Lecture 04. Data Aggregation and Group Operations

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Categorizing a dataset and applying a function to each group, whether an **aggregation** or **transformation**, is often a critical component of a data analysis workflow. After loading and preparing a dataset, you may need to compute group statistics for reporting or visualization purposes.

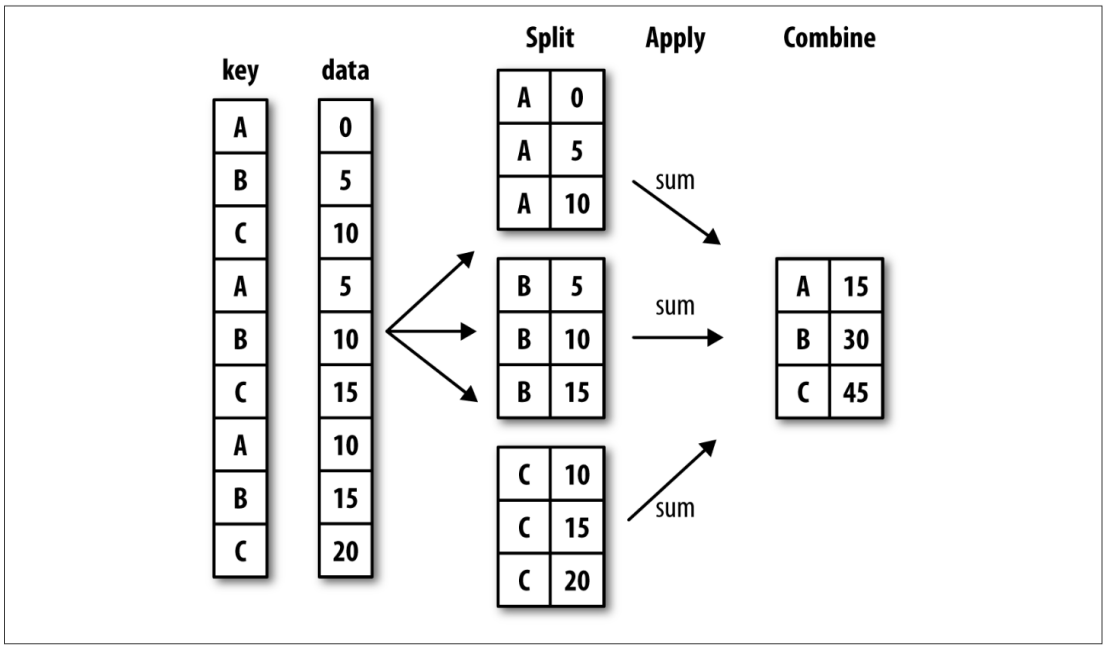
`pandas` provides a flexible `groupby()` interface, enabling you to slice, dice, and summarize datasets in a natural way.

GroupBy Mechanics

Punchline: **split-apply-combine （拆分-应用-合并）**

- In the first stage of the process, data is **split** into groups based on one or more keys that you provide.
- Once this is done, a function is **applied** to each group, producing a new value.
- Finally, the results of all those function applications are **combined** into a result object.

See the following figure for a mockup of a simple group aggregation:



To get started, here is a small tabular dataset as a `DataFrame`:

In [1]:
```
import pandas as pd
import numpy as np
#np.random.randn: generate random numbers

df = pd.DataFrame({'key1' : ['a', 'a', 'b', 'b', 'a'],
                   'key2' : ['one', 'two', 'one', 'two', 'one'],
                   'data1' : np.random.randn(5),
                   'data2' : np.random.randn(5)})

df
```

Out[1]:

	key1	key2	data1	data2
0	a	one	0.191240	-1.631904
1	a	two	-1.676441	0.093311
2	b	one	0.523515	-1.233426
3	b	two	0.269534	0.634182
4	a	one	-0.118640	1.932455

Suppose you wanted to compute the **mean** of the `data1` column using the labels from `key1`.

There are a number of ways to do this. One is to access `data1` and call `groupby()` with the column at `key1`:

In [2]:
```
grouped = df['data1'].groupby(df['key1'])

grouped
```

Out[2]:
```
<pandas.core.groupby.generic.SeriesGroupBy object at 0x110112ce0>
```

This grouped variable is now a `GroupBy object`.

It has not actually computed anything yet except for some intermediate data about the group key `df['key1']`. The idea is that this object has all of the information needed to then apply some operation to each of the groups.

For example, to compute group means we can call the GroupBy's `mean()` method:

In [3]:
```
grouped.mean()
```

Out[3]:
```
key1
a   -0.534614
b    0.396524
Name: data1, dtype: float64
```

The important thing here is that the data has been **aggregated** according to the group key, producing a new Series that is now indexed by the **unique values** in the `key1` column.

If instead we had passed multiple arrays as a list, we'd get something different:

In [4]:
```
df['data1'].groupby([df['key1'], df['key2']]).mean()
```

Out[4]:
```
key1  key2
a     one     0.036300
      two    -1.676441
b     one     0.523515
      two     0.269534
Name: data1, dtype: float64
```

Here we grouped the data using **two keys**, and the resulting Series now has a **hierarchical index** consisting of the **unique pairs** of keys observed.

A generally useful GroupBy method is `size()`, which returns a Series containing group sizes:

In [5]:
```
df.groupby(['key1', 'key2']).size()
```

Out[5]:
```
key1  key2
a     one     2
      two     1
b     one     1
      two     1
dtype: int64
```

Take note that any missing values in a group key will be excluded from the result.

For large datasets, it may be desirable to aggregate only a few columns. For example, in the preceding dataset, to compute means for just the `data2` column, we could write:

In [6]:
```
df.groupby(['key1', 'key2'])['data2'].mean()
```

Out[6]:
```
key1  key2
a     one     0.150275
      two     0.093311
b     one    -1.233426
      two     0.634182
Name: data2, dtype: float64
```

Data Aggregation

Aggregations refer to any data transformation that produces scalar values from arrays. The preceding examples have used several of them, including `mean` and `size`. Built-in functions can be invoked using `agg()`.

Function	Description
count	Number of non-NA values in the group
sum	Sum of non-NA values
mean	Mean of non-NA values
median	Arithmetic median of non-NA values
std, var	Unbiased (n – 1 denominator) standard deviation and variance
min, max	Minimum and maximum of non-NA values
first, last	First and last non-NA values

In [7]:
```
df = df[['key1','data1','data2']]
```

```
df
```

Out[7]:

	key1	data1	data2
0	a	0.191240	-1.631904
1	a	-1.676441	0.093311
2	b	0.523515	-1.233426
3	b	0.269534	0.634182
4	a	-0.118640	1.932455

In [8]:
```
df.groupby('key1').max()
```

Out[8]:

	data1	data2
key1		
a	0.191240	1.932455
b	0.523515	0.634182

In [9]:
```
df.groupby('key1').agg('min')
```

Out[9]:

	data1	data2
key1		
a	-1.676441	-1.631904
b	0.269534	-1.233426

To use your own aggregation functions, pass any function that aggregates an array to the `apply` method:

In [10]:
```
def peak_to_peak(arr):
    return arr.max() - arr.min()
```

In [11]:
```
df.groupby(df['key1']).apply(peak_to_peak)
```

Out[11]:

	data1	data2
key1		
a	1.867681	3.564359
b	0.253981	1.867608

General split-apply-combine

- Create analysis with `.groupby()` and **built-in** functions (`mean` , `sum` , `count` , etc.)
- Create analysis with `.groupby()` and user defined functions
- Use `.transform()` to join group stats to the original dataframe

Let's get started with the tipping dataset:

In [12]:
```
df = pd.read_csv('examples/tips.csv')

df = df[['day','size','total_bill','tip']]

df
```

Out[12]:

	day	size	total_bill	tip
0	Sun	2	16.99	1.01
1	Sun	3	10.34	1.66
2	Sun	3	21.01	3.50
3	Sun	2	23.68	3.31
4	Sun	4	24.59	3.61
...	...	...	...	...
239	Sat	3	29.03	5.92
240	Sat	2	27.18	2.00
241	Sat	2	22.67	2.00
242	Sat	2	17.82	1.75
243	Thur	2	18.78	3.00

244 rows × 4 columns

In [13]:
```
df.groupby('day').mean() #df.groupby('day').agg('mean')
```

Out[13]:

	size	total_bill	tip
day			
Fri	2.105263	17.151579	2.734737
Sat	2.517241	20.441379	2.993103
Sun	2.842105	21.410000	3.255132
Thur	2.451613	17.682742	2.771452

In [14]:
```
df.groupby('day').transform('mean')
```

Out[14]:

	size	total_bill	tip
0	2.842105	21.410000	3.255132
1	2.842105	21.410000	3.255132
2	2.842105	21.410000	3.255132
3	2.842105	21.410000	3.255132
4	2.842105	21.410000	3.255132
...	...	...	...
239	2.517241	20.441379	2.993103
240	2.517241	20.441379	2.993103
241	2.517241	20.441379	2.993103
242	2.517241	20.441379	2.993103
243	2.451613	17.682742	2.771452

244 rows × 3 columns

In [15]:
```
df['day_avg_tip'] = df.groupby('day')['tip'].transform('mean')

df
```

Out[15]:

	day	size	total_bill	tip	day_avg_tip
0	Sun	2	16.99	1.01	3.255132
1	Sun	3	10.34	1.66	3.255132
2	Sun	3	21.01	3.50	3.255132
3	Sun	2	23.68	3.31	3.255132
4	Sun	4	24.59	3.61	3.255132
...	...	...	...	...	...
239	Sat	3	29.03	5.92	2.993103
240	Sat	2	27.18	2.00	2.993103
241	Sat	2	22.67	2.00	2.993103
242	Sat	2	17.82	1.75	2.993103
243	Thur	2	18.78	3.00	2.771452

244 rows × 5 columns

Column-Wise and Multiple Function Application

As you've already seen, aggregating data is a matter of using aggregate with the desired function or calling a method like `mean` or `std`.

However, you may want to aggregate using a different function depending on the column, or multiple functions at once.

In [16]:
```
df = pd.read_csv('examples/tips.csv')
```

```
df['tip_pct'] = df['tip'] / df['total_bill']

df
```

Out[16]:

	total_bill	tip	sex	smoker	day	time	size	tip_pct
0	16.99	1.01	Female	No	Sun	Dinner	2	0.059447
1	10.34	1.66	Male	No	Sun	Dinner	3	0.160542
2	21.01	3.50	Male	No	Sun	Dinner	3	0.166587
3	23.68	3.31	Male	No	Sun	Dinner	2	0.139780
4	24.59	3.61	Female	No	Sun	Dinner	4	0.146808
...	...	...	...	...	...	...	...	...
239	29.03	5.92	Male	No	Sat	Dinner	3	0.203927
240	27.18	2.00	Female	Yes	Sat	Dinner	2	0.073584
241	22.67	2.00	Male	Yes	Sat	Dinner	2	0.088222
242	17.82	1.75	Male	No	Sat	Dinner	2	0.098204
243	18.78	3.00	Female	No	Thur	Dinner	2	0.159744

244 rows × 8 columns

In [17]:
```
df.groupby(['day','smoker'])['tip_pct'].agg('mean')
```

Out[17]:
```
day   smoker
Fri   No        0.151650
      Yes       0.174783
Sat   No        0.158048
      Yes       0.147906
Sun   No        0.160113
      Yes       0.187250
Thur  No        0.160298
      Yes       0.163863
Name: tip_pct, dtype: float64
```

If you pass a list of functions or function names instead, you get back a `DataFrame` with column names taken from the functions:

In [18]:
```
df.groupby(['day','smoker'])['tip_pct'].agg(['mean','median','std'])
```

Out[18]:

		mean	median	std
day	**smoker**			
Fri	**No**	0.151650	0.149241	0.028123
	Yes	0.174783	0.173913	0.051293
Sat	**No**	0.158048	0.150152	0.039767
	Yes	0.147906	0.153624	0.061375
Sun	**No**	0.160113	0.161665	0.042347
	Yes	0.187250	0.138122	0.154134
Thur	**No**	0.160298	0.153492	0.038774
	Yes	0.163863	0.153846	0.039389

The most general-purpose GroupBy method is `apply()`. Suppose you wanted to select the top five `tip_pct` values by group.

In [19]:
```
df
```

Out[19]:

	total_bill	tip	sex	smoker	day	time	size	tip_pct
0	16.99	1.01	Female	No	Sun	Dinner	2	0.059447
1	10.34	1.66	Male	No	Sun	Dinner	3	0.160542
2	21.01	3.50	Male	No	Sun	Dinner	3	0.166587
3	23.68	3.31	Male	No	Sun	Dinner	2	0.139780
4	24.59	3.61	Female	No	Sun	Dinner	4	0.146808
...	...	...	...	...	...	...	...	...
239	29.03	5.92	Male	No	Sat	Dinner	3	0.203927
240	27.18	2.00	Female	Yes	Sat	Dinner	2	0.073584
241	22.67	2.00	Male	Yes	Sat	Dinner	2	0.088222
242	17.82	1.75	Male	No	Sat	Dinner	2	0.098204
243	18.78	3.00	Female	No	Thur	Dinner	2	0.159744

244 rows × 8 columns

First, write a function that selects the rows with the largest values in a particular column:

In [20]:
```
def top(df, n=5, column='tip_pct'):
    return df.sort_values(by=column)[-n:]
```

In [21]:
```
top(df)
```

Out[21]:

	total_bill	tip	sex	smoker	day	time	size	tip_pct
183	23.17	6.50	Male	Yes	Sun	Dinner	4	0.280535
232	11.61	3.39	Male	No	Sat	Dinner	2	0.291990
67	3.07	1.00	Female	Yes	Sat	Dinner	1	0.325733
178	9.60	4.00	Female	Yes	Sun	Dinner	2	0.416667
172	7.25	5.15	Male	Yes	Sun	Dinner	2	0.710345

Now, if we group by smoker and call apply with this function, we get the following:

In [22]:
```
df.groupby('smoker').apply(top)
```

Out[22]:

smoker		total_bill	tip	sex	smoker	day	time	size	tip_pct
No	**88**	24.71	5.85	Male	No	Thur	Lunch	2	0.236746
	185	20.69	5.00	Male	No	Sun	Dinner	5	0.241663
	51	10.29	2.60	Female	No	Sun	Dinner	2	0.252672
	149	7.51	2.00	Male	No	Thur	Lunch	2	0.266312
	232	11.61	3.39	Male	No	Sat	Dinner	2	0.291990
Yes	**109**	14.31	4.00	Female	Yes	Sat	Dinner	2	0.279525
	183	23.17	6.50	Male	Yes	Sun	Dinner	4	0.280535
	67	3.07	1.00	Female	Yes	Sat	Dinner	1	0.325733
	178	9.60	4.00	Female	Yes	Sun	Dinner	2	0.416667
	172	7.25	5.15	Male	Yes	Sun	Dinner	2	0.710345

What has happened here? The `top` function is called on each row group from the DataFrame. The result therefore has a hierarchical index whose inner level contains index values from the original DataFrame.

If you pass a function to apply that takes other **arguments or keywords**, you can pass these after the function:

In [23]:
```
df.groupby(['smoker', 'day']).apply(top, n=1, column='total_bill')
```

Out[23]:

smoker	day		total_bill	tip	sex	smoker	day	time	size	tip_pct
No	**Fri**	**94**	22.75	3.25	Female	No	Fri	Dinner	2	0.142857
	Sat	**212**	48.33	9.00	Male	No	Sat	Dinner	4	0.186220
	Sun	**156**	48.17	5.00	Male	No	Sun	Dinner	6	0.103799
	Thur	**142**	41.19	5.00	Male	No	Thur	Lunch	5	0.121389
Yes	**Fri**	**95**	40.17	4.73	Male	Yes	Fri	Dinner	4	0.117750
	Sat	**170**	50.81	10.00	Male	Yes	Sat	Dinner	3	0.196812
	Sun	**182**	45.35	3.50	Male	Yes	Sun	Dinner	3	0.077178
	Thur	**197**	43.11	5.00	Female	Yes	Thur	Lunch	4	0.115982

Beyond these basic usage mechanics, getting the most out of apply may require some creativity.