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[1]:
```
import pyspark
import os
import sys
from pyspark import SparkContext
os.environ['PYSPARK_PYTHON'] = sys.executable
os.environ['PYSPARK_DRIVER_PYTHON'] = sys.executable

from pyspark.sql import SparkSession
```

[2]:
```
spark = SparkSession.builder.config("spark.driver.memory", "16g").
 ↪appName('chapter_8').getOrCreate()
```

0.0.1 Preparing the Data

[3]:
```
stocks = spark.read.csv(["data/stocksA/ABAX.csv","data/stocksA/AAME.csv","data/
 ↪stocksA/AEPI.csv"], header='true', inferSchema='true')
#stocks=spark.read.format("csv").option("inferSchema","true").
 ↪option("header","true").load('C:/Users/HP/Desktop/aas-pyspark-edition/data/
 ↪stocksA/AAIT.csv').load('C:/Users/HP/Desktop/aas-pyspark-edition/data/stocksA/
 ↪AAME.csv')

stocks.show(2)
```

```
+---------+-----+-----+-----+-----+------+
|     Date| Open| High|  Low|Close|Volume|
+---------+-----+-----+-----+-----+------+
|31-Dec-13|52.94|54.37|52.25|52.83| 79429|
|30-Dec-13|50.36|54.10|50.36|52.95|131095|
+---------+-----+-----+-----+-----+------+
only showing top 2 rows
```

[4]:
```
from pyspark.sql import functions as fun

stocks = stocks.withColumn("Symbol", fun.input_file_name()).\
                withColumn("Symbol",
                  fun.element_at(fun.split("Symbol", "/"), -1)).\
                withColumn("Symbol",
```

```
                  fun.element_at(fun.split("Symbol", "\."), 1))

stocks.show(2)
```

```
+---------+-----+-----+-----+-----+------+------+
|     Date| Open| High|  Low|Close|Volume|Symbol|
+---------+-----+-----+-----+-----+------+------+
|31-Dec-13|52.94|54.37|52.25|52.83| 79429|  AEPI|
|30-Dec-13|50.36|54.10|50.36|52.95|131095|  AEPI|
+---------+-----+-----+-----+-----+------+------+
only showing top 2 rows
```

[5]:
```
factors = spark.read.csv(["data/stocksA/ABAX.csv","data/stocksA/AAME.csv","data/
 ↪stocksA/AEPI.csv"], header='true', inferSchema='true')
factors = factors.withColumn("Symbol", fun.input_file_name()).\
                  withColumn("Symbol",
                    fun.element_at(fun.split("Symbol", "/"), -1)).\
                  withColumn("Symbol",
                    fun.element_at(fun.split("Symbol", "\."), 1))
```

[6]:
```
from pyspark.sql import Window

stocks = stocks.withColumn('count', fun.count('Symbol').\
                over(Window.partitionBy('Symbol'))).\
                filter(fun.col('count') > 260*5 + 10)
```

[7]:
```
spark.sql("set spark.sql.legacy.timeParserPolicy=LEGACY")
```

[7]:
```
DataFrame[key: string, value: string]
```

[8]:
```
stocks = stocks.withColumn('Date',
                  fun.to_date(fun.to_timestamp(fun.col('Date'),
                                               'dd-MMM-yy')))
stocks.printSchema()
```

```
root
 |-- Date: date (nullable = true)
 |-- Open: string (nullable = true)
 |-- High: string (nullable = true)
 |-- Low: string (nullable = true)
 |-- Close: double (nullable = true)
 |-- Volume: integer (nullable = true)
 |-- Symbol: string (nullable = true)
 |-- count: long (nullable = false)
```

[9]:
```
from datetime import datetime

stocks = stocks.filter(fun.col('Date') >= datetime(2009, 10, 23)).\
                filter(fun.col('Date') <= datetime(2014, 10, 23))
```

[10]:
```
factors = factors.withColumn('Date',
                             fun.to_date(fun.to_timestamp(fun.col('Date'),
                                                          'dd-MMM-yy')))

factors = factors.filter(fun.col('Date') >= datetime(2009, 10, 23)).\
                  filter(fun.col('Date') <= datetime(2014, 10, 23))
```

[11]:
```
stocks_pd_df = stocks.toPandas()
factors_pd_df = factors.toPandas()

factors_pd_df.head(5)
```

[11]:

	Date	Open	High	Low	Close	Volume	Symbol
0	2013-12-31	52.94	54.37	52.25	52.83	79429	AEPI
1	2013-12-30	50.36	54.10	50.36	52.95	131095	AEPI
2	2013-12-27	50.38	50.80	49.67	50.52	54354	AEPI
3	2013-12-26	50.50	51.19	49.67	50.00	74414	AEPI
4	2013-12-24	49.85	50.60	49.66	49.99	36872	AEPI

0.0.2 Determining the Factor Weights

[12]:
```
n_steps = 10
def my_fun(x):
    return ((x.iloc[-1] - x.iloc[0]) / x.iloc[0])

stock_returns = stocks_pd_df.groupby('Symbol').Close.\
                             rolling(window=n_steps).apply(my_fun)
factors_returns = factors_pd_df.groupby('Symbol').Close.\
                             rolling(window=n_steps).apply(my_fun)

stock_returns = stock_returns.reset_index().\
                              sort_values('level_1').\
                              reset_index()
factors_returns = factors_returns.reset_index().\
                                  sort_values('level_1').\
                                  reset_index()
```

[13]:
```
# Create combined stocks DF
stocks_pd_df_with_returns = stocks_pd_df.\
                              assign(stock_returns = \
                                     stock_returns['Close'])
```

```
# Create combined factors DF
factors_pd_df_with_returns = factors_pd_df.\
                              assign(factors_returns = \
                                    factors_returns['Close'],
                                    factors_returns_squared = \
                                    factors_returns['Close']**2)

factors_pd_df_with_returns = factors_pd_df_with_returns.\
                                pivot(index='Date',
                                      columns='Symbol',
                                      values=['factors_returns', \
                                              'factors_returns_squared'])

factors_pd_df_with_returns.columns = factors_pd_df_with_returns.\
                                        columns.\
                                        to_series().\
                                        str.\
                                        join('_').\
                                        reset_index()[0]

factors_pd_df_with_returns = factors_pd_df_with_returns.\
                                reset_index()

print(factors_pd_df_with_returns.head(1))
```

```
0        Date  factors_returns_AAME  factors_returns_ABAX  \
0  2009-10-23              0.111111               0.10064

0  factors_returns_AEPI  factors_returns_squared_AAME  \
0              0.097994                     0.012346

0  factors_returns_squared_ABAX  factors_returns_squared_AEPI
0                      0.010128                      0.009603
```

[14]:
```
print(factors_pd_df_with_returns.columns)
```

```
Index(['Date', 'factors_returns_AAME', 'factors_returns_ABAX',
       'factors_returns_AEPI', 'factors_returns_squared_AAME',
       'factors_returns_squared_ABAX', 'factors_returns_squared_AEPI'],
      dtype='object', name=0)
```

[15]:
```
import pandas as pd
from sklearn.linear_model import LinearRegression

# For each stock, create input DF for linear regression training

stocks_factors_combined_df = pd.merge(stocks_pd_df_with_returns,
                                      factors_pd_df_with_returns,
```

```
                                        how="left", on="Date")

feature_columns = list(stocks_factors_combined_df.columns[-6:])

with pd.option_context('mode.use_inf_as_na', True):
    stocks_factors_combined_df = stocks_factors_combined_df.\
                                    dropna(subset=feature_columns \
                                           + ['stock_returns'])


def find_ols_coef(df):
    y = df[['stock_returns']].values
    X = df[feature_columns]

    regr = LinearRegression()
    regr_output = regr.fit(X, y)

    return list(df[['Symbol']].values[0]) + \
                list(regr_output.coef_[0])

coefs_per_stock = stocks_factors_combined_df.\
                      groupby('Symbol').\
                      apply(find_ols_coef)


coefs_per_stock = pd.DataFrame(coefs_per_stock).reset_index()
coefs_per_stock.columns = ['symbol', 'factor_coef_list']

coefs_per_stock = pd.DataFrame(coefs_per_stock.\
                               factor_coef_list.tolist(),
                               index=coefs_per_stock.index,
                               columns = ['Symbol'] + feature_columns)

coefs_per_stock
```

```
C:\Users\HP\AppData\Local\Temp\ipykernel_2592\2334300066.py:12: FutureWarning:
use_inf_as_na option is deprecated and will be removed in a future version.
Convert inf values to NaN before operating instead.
  with pd.option_context('mode.use_inf_as_na', True):
```

[15]:

	Symbol	factors_returns_AAME	factors_returns_ABAX	factors_returns_AEPI	\
0	AAME	1.000000e+00	-1.212194e-15	1.077181e-15	
1	ABAX	3.525968e-16	1.000000e+00	-8.554545e-16	
2	AEPI	2.699569e-16	1.701421e-16	1.000000e+00	

	factors_returns_squared_AAME	factors_returns_squared_ABAX	\
0	-5.909130e-17	-6.765501e-17	

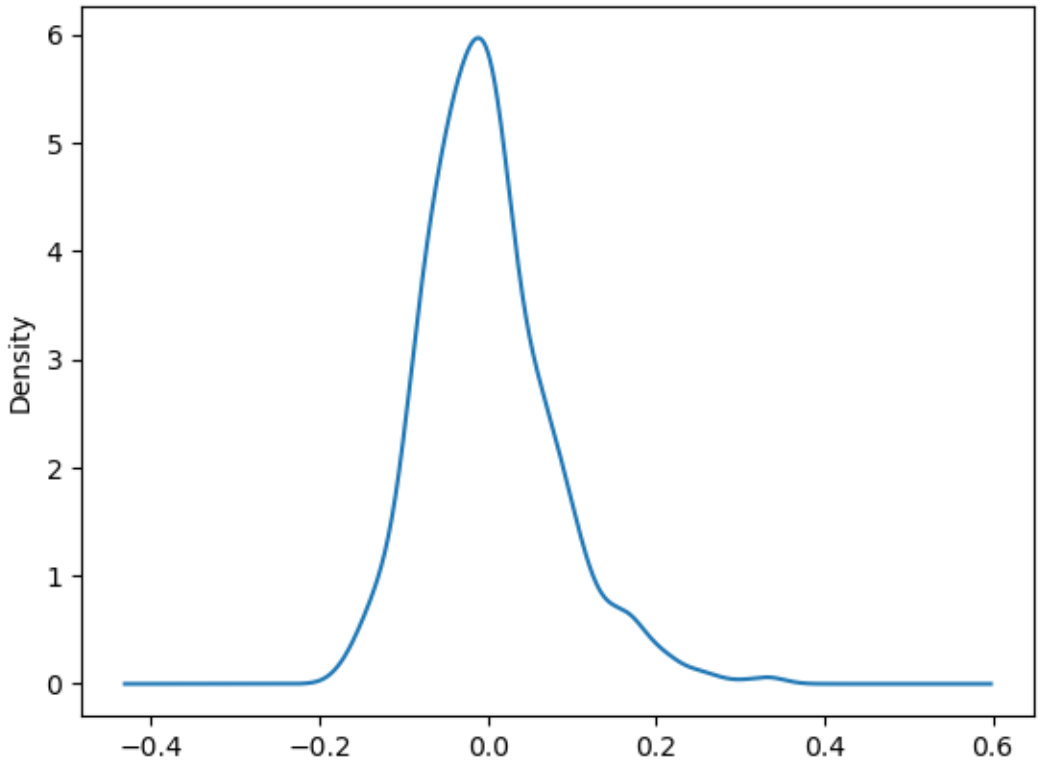
```
1                  -1.541419e-16                   4.739338e-17
2                   1.007988e-16                   7.119061e-17

   factors_returns_squared_AEPI
0                   1.400082e-16
1                   1.836798e-17
2                  -2.742005e-17
```

0.0.3 Sampling

[18]:
```
samples = factors_returns.loc[factors_returns.Symbol == \
                              factors_returns.Symbol.unique()[0]]['Close']
samples.plot.kde()
```

[18]:
```
<Axes: ylabel='Density'>
```



[19]:
```
f_1 = factors_returns.loc[factors_returns.Symbol == \
                          factors_returns.Symbol.unique()[0]]['Close']
f_2 = factors_returns.loc[factors_returns.Symbol == \
                          factors_returns.Symbol.unique()[1]]['Close']
f_3 = factors_returns.loc[factors_returns.Symbol == \
                          factors_returns.Symbol.unique()[2]]['Close']
```

```
print(f_1.size,len(f_2),f_3.size)
pd.DataFrame({'f1': list(f_1)[1:1040], 'f2': list(f_2)[1:1040], 'f3':␣
 ↪list(f_3)}).corr()
```

```
1053 1053 1039
```

[19]:

	f1	f2	f3
f1	1.000000	0.275057	-0.015415
f2	0.275057	1.000000	0.031370
f3	-0.015415	0.031370	1.000000

[20]:
```
factors_returns_cov = pd.DataFrame({'f1': list(f_1)[1:1040],
                                    'f2': list(f_2)[1:1040],
                                    'f3': list(f_3)})\
                                    .cov().to_numpy()
factors_returns_mean = pd.DataFrame({'f1': list(f_1)[1:1040],
                                    'f2': list(f_2)[1:1040],
                                    'f3': list(f_3)}).\
                                     mean()
```

[21]:
```
from numpy.random import multivariate_normal

multivariate_normal(factors_returns_mean, factors_returns_cov)
```

[21]:
```
array([-0.10853148, -0.07406858,  0.12235131])
```

0.0.4 Running the Trials

[22]:
```
b_coefs_per_stock = spark.sparkContext.broadcast(coefs_per_stock)
b_feature_columns = spark.sparkContext.broadcast(feature_columns)
b_factors_returns_mean = spark.sparkContext.broadcast(factors_returns_mean)
b_factors_returns_cov = spark.sparkContext.broadcast(factors_returns_cov)
```

[23]:
```
from pyspark.sql.types import IntegerType

parallelism = 1000
num_trials = 1000000
base_seed = 1496

seeds = [b for b in range(base_seed,
                          base_seed + parallelism)]
seedsDF = spark.createDataFrame(seeds, IntegerType())

seedsDF = seedsDF.repartition(parallelism)
```

[24]:
```
import random
from numpy.random import seed
```

```
from pyspark.sql.types import LongType, ArrayType, DoubleType
from pyspark.sql.functions import udf

def calculate_trial_return(x):
#     return x
    trial_return_list = []

    for i in range(int(num_trials/parallelism)):
        random_int = random.randint(0, num_trials*num_trials)

        seed(x)

        random_factors = multivariate_normal(b_factors_returns_mean.value,
          b_factors_returns_cov.value)

        coefs_per_stock_df = b_coefs_per_stock.value
        returns_per_stock = (coefs_per_stock_df[b_feature_columns.value] *
          (list(random_factors) + list(random_factors**2)))

        trial_return_list.append(float(returns_per_stock.sum(axis=1).sum()/
 ↪b_coefs_per_stock.value.size))

    return trial_return_list

udf_return = udf(calculate_trial_return, ArrayType(DoubleType()))
```

[25]:
```
from pyspark.sql.functions import col, explode


trials = seedsDF.withColumn("trial_return", udf_return(col("value")))
trials = trials.select('value', explode('trial_return').alias('trial_return'))

trials.cache()
```

[25]: DataFrame[value: int, trial_return: double]

0.0.5 TAKES SOME TIME

[26]:
```
trials.approxQuantile('trial_return', [0.05], 0.0)
```

[26]: [-0.010437253718987332]

[27]:
```
 trials.orderBy(col('trial_return').asc()).\
  limit(int(trials.count()/20)).\
  agg(fun.avg(col("trial_return"))).show()
```

```
+--------------------+
|   avg(trial_return)|
```

```
+--------------------+
|-0.01317165711765...|
+--------------------+
```

0.0.6 Visualizing the Distribution of Returns

[28]:
```
import pandas
mytrials=trials.toPandas()
mytrials.plot.line()
```

[28]: <Axes: >