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# Data Scientist Path - Python

## Dataquest

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By

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## Prelude

This set of notes tracks my journey through DataQuests' *Data Scientist Path* module with Python. These notes are one of many that I have decided to polish and make available for anyone interested. One of the benefits of this series are having a compendium of definitions, examples and personal thoughts that I can always refer back to if I need a reminder on a particular topic. In addition, I find that this medium reduces the search time for specific definitions, theorems, examples etc and thus aids in reinforcing my own knowledge when frequented. The act of writing also works as a ritual in helping to encode information within my brain.

In these notes, I have provided many definitions and examples that I have encountered through the *Data Scientist* module on Dataquest. We will now outline their brief summaries:

- §1: **Data Analysis and Visualization** goes over the fundamentals of the Python Pandas and NumPy modules. I also provide details on Data Exploration and Visualization and how to do this in Python.

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# 1 Data Analysis and Visualization

## 1.1 Pandas and NumPy Fundamentals

### 1.1.1 Introduction to NumPy

- CSV: Open, Read etc
- `NdArray.shape`
- Selecting rows/columns from an array
- `NdArray` Arithmetic: Addition, Subtraction, Multiplication, Division
- `NdArray` Methods: Mean, min, max, sum
- Overlap with Numpy Functions and Methods

#### Definition 1.1: NumPy Library

*NumPy is the fundamental package for scientific computing with Python. It contains among other things:*

- A powerful  $N$ -dimensional array object.
- Sophisticated (broadcasting) functions.
- Tools for integrating C/C++ and Fortran code.
- Useful linear algebra, Fourier transform, and random number capabilities

*Besides its obvious scientific uses, NumPy can also be used as an efficient multi-dimensional container of generic data. Arbitrary data-types can be defined. This allows NumPy to seamlessly and speedily integrate with a wide variety of databases.*

#### Definition 1.2: NdArray

```
class numpy.ndarray(shape, dtype=float, buffer=None, offset=0, strides=None,
order=None)
```

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using `array`, `zeros` or `empty` (refer to the See Also section below). The parameters given here refer to a low-level method (`ndarray(...)`) for instantiating an array.

#### PARAMETERS

**shape** : tuple of ints  
Shape of created array.

**dtype** : data-type, optional  
Any object that can be interpreted as a numpy data type.

**buffer**: object exposing buffer interface, optional  
Used to fill the array with data.

**offset**: int, optional  
Offset of array data in buffer.

**strides** : tuple of ints, optional  
Strides of data in memory.

**order:** {'C', 'F'}, optional  
 Row-major (C-style) or column-major (Fortran-style) order.

### Definition 1.3: SIMD

**Single instruction, multiple data (SIMD)** is a class of parallel computers in Flynn's taxonomy. It describes computers with multiple processing elements that perform the same operation on multiple data points simultaneously. Such machines exploit data level parallelism, but not concurrency: there are simultaneous (parallel) computations, but only a single process (instruction) at a given moment.

### Definition 1.4: Slice Object

**class slice(start, stop, step)**

Return a slice object representing the set of indices specified by range(start, stop, step). The start and step arguments default to None. Slice objects have read-only data attributes start, stop and step which merely return the argument values (or their default).

## Ndarray Indexing

Ndarrays can be indexed using the standard Python `x[obj]` syntax, where `x` is the array and `obj` the selection. There are three kinds of indexing available: field access, basic slicing, advanced indexing. Which one occurs depends on `obj`.

Basic slicing extends Python's basic concept of slicing to `N` dimensions. Basic slicing occurs when `obj` is a slice object (constructed by `start:stop:step` notation inside of brackets), an integer, or a tuple of slice objects and integers. Ellipsis and `newaxis` objects can be interspersed with these as well.

### 1.1.2 Boolean Indexing with NumPy

- `genfromtxt` function
- NaN (Not a number)
- Boolean Arrays
- Boolean Indexing
- Assigning values to NdArrays with Indexing

### Definition 1.5: Numpy `genfromtxt()`

`numpy.genfromtxt(fname, dtype=<class 'float'>, comments='#', delimiter=None, skip_header=0)`

Load data from a text file, with missing values handled as specified.

Each line past the first `skip_header` lines is split at the delimiter character, and characters following the comments character are discarded. For further parameters and documentation, see [1].

#### PARAMETERS

**fname:** file, str, `pathlib.Path`, list of str, generator.

File, filename, list, or generator to read. If the filename extension is `gz` or `bz2`, the file is first decompressed. Note that generators must return byte strings in Python 3k. The strings in a list or produced by a generator

are treated as lines.

***dtype***: dtype, optional.

Data type of the resulting array. If None, the dtypes will be determined by the contents of each column, individually.

***comments***: str, optional.

The character used to indicate the start of a comment. All the characters occurring on a line after a comment are discarded.

***delimiter***: str, int, or sequence, optional.

The string used to separate values. By default, any consecutive whitespaces act as delimiter. An integer or sequence of integers can also be provided as width(s) of each field.

***skip\_header***: int, optional.

The number of lines to skip at the beginning of the file.

### Definition 1.6: Numpy nan

*numpy.nan*

Python constant. IEEE 754 floating point representation of Not a Number (NaN).

NaN and NAN are equivalent definitions of nan. Please use nan instead of NAN.

### 1.1.3 Introduction to Pandas

- Dataframe Methods: Head, Tail, Info, Loc
- Series object
- Selecting Columns/Rows in a Dataframe

### Definition 1.7: Pandas Library

Pandas is an open source, BSD-licensed library providing high-performance, easy-to-use data structures and data analysis tools for the Python programming language. Some key features of the library include:

- A fast and efficient *DataFrame* object for data manipulation with integrated indexing.
- Tools for reading and writing data between in-memory data structures and different formats: CSV and text files, Microsoft Excel, SQL databases, and the fast *HDF5* format.
- Intelligent data alignment and integrated handling of missing data: gain automatic label-based alignment in computations and easily manipulate messy data into an orderly form.

### Definition 1.8: Dataframe

***class*** `pandas.DataFrame(data=None, index=None, columns=None, dtype=None, copy=False)`

Two-dimensional size-mutable, potentially heterogeneous tabular data structure with labeled axes (rows and columns). Arithmetic operations align on both row and column labels. Can be thought of as a dict-like container for Series objects. The primary pandas data structure. For a list of methods and further documentation, see [2].

**PARAMETERS**

**data:** ndarray (structured or homogeneous), Iterable, dict, or DataFrame.

Dict can contain Series, arrays, constants, or list-like objects.

Changed in version 0.23.0: If data is a dict, column order follows insertion-order for Python 3.6 and later.

Changed in version 0.25.0: If data is a list of dicts, column order follows insertion-order for Python 3.6 and later.

**index:** Index or array-like.

Index to use for resulting frame. Will default to RangeIndex if no indexing information part of input data and no index provided.

**columns:** Index or array-like.

Column labels to use for resulting frame. Will default to RangeIndex (0, 1, 2,..., n) if no column labels are provided.

**dtype:** dtype, default None.

Data type to force. Only a single dtype is allowed. If None, infer.

**copy:** boolean, default False.

Copy data from inputs. Only affects DataFrame / 2d ndarray input

**Example 1.1: Pandas Dataframe**

In vanilla numpy, our arrays must house elements of the same data type. Pandas extends this by allowing for multiple data types.

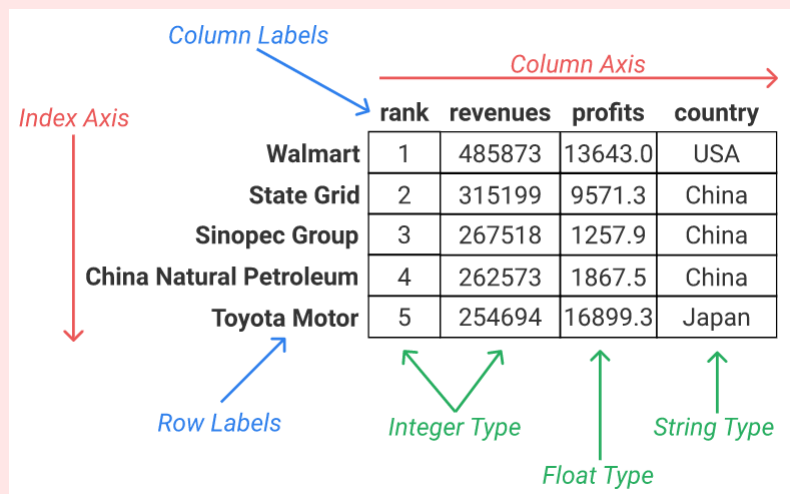


Figure 1.1: Pandas Dataframe

**Definition 1.9: File-like Object (Pandas)**

By file-like object, we refer to objects with a `read()` method, such as a file handler (e.g. via builtin `open` function) or `StringIO`.



**Definition 1.10: Pandas read\_csv()**

```
pandas.read_csv(filepath_or_buffer, sep=',', delimiter=None, header='infer',
names=None, index_col=None)
```

Read a comma-separated values (csv) file into DataFrame. Also supports optionally iterating or breaking of the file into chunks. There are much more parameters available for this function, see documentation [3].

**PARAMETERS**

**filepath\_or\_buffer** : str, path object or file-like object.

Any valid string path is acceptable. The string could be a URL. Valid URL schemes include http, ftp, s3, and file. For file URLs, a host is expected. A local file could be: file://localhost/path/to/table.csv. If you want to pass in a path object, pandas accepts any os.PathLike.

**sep**: str, default ','.

Delimiter to use. If sep is None, the C engine cannot automatically detect the separator, but the Python parsing engine can, meaning the latter will be used and automatically detect the separator by Python's builtin sniffer tool, csv.Sniffer.

**delimiter**: str, default None. Alias for sep.

**header**: int, list of int, default 'infer'.

Row number(s) to use as the column names, and the start of the data. Default behavior is to infer the column names: if no names are passed the behavior is identical to header=0 and column names are inferred from the first line of the file, if column names are passed explicitly then the behavior is identical to header=None. Explicitly pass header=0 to be able to replace existing names. The header can be a list of integers that specify row locations for a multi-index on the columns e.g. [0,1,3]. Intervening rows that are not specified will be skipped (e.g. 2 in this example is skipped). Note that this parameter ignores commented lines and empty lines if skip\_blank\_lines=True, so header=0 denotes the first line of data rather than the first line of the file.

**names**: array-like, optional.

List of column names to use. If file contains no header row, then you should explicitly pass header=None. Duplicates in this list are not allowed.

**index\_col**: int, str, sequence of int / str, or False, default None.

Column(s) to use as the row labels of the DataFrame, either given as string name or column index. If a sequence of int / str is given, a MultiIndex is used.

**Definition 1.11: Series**

```
class pandas.Series(data=None, index=None, dtype=None, name=None, copy=False,
fastpath=False)
```

One-dimensional ndarray with axis labels (including time series).

Labels need not be unique but must be a hashable type. The object supports both integer- and label-based indexing and provides a host of methods for performing operations involving the index. Statistical methods from ndarray have been overridden to automatically exclude missing data (currently represented as NaN). For further methods and documentation, see [4].

Operations between Series (+, -, /, \*) align values based on their associated index values— they need not be the same length. The result index will be the sorted union of the two indexes.

#### PARAMETERS

**data:** array-like, Iterable, dict, or scalar value.

Contains data stored in Series.

Changed in version 0.23.0: If data is a dict, argument order is maintained for Python 3.6 and later.

**index:** array-like or Index (1d).

Values must be hashable and have the same length as data. Non-unique index values are allowed. Will default to RangeIndex (0, 1, 2, .., n) if not provided. If both a dict and index sequence are used, the index will override the keys found in the dict.

**dtype:** str, numpy.dtype, or ExtensionDtype, optional.

Data type for the output Series. If not specified, this will be inferred from data. See the user guide for more usages.

**copy:** bool, default False.

Copy input data.

### Example 1.2: Dataframe Indexing

Let *df* denote a Dataframe. Then, we can select some subset of the dataframe's columns via the following syntax:

Select by Label	Explicit Syntax	Common Shorthand
Single column	<code>df.loc[:, "col1"]</code>	<code>df["col1"]</code>
List of columns	<code>df.loc[:, ["col1", "col7"]]</code>	<code>df[["col1", "col7"]]</code>
Slice of columns	<code>df.loc[:, "col1": "col4"]</code>	

Figure 1.2: Indexing a Dataframe's Columns

### Example 1.3: Series Indexing

Let *s* denote a Series. Then, we can select some subset of the series rows via the following syntax:

Select by Label	Explicit Syntax	Shorthand Convention
Single item from series	<code>s.loc["item8"]</code>	<code>s["item8"]</code>
List of items from series	<code>s.loc[["item1", "item7"]]</code>	<code>s[["item1", "item7"]]</code>
Slice of items from series	<code>s.loc["item2": "item4"]</code>	<code>s["item2": "item4"]</code>

Figure 1.3: Series Item(s) Selection

Select by Label	Explicit Syntax	Shorthand Convention
Single column from dataframe	<code>df.loc[:, "col1"]</code>	<code>df["col1"]</code>
List of columns from dataframe	<code>df.loc[:, ["col1", "col7"]]</code>	<code>df[["col1", "col7"]]</code>
Slice of columns from dataframe	<code>df.loc[:, "col1": "col4"]</code>	
Single row from dataframe	<code>df.loc["row4"]</code>	
List of rows from dataframe	<code>df.loc["row1", "row8"]</code>	
Slice of rows from dataframe	<code>df.loc["row3": "row5"]</code>	<code>df["row3": "row5"]</code>
Single item from series	<code>s.loc["item8"]</code>	<code>s["item8"]</code>
List of items from series	<code>s.loc["item1", "item7"]</code>	<code>s[["item1", "item7"]]</code>
Slice of items from series	<code>s.loc["item2": "item4"]</code>	<code>s["item2": "item4"]</code>

Figure 1.4: Summary of Dataframe / Series Item Selection

### 1.1.4 Exploring Data with Pandas: Fundamentals

- Dataframe Assignment
- Boolean Indexing with Dataframes
- New Columns in Dataframes

#### Pandas Arithmetic with Series

*Because pandas is designed to operate like NumPy, a lot of concepts and methods from Numpy are supported. Recall that one of the ways NumPy makes working with data easier is with vectorized operations, or operations applied to multiple data points at once.*

*Just like with NumPy, we can use any of the standard Python numeric operators with series, including:*

- `series_a + series_b`: Addition
- `series_a - series_b`: Subtraction
- `series_a * series_b`: Multiplication (Element-wise)
- `series_a / series_b`: Division (Element-wise)

#### Definition 1.12: Method Chaining

*Method chaining, also known as named parameter idiom, is a common syntax for invoking multiple method calls in object-oriented programming languages. Each method returns an object, allowing the calls to be chained together in a single statement without requiring variables to store the intermediate results.*

#### Useful Dataframe Methods

- `df.describe()`: Generate descriptive statistics that summarize the central tendency, dispersion and shape of a dataset's distribution, excluding NaN values.
- `df.mean()`: Return the mean of the values for the requested axis.
- `df.rename()`: Alter axes labels. Function / dict values must be unique (1-to-1). Labels not contained in a dict / Series will be left as-is. Extra labels listed don't throw an error.

### 1.1.5 Exploring Data with Pandas: Intermediate

- Dataframe iloc indexing
- Boolean Operators; Combining Boolean Arrays
- Dataframe sort\_values method

Select by integer position	Explicit Syntax	Shorthand Convention
Single column from dataframe	<code>df.iloc[:,3]</code>	
List of columns from dataframe	<code>df.iloc[:,[3,5,6]]</code>	
Slice of columns from dataframe	<code>df.iloc[:,3:7]</code>	
Single row from dataframe	<code>df.iloc[20]</code>	
List of rows from dataframe	<code>df.iloc[[0,3,8]]</code>	
Slice of rows from dataframe	<code>df.iloc[3:5]</code>	<code>df[3:5]</code>
Single items from series	<code>s.iloc[8]</code>	<code>s[8]</code>
List of item from series	<code>s.iloc[[2,8,1]]</code>	<code>s[[2,8,1]]</code>
Slice of items from series	<code>s.iloc[5:10]</code>	<code>s[5:10]</code>

Figure 1.5: Dataframe Integer Indexing

pandas	Python equivalent	Meaning
<code>a &amp; b</code>	<code>a and b</code>	<code>True</code> if both <code>a</code> and <code>b</code> are <code>True</code> , else <code>False</code>
<code>a   b</code>	<code>a or b</code>	<code>True</code> if either <code>a</code> or <code>b</code> is <code>True</code>
<code>~a</code>	<code>not a</code>	<code>True</code> if <code>a</code> is <code>False</code> , else <code>False</code>

Figure 1.6: Boolean Operators in Pandas

### 1.1.6 Data Cleaning Basics

- Data Encoding
- Dataframe Column Cleaning
- Dataframe Text to Numeric Cleaning
- Series.astype() method

#### Example 1.4: Cleaning Column Names

The column labels have a variety of upper and lowercase letters, as well as parentheses, which will make them harder to work with and read. We aim to clean our column labels by using several python string methods that will:

- Replace spaces with underscores.
- Remove special characters.
- Make all labels lowercase.
- Shorten any long column names. (Specifically changing 'Operating System' to 'os')

# CB 1.1.1 #

```

import pandas as pd
laptops = pd.read_csv('laptops.csv', encoding='Latin-1')

def mr_clean(s):
    s = s.strip()
    s = s.replace("Operating_System", "os")
    s = s.replace("_", "-")
    s = s.replace('"', "")
    s = s.replace("(", "")
    sfinal = s.lower()

    return sfinal

new_columns = []
for col in laptops.columns:
    new_columns.append(mr_clean(col))

laptops.columns = new_columns

```

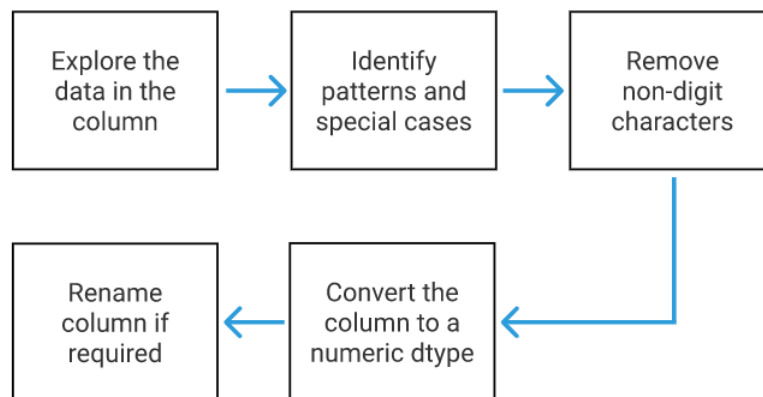


Figure 1.7: Text to Numeric Data Workflow

**Example 1.5: Cleaning Text into Numerical Data**

We now consider the column for *ram* data. Exploring this column, we find a clear pattern that all stored values are strings of integers with the character 'GB' at the end of the string:

```
['8GB', '16GB', '4GB', '8GB', '32GB', '4GB', '8GB', '2GB']
```

Naturally, we want to modify the data type stored in this column so that we can easily manipulate it numerically (such as computing statistics). To do this, we'll remove the GB from the string and then recast the remaining integer-string to an integer.

# CB 1.1.2 #

```

laptops["ram"] = laptops["ram"].str.replace('GB', '').astype(int)
laptops.rename({"ram": "ram_gb"}, axis=1, inplace = True)

```

```
ram_gb_desc = laptops['ram_gb'].describe()
```

### Example 1.6: Extracting Data from Text

```
print(laptops["cpu"].head())
```

0	Intel Core i5 2.3GHz
1	Intel Core i5 1.8GHz
2	Intel Core i5 7200U 2.5GHz
3	Intel Core i7 2.7GHz
4	Intel Core i5 3.1GHz

```
Name: cpu, dtype: object
```

Figure 1.8: First 5 entries of the Laptops['cpu'] column

We can observe that the CPU column in Figure 1.8 contains several pieces of information. They all appear to express the manufacturer and then model. Naturally, we want to break this apart so that we can organize it according to manufacturer and model. We use the fact spaces separate key pieces of information, allowing us to use the `split()` method to construct a list of strings. Selecting the first element out of this list would give us the manufacturer. Constructing a new `cpu_manufacturer` column is therefore achieved with the following code:

```
# CS 1.1.3 #
```

```
laptops["cpu_manufacturer"] = (laptops["cpu"]
                               .str.split()
                               .str[0]
                               )
```

The parenthesis are included so that one line of code can be expressed on multiple lines. This is done for readability purposes.

### Definition 1.13: Pandas Series.map()

*Series.map(self, arg, na\_action=None)*

Map values of Series according to input correspondence. Used for substituting each value in a Series with another value, that may be derived from a function, a dict or a Series. When `arg` is a dictionary, values in Series that are not in the dictionary (as keys) are converted to NaN. However, if the dictionary is a dict subclass that defines `__missing__` (i.e. provides a method for default values), then this default is used rather than NaN. For further documentation, see [5].

#### PARAMETERS

**arg:** function, dict, or Series.

Mapping correspondence.

**na\_action:** None, 'ignore', default None.

If 'ignore', propagate NaN values, without passing them to the mapping correspondence.

**Example 1.7: Who Needs A Map?**

Let  $s$  be a series containing fruit names. We note that  $s$  currently contains incorrectly spelt fruit names. Printing the series gives us a display of that incorrect spelling.

```
# CS 1.1.4 #
```

```
print(s)
```

Output:

```
0      pair
1     oranje
2   bannana
3     oranje
4     oranje
5     oranje
dtype: object
```

Hence, to fix the problem seen in CS 1.1.4, we define a dictionary called *corrections* that will be fed into the argument of the `map()` method. For each string that appears in the dictionary argument, it will be mapped to the corresponding value of that dictionary argument. For instance,  $pair \mapsto pear$ .

```
# CS 1.1.5 #
```

```
corrections = {
    "pair": "pear",
    "oranje": "orange",
    "bananna": "banana"
}
s = s.map(corrections)
print(s)
```

Output:

```
0      pear
1     orange
2     banana
3     orange
4     orange
5     orange
dtype: object
```

**Handling Null Values**

In pandas, null values will be indicated by either **NaN** or **None**. There are a few main options for handling missing values:

- Remove any rows that have missing values.
- Remove any columns that have missing values.
- Fill the missing values with some other values.
- Leave the missing values as is.

The first two options are often used to prepare data for machine learning algorithms, which are unable to

be used with data that includes null values. We can use the `DataFrame.dropna()` method to remove or drop rows and columns with null values.

### Example 1.8: Cleaning the Weight Column

In this example, the weights column is filled with strings of numeric values followed by a *kg* or *kgs* string that needs to be removed. After both these strings are removed, we recast the entries as floats.

*# CS 1.1.6 #*

```
laptops["weight"] = laptops["weight"].str.replace("kg","")
laptops["weight"] = laptops["weight"].str.replace("s","").astype(float)

laptops.rename({"weight": "weight_kg"}, axis=1, inplace = True)

laptops.to_csv('laptops_cleaned.csv', index=False)
```

A subtlety in the above approach is that once *kg* is removed, all entries that contained '*Xkgs*' now contain '*Xs*' (*X* denotes a numeric value), hence why I use the `replace("s","")` argument. In addition, I have to recast as float with the `astype()` method on the second line due to the weight column still containing '*Xs*' entries after the first `replace()` call.

## 1.2 Exploratory Data Visualization

### 1.2.1 Line Charts

#### Definition 1.14: Data Visualization

Data visualization is the graphical representation of information and data. By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data.

#### Definition 1.15: Matplotlib Library

Matplotlib is a Python 2D plotting library which produces publication quality figures in a variety of hardcopy formats and interactive environments across platforms. Matplotlib can be used in Python scripts, the Python and IPython shells, the Jupyter notebook, web application servers, and four graphical user interface toolkits. The library allows us to:

- Quickly create common plots using high-level functions.
- Extensively tweak plots.
- Create new kinds of plots from the ground up.

Matplotlib tries to make easy things easy and hard things possible. You can generate plots, histograms, power spectra, bar charts, error charts, scatter plots, etc., with just a few lines of code.

When working with commonly used plots in matplotlib, the general workflow is:

- Create a plot using data.
- Customize the appearance of the plot.
- Display the plot.
- Edit and repeat until satisfied.



**Definition 1.16: Pyplot Module***matplotlib.pyplot**Provides a MATLAB-like plotting framework.***Definition 1.17: Plot() Function***matplotlib.pyplot.plot(\*args, scalex=True, scaley=True, data=None, \*\*kwargs)**Plot y versus x as lines and/or markers.***PARAMETERS:****x, y:** array-like or scalar.*The horizontal / vertical coordinates of the data points. x values are optional and default to range(len(y)).**Commonly, these parameters are 1D arrays.**They can also be scalars, or two-dimensional (in that case, the columns represent separate data sets).***fmt:** str, optional.*A format string, e.g. 'ro' for red circles. See the Notes section for a full description of the format strings. Format strings are just an abbreviation for quickly setting basic line properties. All of these and more can also be controlled by keyword arguments.***data:** indexable object, optional.*An object with labelled data. If given, provide the label names to plot in x and y.***Returns:***lines - A list of Line2D objects representing the plotted data.***Example 1.9: Plotting Monthly Unemployment Trends in 1948**

# CB 1.2.1 #

```
import matplotlib.pyplot as plt
import pandas as pd
```

```
unrate = pd.read_csv('unrate.csv')
```

```
plt.plot(unrate['DATE'].head(12), unrate['VALUE'].head(12))
plt.xticks(rotation = 90)
plt.xlabel("Month")
plt.ylabel("Unemployment_Rate")
plt.title("Monthly_Unemployment_Trends,_1948")
plt.show()
```

Output:

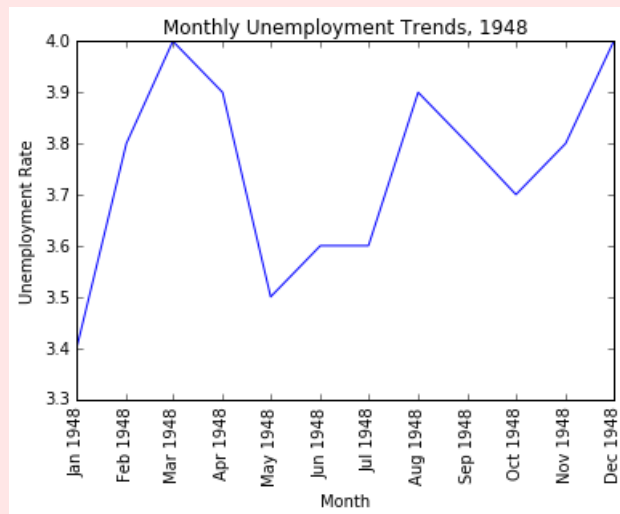


Figure 1.9: Monthly Unemployment Trends, 1948

One can notice that we didn't assign the plot in Example 1.9 to a variable and then call a method on the variable to display it. We instead called the functions `plot()`, `show()` on the pyplot module directly.

This is because every time we call a pyplot function, the module maintains and updates the plot internally (also known as state). When we call `show()`, the plot is displayed and the internal state is destroyed. While this workflow isn't ideal when we're writing functions that create plots on a repeated basis as part of a larger application, it's useful when exploring data.

### 1.2.2 Multiple Plots

When we want to work with multiple plots, however, we need to be more explicit about which plot we're making changes to. This means we need to understand the matplotlib classes that pyplot uses internally to maintain state so we can interact with them directly. Let's first start by understanding what pyplot was automatically storing under the hood when we create a single plot:

- A container for all plots was created (returned as a Figure object)
- A container for the plot was positioned on a grid (the plot returned as an Axes object)
- Visual symbols were added to the plot (using the Axes methods)

#### Definition 1.18: Pyplot Figure Function

`matplotlib.pyplot.figure(num=None, figsize=None, dpi=None, facecolor=None, frameon=True, clear=False, **kwargs)`

Create a new figure. For further documentation, see [6].

#### PARAMETERS:

**num:** integer or string, optional, default: None.

If not provided, a new figure will be created, and the figure number will be incremented. The figure object holds this number in a number attribute. If num is provided, and a figure with this id already exists, make it active, and returns a reference to it. If this figure does not exist, create it and returns it. If num is a string, the window title will be set to this figure's num.

**figsize:** (float, float), optional, default: None.

Width, height in inches. If not provided, defaults to `rcParams["figure.figsize"] = [6.4, 4.8]`.

**dpi:** integer, optional, default: None.

Resolution of the figure. If not provided, defaults to `rcParams["figure.dpi"] = 100.0 = 100`.

**facecolor:** color spec.

The background color. If not provided, defaults to `rcParams["figure.facecolor"] = 'white' = 'w'`.

**frameon:** bool, optional, default: True.

If False, suppress drawing the figure frame.

**clear:** bool, optional, default: False

If True and the figure already exists, then it is cleared.

### Definition 1.19: Matplotlib Axes Class

```
class matplotlib.axes.Axes(fig, rect, facecolor=None, frameon=True, sharex=None, sharey=None, label="",
xscale=None, yscale=None, **kwargs)
```

The Axes contains most of the figure elements: Axis, Tick, Line2D, Text, Polygon, etc., and sets the coordinate system.

Build an axes in a figure. For further documentation, see [7].

#### PARAMETERS:

**fig:** Figure.

The axes is build in the Figure fig.

**rect:** [left, bottom, width, height]

The axes is build in the rectangle rect. rect is in Figure coordinates.

**sharex, sharey:** Axes, optional.

The x or y axis is shared with the x or y axis in the input Axes.

**frameon:** bool, optional.

True means that the axes frame is visible.

### Useful Matplotlib Methods

- `fig = plt.figure(figsize=(width, height))`
- `axes_obj = fig.add_subplot(nrows, ncols, plot_number)`

### Example 1.10: Plotting Monthly Unemployment Trends from 1948-1952 on Subplots

```
# CB 1.2.2 #
```

```
import matplotlib.pyplot as plt
import pandas as pd
```

```

unrate = pd.read_csv('unrate.csv')

fig = plt.figure(figsize=(12,12))

axes = []
height = 5

for axnum in range(height):
    axes.append(fig.add_subplot(height,1,axnum+1))
    axes[axnum].plot(unrate['DATE'][axnum*12:(axnum+1)*12],
                    unrate['VALUE'][axnum*12:(axnum+1)*12])

plt.show()

```

Output:

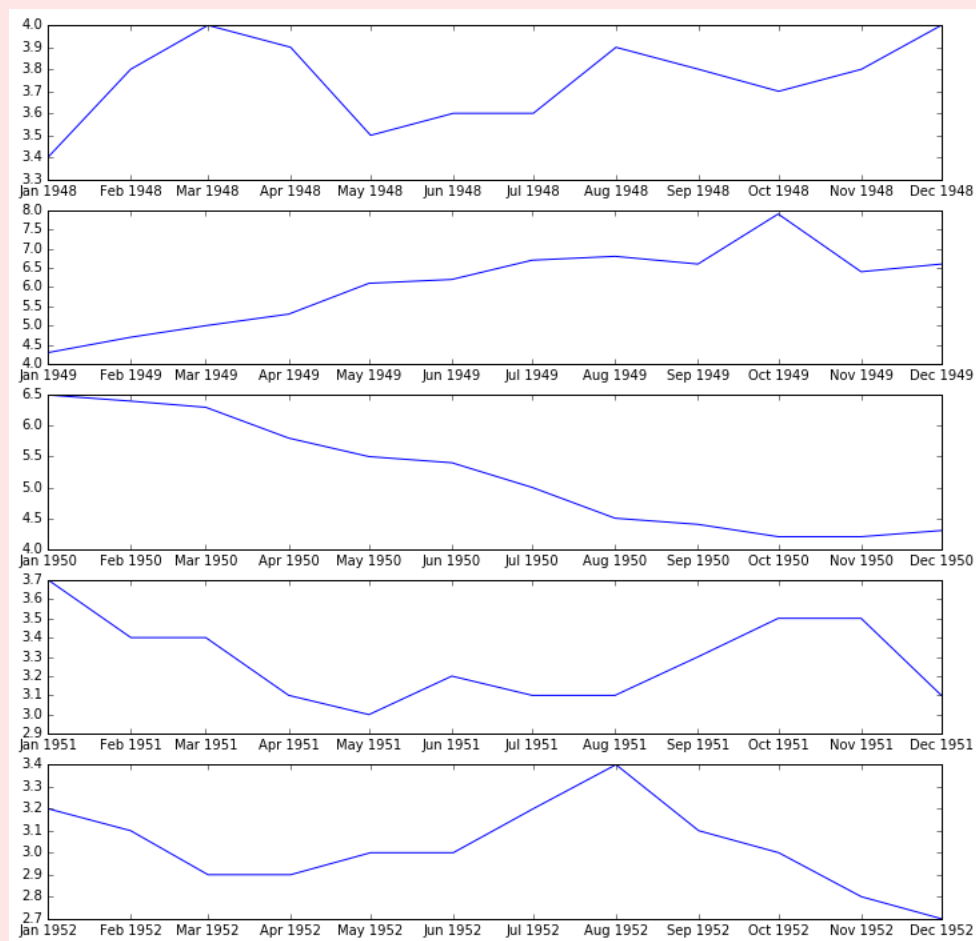


Figure 1.10: Monthly Unemployment Trends, 1948-1952 Subplots

**Example 1.11: Plotting Monthly Unemployment Trends from 1948-1952 on Base Plot**

```
# CB 1.2.3 #
```

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

```
import pandas as pd
```

```
unrate = pd.read_csv('unrate.csv')
```

```
fig = plt.figure(figsize=(10,6))
```

```
colors = ['red', 'blue', 'green', 'orange', 'black']
```

```
for i in range(5):
```

```
    start_index = i*12
```

```
    end_index = (i+1)*12
```

```
    subset = unrate[start_index:end_index]
```

```
    label = str(1948 + i)
```

```
    plt.plot(subset['MONIH'], subset['VALUE'], c=colors[i], label=label)
```

```
plt.title("Monthly Unemployment Trends, 1948-1952")
```

```
plt.xlabel("Month, Integer")
```

```
plt.ylabel("Unemployment Rate, Percent")
```

```
plt.legend(loc='upper left')
```

```
plt.show()
```

Output:

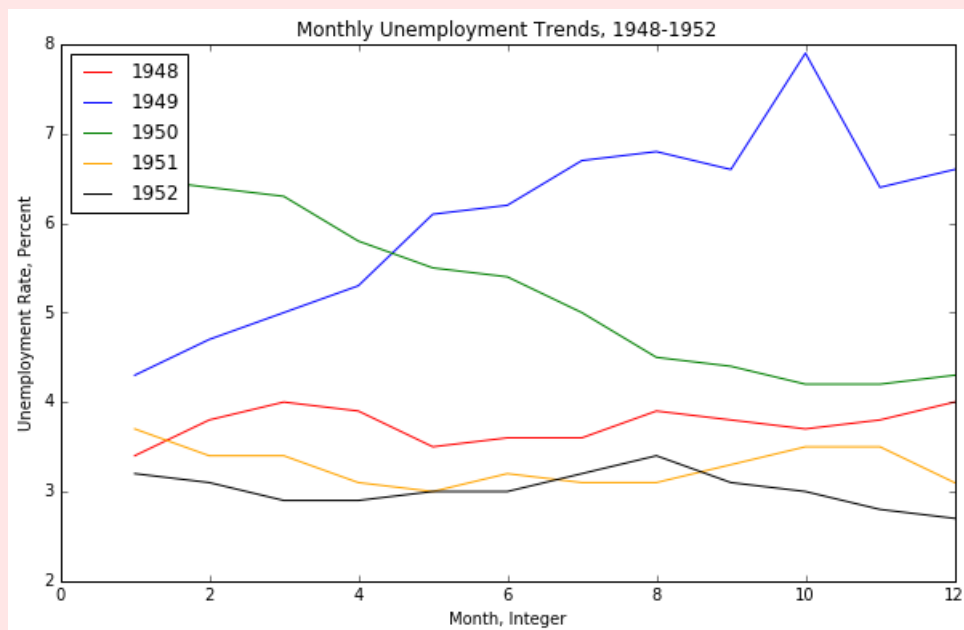


Figure 1.11: Monthly Unemployment Trends, 1948-1952

### 1.2.3 Bar and Scatter Plots

#### Example 1.12: Vertical Bar Plot for Age of Ultron Ratings

```
# CB 1.2.4 #
```

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

```
num_cols = ['RT_user_norm', 'Metacritic_user_norm', 'IMDB_norm',
            'Fandango_Ratingvalue', 'Fandango_Stars']
```

```
bar_heights = norm_reviews[num_cols].iloc[0].values
```

```
bar_positions = arange(5) + 0.75
```

```
tick_positions = range(1,6)
```

```
fig, ax = plt.subplots()
```

```
ax.bar(bar_positions, bar_heights, 0.5)
```

```
ax.set_xticks(tick_positions)
```

```
ax.set_xticklabels(num_cols, rotation=90)
```

```
ax.set_xlabel("Rating_Source")
```

```
ax.set_ylabel("Average_Rating")
```

```
ax.set_title("Average_User_Rating_For_Avengers:_Age_of_Ultron_(2015)")
```

```
plt.show()
```

Output:

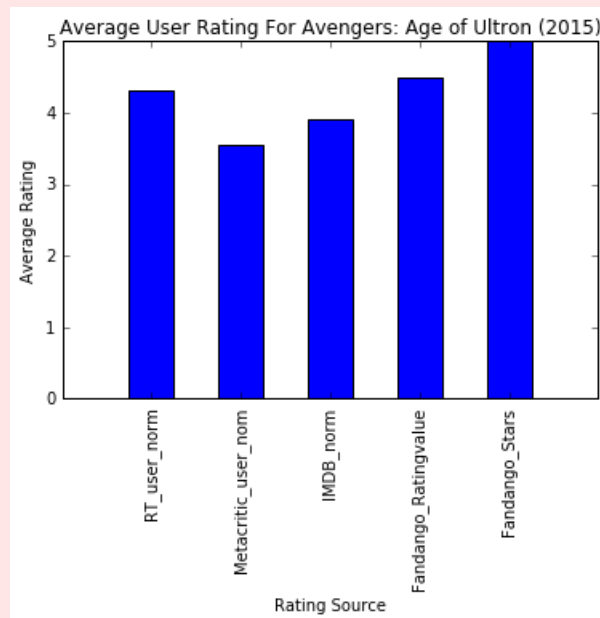


Figure 1.12: Vertical Bar Plot for Age of Ultron Ratings

**Example 1.13: Horizontal Bar Plot for Age of Ultron Ratings**

```
# CB 1.2.5 #
```

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

```
from numpy import arange
```

```
num_cols = ['RT_user_norm', 'Metacritic_user_nom', 'IMDB_norm',  
'Fandango_Ratingvalue', 'Fandango_Stars']
```

```
bar_widths = norm_reviews[num_cols].iloc[0].values
```

```
bar_positions = arange(5) + 0.75
```

```
tick_positions = range(1,6)
```

```
fig, ax = plt.subplots()
```

```
ax.barh(bar_positions, bar_widths, 0.5)
```

```
ax.set_yticks(tick_positions)
```

```
ax.set_yticklabels(num_cols)
```

```
ax.set_ylabel("Rating_Source")
```

```
ax.set_xlabel("Average_Rating")
```

```
ax.set_title("Average_User_Rating_For_Avengers:_Age_of_Ultron_(2015)")
```

```
plt.show()
```

Output:

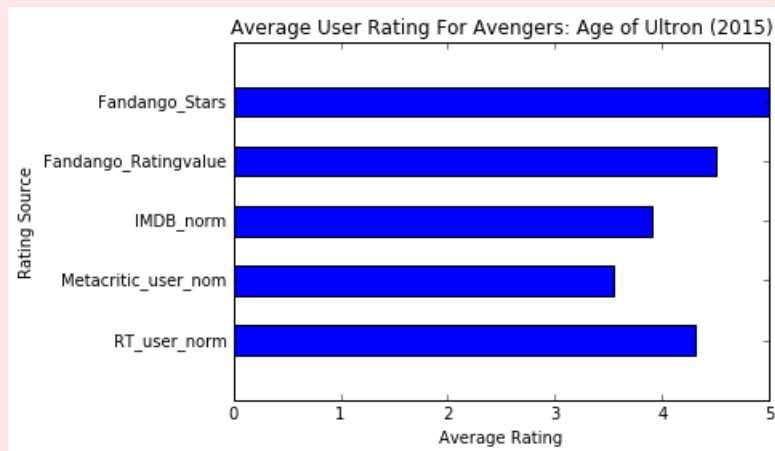


Figure 1.13: Horizontal Bar Plot for Age of Ultron Ratings

**Example 1.14: Scatter Plots for Movie Rating Sites vs Fandango**

```
# CB 1.2.6 #
```

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

```
fig = plt.figure(figsize=(5,10))
```

```
ax1 = fig.add_subplot(3,1,1)
```

```

ax2 = fig.add_subplot(3,1,2)
ax3 = fig.add_subplot(3,1,3)

axes = [ax1, ax2, ax3]

review_cols = ["RT_user_norm", "Metacritic_user_norm", "IMDB_norm"]
labels = ["Rotten_Tomatoes", "Metacritic", "IMDB"]

for i in range(3):
    axes[i].scatter(norm_reviews["Fandango_Ratingvalue"],
                    norm_reviews[review_cols[i]])
    axes[i].set_xlabel("Fandango")
    axes[i].set_ylabel(labels[i])
    axes[i].set_xlim(0,5)
    axes[i].set_ylim(0,5)

plt.show()

```

Output:

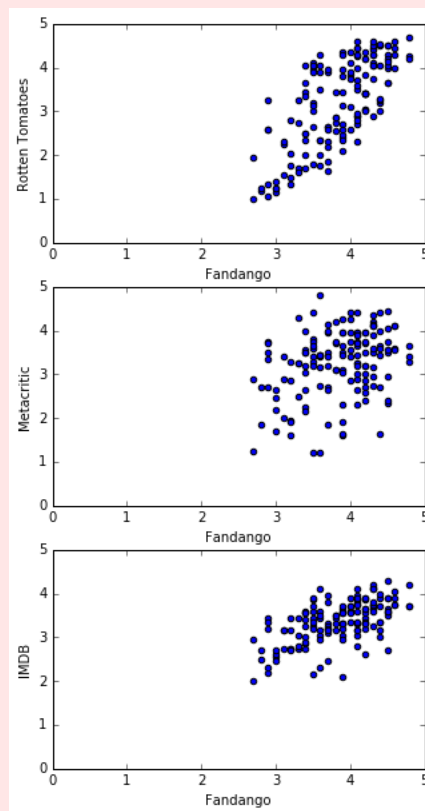


Figure 1.14: Scatter Plots among Movie Rating Sites



### 1.2.4 Histograms and Box Plots

#### Example 1.15: Movie Rating Distribution Histograms

```
# CB 1.2.7 #

import matplotlib.pyplot as plt

fig = plt.figure(figsize=(5,20))
ax1 = fig.add_subplot(4,1,1)
ax2 = fig.add_subplot(4,1,2)
ax3 = fig.add_subplot(4,1,3)
ax4 = fig.add_subplot(4,1,4)
axes = [ax1, ax2, ax3, ax4]

col_titles = ["Fandango", "Rotten_Tomatoes", "Metacritic", "IMDB"]
col_names = ['Fandango_Ratingvalue', 'RT_user_norm', 'Metacritic_user_nom',
'IMDB_norm']

for i in range(4):
    axes[i].hist(norm_reviews[col_names[i]], bins =20, range = (0,5))
    axes[i].set_title("Distribution_of_" + col_titles[i] + "_Ratings")
    axes[i].set_ylim(0,50)

plt.show()
```

Output:

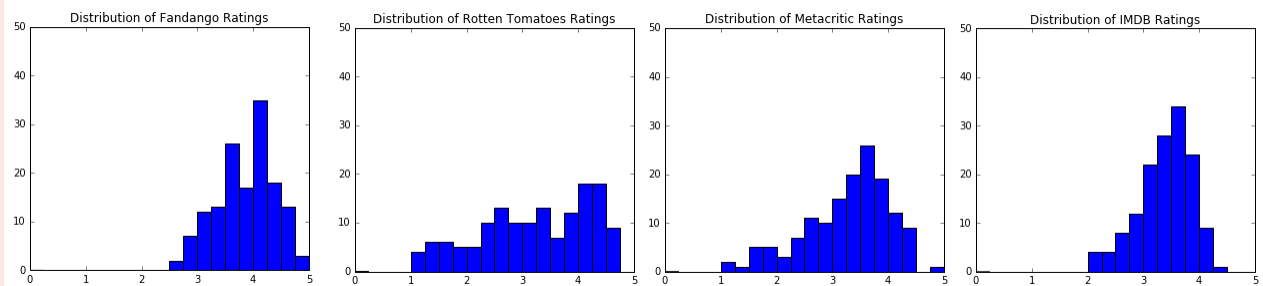


Figure 1.15: Movie Distribution Histogram Ratings

*! For the sake of visual aesthetic, I've placed the plots horizontally. They are normally outputted vertically<sup>a</sup> in the same order presented above (Fandango on top and IMDB on bottom).*

<sup>a</sup>In the same way as Figure 1.14.

#### Box Plot Quartiles

In descriptive statistics, a box plot or boxplot is a method for graphically depicting groups of numerical data through their quartiles. Box plots may also have lines extending vertically from the boxes (whiskers) indicating variability outside the upper and lower quartiles, hence the terms box-and-whisker plot and box-and-whisker diagram.

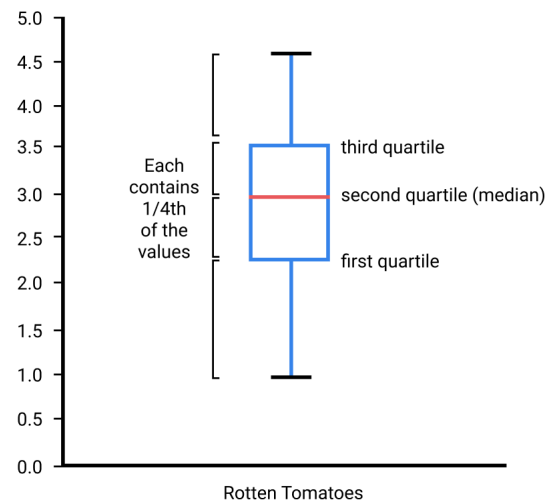


Figure 1.16: Box Plot Quartiles

We have graphically depicted an example of such a box plot in Figure 1.16 for the movie rating website Rotten Tomatoes.

### Example 1.16: Movie Rating Box Plots

```
# CB 1.2.8 #

num_cols = ['RT_user_norm', 'Metacritic_user_nom', 'IMDB_norm',
            'Fandango_Ratingvalue']

fig, ax = plt.subplots()

ax.boxplot(norm_reviews[num_cols].values)
ax.set_xticklabels(num_cols, rotation = 90)
ax.set_ylim(0,5)

plt.show()
```

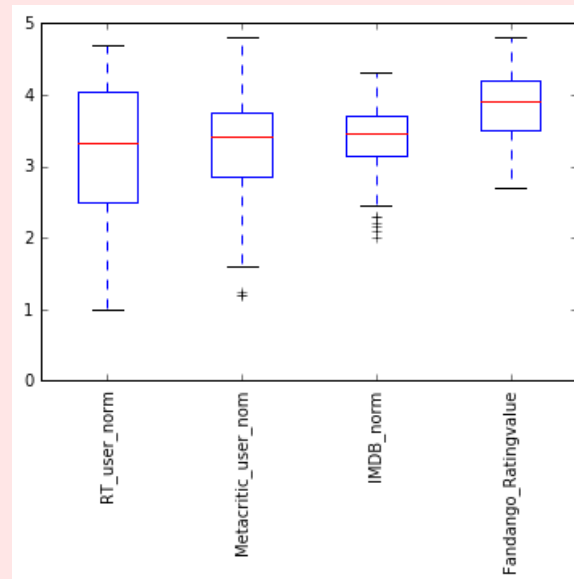


Figure 1.17: Movie Distribution Ratings Box Plot

### 1.2.5 Guided Project: Visualizing Majors Based on College Majors

Pandas has many methods for quickly generating common plots from data in DataFrames. Like pyplot, the plotting functionality in pandas is a wrapper for matplotlib. This means we can customize the plots when necessary by accessing the underlying Figure, Axes, and other matplotlib objects. For further documentation on visualization in Pandas, see [8].

#### Example 1.17: Pandas Plot on Male Dominated Undergrad Majors

*# CB 1.2.9 #*

```
import pandas as pd
import matplotlib.pyplot as plt

recent_grads = pd.read_csv('recent_grads.csv')
male_dominant = recent_grads[recent_grads['ShareWomen'] < 0.25]
male_dominant.plot(x = 'Major', y = 'ShareWomen',
title = 'Male-Dominated Majors', kind = 'bar', legend = None)
```

Output:

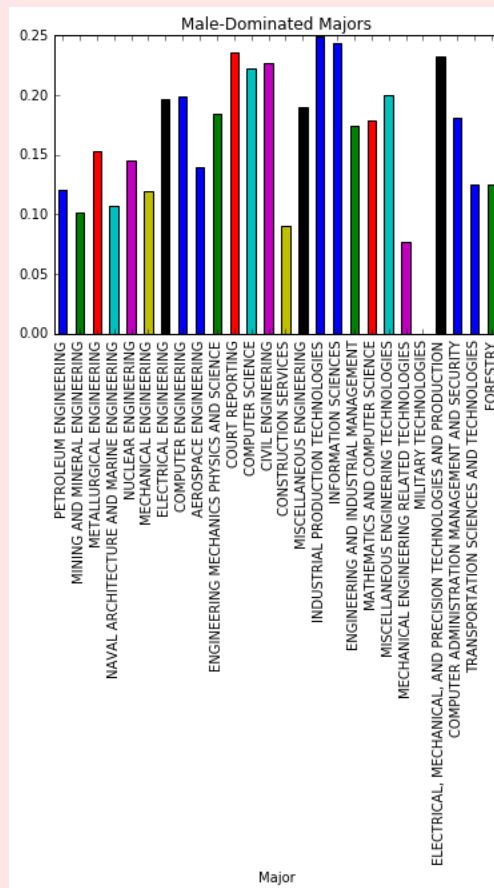


Figure 1.18: Male Dominated Majors

**Example 1.18: Scatter Matrix Plots**

# CB 1.2.10 #

```
import pandas as pd
import matplotlib.pyplot as plt
```

```
recent_grads = pd.read_csv('recent_grads.csv')
scatter_matrix(recent_grads[['Sample_size', 'Median']], figsize=(10,10))
```

Output:

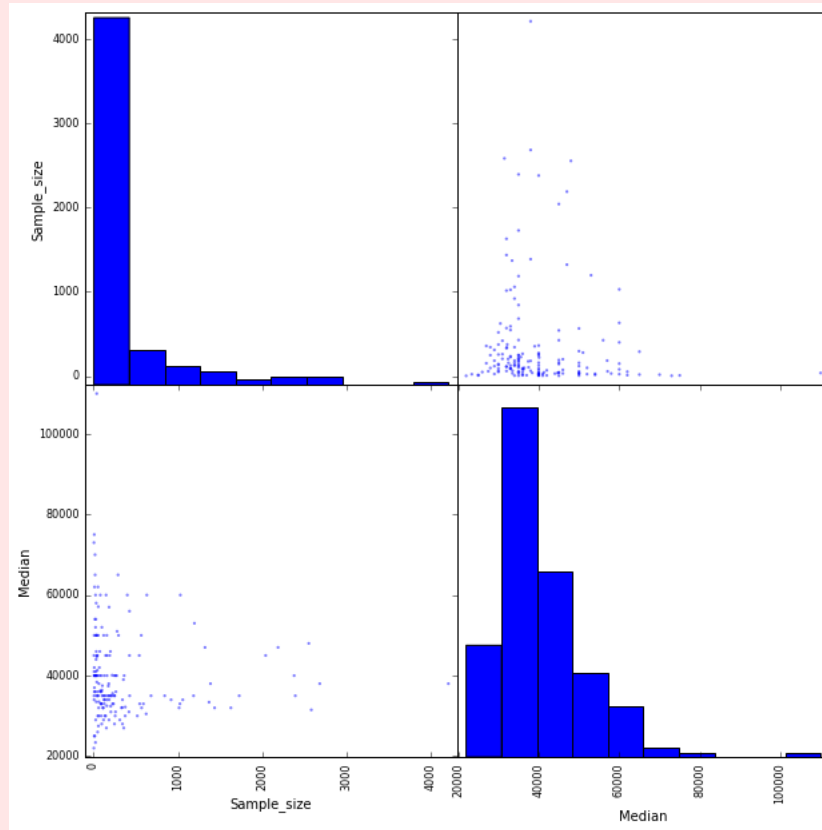


Figure 1.19: Scatter Matrix with 'Sample Size', 'Median' Columns

## 1.3 Storytelling Through Data Visualization

### 1.3.1 Improving Plot Aesthetics

#### Definition 1.20: Chartjunk

*Chartjunk refers to all visual elements in charts and graphs that are not necessary to comprehend the information represented on the graph, or that distract the viewer from this information.*

*Markings and visual elements can be called chartjunk if they are not part of the minimum set of visuals necessary to communicate the information understandably. Examples of unnecessary elements that might be called chartjunk include heavy or dark grid lines, unnecessary text, inappropriately complex or gimmicky font faces, ornamented chart axes, and display frames, pictures, backgrounds or icons within data graphs, ornamental shading and unnecessary dimensions.*

#### Example 1.19: Spine and Tick Removal

*With the axis tick marks gone, the data-ink ratio is improved and the chart looks much cleaner. In addition, the spines in the chart now are no longer necessary. When we're exploring data, the spines and the ticks complement each other to help us refer back to specific data points or ranges. When a viewer is viewing our chart and trying to understand the insight we're presenting, the ticks and spines can get in the way.*

```
# CB 1.3.1 #

import pandas as pd
import matplotlib.pyplot as plt

fig, ax = plt.subplots()
ax.plot(women_degrees['Year'], women_degrees['Biology'], label='Women')
ax.plot(women_degrees['Year'], 100-women_degrees['Biology'], label='Men')
ax.tick_params(bottom="off", top="off", left="off", right="off")
ax.spines["right"].set_visible(False)
ax.spines["left"].set_visible(False)
ax.spines["top"].set_visible(False)
ax.spines["bottom"].set_visible(False)

ax.legend(loc='upper_right')
ax.set_title('Percentage of Biology Degrees Awarded By Gender')
plt.show()
```

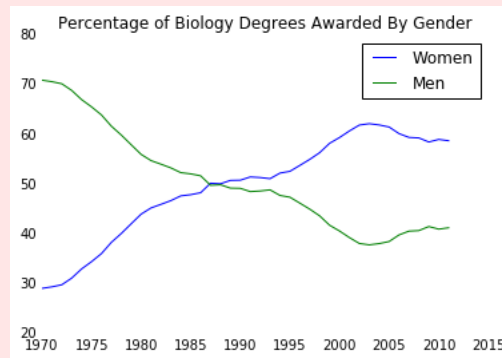


Figure 1.20: Percentage of Women Biology Degree Holders over Time

### 1.3.2 Conditional Plots

#### Definition 1.21: Seaborn Module

*Seaborn is a Python data visualization library based on matplotlib. It provides a high-level interface for drawing attractive and informative statistical graphics. Seaborn works similarly to the pyplot module from matplotlib. We primarily use seaborn interactively, by calling functions in its top level namespace. Like the pyplot module from matplotlib, seaborn creates a matplotlib figure or adds to the current, existing figure each time we generate a plot.*

#### Example 1.20: Seaborn

*Under the hood, seaborn creates a histogram using matplotlib, scales the axes values, and styles it. In addition, seaborn uses a technique called kernel density estimation [9], or KDE for short, to create a smoothed line chart over the histogram.*

```
# CB 1.3.2 #
```

```
import seaborn as sns
import matplotlib.pyplot as plt
sns.distplot(titanic["Age"])
plt.show()
```

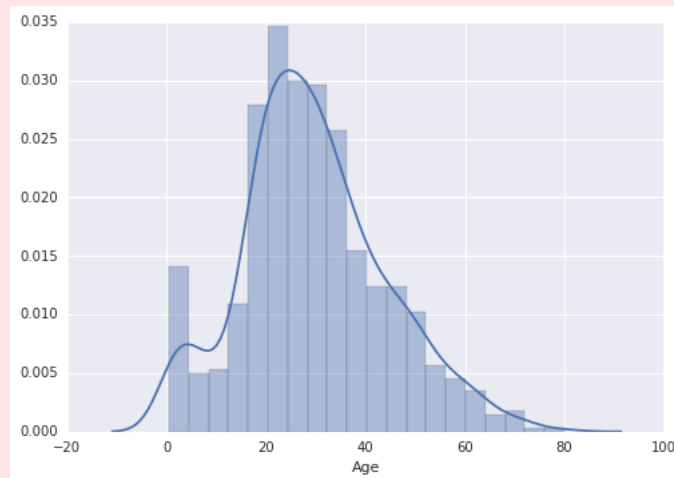


Figure 1.21: Seaborn Plot

### Example 1.21: Seaborn KDE

If we wish to only view the KDE plot in seaborn, one can use the `kdeplot()` function. In addition, shading the area underneath the KDE function can be accomplished by setting the `shade` parameter to `True`.

```
sns.kdeplot(titanic['Age'], shade = True)
plt.xlabel("Age")
```

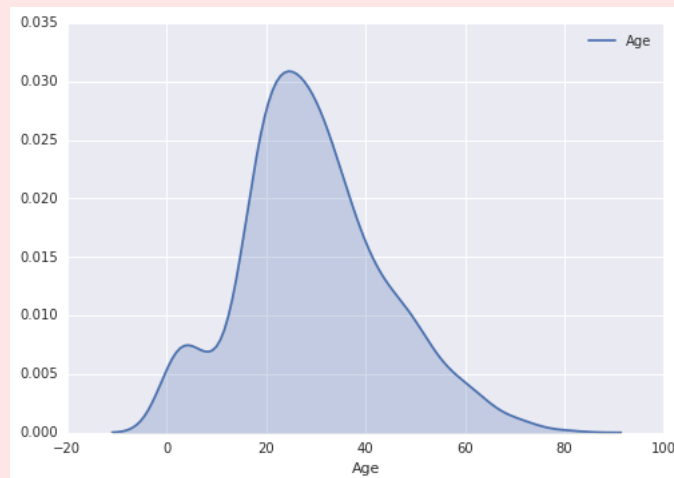


Figure 1.22: KDEplot with Shade

**Example 1.22: Seaborn Despinning and FacetGrid**

The Seaborn `despine` function allows us to remove the spines from the graph. By default it will remove the top and right spines, but to remove left and bottom, we have to set these parameters to `True`.

The `FacetGrid` function allows us to display multiple graphs at the same time through conditional relationships. Along the row and column axes of the graph position in this grid, we can specify how to subset the titanic dataframe. In this example, we subset unique values for 'Pclass' along the column axis and unique values for 'Survived' along the row axis. In addition, we can also plot multiple figures on the same subplot with the `hue` parameter, further allowing us to subset unique values of 'Sex'.

```
# CS 1.3.3 #
```

```
g = sns.FacetGrid(titanic, col="Pclass", row="Survived", hue="Sex", size=3)
g.map(sns.kdeplot, "Age", shade=True).add_legend()
sns.despine(left=True, bottom=True)
plt.show()
```

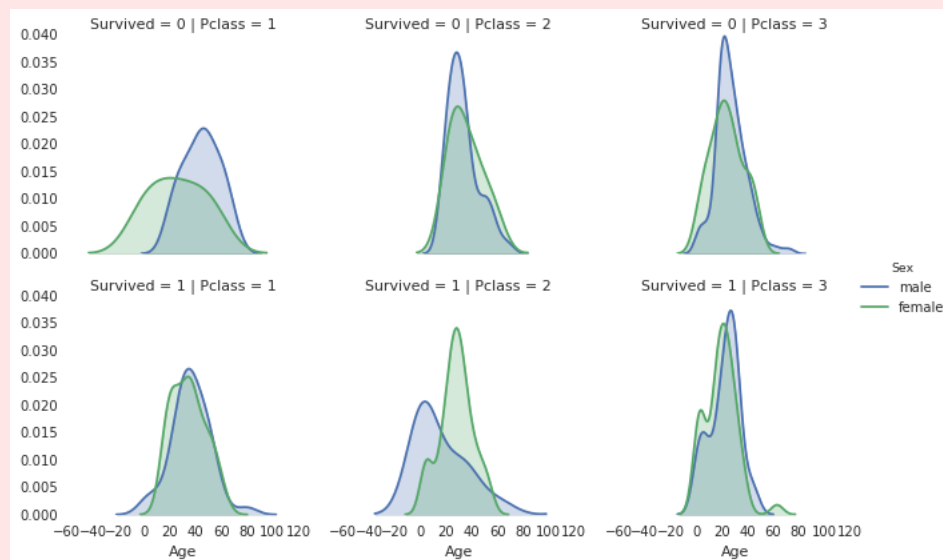


Figure 1.23: Seaborn FacetGrid with Despinning

**1.3.3 Visualizing Geographic Data****Definition 1.22: Basemap**

```
class mpl_toolkits.basemap.Basemap
```

Sets up a `basemap[10]` with specified map projection. and creates the coastline data structures in map projection coordinates.

Calling a `Basemap` class instance with the arguments `lon`, `lat` will convert `lon/lat` (in degrees) to `x/y` map projection coordinates (in meters). The inverse transformation is done if the optional keyword `inverse` is set to `True`.



**Example 1.23: Basemap Visualization with Airline Routes Data**

```
# CB 1.3.4 #

import matplotlib.pyplot as plt
from mpl_toolkits.basemap import Basemap

fig, ax = plt.subplots(figsize=(15, 20))
ax.set_title('Scaled Up Earth With Coastlines')
m = Basemap(projection='merc', llcrnrlat=-80, urcrnrlat=80, llcrnrlon=-180,
            urcrnrlon=180)
longitudes = airports["longitude"].tolist()
latitudes = airports["latitude"].tolist()
x, y = m(longitudes, latitudes)
m.scatter(x, y, s=1)
m.drawcoastlines()
plt.show()
```

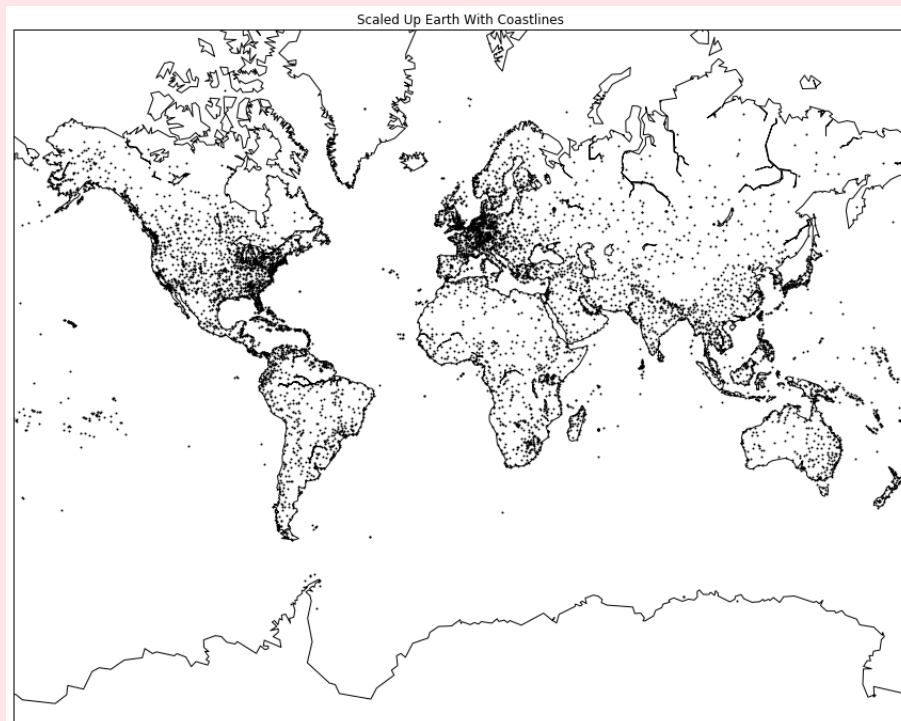


Figure 1.24: Geographic Data With Basemap

**Example 1.24: Great Circles for Airline Flights**

```
# CB 1.3.5 #

fig, ax = plt.subplots(figsize=(15,20))
m = Basemap(projection='merc', llcrnrlat=-80, urcrnrlat=80, llcrnrlon=-180,
```

```

urcrnrlon=180)
m.drawcoastlines()

# Start writing your solution below this line

def create_great_circles(dataframe):

    for index, row in dataframe.iterrows():
        if abs(row['end_lat'] - row['start_lat']) < 180 and
            abs(row['end_lon'] - row['start_lon']) < 180:
            m.drawgreatcircle(row['start_lon'], row['start_lat'],
                              row['end_lon'], row['end_lat'])
        else:
            continue

dfw = geo_routes[geo_routes['source']=='DFW']

create_great_circles(dfw)
plt.show()

```

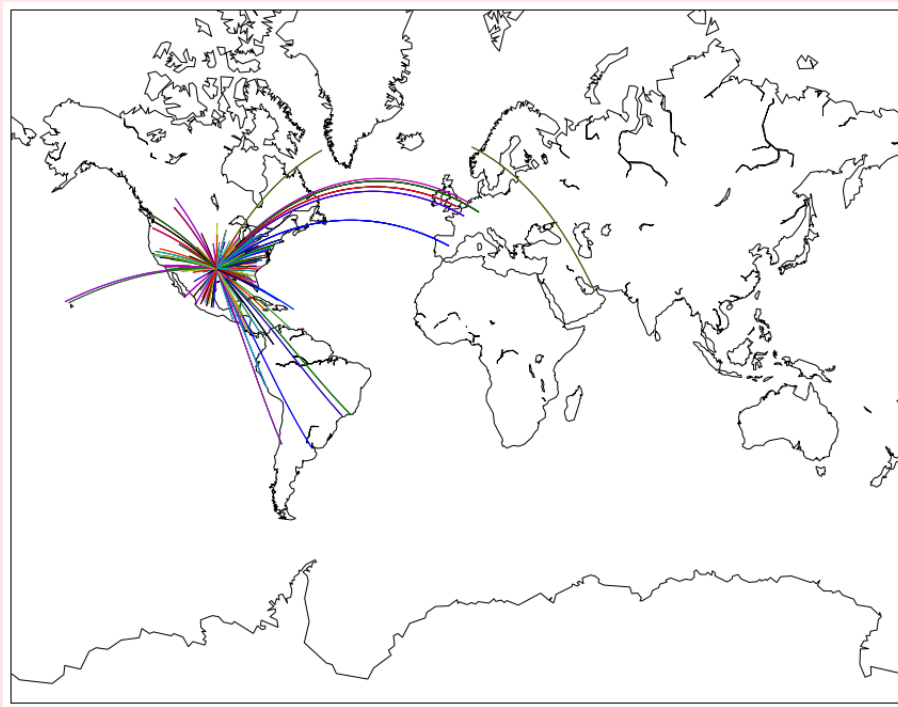


Figure 1.25: Great Circles for Airline Flights

## 2 The Command Line

### 2.1 Elements of the Command Line

#### 2.1.1 Introduction to the Command Line

##### Definition 2.1: Command Line Interface

A *Command Line Interface (CLI)* is a text only interface through which users interact with computers by typing text instructions in a console (or terminal), using specific syntax.

As technology evolved and computers became ubiquitous, terminals were emulated within GUIs, giving rise to terminal emulators (also terminal window or just terminal).

##### Definition 2.2: Commands

Instructions sent to the CLI are called *commands* which, once input, are interpreted by a type of program called a *shell* or *command language interpreter*, and then run by your machine. Some of the most popular shells are Bash, Z shell, KornShell, Command Prompt and Windows PowerShell.

##### Definition 2.3: Command Parameters

The general syntax for commands are:

```
utility_name parameter1 parameter2 ... parameterN
```

By definition, a parameter is either an *option* or an *argument*. An **option** is a string of symbols that modifies the behavior of the command and it always starts with a dash (-). Other possible names for this parameter are *flag* and *switch*, but depending on who you ask they might not always be interchangeable. An **argument** — or *operand* — is an object upon which the command acts. The **utility** (also *command* or *program*) is the first item in the instruction.

## 3 Working with Data Sources

### 3.1 SQL Fundamentals

#### 3.1.1 Introduction to SQL

##### Definition 3.1: SQL

SQL (Structured Query Language) is a domain-specific language used in programming and designed for managing data held in a relational database management system (RDBMS), or for stream processing in a relational data stream management system (RDSMS). It is particularly useful in handling structured data, i.e. data incorporating relations among entities and variables.

##### Definition 3.2: RDBMS

Connolly and Begg define Database Management System (DBMS) as a “software system that enables users to define, create, maintain and control access to the database”. RDBMS is an extension of that acronym that is sometimes used when the underlying database is relational.

#### SQL Comparison Operators

We can use the following comparison operators in SQL:

- <: Less than
- <=: Less than or equal to
- >: Greater than
- >=: Greater than or equal to
- =: Equal to
- !=: Not equal to

#### SQL Logical Operators

We can use the following logical operators in SQL [11]:

Operator	Result
<b>ALL</b>	TRUE if all of the subquery values meet the condition.
<b>AND</b>	TRUE if all the conditions separated by AND is TRUE.
<b>ANY</b>	TRUE if any of the subquery values meet the condition.
<b>BETWEEN</b>	TRUE if any of the subquery values meet the condition.
<b>EXISTS</b>	TRUE if the subquery returns one or more records.
<b>IN</b>	TRUE if the operand is equal to one of a list of expressions.
<b>LIKE</b>	TRUE if the operand matches a pattern.
<b>NOT</b>	Displays a record if the condition(s) is NOT TRUE.
<b>OR</b>	TRUE if any of the conditions separated by OR is TRUE.
<b>SOME</b>	TRUE if any of the subquery values meet the condition.

**Definition 3.3: SELECT Operation**

The *SELECT* statement is used to select data from a database. The data returned is stored in a result table, called the result-set.

If you wish to select columns *column1*, *column2*,..., the syntax is given by:

```
SELECT column1, column2, ...
FROM table_name;
```

If you wish to select all columns from *table\_name*, you can use \*:

```
SELECT * FROM table_name
```

**Definition 3.4: WHERE Operation**

The *WHERE* clause is used to filter records. The *WHERE* clause is used to extract only those records that fulfill a specified condition.

```
SELECT column1, column2, ...
FROM table_name
WHERE condition;
```

**Definition 3.5: ORDER BY Operation**

The *ORDER BY* keyword is used to sort the result-set in ascending or descending order.

```
SELECT column1, column2, ...
FROM table_name
ORDER BY column1, column2, ... ASC|DESC;
```

**Example 3.1: Select, Where and Order**

In this example, we have a table named “recent\_grads”, from which we want to display particular rows and columns matching our criteria. We only want to display the Major, ShareWomen and Unemployment\_rate column so we use the *SELECT* operation to do so. We use *FROM* to indicate the table and *WHERE* to establish the two desired criterions. We want to display rows where women held at least 30% of student population and had an unemployment rate less than 10%. Finally, when we display our information, we want to order it according to the ShareWomen values, descending.

```
# CB 1.4.1 #
```

```
SELECT Major, ShareWomen, Unemployment_rate
FROM recent_grads
WHERE ShareWomen > 0.3 AND Unemployment_rate < 0.1
ORDER BY ShareWomen DESC
```

Output  
[121 rows x 3 columns]

Major	ShareWomen	Unemployment_rate
EARLY CHILDHOOD EDUCATION	0.9679981190000001	0.040104981
MATHEMATICS AND COMPUTER SCIENCE	0.927807246	0
ELEMENTARY EDUCATION	0.923745479	0.046585715
ANIMAL SCIENCES	0.91093257	0.050862499000000005
PHYSIOLOGY	0.9066773370000001	0.069162800000000001
MISCELLANEOUS PSYCHOLOGY	0.90558993	0.05190783
HUMAN SERVICES AND COMMUNITY ORGANIZA...	0.9040745440000001	0.037819026
NURSING	0.896018988	0.044862724000000001
GEOSCIENCES	0.881293889	0.024373731000000003
MASS MEDIA	0.8772275279999999	0.089836827
COGNITIVE SCIENCE AND BIOPSYCHOLOGY	0.854523227	0.075236167
ART HISTORY AND CRITICISM	0.845934379	0.060298284
EDUCATIONAL PSYCHOLOGY	0.8170988090000001	0.065112187
GENERAL EDUCATION	0.8128766059999999	0.057359929000000004

Figure 3.1: Displaying the result of Query CB 1.4.1

### 3.1.2 Summary Statistics

#### Definition 3.6: Aggregate Function

Aggregate functions are applied over columns of values and return a single value. `MIN()` and `MAX()`, for example, calculate and return the minimum and maximum values in a column.

#### Aggregate Functions [12]

Aggregate Function	Description
AVG	The <code>AVG()</code> aggregate function calculates the average of non-NULL values in a set.
CHECKSUM_AGG	The <code>CHECKSUM_AGG()</code> function calculates a checksum value based on a group of rows.
COUNT	The <code>COUNT()</code> aggregate function returns the number of rows in a group, including rows with NULL values.
COUNT_BIG	The <code>COUNT_BIG()</code> aggregate function returns the number of rows (with <code>BIGINT</code> data type) in a group, including rows with NULL values.
MAX	The <code>MAX()</code> aggregate function returns the highest value (maximum) in a set of non-NULL values.
MIN	The <code>MIN()</code> aggregate function returns the lowest value (minimum) in a set of non-NULL values.
STDEV	The <code>STDEV()</code> function returns the statistical standard deviation of all values provided in the expression based on a sample of the data population.
STDEVP	The <code>STDEVP()</code> function also returns the standard deviation for all values in the provided expression, but does so based on the entire data population.
SUM	The <code>SUM()</code> aggregate function returns the summation of all non-NULL values a set.
VAR	The <code>VAR()</code> function returns the statistical variance of values in an expression based on a sample of the specified population.
VARP	The <code>VARP()</code> function returns the statistical variance of values in an expression but does so based on the entire data population.

**Definition 3.7: SQL DISTINCT Statement**

The *SELECT DISTINCT* statement is used to return only distinct (different) values. Inside a table, a column often contains many duplicate values; and sometimes you only want to list the different (distinct) values.

```
SELECT DISTINCT column1, column2, ...
FROM table_name;
```

**Definition 3.8: SQL Alias**

SQL aliases are used to give a table, or a column in a table, a temporary name. Aliases are often used to make column names more readable. An alias only exists for the duration of the query.

```
SELECT column_name AS alias_name
FROM table_name;
```

You may also drop the AS keyword so that the syntax can be expressed by

```
SELECT column_name alias_name
FROM table_name;
```

**Example 3.2: Counting Distinct Values among Columns**

```
# CB 1.4.2 #
```

```
SELECT COUNT(DISTINCT(Major)) "unique_majors",
COUNT(DISTINCT(Major_category)) "unique_major_categories",
COUNT(DISTINCT(Major_code)) "unique_major_codes"
FROM recent_grads
```

Output

[1 rows x 3 columns]

unique_majors	unique_major_categories	unique_major_codes
173	16	173

Figure 3.2: The Number of Unique Values in Major, Major Category and Major Code Columns

**Example 3.3: Displaying Ordered Quartile Spread among Columns**

```
# CB 1.4.3 #
```

```
SELECT Major, Major_category, P75th - P25th quartile_spread FROM recent_grads
ORDER BY quartile_spread LIMIT 10
```

Output  
[10 rows x 3 columns]

Major	Major_category	quartile_spread
MILITARY TECHNOLOGIES	Industrial Arts & Consumer Services	0
SCHOOL STUDENT COUNSELING	Education	2000
LIBRARY SCIENCE	Education	2000
COURT REPORTING	Law & Public Policy	4000
PHARMACOLOGY	Biology & Life Science	5000
EDUCATIONAL ADMINISTRATION AND SUPERV...	Education	6000
COUNSELING PSYCHOLOGY	Psychology & Social Work	6800
SPECIAL NEEDS EDUCATION	Education	10000
MATHEMATICS TEACHER EDUCATION	Education	10000
SOCIAL WORK	Psychology & Social Work	10000

Figure 3.3: Quartile Spread for Majors

### 3.1.3 Group Summary Statistics

#### Definition 3.9: PRAGMA TABLE INFO

The `table.info` pragma is used to query information about a specific table. The result set will contain one row for each column in the table. It will display information such as the type of objects stored in the columns, Null values and meanings.

#### Definition 3.10: SQL GROUP BY Statement

The `GROUP BY` statement groups rows that have the same values into summary rows, like "find the number of customers in each country". The `GROUP BY` statement is often used with aggregate functions (`COUNT`, `MAX`, `MIN`, `SUM`, `AVG`) to group the result-set by one or more columns.

```
SELECT column_name(s)
FROM table_name
WHERE condition
GROUP BY column_name(s)
ORDER BY column_name(s);
```

#### Example 3.4: GROUP BY in Action

The `GROUP BY` statement works by partitioning the relevant column into its unique entries, then performing the desired operation on each group.



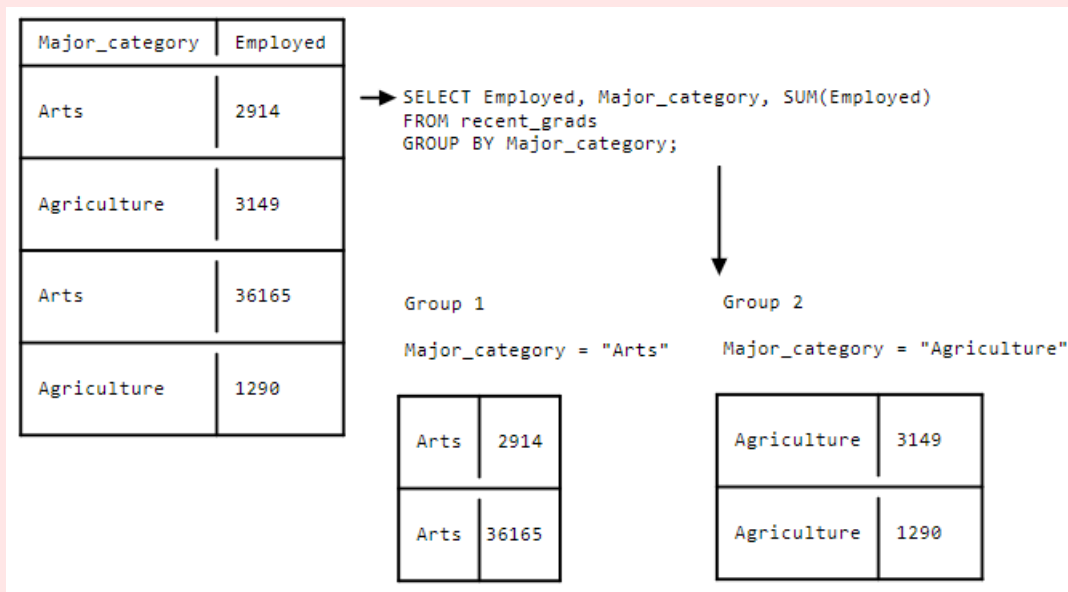


Figure 3.4: Grouping Operation

In this example, we aim to compute the average of women population percentages among each major category. Once done, we display it below in Figure 3.5.

# CB 1.4.4 #

```
SELECT Major_category , AVG(ShareWomen) FROM recent_grads
GROUP BY Major_category
```

Output

[16 rows x 2 columns]

Major_category	AVG(ShareWomen)
Agriculture & Natural Resources	0.6179384232
Arts	0.56185119575
Biology & Life Science	0.584518475857143
Business	0.4050631853076923
Communications & Journalism	0.64383484025
Computers & Mathematics	0.5127519954545455
Education	0.6749855163125
Engineering	0.2571578951034483
Health	0.6168565694166667
Humanities & Liberal Arts	0.6761934042
Industrial Arts & Consumer Services	0.4493512688571429
Interdisciplinary	0.495397153
Law & Public Policy	0.3359896912
Physical Sciences	0.5087494197

Figure 3.5: Group By ShareWomen Averages in Major Categories

### Definition 3.11: SQL HAVING Statement

The *HAVING* clause was added to *SQL* because the *WHERE* keyword could not be used with aggregate functions.

```
SELECT column_name(s)
FROM table_name
WHERE condition
GROUP BY column_name(s)
HAVING condition
ORDER BY column_name(s);
```

### Definition 3.12: ROUND Function

The `ROUND()` function rounds a number to a specified number of decimal places.

```
SELECT ROUND(numeric_column_name, dec_places)
```

### Definition 3.13: CAST Function

The `CAST()` function converts a value (of any type) into the specified datatype.

### Example 3.5: Casting

In this example, we want to display the ratio of women to the total, grouping by each `Major_category`, summing and dividing by the total.

```
# CB 1.4.5 #
```

```
SELECT Major_category, CAST(Sum(Women) as float) / CAST(Sum(total) as float) SW
FROM recent_grads
GROUP BY Major_category
ORDER BY SW
```

Output  
[16 rows x 2 columns]

Major_category	SW
Law & Public Policy	0.030585069260274586
Business	0.08474280852841269
Industrial Arts & Consumer Services	0.16024926890405236
Computers & Mathematics	0.20935560252568494
Engineering	0.2195958577559186
Communications & Journalism	0.25032539397505355
Arts	0.39332735978495226
Humanities & Liberal Arts	0.490051410855147
Health	0.6735876346523325
Interdisciplinary	0.8009108653220559
Social Science	0.8748032892676134
Psychology & Social Work	1.0491780784895022
Education	1.0962729531109994
Biology & Life Science	1.273805694241862

Figure 3.6: The Output of Query 1.4.5

### 3.1.4 Subqueries

#### Definition 3.14: Subquery

A Subquery or Inner query or a Nested query is a query within another SQL query and embedded within the WHERE clause. A subquery is used to return data that will be used in the main query as a condition to further restrict the data to be retrieved. Subqueries can be used with the SELECT, INSERT, UPDATE, and DELETE statements along with the operators like =, <, >, >=, <= IN, BETWEEN, etc.

#### Definition 3.15: IN Operator

The IN operator allows you to specify multiple values in a WHERE clause. The IN operator is a shorthand for multiple OR conditions.

```
SELECT column_name(s)
FROM table_name
WHERE column_name IN (value1, value2, ...);
```

#### Example 3.6: Subqueries with IN Keyword

In this example, we want to write a query that returns the Major, Major\_category columns for the rows where Major\_category is one of the 5 highest group level sums for the Total column.

# CB 1.4.6 #

```
SELECT Major, Major_category FROM recent_grads
WHERE Major_category IN (SELECT Major_category FROM recent_grads
GROUP BY Major_category
ORDER BY SUM(Total) DESC
LIMIT 5)
```

Output

[82 rows x 2 columns]

Major	Major_category
PETROLEUM ENGINEERING	Engineering
MINING AND MINERAL ENGINEERING	Engineering
METALLURGICAL ENGINEERING	Engineering
NAVAL ARCHITECTURE AND MARINE ENGINEE...	Engineering
CHEMICAL ENGINEERING	Engineering
NUCLEAR ENGINEERING	Engineering
ACTUARIAL SCIENCE	Business
MECHANICAL ENGINEERING	Engineering
ELECTRICAL ENGINEERING	Engineering
COMPUTER ENGINEERING	Engineering
AEROSPACE ENGINEERING	Engineering
BIOMEDICAL ENGINEERING	Engineering
MATERIALS SCIENCE	Engineering
ENGINEERING MECHANICS PHYSICS AND SCI...	Engineering

Figure 3.7: The Output of Query CB 1.4.6

### 3.1.5 Guided Project: Analyzing CIA Factbook Data Using SQL

#### Definition 3.16: SQLite

*SQLite is a relational database management system (RDBMS) contained in a C library. In contrast to many other database management systems, SQLite is not a client-server database engine. Rather, it is embedded into the end program.*

#### Example 3.7: Analyzing CIA Factbook Data

To enable the ability to use SQL and load up the `factbook.db` [13], we enter the following code into the Jupyter Notebook:

```
%%capture
%load_ext sql
%sql sqlite:///factbook.db
```

```
In [36]: %%sql
SELECT name, birth_rate, death_rate, ROUND(death_rate - birth_rate, 5) AS "Population Decline"
FROM facts
ORDER BY death_rate DESC
```

Done.

Out[36]:

name	birth_rate	death_rate	Population Decline
Lesotho	25.47	14.89	-10.58
Ukraine	10.72	14.46	3.74
Bulgaria	8.92	14.44	5.52
Guinea-Bissau	33.38	14.33	-19.05
Latvia	10.0	14.31	4.31
Chad	36.6	14.28	-22.32
Lithuania	10.1	14.27	4.17

Figure 3.8: Birth / Death Rates ordered by Death Rate per Country

## 3.2 SQL Intermediate: Table Relations and Joins

### 3.2.1 Joining Data in SQL

#### Definition 3.17: JOIN Operation

A *JOIN* clause is used to combine rows from two or more tables, based on a related column between them. The syntax for a join clause is given below.

```
SELECT [column_names] FROM [table_name_one]
INNER JOIN [table_name_two] ON [join_constraint];
```

*ON*, which tells the SQL engine what columns to use to join the two tables. The syntax for specifying table column names is given by “*table\_name.column\_name*”.

**Definition 3.18: Inner and Outer Join**

**(INNER) JOIN:** Returns records that have matching values in both tables.

**LEFT (OUTER) JOIN:** Returns all records from the left table, and the matched records from the right table.

**RIGHT (OUTER) JOIN:** Returns all records from the right table, and the matched records from the left table.

**FULL (OUTER) JOIN:** Returns all records when there is a match in either left or right table.

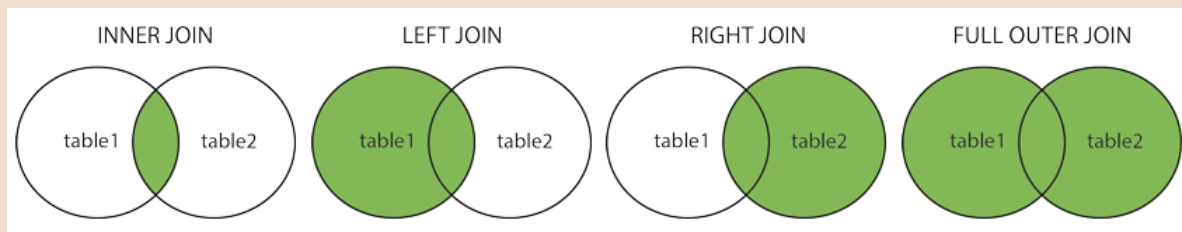


Figure 3.9: Inner and Outer Joins

**Example 3.8: Population among Capital Cities**

We want to write a query that returns the 10 capital cities with the highest population ranked from biggest to smallest population. It will include columns in the following order:

- `capital_city`, the name of the city.
- `country`, the name of the country the city is from.
- `population`, the population of the city.

# CB 1.4.7 #

```
SELECT c.name capital_city, f.name country, c.population population
FROM cities c
INNER JOIN facts f ON f.id = c.facts_id
WHERE c.capital = 1
ORDER BY population DESC
LIMIT 10
```

Output  
[10 rows x 3 columns]

capital_city	country	population
Tokyo	Japan	37217000
New Delhi	India	22654000
Mexico City	Mexico	20446000
Beijing	China	15594000
Dhaka	Bangladesh	15391000
Buenos Aires	Argentina	13528000
Manila	Philippines	11862000
Moscow	Russia	11621000
Cairo	Egypt	11169000
Jakarta	Indonesia	9769000

Figure 3.10: The Output of Query CB 1.4.7

**Example 3.9: Population Density in Cities Across a Country**

We will write a query that generates columns in the following order:

- `country`, the name of the country.
- `urban_pop`, the sum of the population in major urban areas belonging to that country.
- `total_pop`, the total population of the country.
- `urban_pct`, the percentage of the population within urban areas, calculated by dividing `urban_pop` by `total_pop`.

Lastly, we subject these rows to the criteria that we only want countries that have an `urban_pct` greater than 0.5 and that the rows should be sorted by `urban_pct` in ascending order.

# CB 1.4.8 #

```
SELECT f.name country, urb.urban_pop urban_pop, f.population total_pop,
CAST(urban_pop as float) / CAST(f.population as float) urban_pct
FROM facts f
INNER JOIN (SELECT SUM(c.population) urban_pop, facts_id FROM cities c
GROUP BY facts_id) urb ON urb.facts_id = f.id
WHERE urban_pct > 0.5
ORDER BY urban_pct
```

Output  
[18 rows x 4 columns]

country	urban_pop	total_pop	urban_pct
Uruguay	1672000	3341893	0.5003152404939356
Congo, Republic of the	2445000	4755097	0.5141850944365594
Brunei	241000	429646	0.5609269026128487
New Caledonia	157000	271615	0.5780240413821034
Virgin Islands	60000	103574	0.5792959623071428
Falkland Islands (Islas Malvinas)	2000	3361	0.5950609937518596
Djibouti	496000	828324	0.5987995035758954
Australia	13789000	22751014	0.6060828761302683
Iceland	206000	331918	0.6206352171319423
Israel	5226000	8049314	0.6492478737939655
United Arab Emirates	3903000	5779760	0.6752875551926032
Puerto Rico	2475000	3598357	0.6878139106264332
Bahamas, The	254000	324597	0.7825087724162577
Kuwait	2406000	2788534	0.8628189579183901

Figure 3.11: The Output of Query CB 1.4.8

### 3.2.2 Intermediate Joins in SQL

#### Joining more than Two Tables

The syntax for joining more than two tables in SQL is given below:

```
SELECT [column_names] FROM [table_name_one]
[join_type] JOIN [table_name_two] ON [join_constraint]
[join_type] JOIN [table_name_three] ON [join_constraint];
```

## Chinook Database

In this mission, we use a database named chinook. Its schema diagram is presented below:

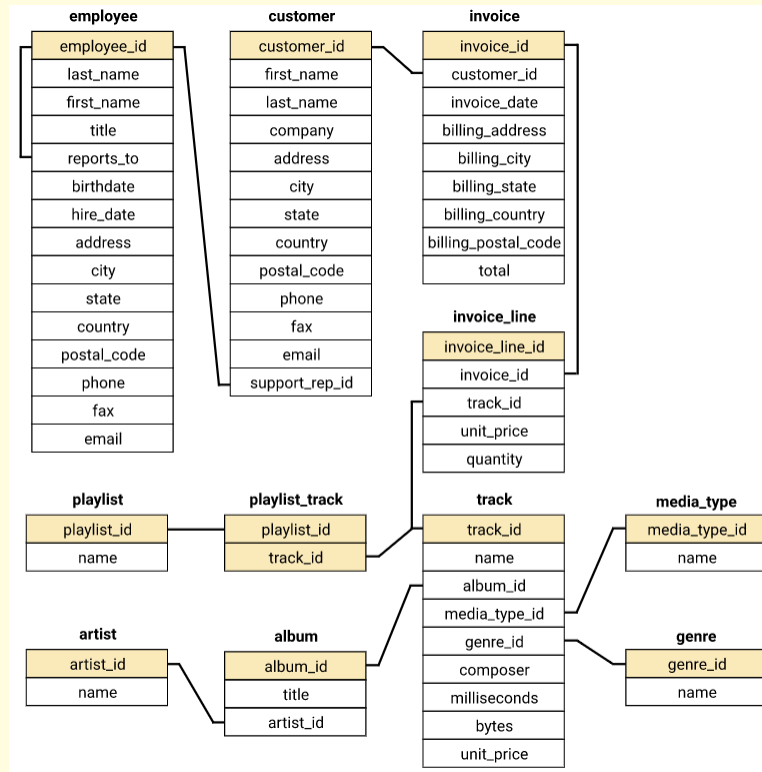


Figure 3.12: Chinook Database Schema

### Example 3.10: Popular Albums

We want to write a query that returns the top 5 albums, as calculated by the number of times a track from that album has been purchased. The query will be sorted from most tracks purchased to least tracks purchased and return the following columns, in order:

- *album*, the title of the album.
- *artist*, the artist who produced the album.
- *tracks\_purchased* the total number of tracks purchased from that album.

# CB 1.4.9 #

```
SELECT
    trkart.album album,
    trkart.artist_name artist,
    SUM(il.quantity) tracks_purchased
FROM invoice_line il
INNER JOIN
    (SELECT
        t.track_id,
        art.name artist_name,
```

```

        alb.title album
    FROM artist art
    INNER JOIN album alb ON alb.artist_id = art.artist_id
    INNER JOIN track t ON t.album_id = alb.album_id
    ) trkart ON trkart.track_id = il.track_id
GROUP BY album
ORDER BY tracks_purchased DESC
LIMIT 5

```

Output  
[5 rows x 3 columns]

album	artist	tracks_purchased
Are You Experienced?	Jimi Hendrix	187
Faceless	Godsmack	96
Mezmerize	System Of A Down	93
Get Born	JET	90
The Doors	The Doors	83

Figure 3.13: The Output of Query CB 1.4.9

**Definition 3.19: Self / Recursive Join**

A self JOIN is a regular join, but the table is joined with itself.

```

SELECT column_name(s)
FROM table1 T1, table1 T2
WHERE condition;

```

T1 and T2 are different table aliases for the same table.

**Definition 3.20: Concatenation Operator**

|| or concatenation operator is use to link columns or character strings. We can also use a literal. A literal is a character, number or date that is included in the SELECT statement.

**Definition 3.21: SQL CONCAT Function**

The CONCAT() function adds two or more strings together.

```
CONCAT(string1, string2, ..., string_n)
```

**Example 3.11: Employees and Supervisors**

We will write a query that returns information about each employee and their supervisor. The report will include employees even if they do not report to another employee. The report will be sorted alphabetically by the employee\_name column. The query will return the following columns, in order:

- **employee\_name** - containing the first\_name and last\_name columns separated by a space (eg Luke Skywalker).
- **employee\_title** - the title of that employee.
- **supervisor\_name** - the first and last name of the person the employee reports to, in the same format as



*employee\_name.*

- **supervisor\_title** - the title of the person the employee reports to.

# CB 1.4.10 #

**SELECT**

```
e1.first_name || " " || e1.last_name employee_name ,
e1.title employee_title ,
e2.first_name || " " || e2.last_name supervisor_name ,
e2.title supervisor_title
```

**FROM** employee e1

**LEFT JOIN** employee e2 **ON** e1.reports\_to = e2.employee\_id

**ORDER BY** employee\_name

Output  
[8 rows x 4 columns]

employee_name	employee_title	supervisor_name	supervisor_title
Andrew Adams	General Manager		
Jane Peacock	Sales Support Agent	Nancy Edwards	Sales Manager
Laura Callahan	IT Staff	Michael Mitchell	IT Manager
Margaret Park	Sales Support Agent	Nancy Edwards	Sales Manager
Michael Mitchell	IT Manager	Andrew Adams	General Manager
Nancy Edwards	Sales Manager	Andrew Adams	General Manager
Robert King	IT Staff	Michael Mitchell	IT Manager
Steve Johnson	Sales Support Agent	Nancy Edwards	Sales Manager

Figure 3.14: The Output of Query CB 1.4.10

### Definition 3.22: SQL LIKE Operator

The *LIKE* operator is used in a *WHERE* clause to search for a specified pattern in a column.

There are two wildcards often used in conjunction with the *LIKE* operator:

% - The percent sign represents zero, one, or multiple characters.

\_ - The underscore represents a single character.

**SELECT** column1, column2, ...

**FROM** table\_name

**WHERE** columnN **LIKE** pattern;

### Definition 3.23: SQL CASE Statement

The *CASE* statement goes through conditions and returns a value when the first condition is met (like an *IF-THEN-ELSE* statement). So, once a condition is true, it will stop reading and return the result. If no conditions are true, it returns the value in the *ELSE* clause.

If there is no *ELSE* part and no conditions are true, it returns *NULL*.

**CASE**

**WHEN** condition1 **THEN** result1

**WHEN** condition2 **THEN** result2

**WHEN** conditionN **THEN** resultN

**ELSE** result

**END**

**AS** *[new\_column\_name]*

### Example 3.12: Customer Spending Habits

We will write a query that summarizes the purchases of each customer. For the purposes of this exercise, we do not have any two customers with the same name. The query will include the following columns, in order:

- **customer\_name** - containing the `first_name` and `last_name` columns separated by a space (eg Luke Skywalker).
- **number\_of\_purchases** - counts the number of purchases made by each customer.
- **total\_spent** - the total sum of money spent by each customer.
- **customer\_category** - a column that categorizes the customer based on their total purchases. The column should contain the following values:
  - small spender - If the customer's total purchases are less than \$40.
  - big spender - If the customer's total purchases are greater than \$100.
  - regular - If the customer's total purchases are between \$40 and \$100 (inclusive).

Results will be ordered by the `customer_name` column.

# CB 1.4.11 #

```

SELECT
  c.first_name || " " || c.last_name customer_name,
  COUNT(i.invoice_id) number_of_purchases,
  SUM(i.total) total_spent,
  CASE
    WHEN sum(i.total) < 40 THEN "small_spender"
    WHEN sum(i.total) > 100 THEN "big_spender"
    ELSE "regular"
  END
  AS customer_category
FROM customer c
LEFT JOIN invoice i ON c.customer_id = i.customer_id
GROUP BY customer_name
ORDER BY customer_name

```

Output  
[59 rows x 4 columns]

customer_name	number_of_purchases	total_spent	customer_category
Aaron Mitchell	8	70.28999999999999	regular
Alexandre Rocha	10	69.3	regular
Astrid Gruber	9	69.3	regular
Bjørn Hansen	9	72.27000000000001	regular
Camille Bernard	9	79.2	regular
Daan Peeters	7	60.38999999999999	regular
Dan Miller	12	95.03999999999999	regular
Diego Gutiérrez	5	39.6	small spender
Dominique Lefebvre	9	72.27	regular
Eduardo Martins	12	60.39	regular
Edward Francis	13	91.08	regular
Ellie Sullivan	12	75.24000000000001	regular
Emma Jones	8	68.31	regular
Enrique Muñoz	11	98.01	regular

Figure 3.15: The Output of Query CB 1.4.11

### 3.2.3 Building and Organizing Complex Queries

#### Query Readability

*A little time put into whitespace and capitalization pays off. A few tips to help make your queries more readable:*

- *If a select statement has more than one column, put each on a new line, indented from the select statement.*
- *Always capitalize SQL function names and keywords*
- *Put each clause of your query on a new line.*
- *Use indenting to make subqueries appear logically separate.*

*Another important consideration when writing readable queries is the use of alias names and shortcuts. Name aliases should be clear— a common convention is using the first letter of the table name, however if you feel that a query is complex you should consider using more explicit aliases. Similarly, at times lines like GROUP BY 1 can be confusing, and explicitly naming the column will make your query more readable. For further information, you can also consult [14].*

#### Definition 3.24: SQL WITH Statement

*WITH clauses allow you to define one or more named subqueries before the start of the main query. The main query then refers to the subquery by its alias name, just as if it's a table in the database.*

*Syntax:*

**WITH** [alias\_name] **AS** ([subquery])

**SELECT** [main\_query]

*To create multiple subqueries with the WITH statement can be done by*

**WITH**  
[alias\_name] **AS** ([subquery]),

```
[alias_name_2] AS ([subquery_2]),
[alias_name_3] AS ([subquery_3])
```

```
SELECT [main-query]
```

While each subquery can be independent, we can actually use the result of the first subquery in subsequent subqueries, and so on. This can be a useful way of building readable complex queries.

### Definition 3.25: SQL CREATE VIEW

In SQL, a view is a virtual table based on the result-set of an SQL statement. A view contains rows and columns, just like a real table. The fields in a view are fields from one or more real tables in the database.

You can add SQL functions, WHERE, and JOIN statements to a view and present the data as if the data were coming from one single table.

Syntax:

```
CREATE VIEW view_name AS
SELECT column1, column2, ...
FROM table_name
WHERE condition;
```

If you wish to add the view to a database, one can use

```
CREATE VIEW database_name.view_name AS
SELECT * FROM database_name.table_name;
```

### Definition 3.26: SQL DROP VIEW Command

A view is deleted with the DROP VIEW command.

Syntax:

```
DROP VIEW view_name;
```

### Example 3.13

We will create a view called `customer_gt_90_dollars`:

The view will only contain the columns from customers, in their original order.

The view will only contain customers who have purchased more than \$90 in tracks from the store.

After the SQL query that creates the view, we will write a second query to display the newly created view.

```
# CB 1.4.12 #
```

```
CREATE VIEW chinook.customer_gt_90_dollars AS
SELECT c.* FROM invoice i
LEFT JOIN customer c ON i.customer_id = c.customer_id
GROUP BY i.customer_id
HAVING SUM(i.total) > 90;
```

```
SELECT * FROM chinook.customer_gt_90_dollars;
```

Output  
[18 rows x 13 columns]

customer_id	first_name	last_name	company	address
1	Luís	Gonçalves	Embraer - Empresa Brasileira de Aeron...	Av. Brigadeiro Faria
3	François	Tremblay		1498 rue Bélanger
5	František	Wichterlová	JetBrains s.r.o.	Klanova 9/506
6	Helena	Holý		Rilská 3174/6
13	Fernanda	Ramos		Qe 7 Bloco G
17	Jack	Smith	Microsoft Corporation	1 Microsoft Way
20	Dan	Miller		541 Del Medio Avenue
21	Kathy	Chase		801 W 4th Street
22	Heather	Leacock		120 S Orange Ave
30	Edward	Francis		230 Elgin Street
34	João	Fernandes		Rua da Assunção 53
37	Fynn	Zimmermann		Berger Straße 10
42	Wyatt	Girard		9, Place Louis Bartho

Figure 3.16: The Output of Query CB 1.4.12

**Definition 3.27: SQL UNION Operator**

The *UNION* operator is used to combine the result-set of two or more *SELECT* statements.

- Each *SELECT* statement within *UNION* must have the same number of columns.
- The columns must also have similar data types.
- The columns in each *SELECT* statement must also be in the same order.

Syntax:

```
[select_statement_one]
UNION
[select_statement_two]
```

<pre>SELECT   first_name,   last_name,   email FROM table_one  UNION  SELECT   user_id,   first_name,   last_name,   email,   phone_number FROM table_two</pre> <p><b>Not Valid</b> Tables have different number of columns</p>	<pre>SELECT   first_name,   last_name,   total_sales FROM table_one  UNION  SELECT   first_name,   last_name,   email FROM table_two</pre> <p><b>Not Valid</b> Types are not compatible (<i>total_sales</i> numeric vs <i>email</i> text)</p>	<pre>SELECT   first_name,   last_name,   email FROM table_one  UNION  SELECT   first_name,   last_name,   email FROM table_two</pre> <p><b>Valid</b> Tables have the same number of columns and compatible types</p>
---	---	--

Figure 3.17: Example of SQL Union Validity

**Definition 3.28: SQL INTERSECT Operator**

The SQL **INTERSECT** operator is used to return the results of 2 or more **SELECT** statements. However, it only returns the rows selected by all queries or data sets. If a record exists in one query and not in the other, it will be omitted from the **INTERSECT** results.

Syntax:

```
[select_statement_one]
INTERSECT
[select_statement_two]
```

**Definition 3.29: SQL EXCEPT Operator**

Selects rows that occur in the first statement, but don't occur in the second statement.

Syntax:

```
[select_statement_one]
EXCEPT
[select_statement_two]
```

**Example 3.14**

We will write a query that works out how many customers that are in the USA and have purchased more than \$90 are assigned to each sales support agent. For the purposes of this exercise, no two employees have the same name.

The result will have the following columns, in order:

- `employee_name` - The first\_name and last\_name of the employee separated by a space.
- `customers_usa_gt_90` - The number of customer assigned to that employee that are both from the USA and have have purchased more than \$90 worth of tracks.

The result will include all employees with the title "Sales Support Agent", but not employees with any other title. Lastly, the results will be ordered by the `employee_name` column.

# CB 1.4.13 #

```
WITH customers_usa_gt_90 AS
(
    SELECT * FROM customer_usa

    INTERSECT

    SELECT * FROM customer_gt_90_dollars
)

SELECT
    e.first_name || " " || e.last_name employee_name,
    COUNT(c.customer_id) customers_usa_gt_90
FROM employee e
LEFT JOIN customers_usa_gt_90 c ON c.support_rep_id = e.employee_id
```

```
WHERE e.title = 'Sales_Support_Agent'
```

Output  
[3 rows x 2 columns]

employee_name	customers_usa_gt_90
Jane Peacock	0
Margaret Park	2
Steve Johnson	2

Figure 3.18: The Output of Query CB 1.4.13

### Example 3.15

We will create a query to find the customer from each country that has spent the most money at the store, ordered alphabetically by country. The query will return the following columns, in order:

- `country` - The name of each country that we have a customer from.
- `customer_name` - The `first_name` and `last_name` of the customer from that country with the most total purchases, separated by a space (eg Luke Skywalker).
- `total_purchased` - The total dollar amount that customer has purchased.

```
# CB 1.4.14 #
```

```
WITH
    customer_totals AS
    (
        SELECT
            SUM(i.total) purchase_total,
            c.*
        FROM invoice i
        INNER JOIN customer c ON c.customer_id = i.customer_id
        GROUP BY c.customer_id
    ),
    customer_max AS
    (
        SELECT
            MAX(purchase_total) max_purchase,
            ct.country country,
            ct.first_name || " " || ct.last_name customer_name
        FROM customer_totals ct
        GROUP BY ct.country
    )

SELECT
    cm.country country,
    cm.customer_name customer_name,
    cm.max_purchase total_purchased
FROM customer_max cm
ORDER BY country
```

Output  
[24 rows x 3 columns]

country	customer_name	total_purchased
Argentina	Diego Gutiérrez	39.6
Australia	Mark Taylor	81.18
Austria	Astrid Gruber	69.3
Belgium	Daan Peeters	60.38999999999999
Brazil	Luís Gonçalves	108.89999999999998
Canada	François Tremblay	99.99
Chile	Luis Rojas	97.02000000000001
Czech Republic	František Wichterlová	144.54000000000002
Denmark	Kara Nielsen	37.61999999999999
Finland	Terhi Hämäläinen	79.2
France	Wyatt Girard	99.99
Germany	Fynn Zimmermann	94.05000000000001
Hungary	Ladislav Kovács	78.21
India	Manoj Pareek	111.86999999999999

Figure 3.19: The Output of Query CB 1.4.14

### 3.2.4 Querying SQLite from Python

#### Definition 3.30: SQLite Connect Function

Once we import the module, we connect to the database we want to query using the `connect()` function. This function requires a single parameter, which is the database we want to connect to. The `connect()` function returns a `Connection` instance, which maintains the connection to the database we want to work with.

#### Definition 3.31: SQLite Cursor Class

The `Cursor` class is a `SQLite` class that allows us to interact with the database such as executing SQL statements and fetching the next row of a query result set [See [15] for further information]. We will use the `Cursor` class to

- Run a query against the database.
- Parse the results from the database.
- Convert the results to native Python objects.
- Store the results within the `Cursor` instance as a local variable.

#### Executing Queries w/o Cursor Instance

The `SQLite` library actually allows us to skip creating a `Cursor` altogether by using the `execute` method within the `Connection` object itself. `SQLite` will create a `Cursor` instance for us under the hood and run our query against the database, allowing us to skip a step. Suppose that `jobs.db` is a database with a `recent_grads` table, then the code could look like:

```
conn = sqlite3.connect("jobs.db")
query = "select * from recent_grads;"
conn.execute(query).fetchall()
```



**Definition 3.32: Cursor Fetching Methods**

Each `Cursor` instance contains an internal counter that updates every time we retrieve results. When we call the `fetchone()` method, the `Cursor` instance will return a single result, and then increment its internal counter by 1. This means that if we call `fetchone()` again, the `Cursor` instance will actually return the second tuple in the results set (and increment by 1 again).

The `fetchmany()` method takes in an integer (`n`) and returns the corresponding results, starting from the current position. It then increments the `Cursor` instance's counter by `n`.

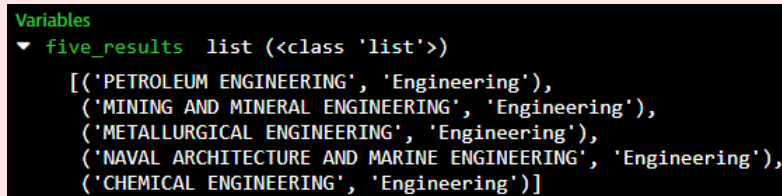
**Example 3.16**

In this example, we want to write and run a query that returns the `Major` and `Major_category` columns from `recent_grads`. We then fetch the first five results and store them as `five_results`.

# CB 1.4.15 #

```
import sqlite3
conn = sqlite3.connect("jobs.db")
cursor = conn.cursor()

query = "SELECT Major, Major_category FROM recent_grads"
five_results = cursor.execute(query).fetchmany(5)
```



```
Variables
▼ five_results list (<class 'list'>)
[('PETROLEUM ENGINEERING', 'Engineering'),
 ('MINING AND MINERAL ENGINEERING', 'Engineering'),
 ('METALLURGICAL ENGINEERING', 'Engineering'),
 ('NAVAL ARCHITECTURE AND MARINE ENGINEERING', 'Engineering'),
 ('CHEMICAL ENGINEERING', 'Engineering')]
```

Figure 3.20: The Output of CB 1.4.15

**3.2.5 Guided Project: Answering Business Questions Using SQL****Definition 3.33: Context Manager**

A context manager is an object that defines the runtime context to be established when executing a `with` statement. The context manager handles the entry into, and the exit from, the desired runtime context for the execution of the block of code. Context managers are normally invoked using the `with` statement (described in section The `with` statement), but can also be used by directly invoking their methods.

Typical uses of context managers include saving and restoring various kinds of global state, locking and unlocking resources, closing opened files, etc. [See [16] for a good article on this].

**Definition 3.34: Python With Statement**

The `with` statement is used to wrap the execution of a block with methods defined by a context manager (see section With Statement Context Managers). This allows common `try...except...finally` usage patterns

to be encapsulated for convenient reuse.

```
with something_that_returns_a_context_manager() as my_resource:
    do_something(my_resource)
```

The execution of the with statement with one “item” proceeds as follows:

1. The context expression (the expression given in the with\_item) is evaluated to obtain a context manager.
2. The context manager’s `__enter__()` is loaded for later use.
3. The context manager’s `__exit__()` is loaded for later use.
4. The context manager’s `__enter__()` method is invoked.
5. If a target was included in the with statement, the return value from `__enter__()` is assigned to it.

(Note: The with statement guarantees that if the `__enter__()` method returns without an error, then `__exit__()` will always be called. Thus, if an error occurs during the assignment to the target list, it will be treated the same as an error occurring within the suite would be. See step 6 below.)

6. The suite is executed.
7. The context manager’s `__exit__()` method is invoked. If an exception caused the suite to be exited, its type, value, and traceback are passed as arguments to `__exit__()`. Otherwise, three None arguments are supplied.

The following code

```
with EXPRESSION as TARGET:
    SUITE
```

is semantically equivalent to:

```
manager = (EXPRESSION)
enter = type(manager).__enter__
exit = type(manager).__exit__
value = enter(manager)
hit_except = False

try:
    TARGET = value
    SUITE
except:
    hit_except = True
    if not exit(manager, *sys.exc_info()):
        raise
finally:
    if not hit_except:
        exit(manager, None, None, None)
```

### Definition 3.35: Pandas `read_sql_query()`

```
pandas.read_sql_query(sql, con, index_col=None, coerce_float=True, params=None, parse_dates=None,
chunksize=None)
```

Read SQL query into a `DataFrame`.

Returns a `DataFrame` corresponding to the result set of the query string. Optionally provide an `index_col` parameter to use one of the columns as the index, otherwise default integer index will be used [See [17] for further information].

**PARAMETERS:**

**sql:** str SQL query or SQLAlchemy Selectable (select or text object)  
SQL query to be executed.

**con:** SQLAlchemy connectable(engine/connection), database str URI  
or sqlite3 DBAPI2 connection. Using SQLAlchemy makes it possible to use any DB supported by that library. If a DBAPI2 object, only sqlite3 is supported.

### Example 3.17: Setting up SQLite in Python

The first task is to import the `SQLite`, `pandas` and `matplotlib` modules, and use the magic command `%matplotlib inline` to make sure any plots render in the notebook.

1. Create a `run_query()` function, that takes a SQL query as an argument and returns a pandas dataframe of that query.
2. Create a `run_command()` function that takes a SQL command as an argument and executes it using the `sqlite` module.
3. Create a `show_tables()` function that calls the `run_query()` function to return a list of all tables and views in the database.
4. Run the `show_tables()` function.

# CB 1.4.16 #

`%matplotlib inline`

```
import sqlite3
import pandas as pd
import matplotlib.pyplot as plt

def run_query(query):
    with sqlite3.connect('chinook.db') as conn:
        return pd.read_sql_query(query, conn)

def run_command(c):
    with sqlite3.connect('chinook.db') as conn:
        conn.isolation_level = None
        conn.execute(c)

def show_tables():
    query = """SELECT name, type FROM sqlite_master
               WHERE type IN ('table', 'view') """
    tables = run_query(query)
    print(tables)

show_tables()
```

	name	type
0	album	table
1	artist	table
2	customer	table
3	employee	table
4	genre	table
5	invoice	table
6	invoice_line	table
7	media_type	table
8	playlist	table
9	playlist_track	table
10	track	table
11	country_cust	view

Figure 3.21: The Output of CB 1.4.16

**Example 3.18: Finding Total Tracks Purchased in Each Genre from the Chinook Database**

We want to write a query that returns each genre, with the number of tracks sold in the USA:

- in absolute numbers.
- in percentages.

We'll create a plot to show this data.

# CB 1.4.17 #

```
query_genre = """
WITH usa_tracks AS
(
    SELECT
        i.invoice_id invoice_id,
        il.track_id track_id,
        il.quantity
    FROM invoice i
    INNER JOIN invoice_line il ON il.invoice_id = i.invoice_id
    WHERE i.billing_country = 'USA'
),
usa_genre_tracks AS
(
    SELECT
        g.name genre,
        SUM(ut.quantity) total_tracks_purchased
    FROM usa_tracks ut
    INNER JOIN track t ON t.track_id = ut.track_id
    INNER JOIN genre g ON g.genre_id = t.genre_id
    GROUP BY 1
)

SELECT
    ugt.*,
    (
        CAST(ugt.total_tracks_purchased AS float) /
        CAST
    (
        (
```

```

SELECT SUM(ugt.total_tracks_purchased)
FROM usa_genre_tracks ugt
)
AS float
)
)*100 total_tracks_percent
FROM usa_genre_tracks ugt
GROUP BY 1
ORDER BY total_tracks_purchased DESC
"""

```

```

invoice_line = run_query(query_genre)
print(invoice_line)

```

	genre	total_tracks_purchased	total_tracks_percent
0	Rock	561	53.377735
1	Alternative & Punk	130	12.369172
2	Metal	124	11.798287
3	R&B/Soul	53	5.042816
4	Blues	36	3.425309
5	Alternative	35	3.330162
6	Latin	22	2.093245
7	Pop	22	2.093245
8	Hip Hop/Rap	20	1.902950
9	Jazz	14	1.332065
10	Easy Listening	13	1.236917
11	Reggae	6	0.570885
12	Electronica/Dance	5	0.475737
13	Classical	4	0.380590
14	Heavy Metal	3	0.285442
15	Soundtrack	2	0.190295
16	TV Shows	1	0.095147

Figure 3.22: The Output of CB 1.4.17

We can use the built-in pandas plotting methods to produce a plot for this data. We do this below.

```
# CS 1.4.18 #
```

```

invoice_line.plot(x = 'genre', y = 'total_tracks_purchased',
                  title = "Total_Number_of_Tracks_Sold_vs_Genre_(USA)",
                  kind = 'bar', legend = None)

```

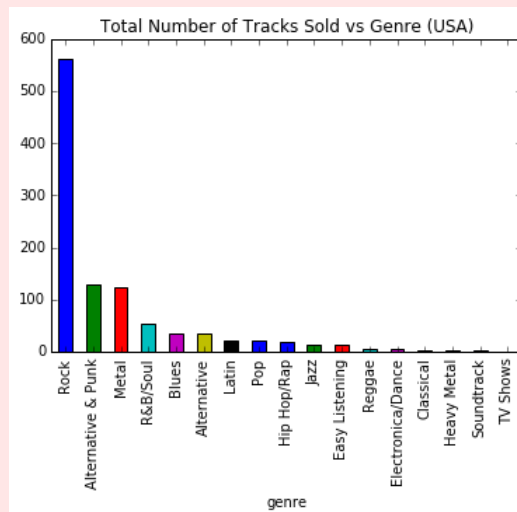


Figure 3.23: The Output of CS 1.4.18

**Example 3.19: Finding Transaction Details for Each Country from the Chinook Database**

We will write a query that collates data on purchases from different countries. When a country has only one customer, we will collect them into an "Other" group.

The results should be sorted by the total sales from highest to lowest, with the "Other" group at the very bottom.

For each country, we will include:

- total number of customers.
- total value of sales.
- average value of sales per customer.
- average order value.

# CB 1.4.19 #

c = """

```
CREATE VIEW country_cust AS
SELECT
    c.first_name || " " || c.last_name customer_name,
    COUNT(i.customer_id) customer_count,
    c.country country,
    SUM(i.total) total_spent
FROM customer c
INNER JOIN invoice i ON i.customer_id = c.customer_id
GROUP BY 1, 1
ORDER BY customer_count DESC
"""
```

d = "DROP\_VIEW\_country\_cust"

run\_command(d)

```

run_command(c)

query = """
With country_info AS
(
    SELECT
        cc.country,
        SUM(cc.customer_count) orders,
        Count(cc.customer_name) unique_customers,
        Sum(total_spent) total_sales
    FROM country_cust cc
    GROUP BY cc.country
    ORDER BY total_sales
),
other_info AS
(
    SELECT
        CASE
            WHEN ci.unique_customers = 1 THEN "Other"
            ELSE 0
        END
        AS country,
        SUM(ci.orders) orders,
        Count(ci.unique_customers) unique_customers,
        SUM(ci.total_sales) total_sales
    FROM country_info ci
    WHERE ci.unique_customers = 1
),
country_other_info AS
(
    SELECT *
    FROM
        (
            SELECT
                coi.*,
                CASE
                    WHEN coi.country = "Other" THEN "1"
                    ELSE 0
                END
                AS count
            FROM
                (
                    SELECT * FROM other_info

                UNION

                SELECT * FROM country_info ci
                WHERE ci.unique_customers != 1
                ) coi
            ORDER BY count ASC
        ) coi_new
)

```

```

SELECT
    country,
    unique_customers,
    total_sales,
    total_sales / CAST(unique_customers as float) average_sale_per_customer,
    total_sales / CAST(orders as float) average_order_value
FROM country_other_info

"""
querydf = run_query(query)
print(querydf)

```

	country	unique_customers	total_sales	average_sale_per_customer	average_order_value
0	Brazil	5	427.68	85.536000	7.011148
1	Canada	8	535.59	66.948750	7.047237
2	Czech Republic	2	273.24	136.620000	9.108000
3	France	5	389.07	77.814000	7.781400
4	Germany	4	334.62	83.655000	8.161463
5	India	2	183.15	91.575000	8.721429
6	Portugal	2	185.13	92.565000	6.383793
7	USA	13	1040.49	80.037692	7.942672
8	United Kingdom	3	245.52	81.840000	8.768571
9	Other	15	1094.94	72.996000	7.448571

Figure 3.24: The Output of CB 1.4.19

The trick in placing the ‘Other’ column at the very end is to assign some ordered value to ‘Other’ with all other countries held at some other constant value. This can be seen in the *country-other-info* subquery in the *WITH* section of CB 1.4.19.

### 3.2.6 Table Relations and Normalization

#### Definition 3.36: SQLite prompt

When you launch the SQLite shell, you will be shown the SQLite prompt, seen below by *sqlite>*.

```

$ sqlite3 chinook.db
— Loading resources from /home/dq/.sqliterc
SQLite version 3.21.0 2017-10-24 18:55:49
Enter ".help" for usage hints.
sqlite>

```

#### Definition 3.37: SQLite Dot Commands

SQLite has a number of dot commands which you can use to help you work with databases. When you use a dot command, you don’t need to use a semicolon. Some common dot commands are

- *.help* - Displays help text showing all dot commands and their function.
- *.tables* - Displays a list of all tables and views in the current database.
- *.shell [command]* - Run a command like *ls* or *clear* in the system shell.



- `.mode` - Allows us to select from a few different display modes. We'll use `.mode column` to allow for easier to read outputs.
- `.quit` - Quits the SQLite shell.

### Example 3.20: Querying on SQLite Shell

We can send query instructions to the SQLite shell so that we can interact with the database.

```
sqlite> SELECT * FROM album LIMIT 10;
album_id  title                                     artist_id
-----
1         For Those About To Rock We Salute You  1
2         Balls to the Wall                     2
3         Restless and Wild                     2
4         Let There Be Rock                     1
5         Big Ones                             3
6         Jagged Little Pill                   4
7         Facelift                             5
8         Warner 25 Anos                       6
9         Plays Metallica By Four Cellos    7
10        Audioslave                       8
sqlite> 
```

Figure 3.25: SQLite Shell Query

### Definition 3.38: CREATE TABLE

The `CREATE TABLE` statement is used to create a new table in a database.

```
CREATE TABLE [table_name] (
    [column1_name] [column1_type],
    [column2_name] [column2_type],
    [column3_name] [column3_type],
    [...]
);
```

Each column in SQLite must have a type. While some database systems have as many as 50 distinct data types, SQLite uses only 5 behind the scenes:

- `TEXT`
- `INTEGER`
- `REAL`
- `NUMERIC`
- `BLOB`

Type	Commonly Used For	Equivalent Types
TEXT	Names Email Addresses Dates and Times Phone Numbers	CHARACTER VARCHAR NCHAR NVARCHAR DATETIME
INTEGER	IDs Quantities	INT SMALLINT BIGINT INT8
REAL	Weights Averages	DOUBLE FLOAT
NUMERIC	Prices Statuses	DECIMAL BOOLEAN
BLOB	Binary Data	BLOB

Figure 3.26: SQLite Types and Their Common Uses

**Definition 3.39: Primary Key & Foreign Key**

A **primary key** is a unique identifier for each row - you cannot have two rows in a table with the same value for the primary key column(s).

When two tables have a relation, there will be a column in one table that is a primary key in another table. For instance, from the Chinook database, in the invoice\_line table, the invoice\_id column is the primary key from the invoice table. This is known as a **foreign key**. By defining a foreign key, our database engine will prevent us from adding rows where the foreign key value doesn't exist in the other table, which helps to prevent errors in our data (note that by default SQLite doesn't force foreign key constraints). If we wanted create a table called user with the user\_id column serving as the primary key, we would use the syntax:

```
CREATE TABLE user (
    user_id INTEGER PRIMARY KEY,
    first_name TEXT,
    last_name TEXT
);
```

Let's say we wanted to create a new table purchase which tracks basic information about a purchase made by one of our users. Our create statement might look like this:

```
CREATE TABLE purchase (
    purchase_id INTEGER PRIMARY KEY,
    user_id INTEGER,
    purchase_date TEXT,
    total NUMERIC,
    FOREIGN KEY (user_id) REFERENCES user(user_id)
);
```

By adding a *FOREIGN KEY* clause, we can define one of our columns as a foreign key and specify the table and column that it references.

### Definition 3.40: Database Normalization

When we created our wishlist table, we didn't include a *track\_id* column to store which tracks are in the users wishlist. To understand why, let's take a look at what the table might look like if we stored all the data in a single table.

wishlist_id	customer_id	name	track_id
1	34	Joao's awesome wishlist	1158
1	34	Joao's awesome wishlist	2646
1	34	Joao's awesome wishlist	1990
2	18	Amy loves pop	3272
2	18	Amy loves pop	3470

Figure 3.27: Wishlist Table with track\_id Column

There are some drawbacks to storing the data this way:

- **Data Duplication** - we are storing the name of each wishlist multiple times.
- **Data Modification** - if we want to change the name of one of the wishlists, we have to modify multiple rows.
- **Data Integrity** - There is nothing to stop a row being added with the wrong wishlist name, and if that happened we wouldn't know which was the correct name.

The process of optimizing the design of databases to minimize these issues is called *database normalization* [See [18]].

### Definition 3.41: Compound Primary Key

When two or more columns combine to form a primary key it is called a compound primary key. To create a compound primary key, you use the *PRIMARY KEY* clause:

```
CREATE TABLE [table_name] (
    [column_one_name] [column_one_type],
    [column_two_name] [column_two_type],
    [column_three_name] [column_three_type],
    PRIMARY KEY (column_one_name, column_two_name)
);
```

### Definition 3.42: SQL INSERT INTO

The *INSERT INTO* statement is used to insert new records in a table. To add rows to a SQL table, we'll use the *INSERT* statement:

```
INSERT INTO [table_name] (
    [column1_name],
    [column2_name],
    [column3_name]
) VALUES (
    [value1],
    [value2],
    [value3]
);
```

If you are inserting values into every column in a table, you don't need to list the column names:

```
INSERT INTO [table_name] VALUES ([value1], [value2], [value3]);
```

Additionally, you can insert multiple rows in a single statement:

```
INSERT INTO [table_name]
VALUES
    ([value1], [value2], [value3]),
    ([value4], [value5], [value6]),
    [...]
```

### Definition 3.43: SQL DELETE Statement

The *DELETE* statement is used to delete existing records in a table.

```
DELETE FROM table_name WHERE condition;
```

If you omit the *WHERE* statement, SQL will delete all rows from the table.

### Definition 3.44: SQL ALTER TABLE

The *ALTER TABLE* statement is used to add, delete, or modify columns in an existing table.

The *ALTER TABLE* statement is also used to add and drop various constraints on an existing table. To add a column, we can use the following syntax:

```
ALTER TABLE [table_name]
ADD COLUMN [column_name] [column_type];
```

To delete a column in a table, use the following syntax (notice that some database systems don't allow deleting a column):

```
ALTER TABLE table_name
DROP COLUMN column_name;
```

### Definition 3.45: SQL UPDATE Statement

The *UPDATE* statement is used to modify the existing records in a table.

```
UPDATE table_name
SET column1 = value1, column2 = value2, ...
WHERE condition;
```

The *WHERE* clause is optional, and can contain any expression that would be valid in a *SELECT* statement.

**Example 3.21**

We will first launch the SQLite shell and connect to the `chinook.db` database. This will be followed by adding two new columns, with values, to the `invoice` table:

- `tax`, with type `NUMERIC`.  
The value for all existing rows should be 0.
- `subtotal`, with type `NUMERIC`.  
The value for each row should be the same as that row's value for `total`.

We will then quit the SQLite shell.

# CB 1.4.20 #

```
$sqlite3 chinook.db
sqlite> ALTER TABLE invoice
...> ADD COLUMN tax NUMERIC;
sqlite> ALTER TABLE invoice
...> ADD COLUMN subtotal NUMERIC;
sqlite> UPDATE invoice
...> SET tax = 0, subtotal = total;
sqlite> SELECT
...>     invoice_id ,
...>     subtotal ,
...>     tax ,
...>     total
...> FROM invoice
...> LIMIT 5;
sqlite> .quit
```

invoice_id	subtotal	tax	total
1	15.84	0	15.84
2	9.9	0	9.9
3	1.98	0	1.98
4	7.92	0	7.92
5	16.83	0	16.83

Figure 3.28: The Output of the SELECT Query in CB 1.4.20

### 3.3 SQL and Databases: Advanced

#### 3.3.1 Using PostgreSQL

##### Definition 3.46: PostgreSQL

PostgreSQL, also known as Postgres, is a free and open-source relational database management system (RDBMS) emphasizing extensibility and technical standards compliance. It is designed to handle a range of workloads, from single machines to data warehouses or Web services with many concurrent users. It is the default database for macOS Server, and is also available for Linux, FreeBSD, OpenBSD, and Windows.

PostgreSQL features transactions with Atomicity, Consistency, Isolation, Durability (ACID) proper-

ties, automatically updatable views, materialized views, triggers, foreign keys, and stored procedures.

### Definition 3.47: Psycopg

Psycopg is the most popular PostgreSQL adapter for the Python programming language. Its core is a complete implementation of the Python DB API 2.0 specifications. Several extensions allow access to many of the features offered by PostgreSQL.

## SQL Transactions

With PostgreSQL, we're dealing with multiple users who could be changing the database at the same time. If one of these fail, it may leave the database in a state that doesn't match the intention of some set of queries.

Transactions prevent this type of behavior by ensuring that all the queries in a transaction block are executed at the same time. If any of the transactions fail, the whole group fails, and no changes are made to the database at all.

Whenever we open a `Connection` in `psycopg2`, a new transaction will automatically be created. All queries run up until the `commit` method is called will be placed into the same transaction block. When `commit` is called, the PostgreSQL engine will run all the queries at once.

If we don't want to apply the changes in the transaction block, we can call the `rollback` method to remove the transaction. Not calling either `commit` or `rollback` will cause the transaction to stay in a pending state, and will result in the changes not being applied to the database.

### Definition 3.48: Psycopg `commit()` and `rollback()` Methods

#### `commit()`

Commit any pending transaction to the database. [See [19] for further information].

#### `rollback()`

Roll back to the start of any pending transaction. Closing a connection without committing the changes first will cause an implicit rollback to be performed.

### Example 3.22

We want to first connect to the `dq` database as the user `dq`.

We will then write a SQL query that creates a table called `notes` in the `dq` database, with the following columns and data types:

- `id`: integer data type, and is a primary key.
- `body`: text data type.
- `title`: text data type.

We'll execute this query using the `execute` method.

We will use the `commit` method on the `Connection` object to apply the changes in the transaction to the database. We now want to execute a SQL query that inserts a row into the `notes` table with the following values:

- `id`: 1

- *body: 'Do more missions on Dataquest.'*
- *title: 'Dataquest reminder'.*

We will then execute a SQL query that selects all of the rows from the *notes* table. We will finally fetch all of the results, print them out and end it off with committing to changes and close the Connection.

*# CB 1.4.21 #*

**import** psycopg2

```
conn = psycopg2.connect("dbname=_dq_user=_dq")
cur = conn.cursor()
query = """
CREATE TABLE notes (
id integer PRIMARY KEY,
body TEXT,
title TEXT);
"""
cur.execute(query)
conn.commit()
query = """
INSERT INTO notes (
id, body, title )
VALUES (
1, 'Do more missions on Dataquest.', 'Dataquest reminder ');
"""
cur.execute(query)
queryrows = """
SELECT * from notes;
"""
cur.execute(queryrows)
conn.commit()
print(cur.fetchall())
conn.close()
```

**Output:**

*[(1, 'Do more missions on Dataquest.', 'Dataquest reminder')]*

### Definition 3.49: SQL CREATE DATABASE

The CREATE DATABASE statement is used to create a new SQL database.

**CREATE** DATABASE database\_name OWNER database\_owner\_name

We can specify the user who will own the database when we create it as well, using the OWNER statement. The database owner is a user that has implied permissions to perform all activities in the database.

### Definition 3.50: SQL DROP DATABASE

We can delete a database using the DROP DATABASE statement. The DROP DATABASE statement will immediately remove a database, provided the user executing the query has the right permissions.

```
DROP DATABASE dbName;
```

## 3.4 APIs and Web Scraping

### 3.4.1 Working with APIs

#### Limitations of Working With Entire Databases

While they're popular resources, there are many cases where it's impractical to use one. Here are a few situations where data sets don't work well:

- The data changes frequently. It doesn't really make sense to regenerate a data set of stock prices, for example, and download it every minute. This approach would require a lot of bandwidth, and be very slow.
- You only want a small piece of a much larger data set. Reddit comments are one example. What if you want to pull just your own comments from reddit? It doesn't make much sense to download the entire reddit database, then filter it for a few items.
- It involves repeated computation. For example, Spotify has an API that can tell you the genre of a piece of music. You could theoretically create your own classifier and use it to categorize music, but you'll never have as much data as Spotify does.

#### Definition 3.51: APIs

In cases like those listed above, an application program interface (API) is the right solution. An API is a set of methods and tools that allows different applications to interact with each other. Programmers use APIs to query and retrieve data dynamically (which they can then integrate with their own apps). A client can retrieve information quickly and effectively through an API.

#### Definition 3.52: API Endpoints

An **endpoint** is a server route for retrieving specific data from an API. For example, the `/comments` endpoint on the reddit API might retrieve information about comments, while the `/users` endpoint might retrieve data about users

#### Definition 3.53: Requests Library

The requests library is the de facto standard for making HTTP requests in Python. It abstracts the complexities of making requests behind a beautiful, simple API so that you can focus on interacting with services and consuming data in your application

#### Definition 3.54: Requests.get() Method

Makes a request to a web page, and returns the status code.

There are many different types of requests. The most common is a GET request, which we use to retrieve data.



**Definition 3.55: Status Codes**

Web servers return status codes every time they receive an API request. A status code provides information about what happened with a request. Here are some codes that are relevant to GET requests:

- 200 - Everything went okay, and the server returned a result (if any).
- 301 - The server is redirecting you to a different endpoint. This can happen when a company switches domain names, or an endpoint's name has changed.
- 401 - The server thinks you're not authenticated. This happens when you don't send the right credentials to access an API.
- 400 - The server thinks you made a bad request. This can happen when you don't send the information the API requires to process your request, among other things.
- 403 - The resource you're trying to access is forbidden; you don't have the right permissions to see it.
- 404 - The server didn't find the resource you tried to access.

We can access the status code of a request with the following syntax:

```
response = requests.get(url)
status_code = response.status_code
```

**Definition 3.56: JSON Module**

Python has a built-in package called `json`, which can be used to work with JSON data. The JSON library has two main methods:

- `dumps`: Takes in a Python object, and converts it to a string
- `loads`: Takes a JSON string, and converts it to a Python object.

**Example 3.23: ISS over San Francisco Request**

Get the duration value of the ISS' first pass over San Francisco and assign the value to `first_pass_duration`. We can get the content of a response as a Python object by using the `.json()` method on the response.

*# CB 1.4.? #*

```
import requests
```

```
parameters = {"lat": 37.78, "lon": -122.41}
response = requests.get("http://api.open-notify.org/iss-pass.json",
params=parameters)
```

```
# Get the response data as a Python object. Verify that it's a dictionary.
json_data = response.json()
first_pass_duration = json_data['response'][0]['duration']
print(type(json_data))
print(json_data)
```

```

Output
<class 'dict'>
{'message': 'success', 'request': {'datetime': 1441417753, 'latitude': 37.78, 'passes': 5, 'longitude':
-122.41, 'altitude': 100}, 'response': [{'risetime': 1441456672, 'duration': 369}, {'risetime':
1441462284, 'duration': 626}, {'risetime': 1441468104, 'duration': 581}, {'risetime': 1441474000,
'duration': 482}, {'risetime': 1441479853, 'duration': 509}]}

Variables
▼ first_pass_duration  int (<class 'int'>)
    369

```

Figure 3.29: The Output of CB 1.4.

### 3.4.2 Intermediate APIs

#### Definition 3.57: Access Tokens for APIs

Access Tokens are used in token-based authentication to allow an application to access an API. The application receives an Access Token after a user successfully authenticates and authorizes access, then passes the Access Token as a credential when it calls the target API. The passed token informs the API that the bearer of the token has been authorized to access the API and perform specific actions specified by the scope that was granted during authorization.

#### Pagination

Sometimes, a request can return a lot of objects. This might happen when you're doing something like listing out all of a user's repositories, for example. Returning too much data will take a long time and slow the server down. For example, if a user has 1,000+ repositories, requesting all of them might take 10+ seconds. This isn't a great user experience, so it's typical for API providers to implement **pagination**. This means that the API provider will only return a certain number of records per page. You can specify the page number that you want to access. To access all of the pages, you'll need to write a loop.

#### Example 3.24

We want to first make an authenticated request to <https://api.github.com/users/VikParuchuri/orgs>. This will give us a list of the organizations a GitHub user belongs to. We'll then assign the JSON content of the response to `orgs` (which can be done with `response.json()`).

*# CB 1.4.? #*

```

import requests
# Create a dictionary of headers containing our Authorization header.
headers = {"Authorization": "token_1f36137fbbe1602f779300dad26e4c1b7fbab631"}

# Make a GET request to the GitHub API with our headers.
# This API endpoint will give us details about Vik Paruchuri.
response = requests.get("https://api.github.com/users/VikParuchuri/orgs",
headers=headers)
orgs = response.json()
# Print the content of the response. As you can see, this token corresponds
to the account of Vik Paruchuri.

```

```
print(response.json())
```

Output

```
[{'events_url': 'https://api.github.com/orgs/dataquestio/events', 'repos_url':
'https://api.github.com/orgs/dataquestio/repos', 'id': 11148054, 'avatar_url':
'https://avatars.githubusercontent.com/u/11148054?v=3', 'login': 'dataquestio', 'public_members_url':
'https://api.github.com/orgs/dataquestio/public_members{/member}', 'members_url':
'https://api.github.com/orgs/dataquestio/members{/member}', 'description': None, 'url':
'https://api.github.com/orgs/dataquestio'}]
```

Figure 3.30: The Output of CB 1.4.

### Definition 3.58: `Requests.post()` Method

The `post()` method sends a `POST` request to the specified url. The `post()` method is used when you want to send some data to the server. `POST` requests to send information (instead of retrieve it), and to create objects on the API's server.

### Github API POST Requests

Check out GitHub's API documentation for repositories [20] to see a full list of what data we can pass in with this `POST` request. Here are just a couple data points:

- `name`: Required, the name of the repository.
- `description`: Optional, the description of the repository.

A successful `POST` request will usually return a `201` status code indicating that it was able to create the object on the server. Sometimes, the API will return the JSON representation of the new object as the content of the response.

### Definition 3.59: `Requests.patch()` & `Requests.put()` Methods

Sometimes we want to update an existing object, rather than create a new one. This is where `PATCH` and `PUT` requests come into play.

We use `PATCH` requests when we want to change a few attributes of an object, but don't want to resend the entire object to the server. Maybe we just want to change the name of our repository, for example.

We use `PUT` requests to send the complete object we're revising as a replacement for the server's existing version.

In practice, API developers don't always respect this convention. Sometimes API endpoints that accept `PUT` requests will treat them like `PATCH` requests, and not require us to send the whole object back.

**Example 3.25: Patch Request to Github Repository**

In this example, we want to make a *PATCH* request to the `https://api.github.com/repos/VikParuchuri/learning-about-apis` endpoint that changes the description to “Learning about requests!”. Assign the status code of the response to `status`.

```
# CB 1.4.? #
```

```
payload = {"description": "Learning_about_requests!", "name":
"learning-about-apis"}
response = requests.patch("https://api.github.com/repos/VikParuchuri/
learning-about-apis", json=payload, headers=headers)
status = response.status_code
print(response.status_code)
```

Output  
200

**Definition 3.60: Requests.delete() Method**

The final major request type is the *DELETE* request. The *DELETE* request removes objects from the server. We can use the *DELETE* request to remove repositories. A successful *DELETE* request will usually return a 204 status code indicating that it successfully deleted the object. Use *DELETE* requests carefully - it's very easy to remove something important by accident.

**3.4.3 Challenge: Working with the Reddit API****3.4.4 Web Scraping****Definition 3.61: Web Scraping**

A lot of data aren't accessible through data sets or APIs. They may exist on the Internet as Web pages, though. One way to access the data without waiting for the provider to create an API is to use a technique called Web scraping.

Web scraping allows us to load a Web page into Python and extract the information we want. We can then work with the data using standard analysis tools like pandas and numpy.

**Definition 3.62: HTML**

Hypertext Markup Language (HTML) is the standard markup language for documents designed to be displayed in a web browser. It can be assisted by technologies such as Cascading Style Sheets (CSS) and scripting languages such as JavaScript.

**Definition 3.63: BeautifulSoup Library**

Beautiful Soup [21] is a Python library designed for quick turnaround projects like screen-scraping. Three features make it powerful:

1. BeautifulSoup provides a few simple methods and Pythonic idioms for navigating, searching, and

*modifying a parse tree: a toolkit for dissecting a document and extracting what you need. It doesn't take much code to write an application.*

2. Beautiful Soup automatically converts incoming documents to Unicode and outgoing documents to UTF-8. You don't have to think about encodings, unless the document doesn't specify an encoding and Beautiful Soup can't detect one. Then you just have to specify the original encoding.
3. Beautiful Soup sits on top of popular Python parsers like lxml and html5lib, allowing you to try out different parsing strategies or trade speed for flexibility.

### Example 3.26: Fetching HTML items with Particular Tag and Class

We consider the following HTML code:

```
<html>
  <head>
    <title>A simple example page</title>
  </head>
  <body>
    <div>
      <p class="inner-text">
        First inner paragraph.
      </p>
      <p class="inner-text">
        Second inner paragraph.
      </p>
    </div>
    <p class="outer-text">
      <b>
        First outer paragraph.
      </b>
    </p>
    <p class="outer-text">
      <b>
        Second outer paragraph.
      </b>
    </p>
  </body>
</html>
```

Figure 3.31: HTML Code for Simple Inner-Outer Paragraph Classes

We want to get the text in the second inner paragraph, and assign the result to `second_inner_paragraph_text`. We then want to get the text of the first outer paragraph, and assign the result to `first_outer_paragraph_text`.

# CB 1.4.? #

# Get the website that contains classes.

```
response = requests.get("http://dataquestio.github.io/web-scraping-pages/
simple_classes.html")
```

```
content = response.content
```

```
parser = BeautifulSoup(content, 'html.parser')
```

```
second_inner_paragraph_text = parser.find_all("p", class_ = "inner-text")[1].text
```

```
first_outer_paragraph_text = parser.find_all("p", class_ = "outer-text")[0].text
```

```
print(second_inner_paragraph_text)
print(first_outer_paragraph_text)
```

Output:

*Second inner paragraph.*

*First outer paragraph.*

### Definition 3.64: CSS

Cascading Style Sheets, or CSS, is a language for adding styles to HTML pages. You may have noticed that our simple HTML pages from the past few screens didn't have any styling; all of the paragraphs had black text and the same font size. Most Web pages use CSS to display a lot more than basic black text. CSS uses selectors to add styles to the elements and classes of elements you specify. You can use selectors to add background colors, text colors, borders, padding, and many other style choices to the elements on HTML pages

### Example 3.27: Nesting CSS Selectors for 2014 Superbowl Data

We consider the following HTML code:

```
<html>
  <head lang="en">
    <meta charset="UTF-8">
    <title>2014 Superbowl Team Stats</title>
  </head>
  <body>
    <table class="stats_table nav_table" id="team_stats">
      <tbody>
        <tr id="teams">
          <th></th>
          <th>SEA</th>
          <th>NWE</th>
        </tr>
        <tr id="first-downs">
          <td>First downs</td>
          <td>20</td>
          <td>25</td>
        </tr>
        <tr id="total-yards">
          <td>Total yards</td>
          <td>396</td>
          <td>377</td>
        </tr>
        <tr id="turnovers">
          <td>Turnovers</td>
          <td>1</td>
          <td>2</td>
        </tr>
        <tr id="penalties">
          <td>Penalties-yards</td>
          <td>7-70</td>
          <td>5-36</td>
        </tr>
        <tr id="total-plays">
          <td>Total Plays</td>
          <td>53</td>
          <td>72</td>
        </tr>
        <tr id="time-of-possession">
          <td>Time of Possession</td>
          <td>26:14</td>
          <td>33:46</td>
        </tr>
      </tbody>
    </table>
  </body>
</html>
```

Figure 3.32: HTML for Simple 2014 Superbowl Web Page

We want to find the Total Plays for the New England Patriots, and assign the result to `patriots_total_plays_count`. We also want to find the Total Yards for the Seahawks, and assign the result to `seahawks_total_yards_count`. We're going to do this by way of nesting CSS selectors.<sup>a</sup>

*# CB 1.4.? #*

*# Get the Superbowl box score data.*

```
response = requests.get("http://dataquestio.github.io/web-scraping-pages/
2014-super-bowl.html")
content = response.content
parser = BeautifulSoup(content, 'html.parser')
```

```
patriots_total_plays_count = parser.select("#total-plays_td")[2].text
seahawks_total_yards_count = parser.select("#total-yards_td")[1].text
```

```
print(patriots_total_plays_count)
print(seahawks_total_yards_count)
```

Output:

```
72
396
```

---

<sup>a</sup>To specify an HTML item with id *identity* and tag *tag\_name* can be done by the selector **#identity tag\_name**.

## 4 Machine Learning Introduction

### 4.1 Machine Learning Fundamentals

#### 4.1.1 Introduction to K-Nearest Neighbours

##### Definition 4.1: Nearest Neighbours

*In pattern recognition, the k-nearest neighbors algorithm (k-NN) is a non-parametric method used for classification and regression. In both cases, the input consists of the k closest training examples in the feature space. The output depends on whether k-NN is used for classification or regression.*

##### Definition 4.2: Pandas apply() Method

`DataFrame.apply(self, func, axis=0, raw=False, result_type=None, args=(), **kwargs)`

Apply a function along an axis of the DataFrame. Objects passed to the function are Series objects whose index is either the DataFrame's index (axis=0) or the DataFrame's columns (axis=1). By default (result\_type=None), the final return type is inferred from the return type of the applied function. Otherwise, it depends on the result\_type argument.

##### Definition 4.3: Pandas sort\_values() Method

`DataFrame.sort_values(self, by, axis=0, ascending=True, inplace=False, kind='quicksort', na_position='last', ignore_index=False)`

Sort by the values along either axis [See [22] for further documentation].

##### PARAMETERS:

**by:** str or list of str

Name or list of names to sort by.

- If axis is 0 or 'index' then by may contain index levels and/or column labels.
- If axis is 1 or 'columns' then by may contain column levels and/or index labels.

Changed in version 0.23.0: Allow specifying index or column level names.

#### Example 4.1: Predicting AirBnB Rental Price with Nearest Neighbours

The `dc_listings` dataframe has some of the following column information:

- **accommodates:** the number of guests the rental can accommodate
- **price:** nightly price for the rental

We will write a function named `predict_price` that can use the k-nearest neighbors machine learning technique to calculate the suggested price for any value for `accommodates`. This function should:

- Take in a single parameter, `new_listing`, that describes the number of bedrooms.
- Code has been added that assigns `dc_listings` to a new Dataframe named `temp_df`. We used the `pandas.DataFrame.copy()` method so the underlying dataframe is assigned to `temp_df`, instead of just a reference to `dc_listings`.



- Calculate the distance between each value in the `accommodates` column and the `new_listing` value that was passed in. Assign the resulting Series object to the `distance` column in `temp_df`.
- Sort `temp_df` by the `distance` column and select the first 5 values in the `price` column. Don't randomize the ordering of `temp_df`.
- Calculate the mean of these 5 values and use that as the return value for the entire `predict_price` function.
- Use the `predict_price` function to suggest a price for a living space that:
  - accommodates 1 person, assign the suggested price to `acc_one`.
  - accommodates 2 people, assign the suggested price to `acc_two`.
  - accommodates 4 people, assign the suggested price to `acc_four`.

# CB 1.6.1 #

```
dc_listings = pd.read_csv('dc_airbnb.csv')
stripped_commas = dc_listings['price'].str.replace(',', '')
stripped_dollars = stripped_commas.str.replace('$', '')
dc_listings['price'] = stripped_dollars.astype('float')
dc_listings = dc_listings.loc[np.random.permutation(len(dc_listings))]

def predict_price(new_listing):
    temp_df = dc_listings.copy()
    temp_df['distance'] = temp_df['accommodates'].apply(lambda x:
    np.abs(x - new_listing))
    temp_df = temp_df.sort_values('distance')
    new_listing = temp_df['price'].head(5).mean()

    return(new_listing)

acc_one = predict_price(1)
acc_two = predict_price(2)
acc_four = predict_price(4)
print(acc_one)
print(acc_two)
print(acc_four)
```

Output:  
68.0  
112.8  
124.8

#### 4.1.2 Evaluating Model Performance

##### Definition 4.4: Error Metric

We now need a metric that quantifies how good the predictions were on the test set. This class of metrics is called an error metric. As the name suggests, an error metric quantifies how inaccurate our predictions were from the actual values

**Definition 4.5: Mean Absolute Error (MAE)**

Consider the context of machine learning. Let  $y$  denote a  $1 \times n$  vector, comprised of the actual values / labels for a given entry and  $\hat{y}$  denote the  $1 \times n$  vector, comprised of the predicted values / labels for each entry. Let  $y_k$  and  $\hat{y}_k$  denote the  $k^{\text{th}}$  entries for  $y$  and  $\hat{y}$  respectively. Then, the MAE is defined as

$$\text{MAE}(y, \hat{y}) = \frac{1}{n} \sum_{k=1}^n |y_k - \hat{y}_k| \quad (4.1)$$

**Definition 4.6: Mean Squared Error (MSE)**

Consider the context of machine learning. Let  $y$  denote a  $1 \times n$  vector, comprised of the actual values / labels for a given entry and  $\hat{y}$  denote the  $1 \times n$  vector, comprised of the predicted values / labels for each entry. Let  $y_k$  and  $\hat{y}_k$  denote the  $k^{\text{th}}$  entries for  $y$  and  $\hat{y}$  respectively. Then, the MSE is defined as

$$\text{MSE}(y, \hat{y}) = \frac{1}{n} (y - \hat{y})^T (y - \hat{y}) = \frac{1}{n} \sum_{k=1}^n (y_k - \hat{y}_k)^2 \quad (4.2)$$

The mean squared error assigns greater penalty towards predictions that are more deviated from the actual values.

**Definition 4.7: Root Mean Squared Error (RMSE)**

An immediate extension of Mean Squared Error is the Root Mean Squared Error (RMSE). Let  $y$  and  $\hat{y}$  denote two  $1 \times n$  vectors. Then, RMSE is defined as

$$\text{RMSE}(y, \hat{y}) = \sqrt{\text{MSE}(y, \hat{y})} = \sqrt{\frac{1}{n} \sum_{k=1}^n (y_k - \hat{y}_k)^2} \quad (4.3)$$

**Proposition 4.1: RMSE Bounds**

Let  $y, \hat{y} \in \mathbb{R}^n$ . Then, the following inequalities hold:

$$\text{MAE}(y, \hat{y}) \leq \text{RMSE}(y, \hat{y}) \leq \sqrt{n} \text{MAE}(y, \hat{y}) \quad (4.4)$$

**Example 4.2: Evaluating Nearest Neighbour Performance with Error Metrics**

We use the same `predict_price` function as in CB 1.6.1 but change the `Dataframe` that `temp_df` is assigned to. We will change it from `dc_listings` to `train_df`, so only the training set is used.

- Use the `Series` method `apply` to pass all of the values in the `bathrooms` column from `test_df` through the `predict_price` function.
- Assign the resulting `Series` object to the `predicted_price` column in `test_df`.
- Apply the function to `test_df` and assign the resulting `Series` object containing the predicted price values to the `predicted_price` column in `test_df`.
- Calculate the squared error between the `price` and `predicted_price` columns in `test_df` and assign the resulting `Series` object to the `squared_error` column in `test_df`.

- Calculate the mean of the `squared_error` column in `test_df` and assign to `mse`. Take the square root of `mse` and assign it to `rmse`.
- Use the `print` function to display the RMSE value.

# CB 1.6.2 #

```
import pandas as pd
import numpy as np

dc_listings = pd.read_csv("dc-airbnb.csv")
stripped_commas = dc_listings['price'].str.replace(',', '')
stripped_dollars = stripped_commas.str.replace('$', '')
dc_listings['price'] = stripped_dollars.astype('float')
train_df = dc_listings.iloc[0:2792]
test_df = dc_listings.iloc[2792:]

def predict_price(new_listing):
    ## DataFrame.copy() performs a deep copy
    temp_df = train_df.copy()
    temp_df['distance'] = temp_df['bathrooms'].apply(lambda x:
    np.abs(x - new_listing))
    temp_df = temp_df.sort_values('distance')
    nearest_neighbor_prices = temp_df.iloc[0:5]['price']
    predicted_price = nearest_neighbor_prices.mean()

    return predicted_price

test_df['predicted_price'] = test_df['bathrooms'].apply(lambda x:
predict_price(x))
test_df['squared_error'] = (test_df['predicted_price'] - test_df['price'])**(2)
mse = test_df['squared_error'].mean()
rmse = np.sqrt(mse)
print(rmse)
```

Output:

135.66666532952246

### 4.1.3 Multivariate K-Nearest Neighbors

#### Definition 4.8: Nominal Data

A nominal scale describes a variable with categories that do not have a natural order or ranking. You can code nominal variables with numbers if you want, but the order is arbitrary and any calculations, such as computing a mean, median, or standard deviation, would be meaningless.

Examples of nominal variables include:

- genotype
- blood type

- zip code
- race
- political party

#### Definition 4.9: Ordinal Data

An ordinal scale is one where the order matters but not the difference between values.

Examples of ordinal variables include:

- socio-economic status (“low income”, “middle income”, “high income”)
- education level (“high school”, “BS”, “MS”, “PhD”)
- satisfaction rating (“extremely dislike”, “dislike”, “neutral”, “like”, “extremely like”).

#### Definition 4.10: Scikit-Learn Library

Scikit-learn (formerly `scikits.learn` and also known as `sklearn`) is a free software machine learning library for the Python programming language. It features various classification, regression and clustering algorithms including support vector machines, random forests, gradient boosting, k-means and DBSCAN, and is designed to interoperate with the Python numerical and scientific libraries NumPy and SciPy.

#### Scikit-Learn Workflow

The scikit-learn workflow consists of 4 main steps:

- instantiate the specific machine learning model you want to use
- fit the model to the training data
- use the model to make predictions
- evaluate the accuracy of the prediction

#### Definition 4.11: Scikit-Learn Fit Method

We can fit the model to the data using the fit method. For all models, the fit method takes in 2 required parameters:

- matrix-like object, containing the feature columns we want to use from the training set.
- list-like object, containing correct target values.

Matrix-like object means that the method is flexible in the input and either a Dataframe or a NumPy 2D array of values is accepted. This means you can select the columns you want to use from the Dataframe and use that as the first parameter to the fit method.

When the `fit()` method is called, scikit-learn stores the training data we specified within the chosen model instance. If you try passing in data containing missing values or non-numerical values into the fit method, scikit-learn will return an error. Scikit-learn contains many such features that help prevent us from making common mistakes.

**Definition 4.12: Scikit-Learn Predict Method**

Once we have specified the training data we want to use to make predictions, we can use the predict method to make predictions on the test set. The predict method has only one required parameter:

- **matrix-like object**, containing the feature columns from the dataset we want to make predictions on the number of feature columns you use during both training and testing need to match or scikit-learn will return an error.

**Definition 4.13: Scikit-Learn KNeighborsRegressor Class**

```
class sklearn.neighbors.KNeighborsRegressor(n_neighbors=5, weights='uniform', algorithm='auto', leaf_size=30, p=2, metric='minkowski', metric_params=None, n_jobs=None, **kwargs)
```

Regression based on k-nearest neighbors.

The target is predicted by local interpolation of the targets associated of the nearest neighbors in the training set [See [23] for further documentation].

PARAMETERS:

- **n\_neighbors:** int, optional (default = 5)  
Number of neighbors to use by default for kneighbors queries.
- **algorithm:** {'auto', 'ball\_tree', 'kd\_tree', 'brute'}, optional  
Algorithm used to compute the nearest neighbors:
  - 'ball\_tree' will use BallTree.
  - 'kd\_tree' will use KDTree.
  - 'brute' will use a brute-force search.
  - 'auto' will attempt to decide the most appropriate algorithm based on the values passed to fit method.
- **metric:** string or callable, default 'minkowski'  
The distance metric to use for the tree. The default metric is minkowski, and with p=2 is equivalent to the standard Euclidean metric. See the documentation of the DistanceMetric class for a list of available metrics. If metric is "precomputed", X is assumed to be a distance matrix and must be square during fit. X may be a Glossary, in which case only "nonzero" elements may be considered neighbors.

**Example 4.3: K-Nearest Neighbours for Regression**

In this exercise, we want to normalize all of the feature columns in `dc_listings` and assign the new Dataframe containing just the normalized feature columns to `normalized_listings`. Afterwards, we will add the price column from `dc_listings` to `normalized_listings`.

We will then create a new instance of the `KNeighborsRegressor` class with the following parameters:

- **n\_neighbors:** 5
- **algorithm:** brute
- **metric:** euclidean

We will use all of the columns, except for the price column, to train a k-nearest neighbors model using the above parameters. We will then

- Use the model to make predictions on the test set and assign the resulting NumPy array of predictions to `all_features_predictions`.
- Calculate the MSE and RMSE values and assign to `all_features_mse` and `all_features_rmse` accordingly.
- Use the print function to display both error scores.

# CB 1.6.3 #

```
from sklearn.neighbors import KNeighborsRegressor

normalized_listings = (dc_listings - dc_listings.mean()) / dc_listings.std()
normalized_listings['price'] = dc_listings['price']

train_df = normalized_listings.iloc[0:2792]
test_df = normalized_listings.iloc[2792:]

features = train_df.drop('price', axis=1).columns

knn = KNeighborsRegressor(n_neighbors = 5, algorithm = 'brute',
metric = 'euclidean')

knn.fit(train_df[features], train_df['price'])

all_features_predictions = knn.predict(test_df[features])

all_features_mse = mean_squared_error(all_features_predictions, test_df['price'])
all_features_rmse = np.sqrt(all_features_mse)
print(all_features_mse)
print(all_features_rmse)
```

Output:

```
15455.275631399316
124.31924883701363
```

Interestingly enough, when we only included the columns {accommodates, bathrooms, bedrooms, number\_of\_reviews}, we obtained an RMSE value of 115.4, a score lower than what was found when we included all features. Hence, the principle we should really invoke is the following:

*Select the relevant attributes the model uses to calculate similarity when ranking the closest neighbors, which encodes the essence of feature selection.*

#### Definition 4.14: Feature Selection

The process of selecting features to use in a model is known as feature selection. You want to select the relevant attributes for the model to use when computing error metrics such as similarity in closest neighbors.

#### 4.1.4 Hyperparameter Optimization

##### Definition 4.15: Hyperparameter Optimization

Values that affect the behavior and performance of a model that are unrelated to the data that's used are referred to as hyperparameters. The process of finding the optimal hyperparameter value is known as hyperparameter optimization.

##### Definition 4.16: Grid Search

A simple but common hyperparameter optimization technique is known as grid search, which involves:

- selecting a subset of the possible hyperparameter values
- training a model using each of these hyperparameter values
- evaluating each model's performance
- selecting the hyperparameter value that resulted in the lowest error value.

##### Example 4.4: Hyperparameter Tuning for K-Nearest Neighbor Regression

While using only the `accommodates` and `bathrooms` columns:

- Train a model for each `k` value between 1 and 20 using the training data.
- Use each model to make predictions on the test set (using just the `accommodates` and `bathrooms` columns).
- Calculate each model's MSE value by comparing each set of predictions to the true price values.
- Find the `k` value that obtained the lowest MSE value.
- Create a dictionary named `two_hyp_mse` that contains 1 key-value pair:
  - key: `k` value that resulted in lowest MSE value.
  - value: corresponding MSE value.

Repeat this process while using only the `accommodates`, `bathrooms`, and `bedrooms` columns:

- Create a dictionary named `three_hyp_mse` that contains 1 key-value pair:
  - key: `k` value that resulted in lowest MSE value.
  - value: corresponding MSE value.

Display both `two_hyp_mse` and `three_hyp_mse` using the `print()` function.

Lastly, we will use the `scatter()` method from `matplotlib.pyplot` to generate a line plot with:

- `hyper_params` on the x-axis
- `mse_values` on the y-axis

for both *two features* and *three features* figures.

```

# CB 1.6.4 #

from sklearn.neighbors import KNeighborsRegressor
from sklearn.metrics import mean_squared_error
import matplotlib.pyplot as plt

two_features = ['accommodates', 'bathrooms']
three_features = ['accommodates', 'bathrooms', 'bedrooms']
hyper_params = [x for x in range(1,21)]
# Append the first model's MSE values to this list.
two_mse_values = list()
# Append the second model's MSE values to this list.
three_mse_values = list()
two_hyp_mse = dict()
three_hyp_mse = dict()

def hyper_search(features, hyper_params, mse_values, hyp_mse):

    for hp in hyper_params:
        knn = KNeighborsRegressor(n_neighbors = hp, algorithm = 'brute')
        knn.fit(train_df[features], train_df['price'])
        predictions = knn.predict(test_df[features])
        mse = mean_squared_error(predictions, test_df['price'])
        mse_values.append(mse)

        if hp == hyper_params[0]:
            opt_mse = mse
            opt_hyp = hp
        else:
            if mse < opt_mse:
                opt_hyp = hp
                opt_mse = mse
            else:
                continue

    hyp_mse[opt_hyp] = opt_mse

    return mse_values, hyp_mse

two_mse_values, two_hyp_mse = hyper_search(two_features, hyper_params,
two_mse_values, two_hyp_mse)
three_mse_values, three_hyp_mse = hyper_search(three_features, hyper_params,
three_mse_values, three_hyp_mse)

print(two_hyp_mse)
print(three_hyp_mse)

fig = plt.figure(figsize = (10,5))
ax1 = fig.add_subplot(1,2,1)
ax2 = fig.add_subplot(1,2,2)

ax1.scatter(x = hyper_params, y = two_mse_values)

```



```
ax1.set_title('Two_Features')

ax2.scatter(x = hyper_params, y = three_mse_values)
ax2.set_title('Three_Features')

plt.show()
```

Output

```
{5: 14790.314266211606}
{7: 13518.769009310208}
```

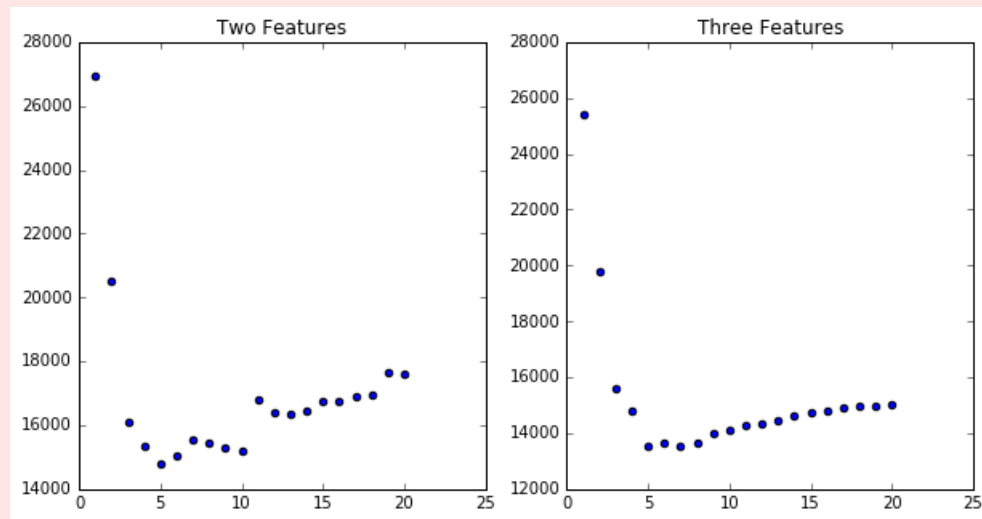


Figure 4.1: The Figure Output of CB 1.6.4

#### 4.1.5 Cross Validation

##### Definition 4.17: K-Fold Cross Validation

Here's the algorithm from *k*-fold cross validation:

- *splitting the full dataset into  $k$  equal length partitions.*
  - *selecting  $k-1$  partitions as the training set and*
  - *selecting the remaining partition as the test set*
- *training the model on the training set.*
- *using the trained model to predict labels on the test fold.*
- *computing the test fold's error metric.*
- *repeating all of the above steps  $k-1$  times, until each partition has been used as the test set for an iteration.*
- *calculating the mean of the  $k$  error values.*

**Example 4.5: Five-Fold Cross Validation**

In the following figure, we consider what  $K$ -Fold cross validation could look like for the  $k = 5$  case.

	Test	Train	Train	Train	Train
	Train	Test	Train	Train	Train
	Train	Train	Test	Train	Train
	Train	Train	Train	Test	Train
	Train	Train	Train	Train	Test
Errors	120.55	122.11	125.91	123.41	122.81
Mean Error	122.96				

Figure 4.2: 5-Fold Cross Validation

**Example 4.6: Custom 5-Fold Cross Validation for KNeighborsRegressor**

We begin by partitioning our data into 5 roughly equal parts. To do this, we will add a new column to `dc_listings` named `fold` that contains the fold number each row belongs to:

- Fold 1 should have rows from index 0 up to 745, not including 745.
- Fold 2 should have rows from index 745 up to 1490, not including 1490.
- Fold 3 should have rows from index 1490 up to 2234, not including 2234.
- Fold 4 should have rows from index 2234 up to 2978, not including 2978.
- Fold 5 should have rows from index 2978 up to 3723, not including 3723.

We will now write a function named `train_and_validate` that takes in a dataframe as the first parameter (`df`) and a list of fold values (1 to 5 in our case) as the second parameter (`folds`). This function should:

- Train  $n$  models (where  $n$  is number of folds) and perform  $k$ -fold cross validation (using  $n$  folds). Use the default  $k$  value for the `KNeighborsRegressor` class.
- Return a list of RMSE values, where the first element is the RMSE for when fold 1 was the test set, the second element is the RMSE for when fold 2 was the test set, and so on.

We will then use the `train_and_validate` function to return the list of RMSE values for the `dc_listings` Dataframe and assign it to `rmse`s. Lastly, we will calculate the mean of these values and assign to `avg_rmse`.

```
# CB 1.6.5 #
from sklearn.neighbors import KNeighborsRegressor
from sklearn.metrics import mean_squared_error
import numpy as np

fold_ids = [1,2,3,4,5]
```

```

dc_listings.loc[dc_listings.index[0:745], 'fold'] = 1
dc_listings.loc[dc_listings.index[745:1490], 'fold'] = 2
dc_listings.loc[dc_listings.index[1490:2234], 'fold'] = 3
dc_listings.loc[dc_listings.index[2234:2978], 'fold'] = 4
dc_listings.loc[dc_listings.index[2978:3723], 'fold'] = 5

def train_and_validate(df, folds):

    rmse = list()
    model = KNeighborsRegressor()

    for fold in folds:

        train_df = df[df['fold'] != fold]
        test_df = df[df['fold'] == fold]

        model.fit(train_df[['accommodates']], train_df['price'])
        prediction = model.predict(test_df[['accommodates']])

        mse = mean_squared_error(prediction, test_df['price'])
        rmse = np.sqrt(mse)
        rmse.append(rmse)

    return rmse

rmse = train_and_validate(dc_listings, fold_ids)

avg_rmse = np.mean(rmse)

print(rmse, avg_rmse)

```

Output:

```

[123.64816897663778, 104.90933995950148, 164.72575286188246, 102.32103626510822,
148.42036980986353]
128.8049335745987

```

#### Definition 4.18: Sklearn KFold Class

The K-Folds cross-validator provides train/test indices to split data in train/test sets. Split dataset into k consecutive folds (without shuffling by default). Each fold is then used once as a validation while the k - 1 remaining folds form the training set.

```

from sklearn.model_selection import KFold
kf = KFold(n_splits, shuffle=False, random_state=None)

```

PARAMETERS:

- **n\_splits** is the number of folds you want to use
- **shuffle** is used to toggle shuffling of the ordering of the observations in the dataset
- **random\_state** is used to specify the random seed value if shuffle is set to True.

**Definition 4.19: Sklearn cross\_val\_score() Function**

The `cross_val_score` function evaluates a score by cross-validation [See [24] for further documentation].

```
from sklearn.model_selection import cross_val_score
cross_val_score(estimator, X, Y, scoring=None, cv=None)
```

**PARAMETERS:**

- **estimator** is a sklearn model that implements the fit method (e.g. instance of `KNeighborsRegressor`)
- **X** is the list or 2D array containing the features you want to train on
- **y** is a list containing the values you want to predict (target column)
- **scoring** is a string describing the scoring criteria (list of accepted values here)
- **cv** describes the number of folds. Here are some examples of accepted values:
  - an instance of the `KFold` class,
  - an integer representing the number of folds.

**Example 4.7: 5-Fold Cross Validation with KFold and Cross\_val\_score**

We will create a new instance of the `KFold` class with the following properties:

- 5 folds,
- shuffle set to `True`,
- random seed set to 1 (so we can answer check using the same seed), assigned to the variable `kf`.

In addition, we will also create a new instance of the `KNeighborsRegressor` class and assign to `knn`.

Use the `cross_val_score()` function to perform k-fold cross-validation:

- using the `KNeighborsRegressor` instance `knn`,
- using the `accommodates` column for training,
- using the `price` column as the target column,
- returning an array of MSE values (one value for each fold).

Assign the resulting list of MSE values to `mses`. Then, take the absolute value followed by the square root of each MSE value. Then, calculate the average of the resulting RMSE values and assign to `avg_rmse`.

```
# Cb 1.6.6 #
```

```
from sklearn.model_selection import cross_val_score, KFold
```

```
kf = KFold(n_splits = 5, shuffle = True, random_state = 1)
knn = KNeighborsRegressor()
mses = cross_val_score(knn, X = dc_listings[['accommodates']], cv = kf,
                      y = dc_listings['price'], scoring = "neg_mean_squared_error")
```

```
rmse = np.sqrt(np.abs(mses))
avg_rmse = np.mean(rmse)
```

```
print(avg_rmse)
```

Output:

```
130.57004998596955
```

Choosing the right  $k$  value when performing  $k$ -fold cross validation is more of an art and less of a science. **Through lots of trial and error, data scientists have converged on 10 as the standard  $k$  value.**

## 4.2 Linear Regression for Machine Learning

### 4.2.1 The Linear Regression Model

#### Definition 4.20: Parametric Machine Learning

We need to instead learn about parametric machine learning approaches, like linear regression and logistic regression. Unlike the  $k$ -nearest neighbors algorithm, the result of the training process for these machine learning algorithms is a mathematical function that best approximates the patterns in the training set. In machine learning, this function is often referred to as a model.

#### Example 4.8: Univariate Relationships in AmesHousing Data

In this example, we will read *AmesHousing.txt* into a dataframe using the tab delimiter (`\t`) and assign it to `'data'`. Afterwards, we will

- Select the first 1460 rows from data and assign them to `'train'`.
- Select the remaining rows from data and assign to `'test'`.

To explore the data, we will create a plot using the *train* dataframe. We will then create a figure with dimensions 15 x 7 containing three scatter plots in a single row:

- The first plot should plot the `'Garage Area'` column on the x-axis against the `SalePrice` column on the y-axis.
- The second one should plot the `'Gr Liv Area'` column on the x-axis against the `SalePrice` column on the y-axis.
- The third one should plot the `'Overall Cond'` column on the x-axis against the `SalePrice` column on the y-axis.

```
# CB 1.6.7 #
```

```
import matplotlib.pyplot as plt
import pandas as pd
```

```
data = pd.read_csv('AmesHousing.txt', delimiter = '\t')
```

```
train = data[0:1460]
test = data[1460:]
```

```
fig = plt.figure(figsize=(15,7))
```

```
ax1 = fig.add_subplot(1,3,1)
```

```

ax2 = fig.add_subplot(1,3,2)
ax3 = fig.add_subplot(1,3,3)

train.plot(x = 'Garage_Area', y = 'SalePrice', ax = ax1, kind = 'scatter')
train.plot(x = 'Gr_Liv_Area', y = 'SalePrice', ax = ax2, kind = 'scatter')
train.plot(x = 'Overall_Cond', y = 'SalePrice', ax = ax3, kind = 'scatter')

plt.show()

```

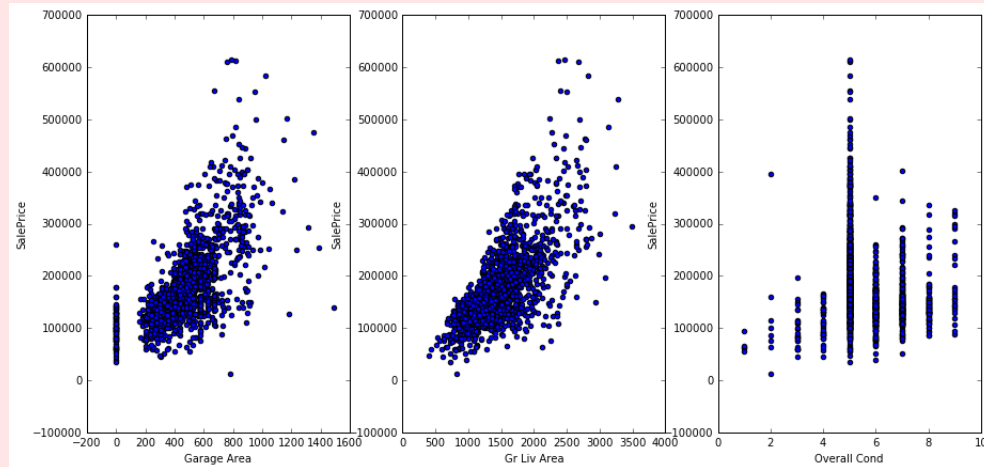


Figure 4.3: The Output Plots of CB 1.6.7

#### Example 4.9: Multivariate Linear Regression with Scikit-Learn

In this exercise, we will train a linear regression model using the columns 'Overall Cond', 'Gr Liv Area' and assign it to `cols`. We will then perform the following:

1. Use the fitted model to make predictions on both the training and test dataset.
2. Calculate the RMSE value for the predictions on the training set and assign to `train_rmse_2`.
3. Calculate the RMSE value for the predictions on the test set and assign to `test_rmse_2`.
4. Retrieve the coefficients of the linear regression model and display it.

# CB 1.6.8 #

```

import numpy as np
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error

cols = ['Overall_Cond', 'Gr_Liv_Area']

model = LinearRegression()
model.fit(train[cols], train['SalePrice'])

train_predictions = model.predict(train[cols])

```

```

test_predictions = model.predict(test[cols])

train_rmse_2 = np.sqrt(mean_squared_error(train_predictions, train['SalePrice']))
test_rmse_2 = np.sqrt(mean_squared_error(test_predictions, test['SalePrice']))

a1, a2 = model.coef_
a0 = model.intercept_

print("Linear_Model: f(x1,x2) = " + str(a0) + " + " + str(a1) + " x1"
      + " + " + str(a2) + " x2\n")
print(train_rmse_2)
print(test_rmse_2)

Output:
Linear Model: f(x1,x2) = 7858.691146390454 + -409.56846611223847 x1 +
116.73118338867957 x2

56032.39801525867
57066.90779448559

```

### 4.2.2 Feature Selection

#### Example 4.10: Correlation Matrix Heatmap

In this exercise, we will read ‘AmesHousing.txt’ into a dataframe named ‘data’ with the \t delimiter. Afterwards, we will create a dataframe called ‘train’, which contains the first 1460 rows of data and a dataframe called ‘test’, which contains the rest of the rows of data. We only want to keep the numeric columns so we’ll select the integer and float columns from train and assign them to the variable ‘numerical\_train’. We’ll drop the following columns from numerical\_train:

- PID (place ID isn’t useful for modeling)
- Year Built
- Year Remod/Add
- Garage Yr Blt
- Mo Sold
- Yr Sold

We’ll calculate the number of missing values from each column in numerical\_train. We’ll create a Series object where the index is made up of column names and the associated values are the number of missing values. We’ll assign this Series object to null\_series. Select the subset of null\_series to keep only the columns with no missing values, and assign the resulting Series object to full\_cols\_series.

We’ll compute the pairwise correlation coefficients between all of the columns in train\_subset and just select the SalePrice column from the resulting data frame. We’ll compute the absolute value of each term, sort the resulting Series by the correlation values, and assign to sorted\_corrs.

We’ll only select the columns in sorted\_corrs with a correlation above 0.3 and assign to strong\_corrs. We’ll filter train\_subset using the indexes of strong\_corrs and store the correlations to corrmatrix. Lastly,

we'll use the `seaborn.heatmap()` function to generate a correlation matrix heatmap for the columns in `strong_corrs`.

*# CB 1.6.9 #*

```
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt

data = pd.read_csv('AmesHousing.txt', delimiter="\t")
train = data[0:1460]
test = data[1460:]

numerics = ['float', 'int']
numerical_train = train.select_dtypes(include = numerics)

drop_cols = ['PID', 'Year_Built', 'Year_Remod/Add', 'Garage_Yr_Blt', 'Mo_Sold', 'Yr_Sold']
numerical_train = numerical_train.drop(labels = drop_cols, axis = 1)

null_series = numerical_train.isna().sum()
full_cols_series = null_series[null_series == 0]

train_subset = train[full_cols_series.index]
correlation_matrix = train_subset.corr()
sorted_corrs = correlation_matrix['SalePrice'].apply(lambda x: np.abs(x)).sort_values()

strong_corrs = sorted_corrs[sorted_corrs > 0.3]

corrmatrix = train_subset[strong_corrs.index].corr()
sns.heatmap(corrmatrix)
```

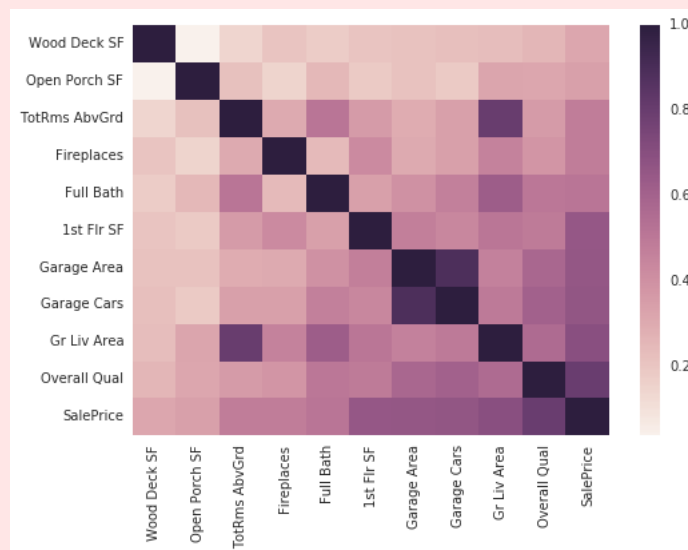


Figure 4.4: The Output Plot of CB 1.6.9



**Definition 4.21: Rescaling through Min-Max Normalization**

Let  $A \subset \mathbb{R}$  be a finite set with at least two distinct values; required so that  $\max(A) \neq \min(A)$ . Then, we define a function  $f : A \rightarrow [0, 1]$  by

$$f(x) = \frac{x - \min(A)}{\max(A) - \min(A)}. \quad (4.5)$$

The listed co-domain is intentional, as to emphasize that  $0 \leq f(x) \leq 1 \ \forall x \in A$ . This function is known as min-max normalization for a min-max of  $[0, 1]$ .

**Example 4.11: Min-Max Normalization**

In this exercise, we select the columns in ‘features’ from the ‘train’ data frame. Rescale each of the columns so the values range from 0 to 1, by using `train[features]` instead of in the formula above. Assign the result to `unit_train`.

# CB 1.6.10 #

```
unit_train = (train[features] - train[features].min()) /
              (train[features].max() - train[features].min())
```

**Example 4.12: Training Multivariate Linear Regression Model on Selected Features**

In this exercise we’ll filter the ‘test’ data frame so it only contains the columns from `final_corr_cols.index`. Then, drop the row containing missing values and assign the result to `clean_test`.

We’ll now remove the ‘Open Porch SF’ feature and build a linear regression model using the remaining features. We will calculate the RMSE on the test and train sets and assign the train RMSE to `train_rmse_2` and the test RMSE to `test_rmse_2`.

# CB 1.6.11 #

```
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error

final_corr_cols = strong_corrs.drop(['Garage_Cars', 'TotRms_AbvGrd'])
features = final_corr_cols.drop(['SalePrice']).index
target = 'SalePrice'

clean_test = test[final_corr_cols.index].dropna()
features = features.drop('Open_Porch_SF')

model = LinearRegression()

model.fit(train[features], train['SalePrice'])

test_predictions = model.predict(clean_test[new_features])
train_predictions = model.predict(train[features])

test_rmse_2 = np.sqrt(mean_squared_error(test_predictions, clean_test['SalePrice']))
train_rmse_2 = np.sqrt(mean_squared_error(train_predictions, train['SalePrice']))
```

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