Python Workshop 5

July 19, 2017

Aggregation

In this workshop we're going to investigate some **pandas** features related to aggregating data based on grouping. We'll use a dataset that comes with most R distributions called `ChickWeight`. If you cloned this repository or manually downloaded its artifacts, you should have a file in your current directory named `ChickWeight.csv`. Let's read this in.

In [1]:
```
import numpy as np
import pandas as pd

cw = pd.read_csv('ChickWeight.csv')
cw.head(15)
```

Out[1]:

	weight	Time	Chick	Diet
0	42	0	1	1
1	51	2	1	1
2	59	4	1	1
3	64	6	1	1
4	76	8	1	1
5	93	10	1	1
6	106	12	1	1
7	125	14	1	1
8	149	16	1	1
9	171	18	1	1
10	199	20	1	1
11	205	21	1	1
12	40	0	2	1
13	49	2	2	1
14	58	4	2	1

The data tracks the weights of baby chickens in four groups based their diets. The diets are just referred to as `1`, `2`, `3`, and `4`. The chicks are numbered as well.

Let's create a grouping of the chick weights based on `Time` of the weight and the `Diet`. What we **won't** include is the identifier of the `Chick`. Each `Time + Diet` group will contain weights for all chicks.

In [2]:
```
chickgrp = cw['weight'].groupby([cw.Time, cw.Diet])
type(chickgrp)
```

Out[2]:
```
pandas.core.groupby.SeriesGroupBy
```

Let's break this down.

1. `cw` is a dataframe with an index and four columns.
2. `cw['weight']` is a Series with the same index as the `cw` dataframe.
3. `cw['weight'].groupby([cw.Time, cw.Diet])` is a `SeriesGroupBy` object.

The `chickgrp` object is the basis for aggregations we might like to perform. We can average them, sum them, extract their min/max and many other things.

In [3]:
```
avgchick = chickgrp.mean()
maxchick = chickgrp.max()
minchick = chickgrp.min()
allchick = chickgrp.sum()
avgchick.head(15)
```

Out[3]:
```
Time  Diet
0     1       41.400000
      2       40.700000
      3       40.800000
      4       41.000000
2     1       47.250000
      2       49.400000
      3       50.400000
      4       51.800000
4     1       56.473684
      2       59.800000
      3       62.200000
      4       64.500000
6     1       66.789474
      2       75.400000
      3       77.900000
Name: weight, dtype: float64
```

The `chickgrp` object is meant to be reused across many aggegrations. But if you only need it once, you usually issue the **combine** action in the same step.

In [4]:
```
avgchick = cw['weight'].groupby([cw.Time, cw.Diet]).mean()
```

Stack and Unstack: Pivot Tables

Take another look at the first 15 rows of the `avgchick` dataset. It's easy to compare the weights of two diets at the same point in time since the diet measurements are next to each other. But comparing the same diet over time causes our eyes to have to skip over rows. Pandas refers to this as a *stacked dataframe*. We can *unstack* it (or pivot on the `Diet` column).

In [5]:
```
widechick = avgchick.unstack()
widechick
```

Out[5]:

Diet	1	2	3	4
Time				
0	41.400000	40.7	40.8	41.000000
2	47.250000	49.4	50.4	51.800000
4	56.473684	59.8	62.2	64.500000
6	66.789474	75.4	77.9	83.900000
8	79.684211	91.7	98.4	105.600000
10	93.052632	108.5	117.1	126.000000
12	108.526316	131.3	144.4	151.400000
14	123.388889	141.9	164.5	161.800000
16	144.647059	164.7	197.4	182.000000
18	158.941176	187.7	233.1	202.900000
20	170.411765	205.6	258.9	233.888889
21	177.750000	214.7	270.3	238.555556

You can see that the `Diet` portion of the hierarchical index was unstacked (pivoted) into a column for each value. How did it know we wanted to pivot `Diet` instead of `Time`? By default, the `unstack` method pivots the inner-most component of a heirarchical index.

The column names of `1`, `2`, `3`, and `4` almost seem numeric even though they are intended to be categorical. Let's change the column names to make this explicit.

In [6]:
```
widechick.columns = ['diet1', 'diet2', 'diet3', 'diet4']
widechick
```

Out[6]:

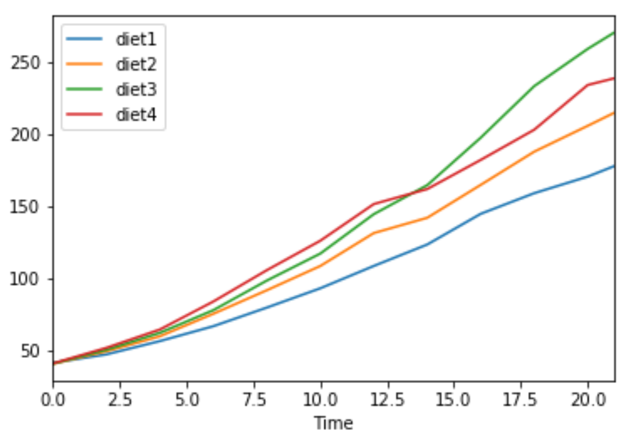
	diet1	diet2	diet3	diet4
Time				
0	41.400000	40.7	40.8	41.000000
2	47.250000	49.4	50.4	51.800000
4	56.473684	59.8	62.2	64.500000
6	66.789474	75.4	77.9	83.900000
8	79.684211	91.7	98.4	105.600000
10	93.052632	108.5	117.1	126.000000
12	108.526316	131.3	144.4	151.400000
14	123.388889	141.9	164.5	161.800000
16	144.647059	164.7	197.4	182.000000
18	158.941176	187.7	233.1	202.900000
20	170.411765	205.6	258.9	233.888889
21	177.750000	214.7	270.3	238.555556

We should be able to plot these easily.

In [26]:
```
from matplotlib import pyplot as plt
%matplotlib inline
plt.figure()
widechick.plot()
```

Out[26]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x10a9325f8>
```

```
<matplotlib.figure.Figure at 0x1034fb048>
```



This is not a bad plot considering we got it for free (didn't provide any customization parameters). But we can provide additional parameters to get other effects. Let's see what we can get if we do decide to set some parameters.

In the figure below, I appealed to the `plot` method API at

http://pandas.pydata.org/pandas-docs/stable/generated/pandas.DataFrame.plot.html#pandas.DataFrame.plot (http://pandas.pydata.org/pandas-docs/stable/generated/pandas.DataFrame.plot.html#pandas.DataFrame.plot)

and chose the

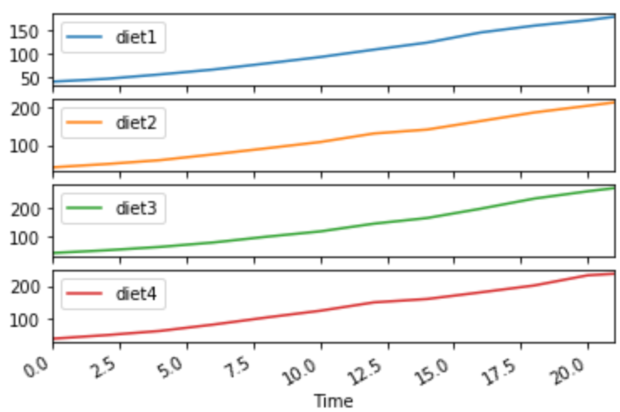
- `subplots`
- `sharex`

parameters to override.

In [28]:
```
plt.figure()
widechick.plot(subplots=True, sharex=True)
```

Out[28]:
```
array([<matplotlib.axes._subplots.AxesSubplot object at 0x10b03ae10>,
       <matplotlib.axes._subplots.AxesSubplot object at 0x10b0e6f98>,
       <matplotlib.axes._subplots.AxesSubplot object at 0x10adfcef0>,
       <matplotlib.axes._subplots.AxesSubplot object at 0x10b14d9e8>], dtype=obj
ect)
```

```
<matplotlib.figure.Figure at 0x109dc5908>
```



OK. Maybe that didn't look so good. In the next one, I choose

- `title`
- `grid`

I also use the Matplotlib `Axes` object that is returned from the `plot` invocation. The Matplotlib documentation has a list of all kinds of things one can do with an `Axes` object here.

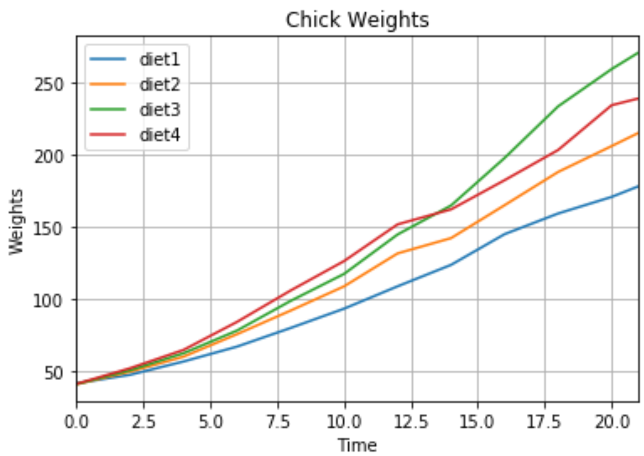
http://matplotlib.org/api/axes_api.html (http://matplotlib.org/api/axes_api.html)

I settle for labeling the Y-axis.

In [35]:
```
plt.figure()
ax = widechick.plot(title="Chick Weights", grid=True)
ax.set_ylabel("Weights")
```

Out[35]:
```
<matplotlib.text.Text at 0x10b6043c8>

<matplotlib.figure.Figure at 0x10b6e4630>
```



There are many buttons and knobs for customizing your figure. But let's get back to stracking and unstacking.

The reverse of `unstack` is `stack`. This creates a **long** dataframe from a **wide** dataframe.

In [7]:
```
longchick = widechick.stack()
longchick.head(15)
```

Out[7]:
```
Time
0     diet1    41.400000
      diet2    40.700000
      diet3    40.800000
      diet4    41.000000
2     diet1    47.250000
      diet2    49.400000
      diet3    50.400000
      diet4    51.800000
4     diet1    56.473684
      diet2    59.800000
      diet3    62.200000
      diet4    64.500000
6     diet1    66.789474
      diet2    75.400000
      diet3    77.900000
dtype: float64
```

We have our original dataframe back with the inner component of the hierarchical index as a string.

Code Organization

In this section we introduce some concepts related to organizing your code into script files. Most of the information and even some of the examples come from the online Python tutorial.

https://docs.python.org/3.5/tutorial/index.html (https://docs.python.org/3.5/tutorial/index.html)

- Chapter 6 - Modules (https://docs.python.org/3.5/tutorial/modules.html)
- Chapter 9 - Classes (https://docs.python.org/3.5/tutorial/classes.html)

These sections and the tutorial in general are recommended reading.

Modules

For the most part, our experience with modules have been limited to importing them. We hardly do anything in these workshops before we import `numpy` and `pandas`.

```
import numpy as np
import pandas as pd
```

These statements make the **NumPy** and **pandas** modules available as `np` and `pd` respectively. Let's create our own module and determine how to reference it.

What's in a `__name__`?

For most of this workshop we've been working directly in IPython rather than executing script files. But even at the Python interpter prompt we are executing within a module. To determine its name, print the value of the `__name__` variable which is a module attribute populated for every module.

In [8]:
```
__name__
```

Out[8]: `'__main__'`

The value `__main__` is the default module. Our code runs in this module under two conditions.

1. Entering commands interactively through the Python or IPython environments.
2. Running a Python script from the command line as in: `python my_script.py`.

We saw the first case above. Let's try the second case.

1. Exit the IPython shell.
2. Create a file named `simple.py` that contains a single line: `print(__name__)`
3. Run: `python simple.py`

You should see the same result. Within your Python script **invoked directly from the Python interpreter**, your module is named `__main__`. Let's place our `print` function inside of another function. Change `simply.py` like the sample below.

In [9]:
```
def show_module_name():
   print(__name__)

show_module_name()
```

```
__main__
```


You can see above that when the function is defined interactively from the command line, we're still executing within the `__main__` module. Verify the same behavior from your OS command line by running

```
python simple.py
```

The result should still be `__main__` since we invoked our new version of `simple.py` directly from the Python interpreter. The fact that we called another method before printing the value does not change anything. At this point we have two things in the `__main__` module.

1. An attribute named `__name__` with the value `__main__`.
2. A function we defined named `show_module_name`.

Because our code runs in the `__main__` module, we don't need to provide the module name while referencing these two things. They are available to us unqualified.

Now let's make things more interesting. Start your IPython shell again. You should be starting from the directory that contains your script `simple.py`. Try running your function.

Strike 1! You've done nothing to load your module into your current Python environment. Execute the following in your IPython sessions. Note that we do **not** specify the `.py` file extension. Just the base name.

```
import simple
show_module_name()
```

Strike 2! The `simple` module is available. But it's components must be qualified with the module name to reference them. Now try this.

```
simple.show_module_name()
```

It should respond with `simple`, because that's the module name for the `simple.show_module_name()` function. You've just created and invoked your own module. Let's review the steps.

1. Create a Python script file with your function definitions. The name should end with `.py`.
2. Start your Python interpreter.
3. Import your module using the base name of the file.
4. Invoke your functions qualified by your module name.

Module or Script?

We've seen that creating a module is as simple is creating a script. But sometimes we want to do things differently depending on whether we're called directly as a script versus as a module called by another script. For example, look back at your IPython window. Notice how when you imported `simple`, the result was printing out the module name. That's because importing the module executes the whole Python program **once**. Most modules just define things. But the last line of `simple.py` executes `show_module_name()` after the definition. That's what we wanted when executing the script from the OS command line: `python simple.py`. But when we load the `simple` module, we don't want the method executed until we call it. We want to make the invocation of `show_module_name` conditional on whether it was **called from a script** or **is the script**.

The stock way of doing this is to compare the module name with `__main__`. If your module's `__name__` attribute is `__main__`, then your module is being invoked as a top-level Python script. Unless you execute some commands, your script will simply define some functions and then execute without doing anything. On the otherhand, when other Python modules import your module, they do for access to your module's functions. They usually prefer to be the ones doing the function calling; not your module.

Let's implement this with `simple.py`. Exit your IPython shell and change `simple.py` to the following.

```
def show_module_name():
    print(__name__)
```

Namespaces and Scopes

There are at least three scopes for any code being executed by a Python interpreter.

1. **local scope** - This may be in a code block or at the top level of the interpeter.
2. **enclosing functions** - This refers to variables within enclosing functions. This does not refer functions deeper in the call stack (which is dynamic).
3. **next_to_last** - This is the global scope of the current module.
4. **outermost** - This is the scope of the **builtin** functions.

There are at least three, because there can be zero to many enclosing functions. But the `builtin` scope is always there; we saw from the last section that we're always in a module; and we always have a local scope where new variables get created. (It may be that we haven't added any variables to this local scope, but the scope is still there.)

While the scopes listed above are hierarchical, namespaces are not. Each module defines its own namespace and there is only one namespace excecuting at any given moment.

Classes

Let's create a class that reads some crime data and makes it available through some methods. We'll use a dataset that is available in R distributions as `USArrests`. It's a table of arrests by state for various crimes recorded in 1973.

In [10]:
```
ar = pd.read_csv('USArrests.csv')
ar.head()
```

Out[10]:

	State	Murder	Assault	UrbanPop	Rape
0	Alabama	13.2	236	58	21.2
1	Alaska	10.0	263	48	44.5
2	Arizona	8.1	294	80	31.0
3	Arkansas	8.8	190	50	19.5
4	California	9.0	276	91	40.6

As you can see above, **pandas** already has a class called `DataFrame` that works pretty well. But we're going to create our own for illustrative purposes.

Aside: Tuples

We briefly mentioned tuples before. But we didn't talk much about unpacking. This is really helpful when you're dealing with rows that contain fields. Recall that a tuple look like arrays, but are delimited by `(` and `)` instead of square brackets.

In [11]:
```
a_tuple = (3, 5, 6, 'hi', 'there', ('x', 'y'))
```

They are very convenient to unpack.

In [12]:
```python
three = a_tuple[0]  # Please don't
five  = a_tuple[1]  # unpack it
six   = a_tuple[2]  # like this
hi    = a_tuple[3]  # even
there = a_tuple[4]  # though
pair  = a_tuple[5]  # you can.

three, five, six, hi, there, pair = a_tuple  # Unpack this way.

print(three, five, six, hi, there, pair)
```

```
3 5 6 hi there ('x', 'y')
```

Tuples are read-only once created.

In [13]:
```python
a_tuple[2] = 4
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-13-c7a2076512e7> in <module>()
----> 1 a_tuple[2] = 4

TypeError: 'tuple' object does not support item assignment
```

Aside: CSV Module

The CSV module provides for parsing of CSV files. It basically makes the result of each row of the file available as a list. A list can be assigned to a tuple.

In [14]:
```python
import csv
states = {}
with open('USArrests.csv', newline='') as csvfile:
    arrestReader = csv.reader(csvfile)
    header = next(arrestReader) # read header
    for row in arrestReader:    # row is a list
        name = row[0]
        states[name] = tuple(row[1:])
header
```

Out[14]:
```
['State', 'Murder', 'Assault', 'UrbanPop', 'Rape']
```

Let's recall some things.

- The **with** statement is used to scope a resource. In this case, the resource is a file object named `csvfile`.
- The `csv.reader` function wraps a file object with a CSV interface. We name this wrapper `arrestReader`.
- The first line is header, not data. We read it outside the loop using the **next** function. This function, when invoked on any Python object that implements the iterator interface, tells that object to read the current item and advance the pointer to the next element.
- Each `row` instance represents a row from the CSV as a list of fields. The first one, `name` will be the key of the `dict` entry. The rest will become a `tuple` value.

In [15]:
```python
states['Arkansas']
```

Out[15]:
```
('8.8', '190', '50', '19.5')
```

This is not too bad; so long as we remember the order of the fields. We can add field names using class from the **collections** module called **namedtuple**. It allows us to name the elements within a tuple.

In [16]:
```
from collections import namedtuple
State = namedtuple('State', 'Murder Assault UrbanPop Rape')
tx = State(12.7, 201, 80, 25.5)
tx
```

Out[16]:
```
State(Murder=12.7, Assault=201, UrbanPop=80, Rape=25.5)
```

We've, in effect, defined a value object of type `State`. We named the fields with a single string using the space as a separator.

In [17]:
```
tx.Murder
```

Out[17]:
```
12.7
```

Let's apply this to reading the CSV file. Whereas the **tuple** class accepted a list in its constructor, the **namedtuple** `State` expects four separate parameters. We convert `row[1:]` from a list to a set of parameters by putting a `*` in front. This substitutes the elements of the list `row[1:]` into the function call as if they had been placed there individually. The `*` symbol is **not a pointer dereferencing** like in C or C++.

In [18]:
```
states = {}
with open('USArrests.csv', newline='') as csvfile:
    arrestReader = csv.reader(csvfile)
    next(arrestReader)          # skip header
    for row in arrestReader:    # row is a list
        name = row[0]
        states[name] = State(*row[1:])
len(states)
```

Out[18]:
```
50
```

In [19]:
```
states['Arkansas'].Murder
```

Out[19]:
```
'8.8'
```

Back to the Class

Let's create a class that reads crime data from a file and makes certain information about it available through methods.

In [20]:
```
import csv
from collections import namedtuple

State = namedtuple('State', 'Murder Assault UrbanPop Rape')

class Crime:
    states = {}

    def __init__(self, filename):
        self._readfrom = filename
        with open(filename, newline='') as csvfile:
            arrestReader = csv.reader(csvfile)
            next(arrestReader)         # skip header
            for row in arrestReader:   # row is a list
                name = row[0]
                self.states[name] = State(*row[1:])
        self._year = 1973

    def year(self):
        return self._year

    def file(self):
        return self._readfrom

    def __len__(self):
        return len(self.states)

    def __getitem__(self, name):
        return self.states[name]

    def __repr__(self):
        return "Crime data from <{}>, year={}".format(self._readfrom, self._year)

    def __str__(self):
        return ' '.join(self.states.keys())

c1973 = Crime('USArrests.csv')
len(c1973)
```

Out[20]: 50

The **class** keyword begins a class definition. There are several things to note.

1. Like other kinds of code blocks, the indentation determines how far the class definition extends.
2. The `states` element is a class variable. It is neither private nor specific to an instance.
3. The `__init__` is the constructor. The first parameter, `self` represents a reference to instance content.
4. The `self._readfrom` was created without declaring it outside the `__init__` method. It will be available for other instance methods (through the `self` reference).
5. All references to instance state must be made through the `self` reference. You'll remember this after you screw it up a few dozen times.
6. The `year` and `file` methods are just plain methods.
7. The `__len__` special method is invoked on this instance when consumers of this class invoke `len(myObject)`. Classes that have a notion of length implement this.
8. The `__getitem__` special method works like a dictionary.
9. The `__repr__` special method provides a summary for programmers using your class.
10. The `__str__` special method is used by `print` functions.

See the Python API Documentation for a list of Python special names (https://docs.python.org/3.5/reference/datamodel.html#special-method-names).

The Python class model is a big topic; we're only scatching the surface here. The `__repr__` method is what prints at the command line. It is meant to be seen by other developers.

In [21]:
```
c1973
```

Out[21]:
```
Crime data from <USArrests.csv>, year=1973
```

In contrast, the `__str__` method is what results from passing the object to the `print` method.

In [22]:
```
print(c1973)
```

```
North Carolina Ohio Washington Kansas New Hampshire Georgia North Dakota Missour
i Idaho Hawaii Colorado Texas Maine Massachusetts Indiana Vermont Illinois Michi
gan New York New Mexico Nevada Oklahoma Rhode Island Wisconsin Delaware Utah Mar
yland Nebraska Alabama Connecticut Pennsylvania Arizona South Dakota Wyoming Ala
ska South Carolina New Jersey Mississippi Tennessee Montana Arkansas West Virgin
ia California Kentucky Louisiana Minnesota Iowa Oregon Virginia Florida
```

The `__getitem__` is invoked when an instance is indexed like a dictionary.

In [23]:
```
c1973['Kansas']
```

Out[23]:
```
State(Murder='6', Assault='115', UrbanPop='66', Rape='18')
```

The other methods, such as `file` are not *special*. They are invoked on the object.

In [24]:
```
c1973.file()
```

Out[24]:
```
'USArrests.csv'
```

You can also invoke the class directly, passing in the instance explicitly.

In [25]:
```
Crime.file(c1973)
```

Out[25]:
```
'USArrests.csv'
```

This was a very brief look at classes. There are all kinds of special methods your class can implement to make it seemlessly integrate with the Python universe.

End of Workshop 5