Data Science: Performance of Python vs Pandas vs Numpy

July 15, 2017 (http://croock.webfactional.com/data-science-performance-of-python-vs-pandas-vs-numpy/) Lucas KM (http://croock.webfactional.com/author/lukas_km/) Tips and Tricks (http://croock.webfactional.com/category/tips-and-tricks/)

Note: this is updated version of original post from 15 July 2017. Updates have been inspired by comments to this post and discussion on Hacker News.

Speed and time is a key factor for any Data Scientist. In business, you do not usually work with toy datasets having thousands of samples. It is more likely that your datasets will contain millions or hundreds of millions samples. Customer orders, web logs, billing events, stock prices – datasets now are huge.

I assume you do not want to spend hours, waiting for your data processing to complete. The biggest dataset I worked with so far contained over 30 million of records. I do not have very powerful machine (Macbook Air with i5 and 4 GB of RAM), but the most I could accept was running the script over one hour, not multiple hours.

The Experiment

This post is a result of my toy experiment – comparing data processing of three different approaches from "Python" family.

I will consider here two approaches to measure software solution performance speed. In both cases inputs and outputs are the same (Python list of lists).

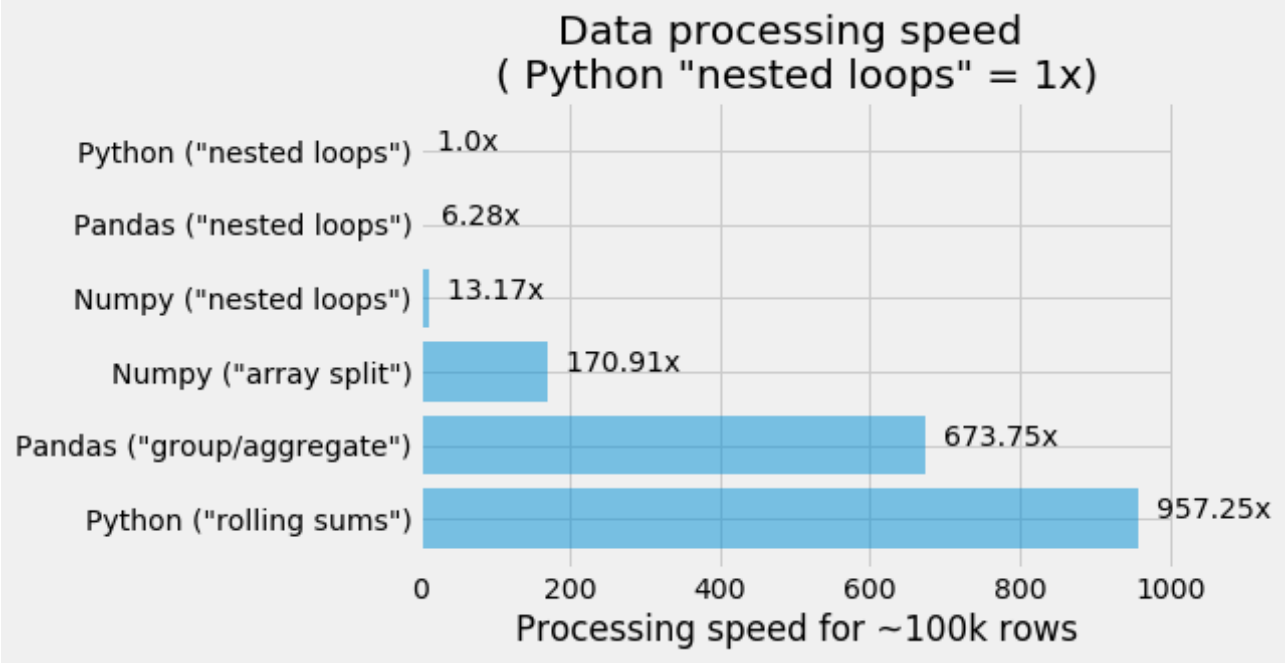
A. "Fair competition" – comparing (possibly) the same implementations, . It means that data processing steps in a given algorithm should be as similar as possible. However, algorithms itself are not "optimized" or

"optimal", meaning they do not take advantage of features specific for each chosen language/technology/framework.

B. "Free style competition" – comparing implementations "optimized" for each chosen language/technology/framework. I do not say these implementations are "optimal", as it is quite likely someone can invent better implementations that I included in my notebook. Still, I try to use here features specific for each language/framework to show power of each solution.

I am very aware that the actual performance may vary significantly, depending on a task and type of processing. So please, treat these result as indicative only. There is no single test that can shown "overall" comparison of performance for any set of software tools.

The graph below shows result of my toy performance comparison (details in the notebook), calculated as processing speed measured against processing speed of pure Python "nested loops" code.



The Conclusion

For comparison "A" (not optimal, nested loops implementations) , Numpy performance is several times bigger than Pandas performance. This implementation is really comparing how good each solution is doing sub-selection from a bigger array and summing data in rows for each product id.

For comparison “B” , things change significantly. Python and Pandas show considerable performance. Numpy is behind these two, but please note that Numpy implementations is not optimal, it is just the best I could find for a given moment.

Python can be quite fast cause it does not have to send data to BLAS library and back. Pandas grouping and aggregation is also very powerful and it is not easy to write similar powerful solution in Numpy (please share in comments if you have a better one).

You can experiment with the code yourself and draw your own conclusions.

The Notebook

Please review the notebook below for details of the performance test. You can also reviev the Notebook on Github (https://github.com/lukaszkm/machinelearningexp/blob/master/DataScience_Performance_Python_Pandas_Numpy.ipynb).

Data Science: Performance of Pure Python vs Pandas vs Numpy

01. Intro & Imports

Data Science: Performance of Pure Python vs Pandas vs Numpy Notebook

In this notebook we will compare data processing speed of pure Python, Pandas and Numpy

- Notebook @author Lukasz Kamieniecki-Mruk, lucas.mlexp@gmail.com, http://machinelearningexp.com (http://machinelearningexp.com)
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In [1]:

```
# Python 3.6
import os
import sys
import gc
import random
import time
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
%matplotlib inline
```

02. Prepare dummy random dataset

In [2]:

```
# We will prepare artificial dataset that contains orders
of the product.
# Each order will have random number of items ordered and
random price within given range
dataset_python = []
range_products = [1,10000] # number of products in the dat
aset
range_orders = [1,20] # range of orders for product from w
hich to select one random value
range_quantity = [1,100] # range of quantity in order from
which to select one random value
range_price = [0.1,50.00] # range of product prices from w
hich to select one random value
```

In [3]:

```
def generate_dummy_dataset(range_products,range_orders,pro
ducts_quantity,products_price):
    generated_dataset = []
    for idx in range(range_products[0],range_products[1]):
        random_orders = random.randint(range_orders[0],ran
ge_orders[1])
        for odx in range(random_orders):
            quantity = random.randint(range_quantity[0],ra
nge_quantity[1])
            price = random.uniform(range_price[0],range_pr
ice[1])
            generated_dataset.append([idx,odx,quantity,pri
ce])
    return generated_dataset
```

In [4]:

```
dataset_python = generate_dummy_dataset(range_products,ran
ge_orders,range_quantity,range_price)
print ("Dataset size",len(dataset_python),"records\n")
print ('product_id,','product_order_num,','quantity,','pri
ce,')
dataset_python[0:3]
```

```
Dataset size 106122 records

product_id, product_order_num, quantity, price,
```

Out[4]:

```
[[1, 0, 29, 9.823151448371421],
 [1, 1, 18, 49.21229550643979],
 [1, 2, 86, 6.406249725444821]]
```

03a. Pure Python function (nested loops)

In [5]:

```
def gen_stats_python1(dataset_python):
    start = time.time()
    tag = 'Python ("nested loops")'
    product_stats = []
    unique_products = set([x[0] for x in dataset_python])
    for product_id in unique_products:
        product_items = [x for x in dataset_python if x[0]
==product_id ]
        num_orders = len(product_items)
        total_quantity = 0
        total_price = 0
        for row in product_items:
            total_quantity += row[2]
            total_price += row[3]
        avg_price = float(total_price/num_orders)
        product_stats.append([int(product_id),int(num_orde
rs),int(total_quantity),round(avg_price,2)])
    end = time.time()
    working_time = end-start
    return product_stats,working_time,tag
```

03b. Pure Python function (rolling sums)

In [6]:

```
def gen_stats_python2(dataset_python):
    start = time.time()
    tag = 'Python ("rolling sums")'
    dataset_python = sorted(dataset_python, key=lambda ite
m: item[0])
    product_stats = []
    prev_product_id = dataset_python[0][0]
    num_orders = 0
    sum_quantity = 0
    sum_prices = 0
    for row in dataset_python:
        if row[0]==prev_product_id:
            num_orders += 1
            sum_quantity += row[2]
            sum_prices += row[3]
        else:
            product_stats.append([prev_product_id,int(num_
orders),int(sum_quantity),round(sum_prices/num_orders,2)])
            prev_product_id = row[0]
            num_orders = 1
            sum_quantity = row[2]
            sum_prices = row[3]
    product_stats.append([prev_product_id,int(num_orders),
int(sum_quantity),round(sum_prices/num_orders,2)])
    end = time.time()
    working_time = end-start
    return product_stats,working_time,tag
```

04a. Pandas function (nested loops)

In [7]:

```
def gen_stats_pandas1(dataset_python):
    start = time.time()
    tag = 'Pandas ("nested loops")'
    dataset_pandas = pd.DataFrame(data=dataset_python,colu
mns=['product_id','product_order_num','quantity','price'])
    product_stats = []
    for product_id in pd.unique(dataset_pandas['product_id
']):
        product_items = dataset_pandas.loc[dataset_pandas[
'product_id'] == product_id]
        num_orders = product_items.shape[0]
        total_quantity = product_items['quantity'].sum()
        avg_price = float(product_items['price'].mean())
        product_stats.append([int(product_id),int(num_orde
rs),int(total_quantity),round(avg_price,2)])
    end = time.time()
    working_time = end-start
    return product_stats,working_time,tag
```

04b. Pandas function (group & aggregate)

In [8]:

```
def gen_stats_pandas2(dataset_python):
    start = time.time()
    tag = 'Pandas ("group/aggregate")'
    dataset_pandas = pd.DataFrame(data=dataset_python,colu
mns=['product_id','product_order_num','quantity','price'])
    product_stats = []
    calc_stats = dataset_pandas.groupby('product_id')
    calc_stats = calc_stats.aggregate({'product_order_num'
: 'count','quantity': 'sum','price': 'mean'})
    calc_stats = calc_stats.reset_index().values.tolist()
    product_stats = [[int(item[0]),int(item[1]),int(item[2
]),round(item[3],2)] for item in calc_stats]
    end = time.time()
    working_time = end-start
    return product_stats,working_time,tag
```

05a. Numpy function (nested loops)

In [9]:

```
def gen_stats_numpy1(dataset_python):
    start = time.time()
    tag = 'Numpy ("nested loops")'
    dataset_numpy = np.array(dataset_python)
    product_stats = []
    for product_id in np.nditer(np.unique(dataset_numpy[:,
0]),op_dtypes=['float64']):
        product_items = dataset_numpy[dataset_numpy[:,0] =
= product_id]
        num_orders = product_items.shape[0]
        total_quantity = product_items[:,2].sum()
        avg_price = float(product_items[:,3].mean())
        product_stats.append([int(product_id),int(num_orde
rs),int(total_quantity),round(avg_price,2)])
    end = time.time()
    working_time = end-start
    return product_stats,working_time,tag
```

05b. Numpy function (array split)

In [10]:

```
def gen_stats_numpy2(dataset_python):
    start = time.time()
    tag = 'Numpy ("array split")'
    dataset_numpy = np.array(dataset_python)
    unique_products,unique_indices = np.unique(dataset_num
py[:,0],return_index = True)
    split = np.split(dataset_numpy,unique_indices)[1:]
    product_stats = \
    [[int(item[0,0]),item.shape[0],int(np.sum(item[:,2])),
float(np.round(np.sum(item[:,3])/item.shape[0],2))]\
     for item in split]
    end = time.time()
    working_time = end-start
    return product_stats,working_time,tag
```

06. Prepare function dispatcher

In [11]:

```
dispatcher  = [gen_stats_python1,
               gen_stats_python2,
               gen_stats_pandas1,
               gen_stats_pandas2,
               gen_stats_numpy1,
               gen_stats_numpy2]
```

07. Check if all functions generate the same result

In [12]:

```
gc.collect()
test_results = []
prev_result = None
for i in dispatcher:
    result = i(dataset_python)
    test_results.append(result)
    if prev_result == None:
        equal = None
    else:
        equal = (prev_result == result[0])
    prev_result = result[0]
    print (result[2],result[0][0:3],'equal : ',equal)
```

```
Python ("nested loops") [[1, 16, 888, 24.38], [2, 19, 893,
30.55], [3, 12, 710, 34.16]] equal :  None
Python ("rolling sums") [[1, 16, 888, 24.38], [2, 19, 893,
30.55], [3, 12, 710, 34.16]] equal :  True
Pandas ("nested loops") [[1, 16, 888, 24.38], [2, 19, 893,
30.55], [3, 12, 710, 34.16]] equal :  True
Pandas ("group/aggregate") [[1, 16, 888, 24.38], [2, 19, 8
93, 30.55], [3, 12, 710, 34.16]] equal :  True
Numpy ("nested loops") [[1, 16, 888, 24.38], [2, 19, 893,
30.55], [3, 12, 710, 34.16]] equal :  True
Numpy ("array split") [[1, 16, 888, 24.38], [2, 19, 893, 3
0.55], [3, 12, 710, 34.16]] equal :  True
```

In [13]:

```
# clear memory
del test_results
gc.collect()
```

Out[13]:

```
49
```

08. Compare running time

In [14]:

```
NUM_ITERATIONS = 3
```

In [15]:

```
running_time = []
for i in dispatcher:
    gc.collect()
    alg_time = []
    for j in range (NUM_ITERATIONS):
        result = i(dataset_python)
        alg_time.append(result[1])
    print (result[2],min(alg_time),'sec')
    running_time.append ([result[2],min(alg_time)])
```

```
Python ("nested loops") 81.08451509475708 sec
Python ("rolling sums") 0.08470582962036133 sec
Pandas ("nested loops") 12.91911792755127 sec
Pandas ("group/aggregate") 0.12034893035888672 sec
Numpy ("nested loops") 6.156933069229126 sec
Numpy ("array split") 0.47443199157714844 sec
```

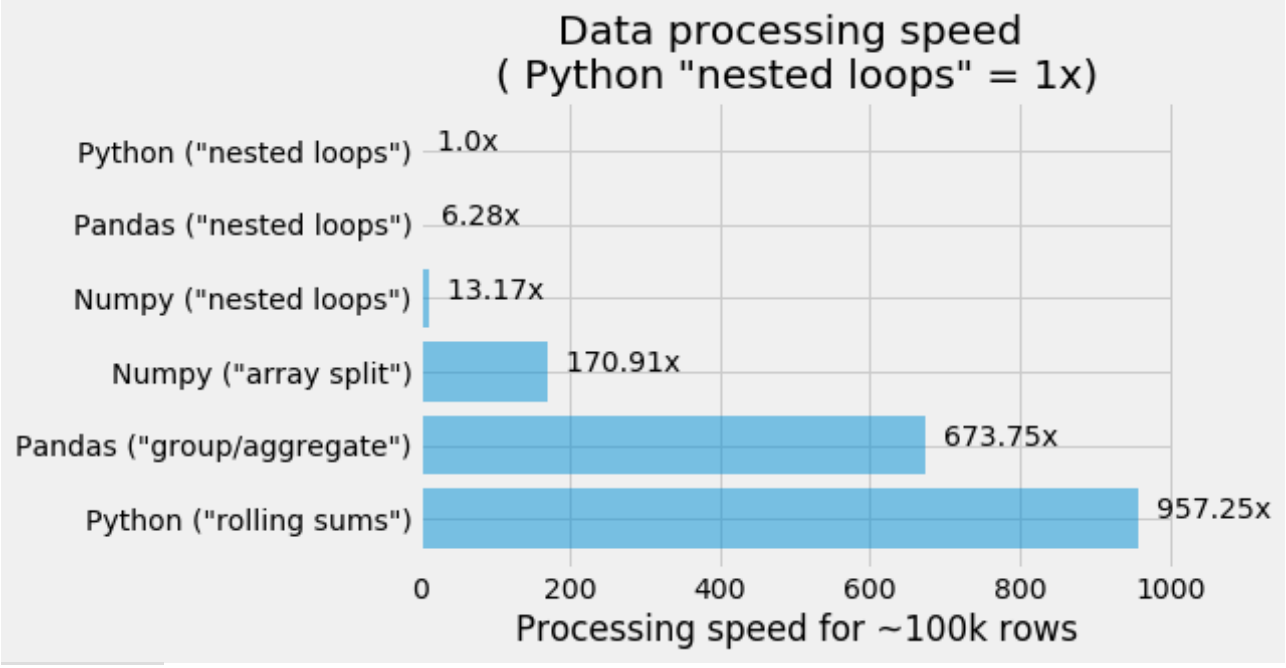
09. Present results

In [16]:

```
running_time = sorted(running_time, key=lambda item: item[
1])
base_time_1x = running_time[-1][1]
```

In [17]:

```
plt.style.use('fivethirtyeight')
objects = [x[0] for x in running_time]
y_rng = np.arange(len(objects))
performance = [base_time_1x/x[1] for x in running_time]
plt.barh(y_rng, performance, align='center', alpha=0.5)
plt.yticks(y_rng, objects)
plt.xlabel('Processing speed for ~100k rows')
plt.title('Data processing speed \n( Python "nested loops"
= 1x)')
for a,b in zip(performance, y_rng):
    plt.text(a, b, "  "+str(round(a,2))+"x")
plt.show()
```



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My name is Lucas and I am an Senior IT Business Anayst with over 10 years of experience in IT system development and integration. I have worked for several large international companies from industries such as: IT, finance, insurance, telecommunications, pharmacy and gambling. I took part in multiple IT projects, ranging from small budgets (hundreds thousands of US dollars) to large (multiple millions of US dollars). A year ago (in 2016), encouraged by a friend, I completed Andrew Ng Machine Learning course on Coursera and I got fascinated by this subject. So I decided to master it. Feel free to contact me via my Email address:

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