The need for efficient coding I

WRITING EFFICIENT CODE WITH PANDAS

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How do we measure time?

`time.time()` : returns current time in seconds since 12:00am, January 1, 1970

```
import time
# record time before execution
start_time = time.time()
# execute operation
result = 5 + 2
# record time after execution
end_time = time.time()
print("Result calculated in {} sec".format(end_time - start_time))
```

```
Result calculated in 9.48905944824e-05 sec
```

For loop vs List comprehension

- List comprehension:

```
list_comp_start_time = time.time()
result = [i*i for i in range(0,1000000)]
list_comp_end_time = time.time()
print("Time using the list_comprehension: {} sec".format(list_comp_end_time -
list_comp_start_time))
```

- For loop:

```
for_loop_start_time= time.time()
result=[]
for i in range(0,1000000):
  result.append(i*i)
for_loop_end_time= time.time()
print("Time using the for loop: {} sec".format(for_loop_end_time - for_loop_start_time
```

For loop vs List comprehension II

```
Time using the list comprehension: 0.11042404174804688 sec
Time using the for loop: 0.2071230411529541 sec
```

```
list_comp_time = list_comp_end_time - list_comp_start_time
for_loop_time = for_loop_end_time - for_loop_start_time
print("Difference in time: {} %".format((for_loop_time - list_comp_time)/
list_comp_time*100))
```

```
Difference in time: 87.55527367398622 %
```

Where time matters I

Calculate $1 + 2 + ... + 1000000$.

- Adding numbers one by one:

```
def sum_brute_force(N):
    res = 0
    for i in range(1,N+1):
        res+=i
    return res
```

- Using $1 + 2 + ... + N = \frac{N \cdot (N+1)}{2}$

```
def sum_formula(N):
    return N*(N+1)/2
```

Where time matters II

- Using the formula:

```
# Using the formula
formula_start_time = time.time()
formula_result = formula(1000000)
formula_end_time = time.time()

print("Time using the formula: {}
sec".format(formula_end_time - formula_start_time))
```

```
Using the formula: 0.000108957290649 sec
```

- Using brute force:

```
# Using brute force
bf_start_time = time.time()
bf_result = sum_brute_force(1000000)
bf_end_time = time.time()

print("Time using brute force: {}
sec".format(bf_end_time - start_time))
```

```
Time using brute force: 0.174870967865 sec
```

```
Difference in speed: 160,394.967179%
```

Let's do it!

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Locate rows: .iloc[] and .loc[]

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The poker dataset

	S1	R1	S2	R2	S3	R3	S4	R4	S5	R5
1	♦	10	♣	Jack	♣	King	♠	4	♥	Ace
2	♦	Jack	♦	King	♦	10	♦	Queen	♦	Ace
3	♣	Queen	♣	Jack	♣	King	♣	10	♣	Ace

	S1	R1	S2	R2	S3	R3	S4	R4	S5	R5
1	2	10	3	11	3	13	4	4	1	1
2	2	11	2	13	2	10	2	12	2	1
3	3	12	3	11	3	13	3	10	3	1

Sn: symbol of the n-th card

1 (Hearts), 2 (Diamonds), 3 (Clubs), 4 (Spades)

Rn: rank of the n-th card

1 (Ace), 2-10, 11 (Jack), 12 (Queen), 13 (King)

Locate targeted rows

`.loc[]` — index name locator

```
# Specify the range of rows to select
rows = range(0, 500)
# Time selecting rows using .loc[]
loc_start_time = time.time()
data.loc[rows]
loc_end_time = time.time()

print("Time using .loc[] : {} sec".format(
            loc_end_time - loc_start_time))
```

```
Time using .loc[]: 0.001951932 seconds
```

`.iloc[]` — index number locator

```
# Specify the range of rows to select
rows = range(0, 500)
# Time selecting rows using .iloc[]
iloc_start_time = time.time()
data.iloc[rows]
iloc_end_time = time.time()

print("Time using .iloc[]: {} sec".format(
            iloc_end_time - iloc_start_time)
```

```
Time using .iloc[] : 0.0007140636 sec
```

```
Difference in speed: 173.355592654%
```

Locate targeted columns

`.iloc[]` — index number locator

```
iloc_start_time = time.time()
data.iloc[:,:3]
iloc_end_time = time.time()
print("Time using .iloc[]: {} sec".format(
            iloc_end_time - iloc_start_time))
```

```
Time using .iloc[]: 0.00125193595886 sec
```

Locating columns by names

```
names_start_time = time.time()
data[['S1', 'R1', 'S2']]
names_end_time = time.time()
print("Time using selection by name: {} sec".format(
            names_end_time - names_start_time))
```

```
Time using selection by name: 0.000964879989624 sec
```

```
Difference in speed: 29.7504324188%
```

Let's do it!

Select random rows

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Sampling random rows using pandas

```
start_time = time.time()
poker.sample(100, axis=0)
print("Time using sample: {} sec".format(time.time() - start_time))
```

```
Time using sample: 0.000750064849854 sec
```

Sampling random rows using numpy

```
start_time = time.time()
poker.iloc[np.random.randint(low=0, high=poker.shape[0], size=100)]
print("Time using .iloc[]: {} sec".format(time.time() - start_time))
```

```
Time using .iloc[]: 0.00103211402893 sec
```

```
Difference in speed: 37.6033057849%
```

Sampling random columns

```
start_time = time.time()
poker.sample(3, axis=1)
print("Time using .sample(): {} sec".format(time.time() - start_time))
```

```
Time using .sample(): 0.000683069229126 sec
```

```
N = poker.shape[1]
start_time = time.time()
poker.iloc[:,np.random.randint(low=0, high=N, size=3)]
print("Time using .iloc[]: {} sec".format(time.time() - start_time))
```

```
ime using .iloc[]: 0.0010929107666 sec
```

```
Difference in speed: 59.9999999998%
```

Let's do it!

Replace scalar values using .replace()

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The popular name dataset

Year of Birth	Gender	Ethnicity	Child's First Name	Count	Rank
2011	FEMALE	ASIAN AND PACIFIC ISLANDER	SOPHIA	119	1
2011	FEMALE	ASIAN AND PACIFIC ISLANDER	CHLOE	106	2

Replace values in pandas

```
start_time = time.time()
names['Gender'].loc[names.Gender=='MALE'] = 'BOY'
print("Replace values using .loc[]: {} sec".format(time.time() - start_time))
```

```
Results from the first method calculated in 0.0311849 seconds
```

Replace values using .replace()

```
start_time = time.time()
names['Gender'].replace('MALE', 'BOY', inplace=True)
print("Time using .replace(): {} sec".fomrat(time.time() - start_time))
```

```
Time using .replace(): 0.0016758441925 sec
```

```
Differerence in speed: 1,704.52411439%
```

Let's do it

Replace values using lists

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Replace multiple values with one value

Year of Birth	Gender	Ethnicity	Child's First Name	Count	Rank
2011	FEMALE	WHITE NON HISP	HELENA	97	4

```
start_time = time.time()
names['Ethnicity'].loc[(names["Ethnicity"] == 'WHITE NON HISPANIC') |
(names["Ethnicity"] == 'WHITE NON HISP')] = 'WNH'
print("Results from the above operation calculated in %s seconds" %
 (time.time() - start_time))
```

```
Results from the second method calculated in 0.0276169776917 seconds
```

Replace multiple values using .replace() I

```
start_time = time.time()
names['Ethnicity'].replace(['WHITE NON HISPANIC','WHITE NON HISP'],
'WNH', inplace=True)
print("Time using .replace(): {} sec".format(time.time() - start_time))
```

```
Time using .replace():  0.00144791603088 sec
```

```
Difference in speed: 2160.68681809%
```

```python
names['Ethnicity'].replace(['WHITE NON HISP'], 'WHITE NON HISPANIC', inplace=True)
names['Ethnicity'].replace(['BLACK NON HISP'], 'BLACK NON HISPANIC', inplace=True)
```

```python
names['Ethnicity'].replace(['BLACK NON HISP','WHITE NON HISP'], ['BLACK NON HISPANIC',
'WHITE NON HISPANIC'], inplace=True)
```

Let's do it

Replace values using dictionaries

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Replace single values with dictionaries

```
start_time = time.time()
names['Gender'].replace({'MALE':'BOY', 'FEMALE':'GIRL'},
inplace=True)
print("Time using .replace() with dictionary: {} sec".format(time.time() - start_time))
```

```
Time using .replace() with dictionary: 0.00197792053223 sec
```

```
start_time = time.time()
names['Gender'].replace('MALE', 'BOY', inplace=True)
names['Gender'].replace('FEMALE', 'GIRL', inplace=True)
print("Time using multiple .replace(): {} sec".format(time.time() - start_time))
```

```
Time using multiple .replace(): 0.00307083129883 sec
```

```
Difference in speed: 55.2555448407%
```

Replace multiple values using dictionaries

```
start_time = time.time()
names.replace({'Ethnicity': {'ASIAN AND PACI': 'ASIAN', 'ASIAN AND PACIFIC ISLANDER': 'ASIAN',
                             'BLACK NON HISPANIC': 'BLACK', 'BLACK NON HISP': 'BLACK',
                             'WHITE NON HISPANIC': 'WHITE', 'WHITE NON HISP': 'WHITE'}})

print("Time using .replace() with dictionary: {} sec".format (time.time() - start_time))
```

```
Time using .replace() with dictionary: 0.0028018 sec
```

Let's do it!

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Looping using the .iterrows() function

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The poker dataset

	S1	R1	S2	R2	S3	R3	S4	R4	S5	R5
1	1	10	3	11	3	13	4	4	2	1
2	2	11	2	13	2	10	2	12	2	1
3	3	12	3	11	3	13	3	10	3	1

1. Hearts
2. Diamonds
3. Clubs
4. Spades

Generators in Python

```
def city_name_generator():
    yield('New York')
    yield('London')
    yield('Tokyo')
    yield('Sao Paolo')

city_names = city_name_generator()
```

```
next(city_names)
'New York'
next(city_names)
'London'
next(city_names)
'Tokyo'
next(city_names)
'Sao Paolo'
```

```
next(city_names)
```

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

Looping using the .iterrows() function

```
gen = poker.iterrows()
first_element = next(gen)
```

```
first_element[0]
0
```

```
first_element[1]
S1     2
R1    11
S2     2
R2    13
S3     2
R3    10
S4     2
R4    12
S5     2
R5     1
Name: 1, dtype: int64
```

Using the .iterrows() function

```
start_time = time.time()
for index, values in range(poker.shape[0]):
    next
print("Time using range(): {} sec".format(time.time() - start_time))
```

```
Results using range(): 0.006870031 sec
```

```
data_generator = poker.iterrows()

start_time = time.time()
for index, values in data_generator:
    next
print("Time using .iterrows(): {} sec".format(time.time() - start_time))
```

```
Time using .iterrows(): 1.55003094673 sec
```

Let's do it!

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Looping using the .apply() function

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The .apply() function

```
data_sqrt = poker.apply(lambda x: np.sqrt)
head(data_sqrt, 4)
```

	S1	R1	S2	R2	S3	R3
0	1.000000	3.162278	1.000000	3.316625	3.464102	1.000000
1	1.414214	3.316625	1.414214	3.605551	1.414214	3.162278
2	1.732051	3.464102	1.732051	3.316625	1.732051	3.605551
3	2.000000	3.162278	2.000000	3.316625	2.000000	1.000000

```
data_sqrt_2 = np.sqrt(poker)
```

The .apply() function for rows

```
apply_start_time = time.time()
poker[['R1', 'R2', 'R3', 'R4', 'R5']].apply(lambda x: sum(x), axis=1)
print("Time using .apply(): {} sec".format(time.time() - apply_start_time))
```

```
Time using .apply(): 0.636334896088 sec
```

```
start_time = time.time()
for ind, value in poker.iterrows():
    sum([value[1], value[3], value[5], value[7], value[9]])
print("Time using .iterrows(): {} sec".format(time.time() - start_time))
```

```
Time using .iterrows(): 3.15526986122 sec
```

```
Difference in speed: 395.85051529%
```

The .apply() function for columns

```
start_time = time.time()
poker[['R1', 'R2', 'R3', 'R4', 'R5']].apply(lambda x: sum(x), axis=0)
print("Time using .apply(): {} sec".format(time.time() - apply_start_time))
```

```
Time using .apply(): 0.00490880012 seconds
```

```
start_time = time.time()
poker[['R1', 'R1', 'R3', 'R4', 'R5']].sum(axis=0)
print("Time using pandas: {} sec".format(time.time() - start_time))
```

```
Time using pandas: 0.00279092788 sec
```

```
Difference in speed: 160.310951649%
```

Let's do it!

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Vectorization over Pandas series

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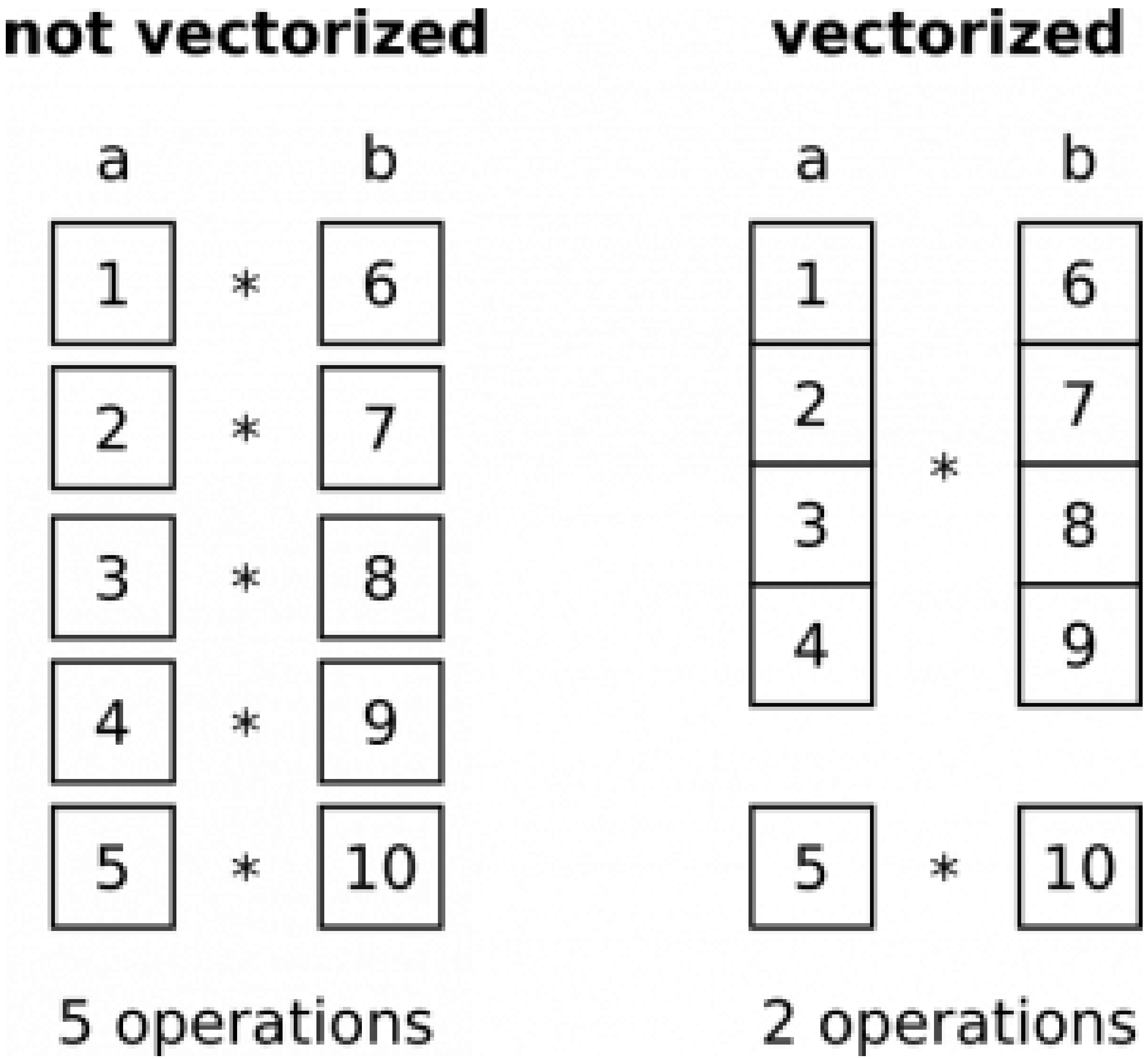
DataFrames as arrays



How to perform pandas vectorization

```
start_time = time.time()
poker[['R1', 'R2', 'R3', 'R4', 'R5']].sum(axis=1)
print("Time using pandas vectorization: {} sec".format(time.time() - start_time))
```

```
Time using pandas vectorization: 0.0026819705 sec
```

```
poker[['R1', 'R2', 'R3', 'R4', 'R5']].sum(axis=1).head()
```

0	47
1	47
2	47
3	47
4	47
dtype: int64	--

Comparison to the previous methods

```
data_generator = data.iterrows()

start_time = time.time()
for index, value in data_generator:
        sum([value[1], value[3], value[5], value[7]])
print("Time using .iterrows(){} seconds" % (time.time() - start_time))
```

```
Results from the above operation calculated in 3.37918996 seconds
```

```
start_time = time.time()
data[['R1', 'R2', 'R3', 'R4', 'R5']].apply(lambda x: sum(x),axis=1)
print("Results from the above operation calculated in %s seconds" % (time.time() - start_time))
```

```
Results from the above operation calculated in 0.637711048 seconds
```

```
- Difference between vectorization and the `.iterows()` function: 111,800.75%
- Difference between vectorization and the `.apply()` function: 20,853%
```

Let's do it!

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Vectorization with NumPy arrays using .values()

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NumPy in pandas

```
df = pd.DataFrame({'Col1':[0, 1,
2, 3, 4, 5, 6]}, dtype=np.int8)
print(df)
```

```
|        | Col1 |
|--------|------|
| 0      | 0    |
| 1      | 1    |
| 2      | 2    |
| 3      | 3    |
| 4      | 4    |
| 5      | 5    |
| 6      | 6    |
```

```
nd = np.array(range(7))
print(nd)

[0 1 2 3 4 5 6]
```

How to perform NumPy vectorization

```
start_time = time.time()
poker[['R1', 'R2', 'R3', 'R4', 'R5']].values.sum(axis=1)
print("Time using NumPy vectorization: {} sec(time.time() - start_time))
```

```
Results from the above operation calculated in 0.00157618522644 seconds
```

```
start_time = time.time()
poker[['R1', 'R2', 'R3', 'R4', 'R5']].sum(axis=1)
print("Results from the above operation calculated in %s seconds" % (time.time() - start_time))
```

```
Results from the above operation calculated in 0.00268197059631 seconds
```

```
Difference in time: 39.0482%
```

Let's do it!

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Data transformation using .groupby().transform

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The restaurant dataset

```
| total_bill    | tip    | sex        | smoker     | day    | time       |
|---------------|--------|------------|------------|--------|------------|
| 16.99         | 1.01   | Female     | No         | Sun    | "Dinner"   |
| 10.34         | 1.66   | Male       | No         | Sun    | "Dinner"   |
```

```
restaurant_grouped = restaurant.groupby('smoker')
```

```
print(restaurant_grouped.count())
```

```
|                   | total_bill |    tip |    sex  |  day    |   time |
|-------------------|------------|--------|---------|---------|--------|
| smoker            |            |        |         |         |        |
| No                | 151        | 151    | 151     | 151     | 151    |
| Yes               | 93         | 93     | 93      | 93      | 93     |
```

Data transformation

```
zscore = lambda x: (x - x.mean()  ) / x.std()
```

```
restaurant_grouped = restaurant.groupby('time')
restaurant_transformed = restaurant_grouped.transform(zscore)
```

```
restaurant_transformed.head()
```

```
   total_bill       tip      size
0   -0.416446 -1.457045 -0.692873
1   -1.143855 -1.004475  0.405737
2    0.023282  0.276645  0.405737
3    0.315339  0.144355 -0.692873
```

Comparison with native methods

```
restaurant.groupby('sex').transform(zscore)

mean_female = restaurant.groupby('sex').mean()['total_bill']['Female']
mean_male = restaurant.groupby('sex').mean()['total_bill']['Male']
std_female = restaurant.groupby('sex').std()['total_bill']['Female']
std_male = restaurant.groupby('sex').std()['total_bill']['Male']

for i in range(len(restaurant)):
    if restaurant.iloc[i][2] == 'Female':
        restaurant.iloc[i][0] = (restaurant.iloc[i][0] - mean_female)/std_female
    else:
        restaurant.iloc[i][0] = (restaurant.iloc[i][0] - mean_male)/std_male
```

```
Time using .groupby(): 0.016291141 seconds
Time using native Python: 3.937326908 seconds

Difference in time: 24,068.5145%
```

Let's practice!

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Missing value imputation using transform()

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Counting missing values

```
prior_counts = restaurant.groupby('time')
['total_bill'].count()
```

```
missing_counts = restaurant_nan.groupby('time')
['total_bill'].count()
print(prior_counts - missing_counts)
```

```
time
Dinner    32
Lunch     13
Name: total_bill, dtype: int64
```

Missing value imputation

```
missing_trans = lambda x: x.fillna(x.mean())
```

```
restaurant_nan_grouped = restaurant_nan.groupby('time')['total_bill']
restaurant_nan_grouped.transform(missing_trans)
```

```
Time using .transform(): 0.00368881225586 sec
```

```
0     20.676573
1     10.340000
2     21.010000
3     23.680000
4     24.590000
5     25.290000
6     20.676573
Name: total_bill, dtype: float64
```

Comparison with native methods

```
start_time = time.time()
mean_din = restaurant_nan.loc[restaurant_nan.time ==
'Dinner']['total_bill'].mean()
mean_lun = restaurant_nan.loc[restaurant_nan.time ==
'Lunch']['total_bill'].mean()

for row in range(len(restaurant_nan)):
    if restaurant_nan.iloc[row]['time'] == 'Dinner':
        restaurant_nan.loc[row, 'total_time'] = mean_din
    else:
        restaurant_nan.loc[row, 'total_time'] = mean_lun
print("Results from the above operation calculated in %s seconds" % (time.time() - start_time))
```

```
Time using native Python: 0.172566890717 sec
```

```
Difference in time: 4,578.115%
```

Let's do it!

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Data filtration using the filter() function

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Purpose of filter()

Limit results based on an aggregate feature

- Number of missing values
- Mean of a specific feature
- Number of occurrences of the group

Filter using groupby().filter()

```
restaurant_grouped = restaurant.groupby('day')
filter_trans = lambda x : x['total_bill'].mean() > 20
restaurant_filtered = restaurant_grouped.filter(filter_trans)
```

```
Time using .filter() 0.00414085388184 sec
```

```
print(restaurant_filtered['tip'].mean())
```

```
3.11527607362
```

```
print(restaurant['tip'].mean())
```

```
2.9982786885245902
```

Comparison with native methods

```
t=[restaurant.loc[df['day'] == i]['tip'] for i in restaurant['day'].unique()
    if restaurant.loc[df['day'] == i]['total_bill'].mean()>20]
restaurant_filtered = t[0]
for j in t[1:]:
    restaurant_filtered=restaurant_filtered.append(j,ignore_index=True)
```

```
Time using native Python: 0.00663900375366 sec
```

```
print(restaurant_filtered.mean())
```

```
3.11527607362
```

```
Difference in time: 60.329341317157024%
```

Let's do it!

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Congratulations!

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What you have learned

- Why and how to time operations
- Select targeted rows and columns efficiently
- Select random rows and columns efficiently
- Replace values of a DataFrame efficiently using replace()
  - Replace multiple values using lists
  - Replace multiple values using dictionaries

What you have learned

- Iterate on a DataFrame using the .iterrows() function
- Iterate on a DataFrame using the .apply() function
- Iterate on a DataFrame using pandas optimization
- Iterate on a DataFrame using numpy optimization
- Comparison of the groupby() function compared to native python code
  - When transforming the data group-wise
  - When imputing missing values group-wise
  - When filtering groups with specific characteristics

Congratulations!

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