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Comparison with SQL¶

Since many potential pandas users have some familiarity with SQL, this page is meant to provide some examples of how various SQL operations would be performed using pandas.

If you're new to pandas, you might want to first read through 10 Minutes to pandas to familiarize yourself with the library.

As is customary, we import pandas and NumPy as follows:

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

In [2]: import numpy as np
```

Most of the examples will utilize the `tips` dataset found within pandas tests. We'll read the data into a DataFrame called *tips* and assume we have a database table of the same name and structure.

```
In [3]: url = ('https://raw.github.com/pandas-dev'
   ...:        '/pandas/master/pandas/tests/io/data/csv/tips.csv')
   ...:

In [4]: tips = pd.read_csv(url)

In [5]: tips.head()
Out[5]:
   total_bill   tip     sex smoker  day    time  size
0       16.99  1.01  Female     No  Sun  Dinner     2
1       10.34  1.66    Male     No  Sun  Dinner     3
2       21.01  3.50    Male     No  Sun  Dinner     3
3       23.68  3.31    Male     No  Sun  Dinner     2
4       24.59  3.61  Female     No  Sun  Dinner     4
```

SELECT

In SQL, selection is done using a comma-separated list of columns you'd like to select (or a `*` to select all columns):

```
SELECT total_bill, tip, smoker, time
FROM tips
LIMIT 5;
```

With pandas, column selection is done by passing a list of column names to your DataFrame:

```
In [6]: tips[['total_bill', 'tip', 'smoker', 'time']].head(5)
Out[6]:
   total_bill   tip smoker    time
0       16.99  1.01     No  Dinner
1       10.34  1.66     No  Dinner
2       21.01  3.50     No  Dinner
3       23.68  3.31     No  Dinner
4       24.59  3.61     No  Dinner
```

Calling the DataFrame without the list of column names would display all columns (akin to SQL's `*`).

In SQL, you can add a calculated column:

```
SELECT *, tip/total_bill as tip_rate
FROM tips
LIMIT 5;
```

With pandas, you can use the `DataFrame.assign()` method of a DataFrame to append a new column:

```
In [7]: tips.assign(tip_rate=tips['tip'] / tips['total_bill']).head(5)
Out[7]:
   total_bill   tip     sex smoker  day    time  size  tip_rate
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
```

WHERE

Filtering in SQL is done via a WHERE clause.

```
SELECT *
FROM tips
WHERE time = 'Dinner'
LIMIT 5;
```

DataFrames can be filtered in multiple ways; the most intuitive of which is using boolean indexing

```
In [8]: tips[tips['time'] == 'Dinner'].head(5)
Out[8]:
   total_bill   tip     sex smoker  day    time  size
0       16.99  1.01  Female     No  Sun  Dinner     2
1       10.34  1.66    Male     No  Sun  Dinner     3
2       21.01  3.50    Male     No  Sun  Dinner     3
3       23.68  3.31    Male     No  Sun  Dinner     2
4       24.59  3.61  Female     No  Sun  Dinner     4
```

The above statement is simply passing a `Series` of True/False objects to the DataFrame, returning all rows with True.

```
In [9]: is_dinner = tips['time'] == 'Dinner'

In [10]: is_dinner.value_counts()
Out[10]:
True     176
False     68
Name: time, dtype: int64

In [11]: tips[is_dinner].head(5)
Out[11]:
   total_bill   tip     sex smoker  day    time  size
0       16.99  1.01  Female     No  Sun  Dinner     2
1       10.34  1.66    Male     No  Sun  Dinner     3
2       21.01  3.50    Male     No  Sun  Dinner     3
3       23.68  3.31    Male     No  Sun  Dinner     2
4       24.59  3.61  Female     No  Sun  Dinner     4
```

Just like SQL's OR and AND, multiple conditions can be passed to a DataFrame using | (OR) and & (AND).

```
-- tips of more than $5.00 at Dinner meals
SELECT *
FROM tips
WHERE time = 'Dinner' AND tip > 5.00;
```

```
# tips of more than $5.00 at Dinner meals
In [12]: tips[(tips['time'] == 'Dinner') & (tips['tip'] > 5.00)]
Out[12]:
     total_bill    tip     sex smoker  day    time  size
23        39.42   7.58    Male     No  Sat  Dinner     4
44        30.40   5.60    Male     No  Sun  Dinner     4
47        32.40   6.00    Male     No  Sun  Dinner     4
52        34.81   5.20  Female     No  Sun  Dinner     4
59        48.27   6.73    Male     No  Sat  Dinner     4
116       29.93   5.07    Male     No  Sun  Dinner     4
155       29.85   5.14  Female     No  Sun  Dinner     5
170       50.81  10.00    Male    Yes  Sat  Dinner     3
172        7.25   5.15    Male    Yes  Sun  Dinner     2
181       23.33   5.65    Male    Yes  Sun  Dinner     2
183       23.17   6.50    Male    Yes  Sun  Dinner     4
211       25.89   5.16    Male    Yes  Sat  Dinner     4
212       48.33   9.00    Male     No  Sat  Dinner     4
214       28.17   6.50  Female    Yes  Sat  Dinner     3
239       29.03   5.92    Male     No  Sat  Dinner     3
```

```
-- tips by parties of at least 5 diners OR bill total was more than $45
SELECT *
FROM tips
WHERE size >= 5 OR total_bill > 45;
```

```
# tips by parties of at least 5 diners OR bill total was more than $45
In [13]: tips[(tips['size'] >= 5) | (tips['total_bill'] > 45)]
Out[13]:
     total_bill    tip     sex smoker   day    time  size
59        48.27   6.73    Male     No   Sat  Dinner     4
125       29.80   4.20  Female     No  Thur   Lunch     6
141       34.30   6.70    Male     No  Thur   Lunch     6
142       41.19   5.00    Male     No  Thur   Lunch     5
143       27.05   5.00  Female     No  Thur   Lunch     6
155       29.85   5.14  Female     No   Sun  Dinner     5
156       48.17   5.00    Male     No   Sun  Dinner     6
170       50.81  10.00    Male    Yes   Sat  Dinner     3
182       45.35   3.50    Male    Yes   Sun  Dinner     3
185       20.69   5.00    Male     No   Sun  Dinner     5
187       30.46   2.00    Male    Yes   Sun  Dinner     5
212       48.33   9.00    Male     No   Sat  Dinner     4
216       28.15   3.00    Male    Yes   Sat  Dinner     5
```

NULL checking is done using the `notna()` and `isna()` methods.

```
In [14]: frame = pd.DataFrame({'col1': ['A', 'B', np.NaN, 'C', 'D'],
   ....:                       'col2': ['F', np.NaN, 'G', 'H', 'I']})
   ....:

In [15]: frame
Out[15]:
  col1 col2
0    A    F
1    B  NaN
2  NaN    G
3    C    H
4    D    I
```

Assume we have a table of the same structure as our DataFrame above. We can see only the records where `col2` IS NULL with the following query:

```
SELECT *
FROM frame
WHERE col2 IS NULL;
```

```
In [16]: frame[frame['col2'].isna()]
Out[16]:
  col1 col2
1    B  NaN
```

Getting items where `col1` IS NOT NULL can be done with `notna()`.

```
SELECT *
FROM frame
WHERE col1 IS NOT NULL;
```

```
In [17]: frame[frame['col1'].notna()]
Out[17]:
  col1 col2
0    A    F
1    B  NaN
3    C    H
4    D    I
```

GROUP BY

In pandas, SQL's GROUP BY operations are performed using the similarly named `groupby()` method. `groupby()` typically refers to a process where we'd like to split a dataset into groups, apply some function (typically aggregation) , and then combine the groups together.

A common SQL operation would be getting the count of records in each group throughout a dataset. For instance, a query getting us the number of tips left by sex:

```
SELECT sex, count(*)
FROM tips
GROUP BY sex;
/*
Female     87
Male      157
*/
```

The pandas equivalent would be:

```
In [18]: tips.groupby('sex').size()
Out[18]:
sex
Female     87
Male      157
dtype: int64
```

Notice that in the pandas code we used `size()` and not `count()`. This is because `count()` applies the function to each column, returning the number of `not null` records within each.

```
In [19]: tips.groupby('sex').count()
Out[19]:
        total_bill  tip  smoker  day  time  size
sex
Female          87   87      87   87    87    87
Male           157  157     157  157   157   157
```

Alternatively, we could have applied the `count()` method to an individual column:

```
In [20]: tips.groupby('sex')['total_bill'].count()
Out[20]:
sex
Female     87
Male      157
Name: total_bill, dtype: int64
```

Multiple functions can also be applied at once. For instance, say we'd like to see how tip amount differs by day of the week - `agg()` allows you to pass a dictionary to your grouped DataFrame, indicating which functions to apply to specific columns.

```
SELECT day, AVG(tip), COUNT(*)
FROM tips
GROUP BY day;
/*
Fri   2.734737   19
Sat   2.993103   87
Sun   3.255132   76
Thur  2.771452   62
*/
```

```
In [21]: tips.groupby('day').agg({'tip': np.mean, 'day': np.size})
Out[21]:
           tip  day
day
Fri   2.734737   19
Sat   2.993103   87
Sun   3.255132   76
Thur  2.771452   62
```

Grouping by more than one column is done by passing a list of columns to the `groupby()` method.

```
SELECT smoker, day, COUNT(*), AVG(tip)
FROM tips
GROUP BY smoker, day;
/*
smoker day
No     Fri      4  2.812500
       Sat     45  3.102889
       Sun     57  3.167895
       Thur    45  2.673778
Yes    Fri     15  2.714000
       Sat     42  2.875476
       Sun     19  3.516842
       Thur    17  3.030000
*/
```

```
In [22]: tips.groupby(['smoker', 'day']).agg({'tip': [np.size, np.mean]})
Out[22]:
              tip
             size      mean
smoker day
No     Fri    4.0  2.812500
       Sat   45.0  3.102889
       Sun   57.0  3.167895
       Thur  45.0  2.673778
Yes    Fri   15.0  2.714000
       Sat   42.0  2.875476
       Sun   19.0  3.516842
       Thur  17.0  3.030000
```

JOIN

JOINs can be performed with `join()` or `merge()`. By default, `join()` will join the DataFrames on their indices. Each method has parameters allowing you to specify the type of join to perform (LEFT, RIGHT, INNER, FULL) or the columns to join on (column names or indices).

```
In [23]: df1 = pd.DataFrame({'key': ['A', 'B', 'C', 'D'],
   ....:                     'value': np.random.randn(4)})
   ....:

In [24]: df2 = pd.DataFrame({'key': ['B', 'D', 'D', 'E'],
   ....:                     'value': np.random.randn(4)})
   ....:
```

Assume we have two database tables of the same name and structure as our DataFrames.

Now let's go over the various types of JOINs.

INNER JOIN

```
SELECT *
FROM df1
INNER JOIN df2
  ON df1.key = df2.key;
```

```
# merge performs an INNER JOIN by default
In [25]: pd.merge(df1, df2, on='key')
Out[25]:
  key   value_x   value_y
0   B -0.282863  1.212112
1   D -1.135632 -0.173215
2   D -1.135632  0.119209
```

`merge()` also offers parameters for cases when you'd like to join one DataFrame's column with another DataFrame's index.

```
In [26]: indexed_df2 = df2.set_index('key')

In [27]: pd.merge(df1, indexed_df2, left_on='key', right_index=True)
Out[27]:
  key   value_x   value_y
1   B -0.282863  1.212112
3   D -1.135632 -0.173215
3   D -1.135632  0.119209
```

LEFT OUTER JOIN

```
-- show all records from df1
SELECT *
FROM df1
LEFT OUTER JOIN df2
  ON df1.key = df2.key;
```

```
# show all records from df1
In [28]: pd.merge(df1, df2, on='key', how='left')
Out[28]:
  key   value_x   value_y
0   A  0.469112       NaN
1   B -0.282863  1.212112
2   C -1.509059       NaN
3   D -1.135632 -0.173215
4   D -1.135632  0.119209
```

RIGHT JOIN

```
-- show all records from df2
SELECT *
FROM df1
RIGHT OUTER JOIN df2
  ON df1.key = df2.key;
```

```
# show all records from df2
In [29]: pd.merge(df1, df2, on='key', how='right')
Out[29]:
  key   value_x   value_y
0   B -0.282863  1.212112
1   D -1.135632 -0.173215
2   D -1.135632  0.119209
3   E       NaN -1.044236
```

FULL JOIN

pandas also allows for FULL JOINs, which display both sides of the dataset, whether or not the joined columns find a match. As of writing, FULL JOINs are not supported in all RDBMS (MySQL).

```
-- show all records from both tables
SELECT *
FROM df1
FULL OUTER JOIN df2
  ON df1.key = df2.key;
```

```
# show all records from both frames
In [30]: pd.merge(df1, df2, on='key', how='outer')
Out[30]:
  key   value_x   value_y
0   A  0.469112       NaN
1   B -0.282863  1.212112
2   C -1.509059       NaN
3   D -1.135632 -0.173215
4   D -1.135632  0.119209
5   E       NaN -1.044236
```

UNION

UNION ALL can be performed using `concat()`.

```
In [31]: df1 = pd.DataFrame({'city': ['Chicago', 'San Francisco', 'New York City'],
   ....:                     'rank': range(1, 4)})
   ....:

In [32]: df2 = pd.DataFrame({'city': ['Chicago', 'Boston', 'Los Angeles'],
   ....:                     'rank': [1, 4, 5]})
   ....:
```

```
SELECT city, rank
FROM df1
UNION ALL
SELECT city, rank
FROM df2;
/*
         city  rank
      Chicago     1
San Francisco     2
New York City     3
      Chicago     1
       Boston     4
  Los Angeles     5
*/
```

```
In [33]: pd.concat([df1, df2])
Out[33]:
            city  rank
0        Chicago     1
1  San Francisco     2
2  New York City     3
0        Chicago     1
1         Boston     4
2    Los Angeles     5
```

SQL's UNION is similar to UNION ALL, however UNION will remove duplicate rows.

```
SELECT city, rank
FROM df1
UNION
SELECT city, rank
FROM df2;
-- notice that there is only one Chicago record this time
/*
         city  rank
      Chicago     1
San Francisco     2
New York City     3
       Boston     4
  Los Angeles     5
*/
```

In pandas, you can use `concat()` in conjunction with `drop_duplicates()`.

```
In [34]: pd.concat([df1, df2]).drop_duplicates()
Out[34]: 
            city  rank
0        Chicago     1
1  San Francisco     2
2  New York City     3
1         Boston     4
2    Los Angeles     5
```

pandas equivalents for some SQL analytic and aggregate functions

Top n rows with offset

```
-- MySQL
SELECT * FROM tips
ORDER BY tip DESC
LIMIT 10 OFFSET 5;
```

```
In [35]: tips.nlargest(10 + 5, columns='tip').tail(10)
Out[35]: 
     total_bill   tip     sex smoker   day    time  size
183       23.17  6.50    Male    Yes   Sun  Dinner     4
214       28.17  6.50  Female    Yes   Sat  Dinner     3
47        32.40  6.00    Male     No   Sun  Dinner     4
239       29.03  5.92    Male     No   Sat  Dinner     3
88        24.71  5.85    Male     No  Thur   Lunch     2
181       23.33  5.65    Male    Yes   Sun  Dinner     2
44        30.40  5.60    Male     No   Sun  Dinner     4
52        34.81  5.20  Female     No   Sun  Dinner     4
85        34.83  5.17  Female     No  Thur   Lunch     4
211       25.89  5.16    Male    Yes   Sat  Dinner     4
```

Top n rows per group

```
-- Oracle's ROW_NUMBER() analytic function
SELECT * FROM (
  SELECT
    t.*,
    ROW_NUMBER() OVER(PARTITION BY day ORDER BY total_bill DESC) AS rn
  FROM tips t
)
WHERE rn < 3
ORDER BY day, rn;
```

```
In [36]: (tips.assign(rn=tips.sort_values(['total_bill'], ascending=False)
   ....:                     .groupby(['day'])
   ....:                     .cumcount() + 1)
   ....:      .query('rn < 3')
   ....:      .sort_values(['day', 'rn']))
   ....: 
Out[36]: 
     total_bill    tip     sex smoker   day    time  size  rn
95        40.17   4.73    Male    Yes   Fri  Dinner     4   1
90        28.97   3.00    Male    Yes   Fri  Dinner     2   2
170       50.81  10.00    Male    Yes   Sat  Dinner     3   1
212       48.33   9.00    Male     No   Sat  Dinner     4   2
156       48.17   5.00    Male     No   Sun  Dinner     6   1
182       45.35   3.50    Male    Yes   Sun  Dinner     3   2
197       43.11   5.00  Female    Yes  Thur   Lunch     4   1
142       41.19   5.00    Male     No  Thur   Lunch     5   2
```

the same using *rank(method='first')* function

```
In [37]: (tips.assign(rnk=tips.groupby(['day'])['total_bill']
   ....:                      .rank(method='first', ascending=False))
   ....:      .query('rnk < 3')
   ....:      .sort_values(['day', 'rnk']))
   ....: 
Out[37]: 
     total_bill    tip     sex smoker   day    time  size  rnk
95        40.17   4.73    Male    Yes   Fri  Dinner     4  1.0
90        28.97   3.00    Male    Yes   Fri  Dinner     2  2.0
170       50.81  10.00    Male    Yes   Sat  Dinner     3  1.0
212       48.33   9.00    Male     No   Sat  Dinner     4  2.0
156       48.17   5.00    Male     No   Sun  Dinner     6  1.0
182       45.35   3.50    Male    Yes   Sun  Dinner     3  2.0
197       43.11   5.00  Female    Yes  Thur   Lunch     4  1.0
142       41.19   5.00    Male     No  Thur   Lunch     5  2.0
```

```
-- Oracle's RANK() analytic function
SELECT * FROM (
  SELECT
    t.*,
    RANK() OVER(PARTITION BY sex ORDER BY tip) AS rnk
  FROM tips t
  WHERE tip < 2
)
WHERE rnk < 3
ORDER BY sex, rnk;
```

Let's find tips with (rank < 3) per gender group for (tips < 2). Notice that when using `rank(method='min')` function *rnk_min* remains the same for the same *tip* (as Oracle's RANK() function)

```
In [38]: (tips[tips['tip'] < 2]
   ....:     .assign(rnk_min=tips.groupby(['sex'])['tip']
   ....:                         .rank(method='min'))
   ....:     .query('rnk_min < 3')
   ....:     .sort_values(['sex', 'rnk_min']))
   ....: 
Out[38]: 
     total_bill   tip     sex smoker  day    time  size  rnk_min
67         3.07  1.00  Female    Yes  Sat  Dinner     1      1.0
92         5.75  1.00  Female    Yes  Fri  Dinner     2      1.0
111        7.25  1.00  Female     No  Sat  Dinner     1      1.0
236       12.60  1.00    Male    Yes  Sat  Dinner     2      1.0
237       32.83  1.17    Male    Yes  Sat  Dinner     2      2.0
```

UPDATE

```
UPDATE tips
SET tip = tip*2
WHERE tip < 2;
```

```
In [39]: tips.loc[tips['tip'] < 2, 'tip'] *= 2
```

DELETE

```
DELETE FROM tips
WHERE tip > 9;
```

In pandas we select the rows that should remain, instead of deleting them

```
In [40]: tips = tips.loc[tips['tip'] <= 9]
```

<< Comparison with R / R libraries

Comparison with SAS >>