0` - Row number to use as column names
 - `names` - List of column names to use.
 - `index_col=None` - Column(s) to use as the row labels
 - `usecols` - Subset of the columns to use. By default it uses all columns
 - `nrows` - Number of rows of file to read. All by default.
 - `parse_dates` - List of column names to treat as dates.
 - `dtype` - Dictionary of column names to **dtypes** to use

Web pages

- `pd.read_html()` - Read an html file or URL. Whenever possible, parameter compatibility with `pd.read_csv()` is maintained. The most important difference is that it will automatically return a list of **DataFrames** if the file or webpage contains multiple tables.
 - `attrs=0` - A dictionary of HTML attributes that you can pass to use to identify the table in the HTML. `dict` keys must be valid HTML attributes
 - `flavor=None` - Similar to engine for excel files. Use a specific library to process the file. The currently supported ones are "`bs4`", "`html5lib`" or "`lxml`" -The default value of `None` tries them in order until a valid one is found, starting with "`lxml`".

Excel workbook

- `pd.read_excel()` - Read an Excel file. Most parameters work similarly to `pd.read_csv()` but a few other are of particular interest:
 - `sheet_name=0` - Which sheet name to load. Strings are used for sheet names and zero-index Integers are used to specify sheet positions (`0` is the first, `1` the second, etc). If a list is provided, multiple sheets can be loaded at the same time as a `dict` keyed by `sheet_name`.
 - `engine=None` - Use a specific library to process the file. The currently supported ones are `"xlrd"`, `"openpyxl"` or `"odf"` - Each engine will have small differences in the way it works and will support different formats (for example, `"openpyxl"` does not support old `xls` files, while `"odf"` requires an extra package to be installed).
 - `na_values` - Additional values to recognize as `NaN`. You can use a dict to specify different values per column.

Excel workbook

- `DataFrame.to_excel(filename)` - Write the contents of the DataFrame as an Excel file.
`filename` can also be a `file` or `ExcelWriter` object:
 - `sheet_name='Sheet1'` - Which sheet name to write. `'Sheet1'` is the default name when none is specified.
 - `engine=None` - Use a specific library to process the file. Currently supported options are `"openpyxl"` or `'xlsxwriter'`.
 - `index=True` - whether or not to write the row names.
 - `na_rep=""` - String used to represent `Nan` values.

Excel workbook

- `pd.ExcelFile(filename)` - Open an Excel file and return an `ExcelFile` object that represents the entire file:
 - `sheet_names` - list all the sheet names
 - `book` - an object representing the entire work book
 - `.parse(sheet_name)` - parse a specific excel sheet and return it as a `DataFrame`. Most common `read_excel` arguments can be used here as well
- `pd.ExcelWriter(filename, mode)` - open a file for writing (`mode="w"`) or appending (`mode="a"`)
 - return a "file pointer-like" object (similar to the vanilla `open()`) that can be passed to the `.to_excel()` `DataFrame` method.

Time Series

- **pandas** was originally developed to handle financial data
- Temporal sequences (time series) are a common type of data encountered in financial applications, so, naturally, pandas has good support for the most common time series operations.
- **pd.to_datetime** - converts a Series or value into a date time timestamp.
 - Format is inferred by looking at the entire Series data
 - Format can also be manually specified using specific arguments:
 - **format** - detailed string specifying the full format
 - **dayfirst=True** - parse 10/11/12 as Nov 10, 2012
 - **yearfirst=True** - parse 10/11/12 as Nov 12, 2010
- **pd.to_timedelta** - converts a Series into an absolute difference in time
- Dates can also be parse automatically at read time by passing a list of the columns containing dates to the **parse_dates** argument of **pd.read_csv()**, etc...

Time Series

- Sequences of dates/times can be created using `pd.date_range()`, similar to `np.arange()`
 - **start/end** - specify the limits
 - **freq** - specify frequency (step)
 - B - business day frequency
 - D - calendar day frequency
 - W - weekly frequency
 - M - month end frequency
 - Q - quarter end frequency
 - A - year end frequency
 - H - hourly frequency
 - T - minutely frequency
 - S - secondly frequency
- By setting the index to be a date time, we turn the **DataFrame** into a **Time Series**.
- Pandas has several methods that are specialized to this case
- `index.day/index.month/index.year` - return the day, month and year of the time series index value

Transformed values

- We often need to apply some simple transformation to the values in our original **Series**. Pandas offers several methods to accomplish this goal:
 - **map(func)** - Map values of **Series** according to input correspondence.
 - **func** - function, dict or **Series** to use for mapping
 - **transform(func)** - Transform each column/row of the **DataFrame** using a function.
Output must have the same shape as the original
 - **axis = 0** - apply function to columns
 - **axis = 1** - apply function to rows
 - **apply(func)** - Apply a function along an axis of the **DataFrame**
 - Similar to **transform()** but without the limitation of preserving the shape

Lagged values and differences

- While analyzing time series, we often refer to values that our time series took **1, 2, 3**, etc time steps in the past
- These are known as lagged values and denoted:

$$x_{t-l}$$

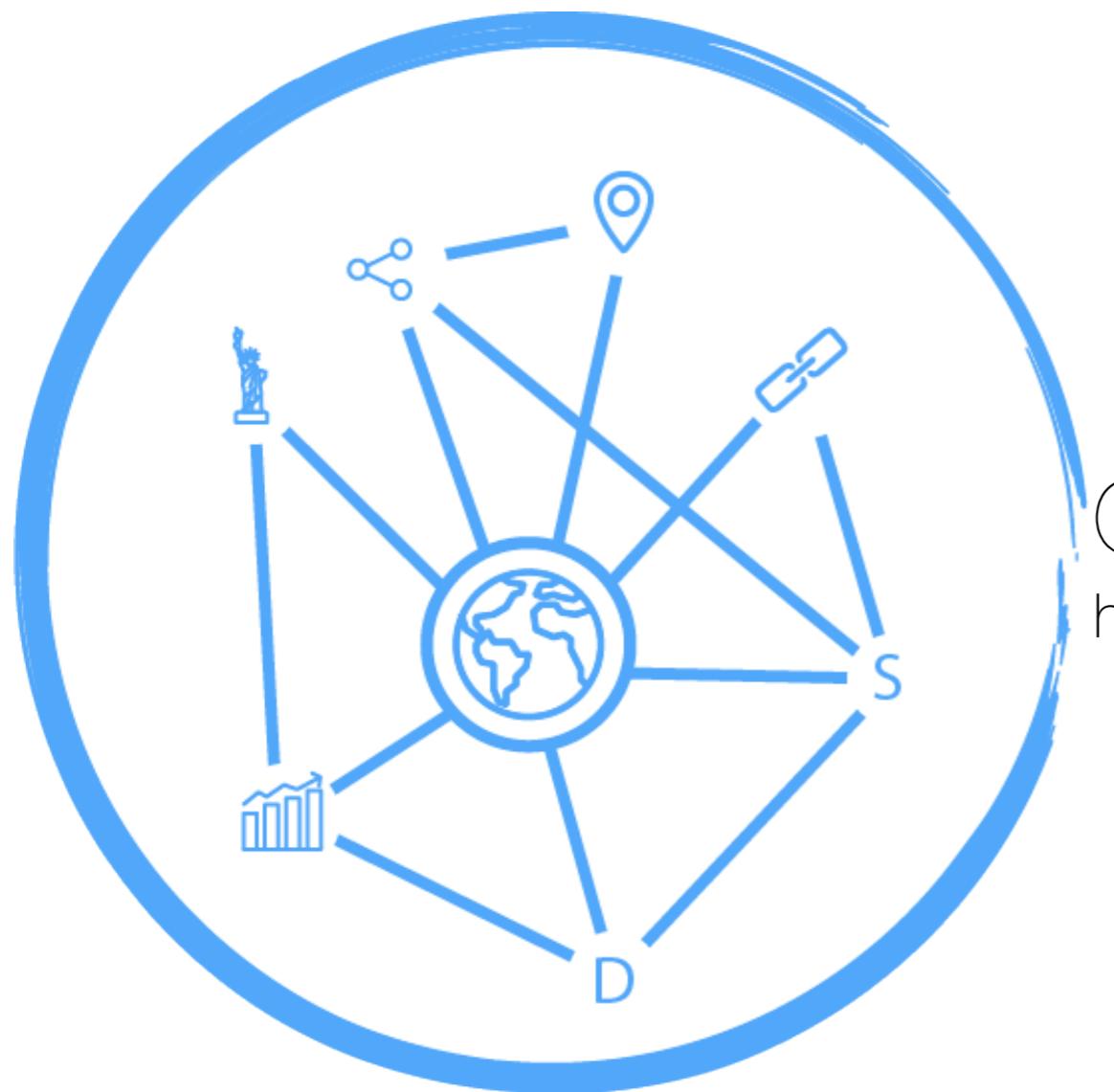
- where **l** is the value of the lag we are considering.
- pandas supports lagged values with the `shift(|)` DataFrame method
- Perhaps the most common use case for lagged values is for the calculation of **differences** of the form:

$$x_t - x_{t-l}$$

- Where **$l \geq 1$** is the value of the lag we are interested in.
- Differences are also a particularly simple way to **detrend** a time series
- pandas supports lagged values with the `diff(|)` DataFrame method

merge/join

- `merge()` and `join()` allows us to perform database-style join operation by columns or indexes (rows)
- Some of the most important arguments are common to both methods:
 - `on` - Column(s) to use for joining, otherwise join on index. Can pass an array as the join key if not already contained in the calling DataFrame. Like an Excel VLOOKUP operation
 - `how` - Type of join to perform: `{'left', 'right', 'outer', 'inner'}`
- `merge()` is more sophisticated and flexible. It also allows us to specify:
 - `left_on/right_on` - Field names to join on for each DataFrame
 - `left_index/right_index` - Whether or not to use the left/right index as join key(s)



Code - Pandas DataFrames
<https://github.com/DataForScience/Excel>

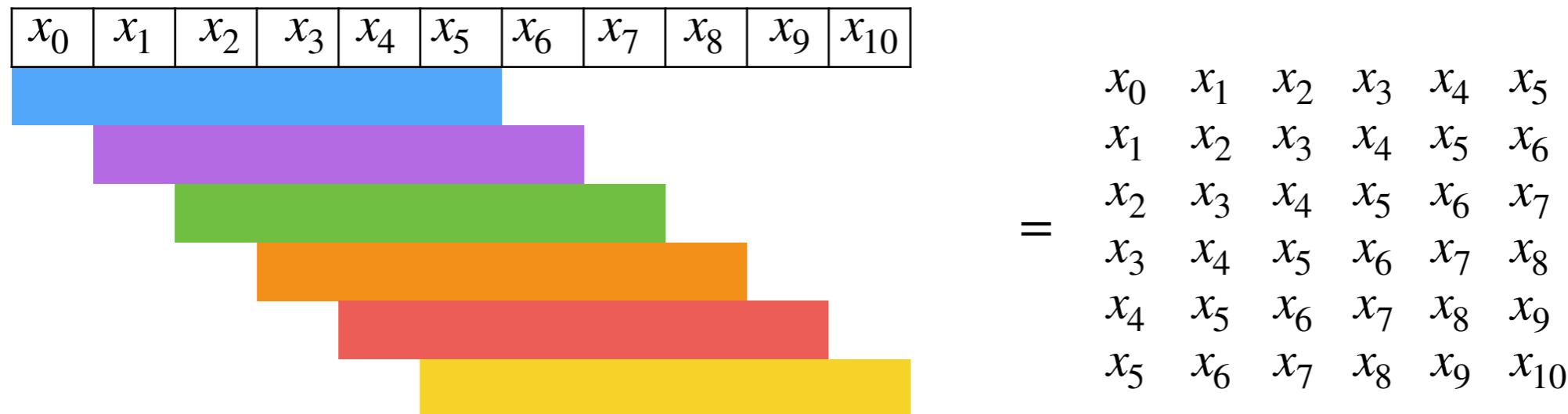


Lesson III:

Simple Data Modeling

Windowing

- When analyzing the temporal behavior of a signal, we often need to evaluate if specific quantities are **time varying** or not
- A common approach is to use **sliding windows** of a given length to evaluate the required values
- So a sliding window of width **6** on a series of length **11** would look like:



- and we would calculate the metric of interest **within each window**.
- In Pandas we use the method **rolling(w)** that returns dynamic view of the data allowing us to daisy-chain other common **numpy** operators. **rolling(w).mean()**, **rolling(w).max()**, etc...

GroupBy

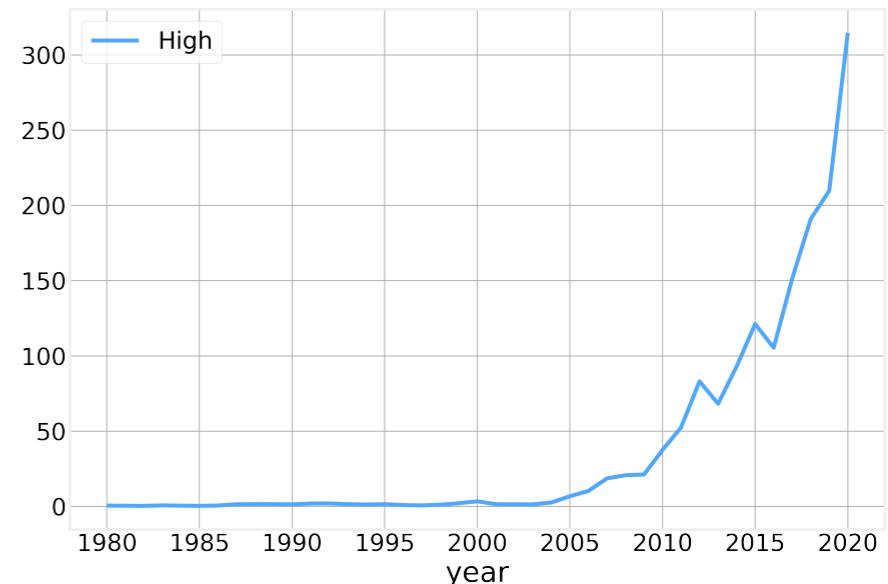
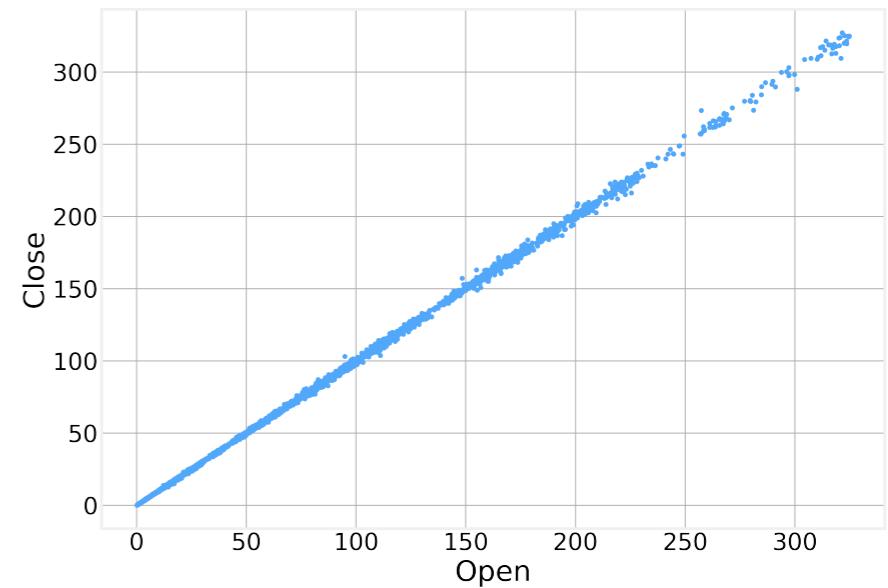
- Sometimes we need to calculate statistics for subsets of our data
- `groupby()` allows us to group data based on the values of a column
- `groupby()` returns a GroupBy object that supports several aggregations functions, including:
 - `max()/min()/mean()/median()`
 - `transform()/apply()`
 - `sum()/cumsum()`
 - `prod()/cumprod()`
 - `quantile()`
- Each of these functions is applied to the contents of each group

Pivot Tables

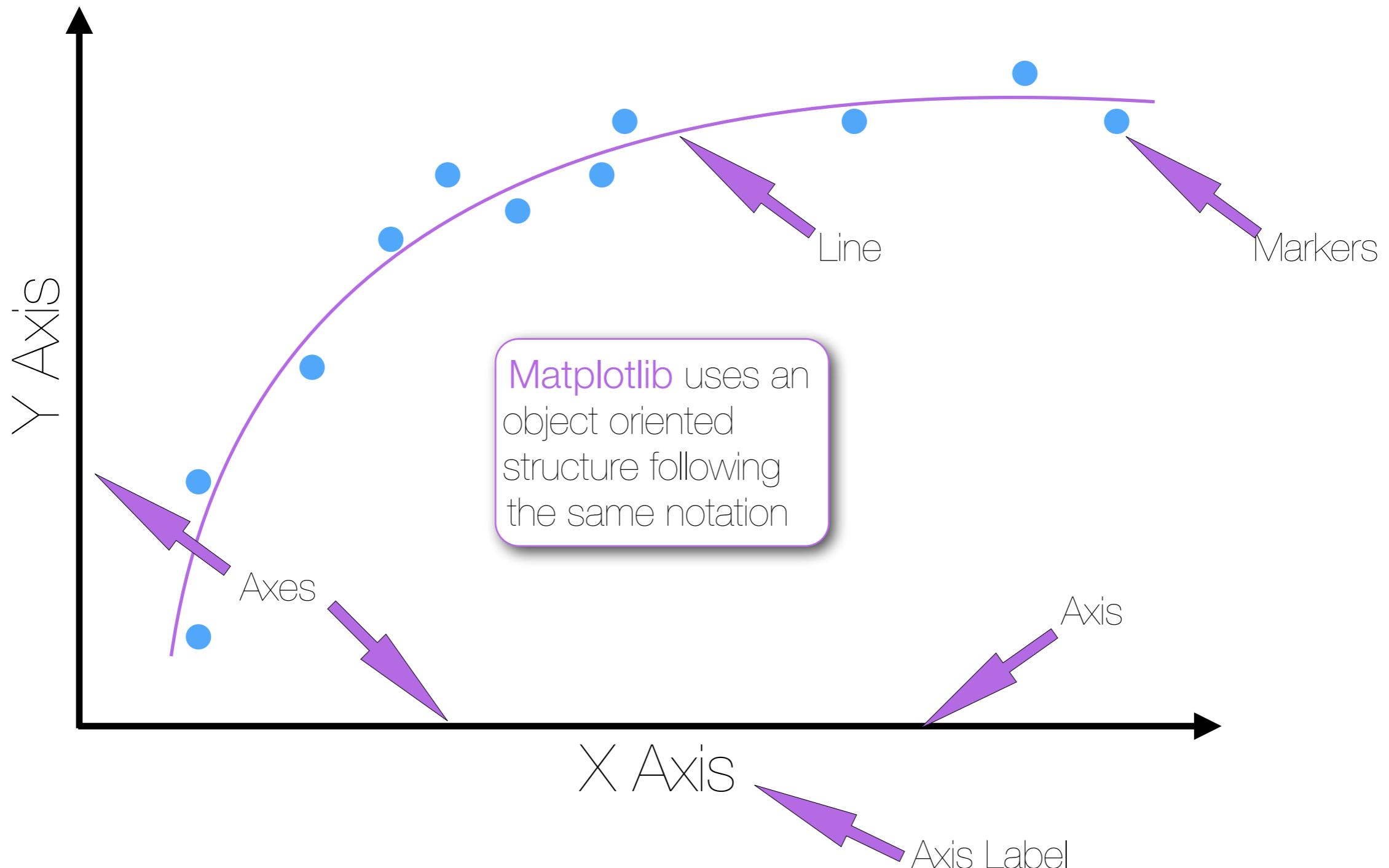
- Pandas provides an extremely flexible pivot table implementation
- `pd.pivot_table()` - Creates a spreadsheet-style pivot table as a `DataFrame`.
- Three important arguments:
 - **values** - column to aggregate
 - **index** - Keys to group by on the pivot table index. If an array is passed, it is being used as the same manner as column values.
 - **columns** - Keys to group by on the pivot table column.
 - **aggfunc** - Function to use for aggregation. Defaults to `np.mean()`
- **index**, **columns** and **aggfunc** can also be lists of keys or functions to use.

plotting

- Finally, pandas also provides a simple interface for basic plotting through the `plot()` function
- By specifying some basic parameters the variables plotted and even the kind of plot can be easily modified:
 - `x/y` - column name to use for the `x/y` axis
 - `kind` - type of plot
 - ‘`line`’ - line plot (default)
 - ‘`bar`/‘`barh`’ - vertical/horizontal bar plot
 - ‘`hist`’ - histogram
 - ‘`box`’ - boxplot
 - ‘`pie`’ - pie plot
 - ‘`scatter`’ - scatter plot
- The `plot()` function returns a `matplotlib Axes` object

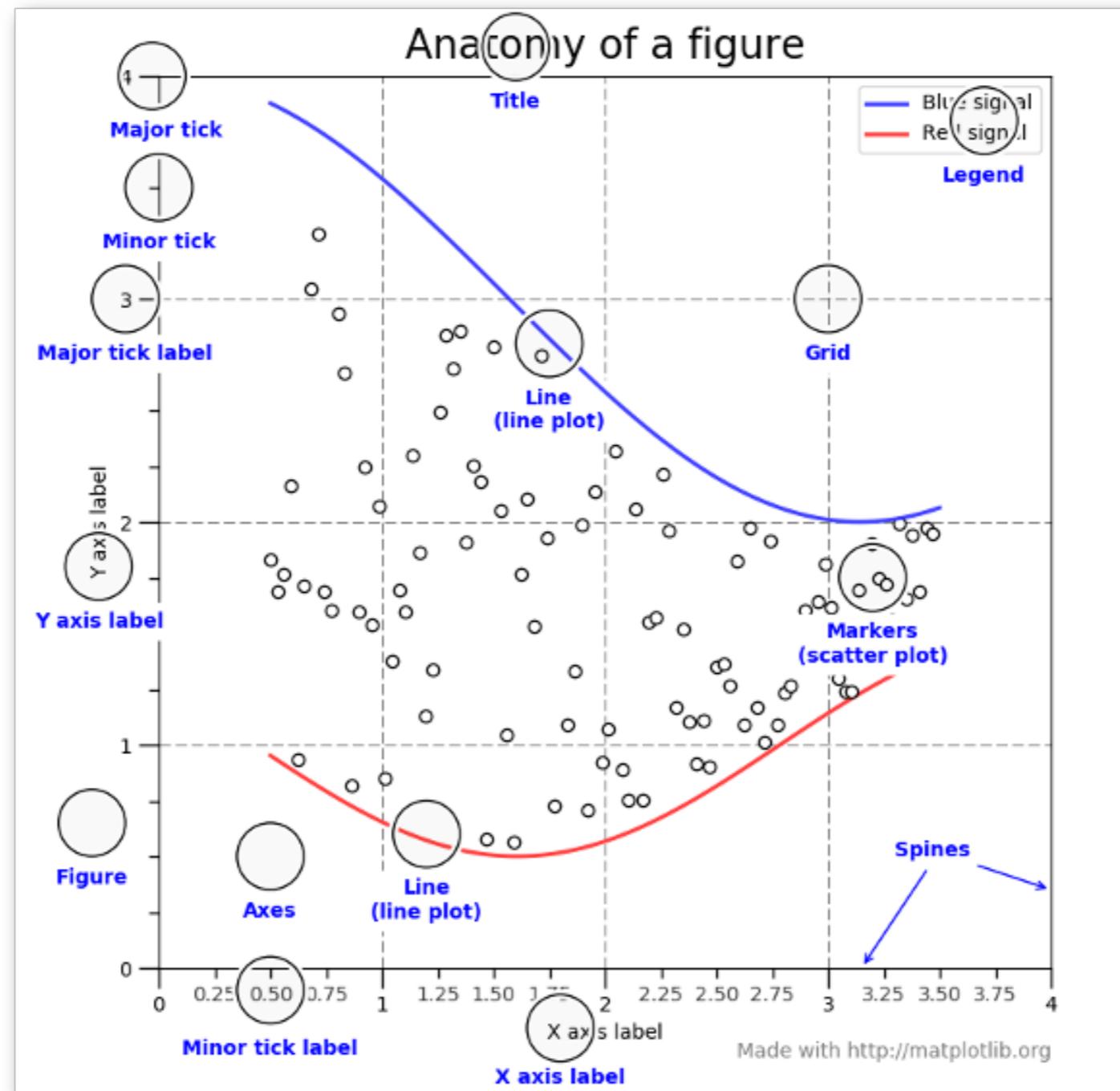


Basic Plotting



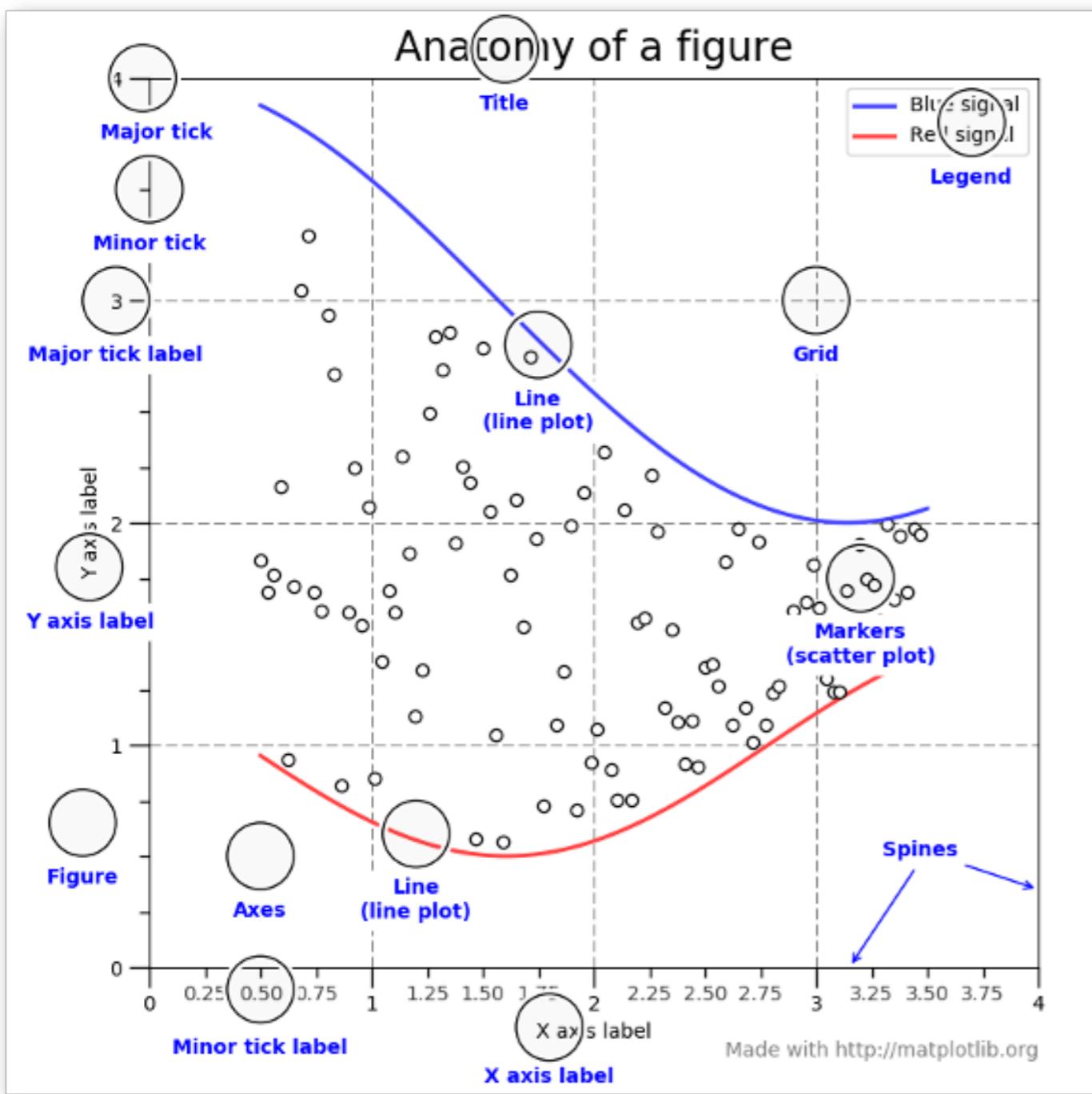
Basic Plotting - Programmatically!

matplotlib.org/3.1.0/



matplotlib - decorations

matplotlib.org/3.1.0/



- The respective functions are named in an intuitive way, Every `Axes` object has as methods:
 - `.set_xlabel(label)`
 - `.set_ylabel(label)`
 - `.set_title(title)`
- And axis limits can be set using:
 - `.set_xlim(xmin, xmax)`
 - `.set_ylim(ymin, ymax)`
- Tick marks and labels are set using:
 - `.set_xticks(ticks)/.set_yticks(ticks)`
 - `.set_xticklabels(labels)/.set_yticklabels(labels)`



- Python has a huge number of high quality libraries that allow us to perform almost any operation we might be interested in
- scikit-learn is a state of the art library for Machine Learning, including
 - Linear Regression
 - Logistic Regression
 - Optimization
 - Support Vector Machines
 - Clustering
 - Neural Networks
 - Decision Tree
 - etc...

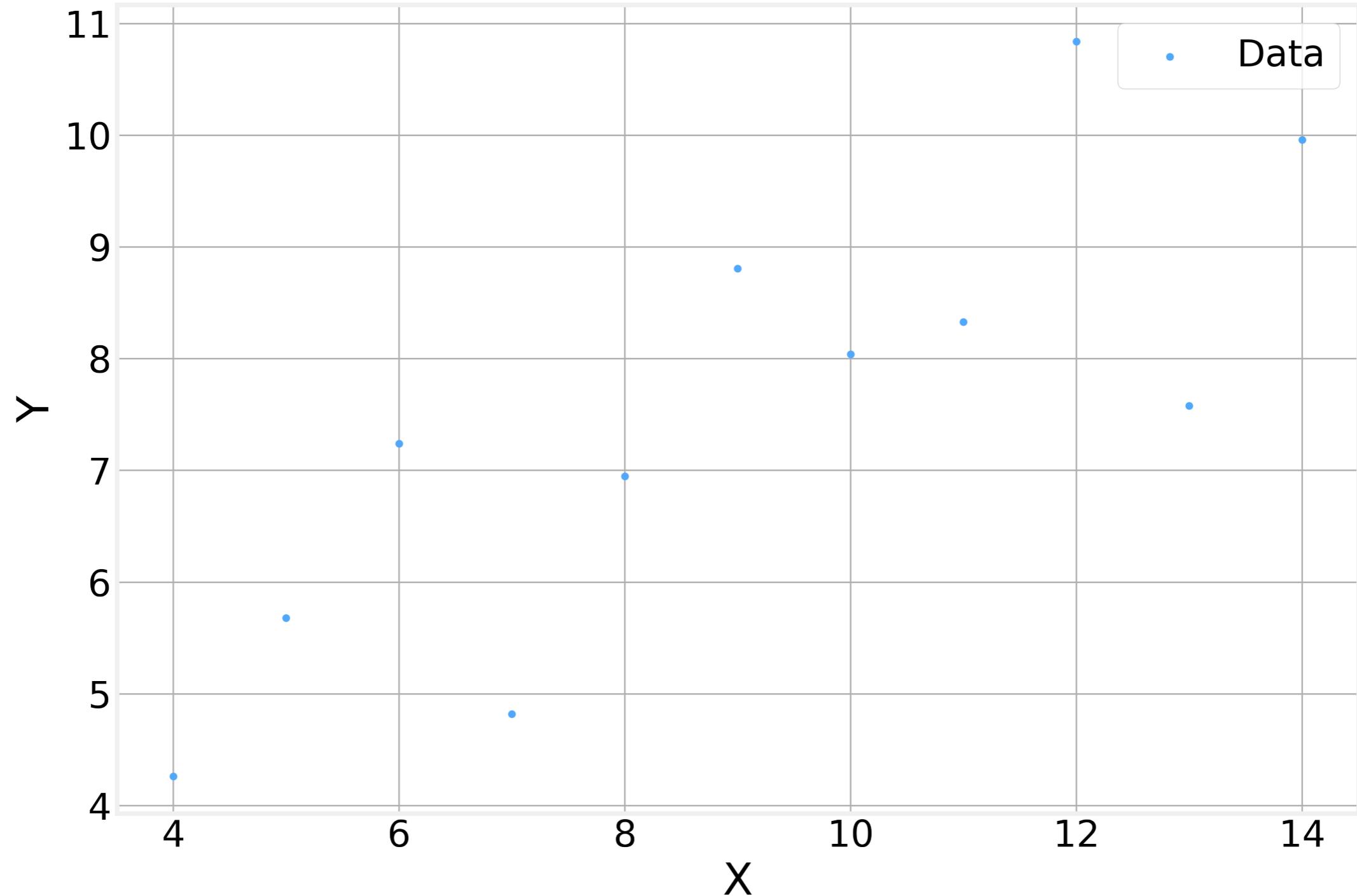


Linear Regression

- `sklearn` provides a `LinearRegression` object under the `sklearn.linear_model` module
- The `LinearRegression` object provides an important methods:
 - `.fit(X, y)` - determine the parameter values for the model. The dimensions of `X` determine the number of parameters computed
- After fitting the model, we can also use:
 - `.predict(X)` - Calculate the predicted value for any input values `X`
 - `.coef_` - returns the computed parameters of the model
 - `.intercept_` - returns the computed intercept value
- The `fit()/predict()` model is used throughout all of `sklearn`'s models making it easy to explore various ML models.

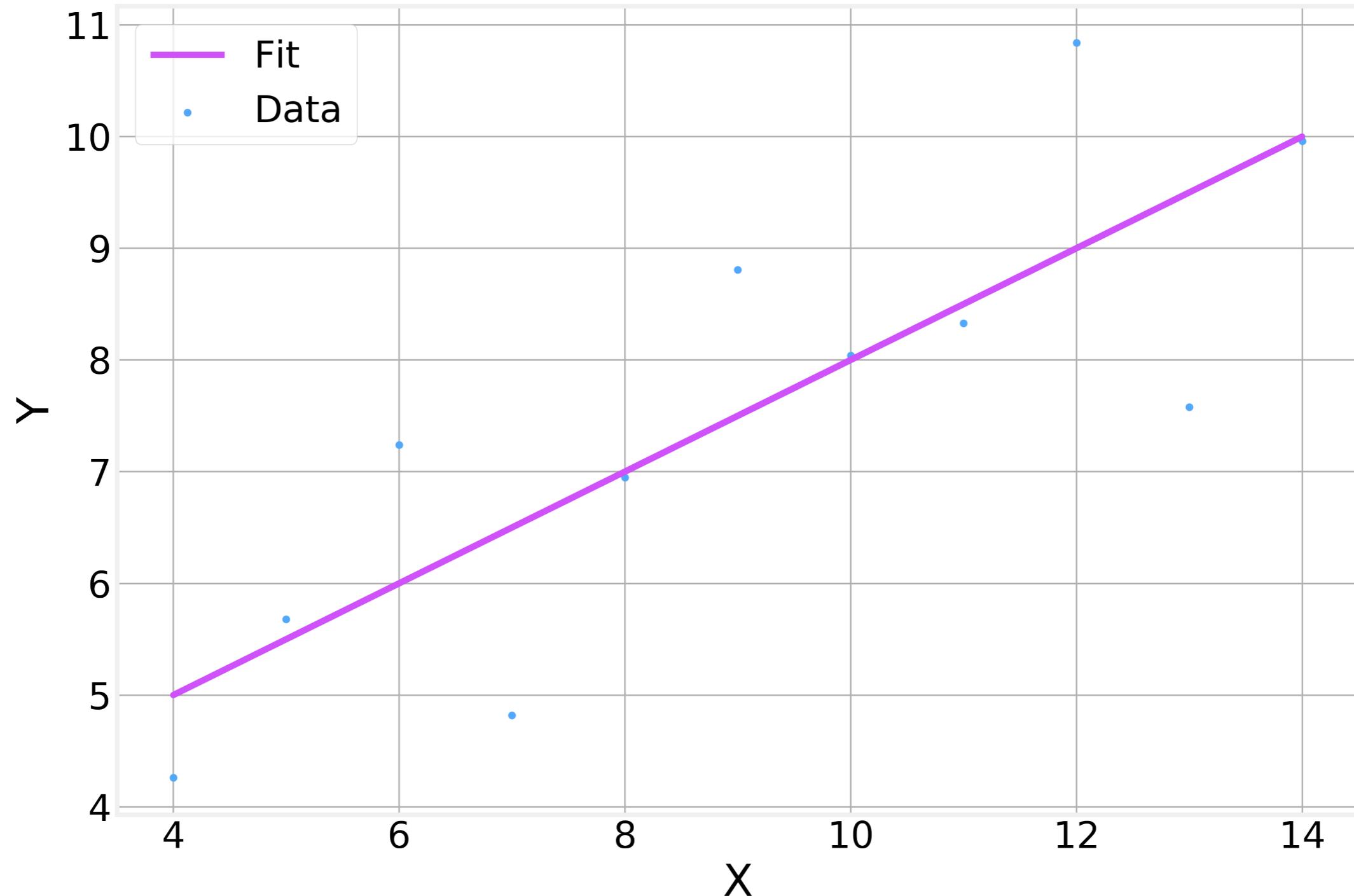


Linear Regression





Linear Regression





- SciPy is a state of the art library for scientific computation.
- Together with numpy, matplotlib, pandas, etc it is part of the Sci-P umbrella project
- Includes functionality for:
 - Special Functions
 - Integration
 - Optimization
 - Signal Processing
 - Linear Algebra
 - Statistics
 - etc

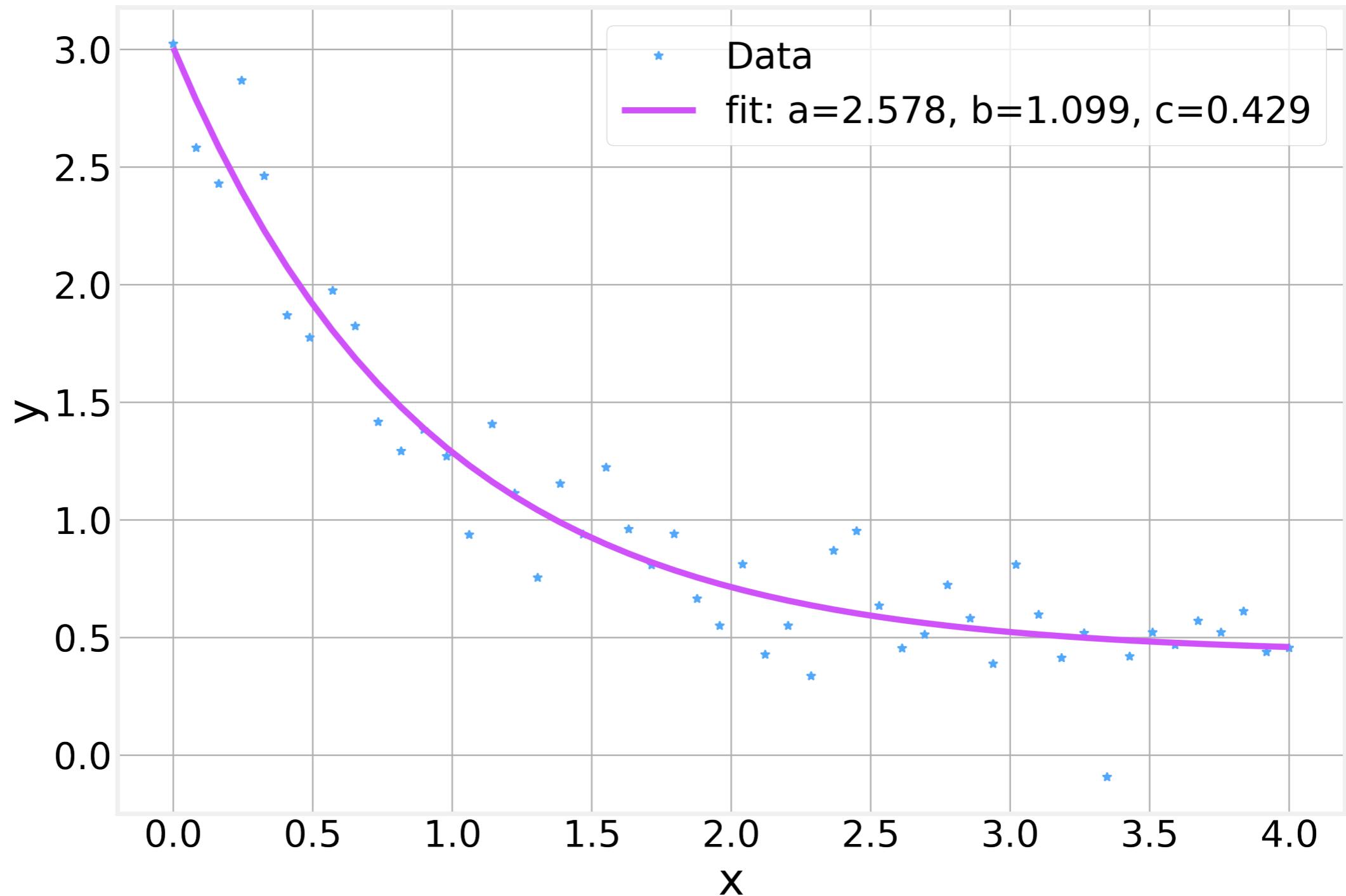


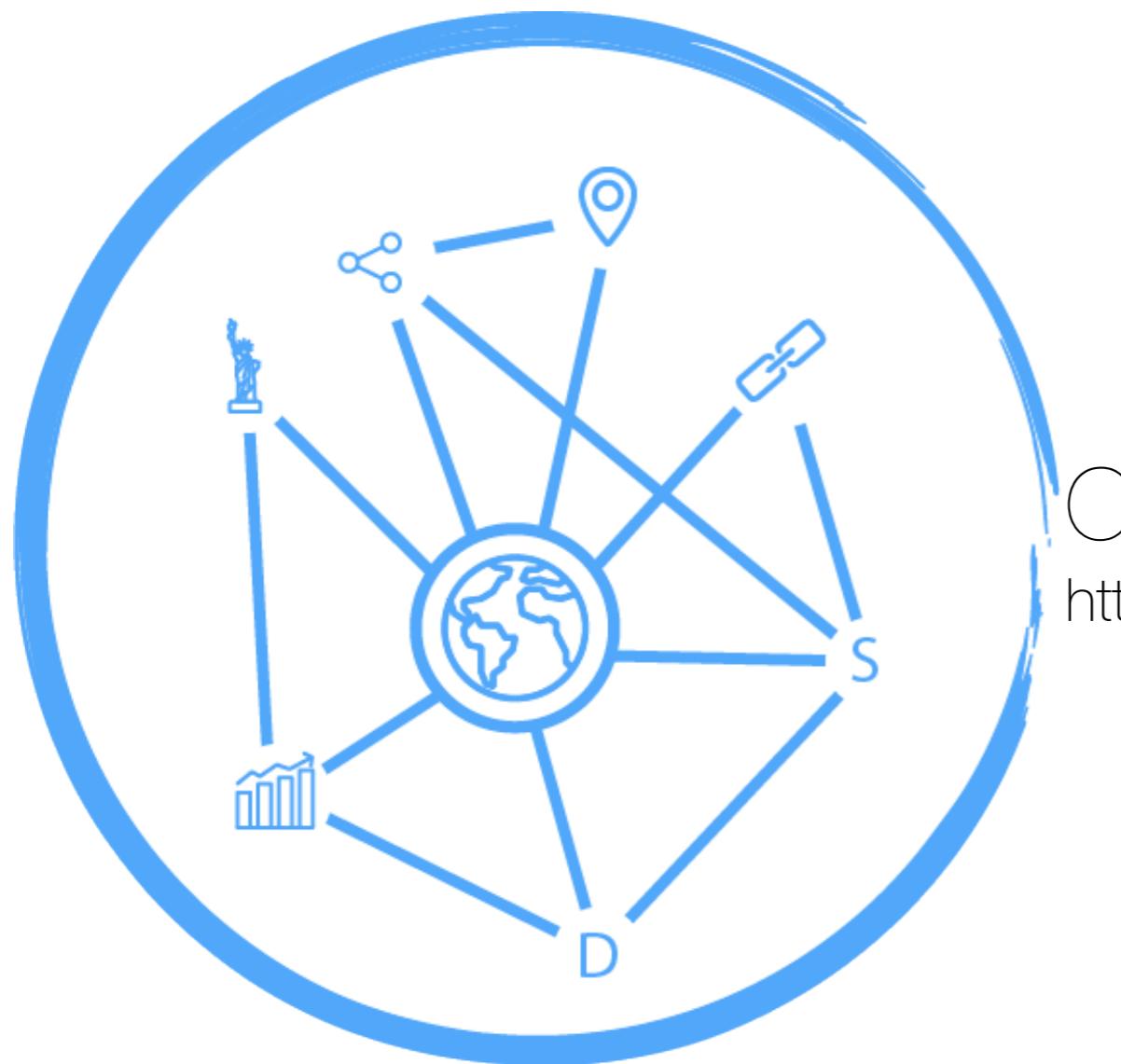
SciPy Curve fitting

- The `scipy` library provides a `curve_fit()` function within the `scipy.optimize` module
- `curve_fit()` takes several fundamental arguments:
 - `func` - The function to fit
 - `xdata` - the x values
 - `ydata` - the y values
 - `p0=None` - the initial guess of the parameters.
- `curve_fit()` figures out the number of parameters to fit from the signature of `func`. If `p0` is set, the number of arguments to `func`



SciPy Curve fitting





Code - Simple Data Modeling
<https://github.com/DataForScience/Excel>



Lesson IV: Manipulating Excel Spreadsheets

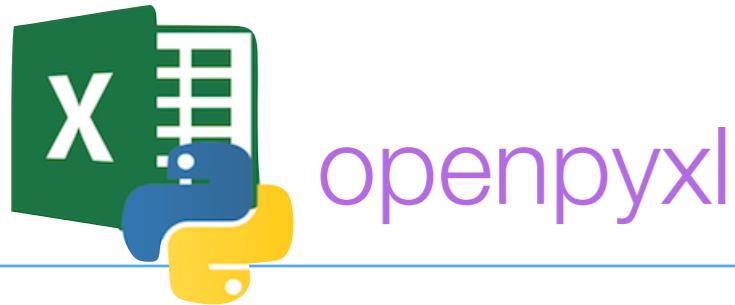
Python packages

- There are several Python packages that allow you to read, write and manipulate Excel files, with varying degrees of ease and compatibility:
 - **pandas** - basic reading and writing
 - **xlrd** - library for reading data and formatting information from Excel files, whether they are .xls or .xlsx files - <https://xlrd.readthedocs.io/en/latest/>
 - **xlwt** - library for writing data and formatting information to older xls Excel files - <https://xlwt.readthedocs.io/en/latest/>
 - **xlutils** - a collection of utilities for working with Excel files, built on top of **xlrd** and **xlwt** - <https://xlutils.readthedocs.io/en/latest/>
 - **pyexcel** - unified application programming interface to read, manipulate and write data in various excel formats - <http://docs.pyexcel.org/en/latest/>
 - **openpyxl** - A Python library to read/write Excel 2010 xlsx/xlsm files
- <https://openpyxl.readthedocs.io/en/stable/>

Python packages

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 - **xlwt** - library for writing data and formatting information to older xls Excel files - <https://xlwt.readthedocs.io/en/latest/>
 - **xlutils** - a collection of utilities for working with Excel files, built on top of **xlrd** and **xlwt** - <https://xlutils.readthedocs.io/en/latest/>
 - **pyexcel** - unified application programming interface to read, manipulate and write data in various excel formats - <http://docs.pyexcel.org/en/latest/>
 - **openpyxl** - A Python library to read/write Excel 2010 xlsx/xlsm files - <https://openpyxl.readthedocs.io/en/stable/>

Most features
and the best
documentation



openpyxl.readthedocs.io

- **openpyxl** provides a complete view of the entire Excel workbook.
- Originally created as a port of the **PHPExcel** library to Python
- It fully supports Excel 2010 **xlsx/xlsm/xltm/xltx**
- In particular, it allows us to:
 - **Open** existing Excel files
 - **Create/modify/delete** sheets from files
 - **Duplicate** sheets within a workbook
 - Embed **images, charts** and **formulas** in to sheets
 - **Stylize** and **format** sheets.

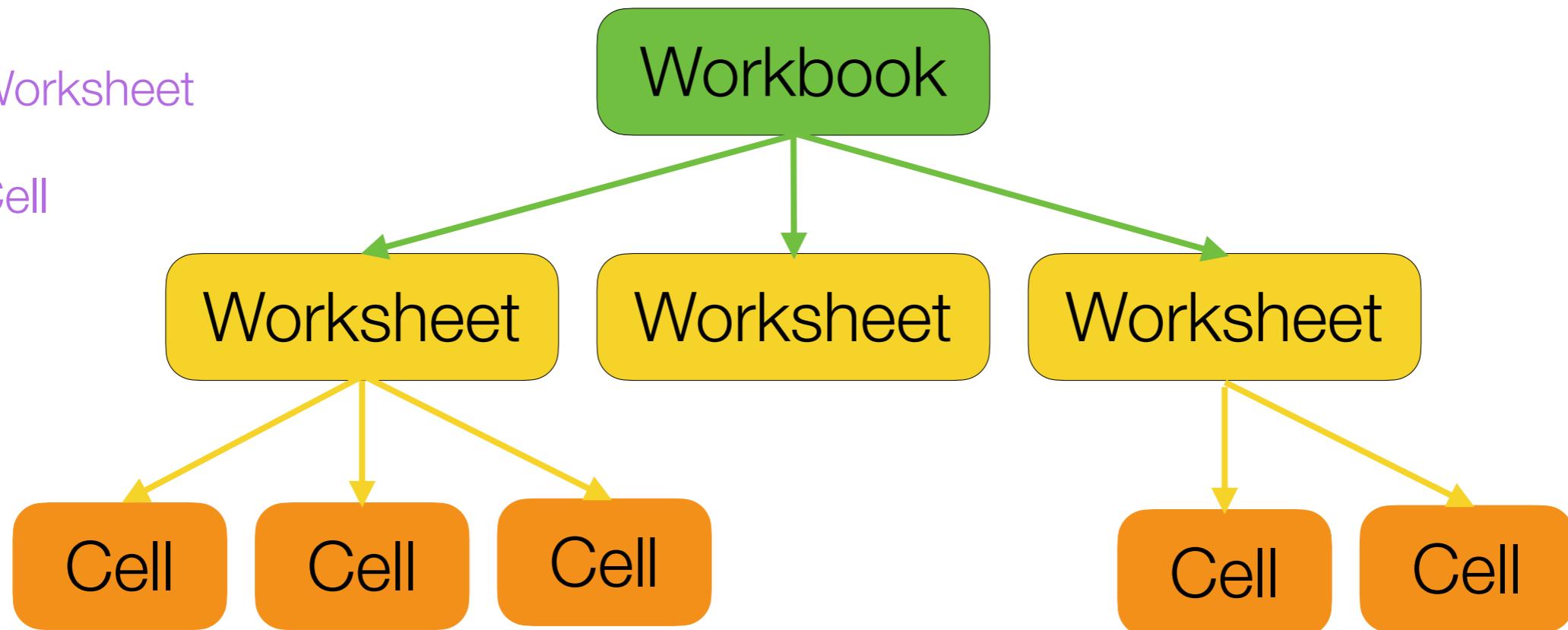


openpyxl

openpyxl.readthedocs.io

- **openpyxl** relies on three fundamental concepts, represented as Python objects:

- Workbook
- Worksheet
- Cell



- **Workbook**s can contain any number of sheets allowed by the specific format, and **Worksheet** objects can contain any number of **Cell**s allowed.

Workbook

- An empty **Workbook** can be created simply by calling `Workbook()`. This will be an empty workbook that exists only in memory. To save it to disk, use `.save(filename)`.
- To load a **Workbook** from a file on disk, we call `load_workbook(filename)`. This function accepts a few optional parameter that are useful to understand:
 - `read_only=False` - Prevent edits. This mode is optimized for reading.
 - `keep_vba=False` - Prevent VBA content from being corrupted (it can not be used)
 - `data_only=False` - Return only the stored values or the formulas. The default is to return the formulas, set to `True` to return the current values instead.
- The list of all **Worksheet**s that are part of the **Workbook** is available in the `.sheetnames` list, while the `.worksheets` member list contains the respective sheet objects.
- You can get the currently **active** worksheet (equivalent to the currently selected sheet in Excel) by accessing the `.active` field of the **Workbook** object.

Workbook

- The `Workbook` object provides a `dict` like interface to access `Worksheets` by name.
- To save a `Workbook` we use `.save(filename)`

Worksheet

- To create a new worksheet we use `.create_worksheet(title=None, index=None)`. Both arguments are optional, the default names will be `Sheet`, `Sheet1`, `Sheet2`, etc... `index` provides the location where to insert the new sheet, and by default each new sheet will be placed at the end of the workbook.
- To duplicate a `Worksheet` within the `Workbook`, you use `.copy_worksheet(name)`.
- The name of the Worksheet can be assigned it to the `.title` member field.
- The `Worksheet` contains several useful fields:
 - `min_column/max_column/min_row/max_row` - column and row ranges
 - `dimensions` - reference of the upper-left and lower-right cells.

Worksheet

- And useful methods:
 - `.insert_rows(idx)/.insert_columns(idx)` - insert a row/column BEFORE position `idx`
 - `.delete_rows(idx)/.delete_columns(idx)` - delete a row/column AT position `idx`
 - `amount=1` - All these functions take an optional parameter `amount` to specify how many row/column to add/delete
 - row/column indices start at 1
- The `Worksheet` object provides a `dict` like interface to access `Cells` by name ("A1", "B3", etc).

Worksheet

- We can efficiently iterate over rows/columns using `.iter_rows()/iter_columns()`. These methods take 5 arguments, all of which are optional
 - `min_row=None` - Starting row (inclusive)
 - `max_row=None` - Ending row (inclusive)
 - `min_col=None` - Starting column (inclusive)
 - `max_col=None` - Ending column (inclusive)
 - `values_only=False` - Return the current numerical values (`True`) or the corresponding formula (`False`)
- By default, all `rows/columns` are returned as tuples of `Cell` objects.
- We can `append()` rows to an existing Worksheet, by providing tuples of values.
- When a `WorkSheet` is first created, it contains no `Cells`. `Cells` are dynamically created when they are accessed for the first time.

Cell

- We can access a specific **Cell** directly from the **Worksheet** object:
 - `sheet[cell_ref]` - where `cell_ref` is the Excel cell reference
 - Assigning a value to this object, changes the value of the cell
- Another alternative to set the value of a cell is to use the `.cell(row, column, value)` method.
- Ranges can be specified using Excel slice notation (similar to Python notation):
 - `sheet["A3:B5"]` - returns the **3x2** matrix of cells between **A3** and **B5** (inclusive) as a tuple of tuples of **Cell** objects.
 - Ranges **can't** be used for assignment (tuples are immutable)
- **Cell** objects have several useful fields:
 - `.value` - returns the value of the cell. Also useful for assignment
 - `.row/.column` - returns the row/column coordinates of the **Cell**



Code - Basic Excel Spreadsheets
<https://github.com/DataForScience/Excel>



Lesson V: Advanced Spreadsheet Functionality

Formulas

- **Cell**s can contain formulas that compute values.
- We can simply assign a formula as a string to a specific cell
- **openpyxl** doesn't evaluate formula values
- **openpyxl.utils.FORMULAE** - A frozenset containing a list of 352 known Excel function names that you may use as a quick reference.

Images

- Adding images to a `Worksheet` is a two step process:
 - load the image using the `Image()` object in the `openpyxl.drawing.image` module
 - place the image into a `Worksheet` using `.add_image(img, anchor=None)` where `img` is the `Image` object and `anchor` is the `Cell` where to place the top left hand corner of the image
- Image natively support '`gif`', '`jpeg`', and '`png`' images. it will attempt to convert all other formats to '`png`'.
- `openpyxl` provides very limited support for images beyond simply placing them in a specific location. It's up to you to make sure the image is the right size to display properly

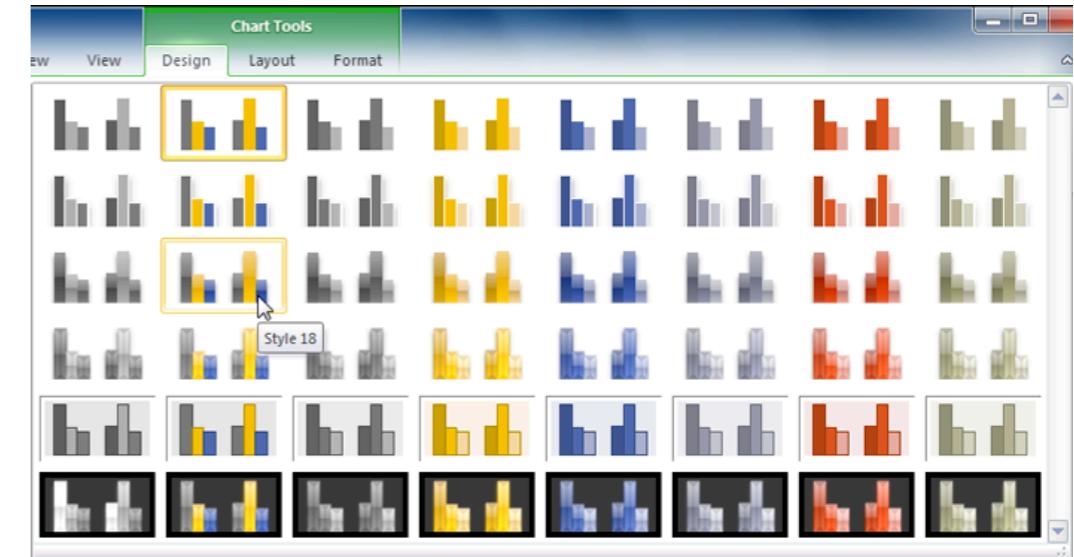
Charts

- **Excel** supports many different kinds of charts for visualization
- **openpyxl** allows us to add charts to a **Worksheet** in a simple and convenient way.
- You can create **AreaChart**, **AreaChart3D**, **BarChart**, **BarChart3D**, **BubbleChart**, **DoughnutChart**, **LineChart**, **LineChart3D**, **PieChart**, **PieChart3D**, **ProjectedPieChart**, **RadarChart**, **ScatterChart**, **StockChart**, **SurfaceChart**, **SurfaceChart3D**
- The process to create a **Chart** requires several steps:
 - Create a **Chart** object and configuring it with labels, legends, etc
 - Define the data to use, by creating a **Reference** object
 - Pass the **Reference** object to the **Chart** object using **add_data()**
 - Add the **Chart** to a **Worksheet** (similarly to an **Image**)
- Chart and Reference Objects live inside the **openpyxl.chart** module

Charts

- All Chart objects contain fields that allow us to customize them. In particular:

- **.title** - The main title for the chart
- **.style** - The style to use, represented as an integer.
- **.x_axis.title** - x-label
- **.y_axis.title** - y-label
- **.x_axis.scaling.min/x_axis.scaling.max** - minimum and maximum limits for the x-axis
- **.y_axis.scaling.min/y_axis.scaling.max** - minimum and maximum limits for the y-axis



Reference

- A **Reference** object requires 5 parameters:
 - **worksheet** - A reference to the Worksheet where the data lives
 - **min_col/max_col/min_row/max_row** - the coordinates delimiting the cells containing the data
- **.add_data(data)** adds the **Reference** object to the **Chart** we are creating. This method takes two optional parameters:
 - **from_rows=False** - Is the data in row format (instead of the more common column format)
 - **titles_from_data=False** - Does the Reference include the column/row names to use for each Series?

Series

- When we add the **Reference** to our **Chart**, it automatically creates a **Series** of data points for each column in the **Reference** object.
- **Series** objects represent individual datasets within the **Chart**, and can be reaccessed from the `.series` list
- **Series** objects contain a wealth of methods and fields to customize the appearance of the respective dataset. In particular:
 - `.smooth` - Boolean to specify whether the line should be smooth or not
 - `.marker.symbol` - The symbol to use for each point, ('circle', 'dash', 'diamond', 'dot', 'plus', 'square', 'star', 'triangle', 'x', 'auto')
 - `.graphicalProperties.line.noFill` - Boolean specifying whether to draw a line or not
 - `.marker.graphicalProperties.solidFill` - Hexcode for the marker color
 - `.graphicalProperties.line.width` - Line width
 - etc...

Series

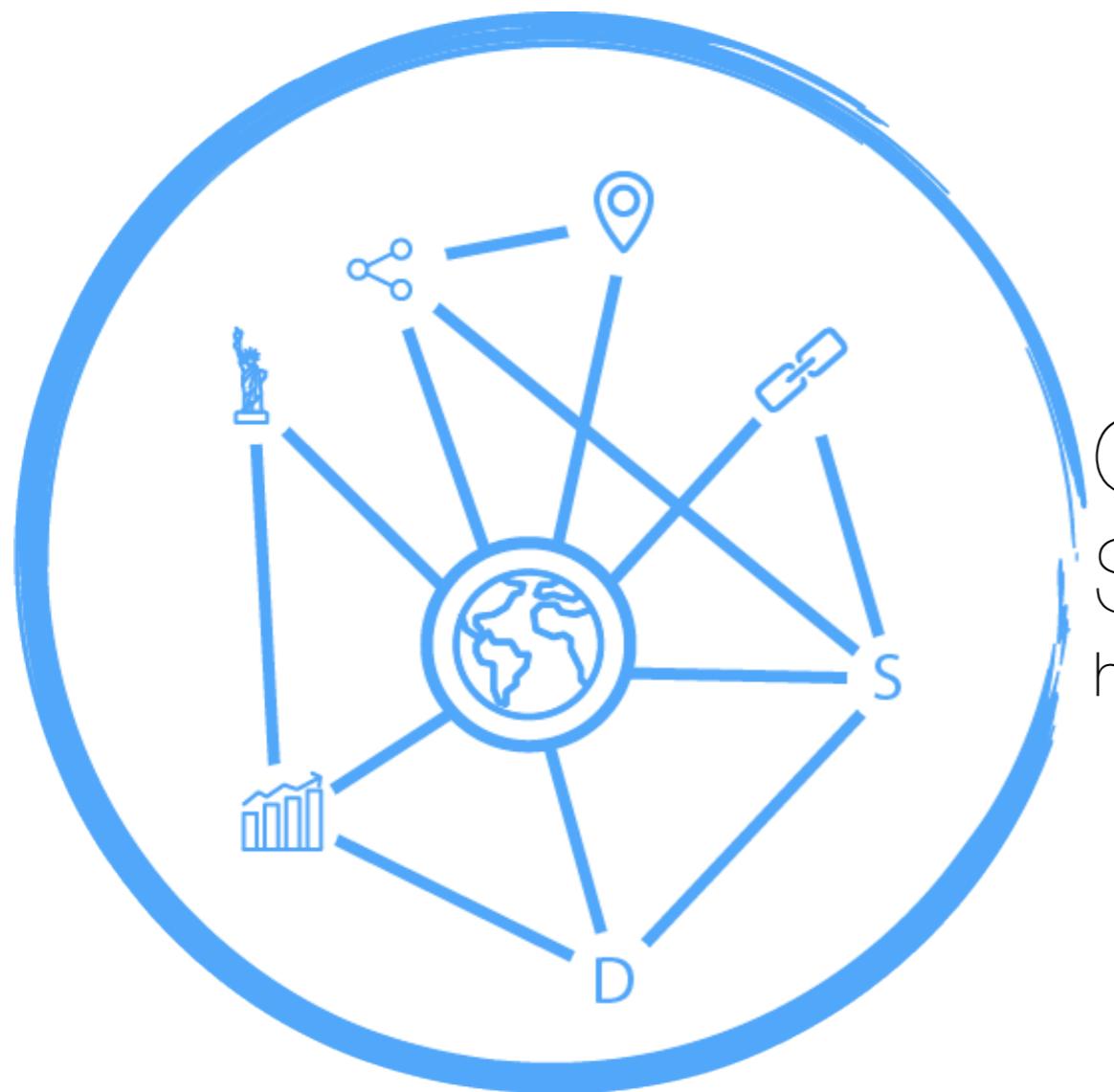
<https://openpyxl.readthedocs.io/en/stable/styles.html>

- By default, the **Series** contain just the y values and using the vector position for the x-value.
- To use specific values for the x-axis, we can create a **Series** "by-hand"
- **Series(ref_y, ref_x)** - where **ref_x** and **ref_y** are References to the x-values and the y-values, respectively
- **Series** can be added to a **Chart** using **.series.append()**. **Chart** behaves as if it were a list of **Series**

openpyxl has extensive support to styles.
You should explore the documentation!

Pandas support

- `openpyxl` was designed with `pandas` in mind, and provides us with some pandas specific functionality to help us integrate both.
- The function `dataframe_to_rows()`, inside the module `openpyxl.utils.dataframe` provides a convenient way to convert `DataFrame` values to `Worksheet` rows by returning an integrator over the `DataFrame` rows.
 - `index=True` - Include the `DataFrame` index
 - `header=True` - Include the `DataFrame` column names

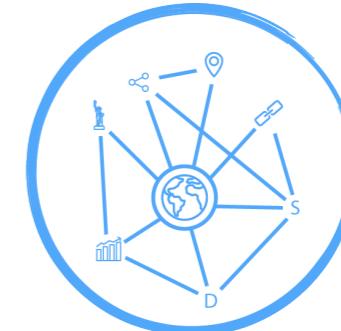


Code - Advanced Excel
Spreadsheets
<https://github.com/DataForScience/Excel>

Events



<http://paypal.me/data4sci>



www.data4sci.com/newsletter

Graphs and Network Algorithms for Everyone

<https://graphs4sci.substack.com/> - Blog

Mar 9, 2021 - 5am-9am (PST)

Why and What If – Causal Analysis for Everyone

Mar 25, 2021 - 5am-9am (PST)

Data Visualization with matplotlib and seaborn for Everyone

Apr 8, 2021 - 5am-9am (PST)

Deep Learning for Everyone

Apr 22, 2021 - 5am-9am (PST)



Natural Language Processing (NLP) from Scratch

<http://bit.ly/LiveLessonNLP> - On Demand