Search the docs ...

Installation

Package overview

Getting started tutorials

What kind of data does pandas handle?

How do I read and write tabular data?

How do I select a subset of a `DataFrame` ?

How to create plots in pandas?

How to create new columns derived from existing columns?

How to calculate summary statistics?

How to reshape the layout of tables?

How to combine data from multiple tables?

How to handle time series data with ease?

How to manipulate textual data?

Comparison with other tools

Community tutorials

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

Data used for this tutorial:

Air quality Nitrate data

For this tutorial, air quality data about NO_2 is used, made available by openaq and downloaded using the py-openaq package.

The `air_quality_no2_long.csv` data set provides NO_2 values for the measurement stations *FR04014*, *BETR801* and *London Westminster* in respectively Paris, Antwerp and London.

To raw data

```
In [2]: air_quality_no2 = pd.read_csv("data/air_quality_no2_long.csv",
   ...:                               parse_dates=True)
   ...:

In [3]: air_quality_no2 = air_quality_no2[["date.utc", "location",
   ...:                                    "parameter", "value"]]
   ...:

In [4]: air_quality_no2.head()
Out[4]: 
                    date.utc location parameter  value
0  2019-06-21 00:00:00+00:00  FR04014       no2   20.0
1  2019-06-20 23:00:00+00:00  FR04014       no2   21.8
2  2019-06-20 22:00:00+00:00  FR04014       no2   26.5
3  2019-06-20 21:00:00+00:00  FR04014       no2   24.9
4  2019-06-20 20:00:00+00:00  FR04014       no2   21.4
```

Air quality Particulate matter data

For this tutorial, air quality data about Particulate matter less than 2.5 micrometers is used, made available by openaq and downloaded using the py-openaq package.

The `air_quality_pm25_long.csv` data set provides PM_{25} values for the measurement stations *FR04014*, *BETR801* and *London Westminster* in respectively Paris, Antwerp and London.

To raw data

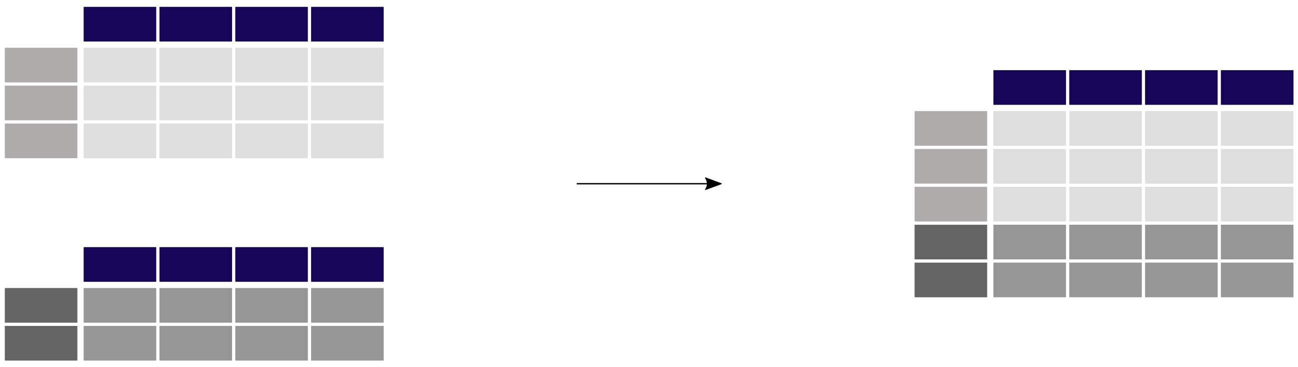
```
In [5]: air_quality_pm25 = pd.read_csv("data/air_quality_pm25_long.csv",
   ...:                                parse_dates=True)
   ...:

In [6]: air_quality_pm25 = air_quality_pm25[["date.utc", "location",
   ...:                                      "parameter", "value"]]
   ...:

In [7]: air_quality_pm25.head()
Out[7]: 
                    date.utc location parameter  value
0  2019-06-18 06:00:00+00:00  BETR801      pm25   18.0
1  2019-06-17 08:00:00+00:00  BETR801      pm25    6.5
2  2019-06-17 07:00:00+00:00  BETR801      pm25   18.5
3  2019-06-17 06:00:00+00:00  BETR801      pm25   16.0
4  2019-06-17 05:00:00+00:00  BETR801      pm25    7.5
```

How to combine data from multiple tables?

Concatenating objects



I want to combine the measurements of NO_2 and PM_{25}, two tables with a similar structure, in a single table

```
In [8]: air_quality = pd.concat([air_quality_pm25, air_quality_no2], axis=0)

In [9]: air_quality.head()
Out[9]:
                    date.utc location parameter  value
0  2019-06-18 06:00:00+00:00  BETR801      pm25   18.0
1  2019-06-17 08:00:00+00:00  BETR801      pm25    6.5
2  2019-06-17 07:00:00+00:00  BETR801      pm25   18.5
3  2019-06-17 06:00:00+00:00  BETR801      pm25   16.0
4  2019-06-17 05:00:00+00:00  BETR801      pm25    7.5
```

The `concat()` function performs concatenation operations of multiple tables along one of the axis (row-wise or column-wise).

By default concatenation is along axis 0, so the resulting table combines the rows of the input tables. Let's check the shape of the original and the concatenated tables to verify the operation:

```
In [10]: print('Shape of the ``air_quality_pm25`` table: ', air_quality_pm25.shape)
Shape of the ``air_quality_pm25`` table:  (1110, 4)

In [11]: print('Shape of the ``air_quality_no2`` table: ', air_quality_no2.shape)
Shape of the ``air_quality_no2`` table:  (2068, 4)

In [12]: print('Shape of the resulting ``air_quality`` table: ', air_quality.shape)
Shape of the resulting ``air_quality`` table:  (3178, 4)
```

Hence, the resulting table has 3178 = 1110 + 2068 rows.

Note

The **axis** argument will return in a number of pandas methods that can be applied **along an axis**. A `DataFrame` has two corresponding axes: the first running vertically downwards across rows (axis 0), and the second running horizontally across columns (axis 1). Most operations like concatenation or summary statistics are by default across rows (axis 0), but can be applied across columns as well.

Sorting the table on the datetime information illustrates also the combination of both tables, with the `parameter` column defining the origin of the table (either `no2` from table `air_quality_no2` or `pm25` from table `air_quality_pm25`):

```
In [13]: air_quality = air_quality.sort_values("date.utc")

In [14]: air_quality.head()
Out[14]:
                       date.utc            location parameter  value
2067  2019-05-07 01:00:00+00:00  London Westminster       no2   23.0
1003  2019-05-07 01:00:00+00:00             FR04014       no2   25.0
100   2019-05-07 01:00:00+00:00             BETR801      pm25   12.5
1098  2019-05-07 01:00:00+00:00             BETR801       no2   50.5
1109  2019-05-07 01:00:00+00:00  London Westminster      pm25    8.0
```

In this specific example, the `parameter` column provided by the data ensures that each of the original tables can be identified. This is not always the case. the `concat` function provides a convenient solution with the `keys` argument, adding an additional (hierarchical) row index. For example:

```
In [15]: air_quality_ = pd.concat([air_quality_pm25, air_quality_no2], keys=["PM25", "NO2"])
In [16]: air_quality_.head()
Out[16]:
                            date.utc location parameter  value
PM25 0  2019-06-18 06:00:00+00:00  BETR801      pm25   18.0
     1  2019-06-17 08:00:00+00:00  BETR801      pm25    6.5
     2  2019-06-17 07:00:00+00:00  BETR801      pm25   18.5
     3  2019-06-17 06:00:00+00:00  BETR801      pm25   16.0
     4  2019-06-17 05:00:00+00:00  BETR801      pm25    7.5
```

Note

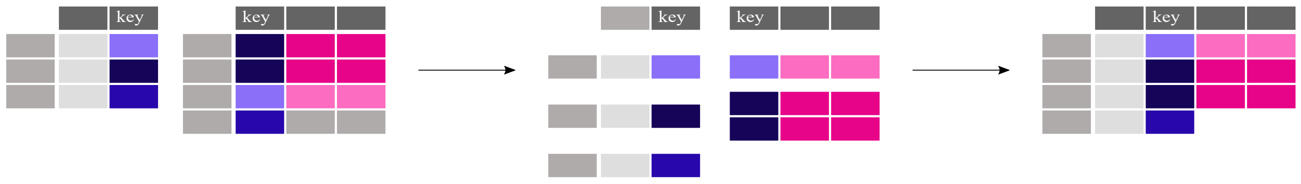
The existence of multiple row/column indices at the same time has not been mentioned within these tutorials. *Hierarchical indexing* or *MultiIndex* is an advanced and powerful pandas feature to analyze higher dimensional data.

Multi-indexing is out of scope for this pandas introduction. For the moment, remember that the function `reset_index` can be used to convert any level of an index to a column, e.g. `air_quality.reset_index(level=0)`

To user guide Feel free to dive into the world of multi-indexing at the user guide section on advanced indexing.

To user guide More options on table concatenation (row and column wise) and how `concat` can be used to define the logic (union or intersection) of the indexes on the other axes is provided at the section on object concatenation.

Join tables using a common identifier



Add the station coordinates, provided by the stations metadata table, to the corresponding rows in the measurements table.

Warning

The air quality measurement station coordinates are stored in a data file `air_quality_stations.csv`, downloaded using the py-openaq package.

```
In [17]: stations_coord = pd.read_csv("data/air_quality_stations.csv")

In [18]: stations_coord.head()
Out[18]:
  location  coordinates.latitude  coordinates.longitude
0  BELAL01              51.23619                4.38522
1  BELHB23              51.17030                4.34100
2  BELLD01              51.10998                5.00486
3  BELLD02              51.12038                5.02155
4  BELR833              51.32766                4.36226
```

Note

The stations used in this example (FR04014, BETR801 and London Westminster) are just three entries enlisted in the metadata table. We only want to add the coordinates of these three to the measurements table, each on the corresponding rows of the `air_quality` table.

```
In [19]: air_quality.head()
Out[19]: 
                       date.utc            location parameter  value
2067  2019-05-07 01:00:00+00:00  London Westminster       no2   23.0
1003  2019-05-07 01:00:00+00:00             FR04014       no2   25.0
100   2019-05-07 01:00:00+00:00             BETR801      pm25   12.5
1098  2019-05-07 01:00:00+00:00             BETR801       no2   50.5
1109  2019-05-07 01:00:00+00:00  London Westminster      pm25    8.0
```

```
In [20]: air_quality = pd.merge(air_quality, stations_coord, how="left", on="location")

In [21]: air_quality.head()
Out[21]: 
                    date.utc            location parameter  value  coordinates.latitude  
coordinates.longitude
0  2019-05-07 01:00:00+00:00  London Westminster       no2   23.0              51.49467  
-0.13193
1  2019-05-07 01:00:00+00:00             FR04014       no2   25.0              48.83724  
2.39390
2  2019-05-07 01:00:00+00:00             FR04014       no2   25.0              48.83722  
2.39390
3  2019-05-07 01:00:00+00:00             BETR801      pm25   12.5              51.20966  
4.43182
4  2019-05-07 01:00:00+00:00             BETR801       no2   50.5              51.20966  
4.43182
```

Using the `merge()` function, for each of the rows in the `air_quality` table, the corresponding coordinates are added from the `air_quality_stations_coord` table. Both tables have the column `location` in common which is used as a key to combine the information. By choosing the `left` join, only the locations available in the `air_quality` (left) table, i.e. FR04014, BETR801 and London Westminster, end up in the resulting table. The `merge` function supports multiple join options similar to database-style operations.

?

Add the parameter full description and name, provided by the parameters metadata table, to the measurements table

Warning

The air quality parameters metadata are stored in a data file `air_quality_parameters.csv`, downloaded using the py-openaq package.

```
In [22]: air_quality_parameters = pd.read_csv("data/air_quality_parameters.csv")

In [23]: air_quality_parameters.head()
Out[23]: 
     id                                        description  name
0    bc                                       Black Carbon    BC
1    co                                    Carbon Monoxide    CO
2   no2                                   Nitrogen Dioxide   NO2
3    o3                                              Ozone    O3
4  pm10  Particulate matter less than 10 micrometers in...  PM10
```

```
In [24]: air_quality = pd.merge(air_quality, air_quality_parameters,
   ....:                         how='left', left_on='parameter', right_on='id')
   ....: 

In [25]: air_quality.head()
Out[25]: 
                    date.utc            location parameter  ...    id  
description   name
0  2019-05-07 01:00:00+00:00  London Westminster       no2  ...   no2  
Nitrogen Dioxide    NO2
1  2019-05-07 01:00:00+00:00             FR04014       no2  ...   no2  
Nitrogen Dioxide    NO2
2  2019-05-07 01:00:00+00:00             FR04014       no2  ...   no2  
Nitrogen Dioxide    NO2
3  2019-05-07 01:00:00+00:00             BETR801      pm25  ...  pm25  Particulate matter less 
than 2.5 micrometers i...  PM2.5
4  2019-05-07 01:00:00+00:00             BETR801       no2  ...   no2  
Nitrogen Dioxide    NO2

[5 rows x 9 columns]
```

Compared to the previous example, there is no common column name. However, the `parameter` column in the `air_quality` table and the `id` column in the `air_quality_parameters_name` both provide the measured variable in a common format. The `left_on` and `right_on` arguments are used here (instead of just `on`) to make the link between the two tables.

pandas supports also inner, outer, and right joins. More information on join/merge of tables is provided in

To user guide the user guide section on database style merging of tables. Or have a look at the comparison with SQL page.

REMEMBER

- Multiple tables can be concatenated both column-wise and row-wise using the `concat` function.
- For database-like merging/joining of tables, use the `merge` function.

To user guide See the user guide for a full description of the various facilities to combine data tables.

Previous
‹ How to reshape the layout of tables?

Next
How to handle time series data with ease? ›

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