Assignment 3

MET CS 777 - Big Data Analytics Batch Gradient Descent
(20 points)

GitHub Classroom Invitation Link

https://classroom.github.com/a/W1bmATsM

1 Description

In this assignment, you will implement Batch Gradient Descent to fit a line into two-dimensional data set. You will implement a set of Spark jobs that will learn parameters for such lines from the New York City Taxi trip reports in 2013. The dataset was released under the FOIL (The Freedom of Information Law) and made public by Chris Whong (https://chriswhong. com/open-data/foil_nyc_taxi/). See Assignment 1 for details about this data set.

We would like to train a linear model between travel distance in miles and fare amount (the money paid to the taxis).

2 Taxi Data Set - Same data set as Assignment 1

This is the same data set as used for Assignment 1. Please have a look at the table description there.

The data set is in Comma Separated Volume Format (CSV). When you read a line and split it by a comma sign ”,” you will find the string array with a length of 17. With the index number starting from zero, we need for this assignment to get the index 5 trip distance (trip distance in miles) and index 11 fare amount (fare amount in dollars) as stated in the following table.

index 5 (this our X-axis)	trip distance	trip distance in miles
index 11 (this our Y-axis)	fare amount	fare amount in dollars

Table 1: Taxi Data Set fields

You can use the following PySpark Code to clean up the data.

```
def isfloat(value):
    try:
        float(value)
        return True

    except:
         return False
def correctRows(p):
    if(len(p)==17):
        if(isfloat(p[5]) and isfloat(p[11])):
            if(float(p[5])!=0 and float(p[11])!=0):
                return p

testDataFrame = spark.read.format('csv').\
      options(header='false', inferSchema='true',  sep =",").\
      load(testFile)
testRDD = testDataFrame.rdd.map(tuple)
taxilinesCorrected = testRDD.filter(correctRows)
```

In addition to the above filtering, you should remove all of the rides with a total amount larger than 600 USD and less than 1 USD. You can preprocess the data, clean it and store it in your own cluster storage. To avoid additional computation in each run.

3 Obtaining the Dataset

The small dataset (93 MB compressed, 384 MB uncompressed) for implementation and testing purposes (roughly 2 million taxi trips) is available from Google Storage using the following link: https://storage.googleapis.com/met-cs-777-data/taxi-data-sorted-small.csv.bz2.

The big dataset (9GB compressed, 32GB uncompressed) is available at this link: https://storage.googleapis.com/met-cs-777-data/taxi-data-sorted-large.csv.bz2.

When running your code on the cluster, to access the datasets, you need to use the following internal Google Storage URLs:

	Google Cloud
Small Data Set	gs://met-cs-777-data/taxi-data-sorted-small.csv.bz2
Large Data Set	gs://met-cs-777-data/taxi-data-sorted-large.csv.bz2

Table 2: Data set on Google Cloud Storage - URL

4 Assignment Tasks

4.1 Task 1: Simple Linear Regression (4 points)

We want to find a simple line to our data (distance, money). Consider a Simple Linear Regression model given in equation (1). The solutions for the ***m*** slope of the line and y-intercept ***b*** are calculated based on equations (2) and (3).

$$Y = mX + b \tag{1}$$

$$m = \frac{N \sum_{i=1}^{N} x_i \, y_i - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{N \sum_{i=1}^{N} x_i^2 - \left(\sum_{i=1}^{N} x_i \right)^2} \tag{2}$$

$$b = \frac{\sum_{i=1}^{N} x_i^2 \sum_{i=1}^{N} y_i - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} x_i y_i}{N \sum_{i=1}^{N} x_i^2 - \left(\sum_{i=1}^{N} x_i \right)^2} \tag{3}$$

Implement a PySpark Job that calculates the exact answers for the parameters ***m*** and ***b***. The line slope is the parameter ***m***, the y-intercept of the line is ***b***, and ***N*** is the number of samples in the dataset.

Run your implementation on the large data set and report the computation time for your Spark Job for this task. You can find the time to complete your Job on the Google Cloud System, or you can write your code to log the completion time.

Note on Task 1: Execution of this task on a large dataset, depending on your implementation, can take a longer time. For example, on a cluster with 12 cores in total, it takes more than 30 min of computation time.

Use RDD caching. Each RDD that is used more than once in the following calculations makes sense to be cached. Use the **`myRDD.cache()`** to cache the RDD. This will allow your code to use the in-memory cached data, and it will be much faster.

Important Note: For this question, you are not allowed to use any libraries. (Pyspark, Scikit Learn, or any other framework). You should formulize the given equations and write your own code using pyspark.

4.2 Task 2 - Find the Parameters using Gradient Descent (8 Points)

In this task, you should implement batch gradient descent to find the optimal parameters for our Simple Linear Regression model.

- You should load the data into spark cluster memory as RDD, or Dataframe

  Cost function will be then:

$$L(m,b) = \sum_{i=1}^{N} (y_i - (mx_i + b))^2 \tag{4}$$

  Partial Derivatives to update the parameters ***m*** and ***b***

$$\frac{\partial}{\partial m} = \frac{2}{N} \sum_{i=1}^{N} -x_i(y_i - (mx_i + b)) \tag{5}$$

$$\frac{\partial}{\partial b} = \frac{2}{N} \sum_{i=1}^{N} -(y_i - (mx_i + b)) \tag{6}$$

  Here is a list of recommended values of the important setup parameters:

- Initialize all parameters with 0
- Start with a very small learning rate and then increase it to speed up the learning. For example, you can start with learningRate=0.0001 and try bigger rates until the process converges.
  Note: The optimal learning rate for the big dataset can be different from the optimal learning rate for the small dataset, depending on how good you clean your dataset. The given small dataset has been cleaned and have only few outliers.
- The maximum number of iterations should be num_iteration=50 iterations. If you failed to converge to a solution in 50 iterations, you can increase the maximum number of iterations.

Run your implementation on the large data set and report the computation time for your Spark Job for this task. Compare the computation time with the previous tasks.

- Print out the costs in each iteration.
- Print out the model parameters in each iteration.
- Comment on how you can interpret the parameters of the model. What is the meaning of ***m*** and ***b*** in this case?

Note: Use RDD caching. Before entering the Gradient Descent Loop, please remember to cache your RDD by using the command: myRDD.cache(). This will allow your gradient descent code to use the in-memory cached data, and it will be much faster.
Note: You might write some code for the iteration of gradient descent in PySpark that can work perfectly on your laptop but does not run on the clusters. The main reason is that on your laptop, it runs in a single process, while on a cluster, it runs on multiple processes (shared-nothing processes).

4.3 Task 3 - Fit Multiple Linear Regression using Gradient Descent (8 Points)

We would like to learn a linear model with four variables to predict the total paid amounts of Taxi rides. The following table describes the variables that we want to use.

index 4 (1st independent variable)	trip_time_in_secs	duration of the trip
index 5 (2nd independent variable)	trip_distance	trip distance in miles
index 11 (3rd independent variable)	fare_amount	fare amount in dollars
index 15 (4th independent variable)	tolls_amount	bridge and tunnel tolls in dollars
index 16 (y-axis dependent variable)	total_amount	total paid amount in dollars

Table 3: Taxi Data Set fields

- Initialize all parameters with 0
- Start with a very small learning rate and then increase it to speed up the learning. For example, you can start with learningRate=0.0000001 and try bigger rates until the process is still converging. **Note**: The optimal learning rate for the big dataset can be different from the optimal learning rate for the small dataset
- The maximum number of iterations should be 50, and can be increased if needed.
- Use NumPy Arrays to calculate the gradients - Vectorization
- Implement the ”**Bold Driver”** technique to change the learning rate dynamically. (3 points of 8 points)
- You need to find parameters that will lead to convergence of the optimization algorithm.

Your task:

- Print out the costs in each iteration
- Print out the model parameters in each iteration
- Comment on how you can interpret the parameters of the model. What is the meaning of $\boldsymbol{m_i}$ and $\boldsymbol{b}$ in this case?

Note: Use RDD caching. Before entering the Gradient Descent Loop, please remember to cache your RDD by using the command: myRDD.cache(). This will allow your gradient descent code to use the in-memory cached data, and it will be much faster.

5 Important Considerations

5.1 Machines to Use

One thing to be aware of is that you can choose virtually any configuration for your Cloud Cluster - you can choose different numbers of machines and different configurations of those machines. And each is going to cost you differently! Since this is real money, it makes sense to develop your code and run your jobs locally, on your laptop, using the small data set. Once things are working, you'll then move to Cloud.

As a proposal for this assignment, you can use the e2-standard-4 (4vCPU+16GB RAM) for the master node and e2-standard (8vCPU+32GB RAM) or e2-highmem-8 (8vCPU+64GB RAM) for two worker nodes.

Please be aware that there is a quota of 24vCPUs total for all nodes in the cluster for our educational accounts.

Remember to delete your cluster after the calculation is finished!!!

More information regarding Google Cloud Pricing can be found here https://cloud.google.com/products/calculator. As you can see average server costs around 50 cents per hour. That is not much, but **IT WILL ADD UP QUICKLY IF YOU FORGET TO SHUT OFF YOUR MACHINES**. Be very careful, and stop your machine as soon as you are done working. You can always come back and start your machine or create a new one easily when you begin your work again. Another thing to be aware of is that Google and Amazon charge you when you move data around. To avoid such charges, do everything in the ”Iowa (us-cental1)” region. That's where data is, and that's where you should put your data and machines.

- You should document your code very well and as much as possible.
- Your code should be compilable on a Unix-based operating system like Linux or macOS.

5.2 Academic Misconduct Regarding Programming

In a programming class like ours, there is sometimes a very fine line between ”cheating” and acceptable and beneficial interaction between peers. Thus, it is essential that you fully understand what is and what is not allowed in collaboration with your classmates. We want to be 100% precise, so there can be no confusion.

The rule on collaboration and communication with your classmates is very simple: you cannot transmit or receive code from or to anyone in the class in any way—visually (by showing someone your code), electronically (by emailing, posting, or otherwise sending someone your code), verbally (by reading code to someone) or in any other way we have not yet imagined. Any other collaboration is acceptable.

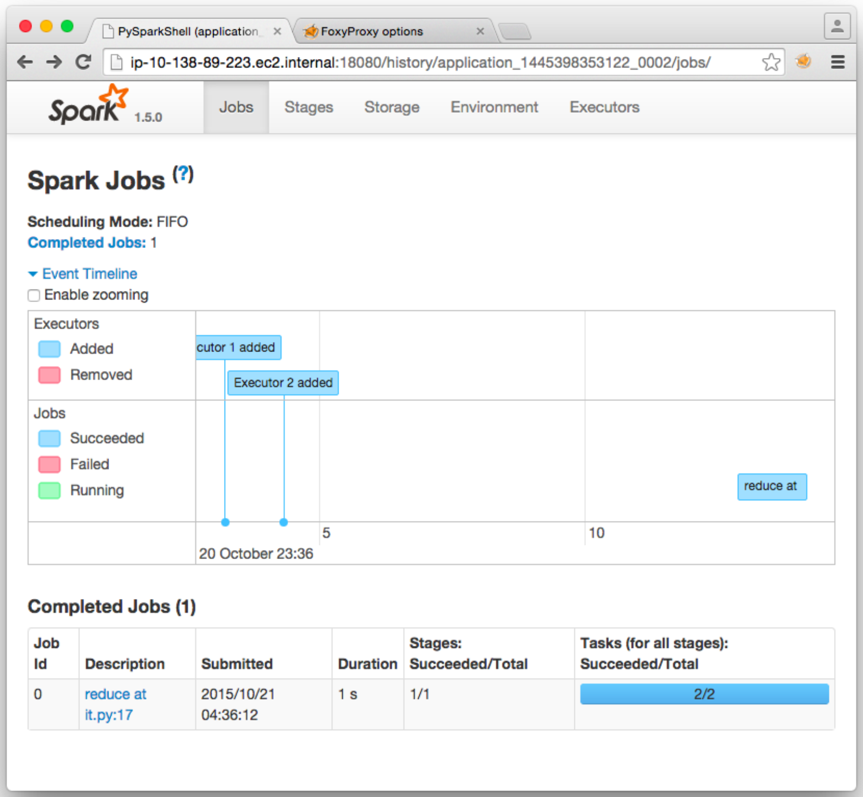
The rule on collaboration and communication with people who are not your classmates (or your TAs or instructor) is also very simple: it is not allowed in any way, period. This disallows (for example) posting any questions of any nature to programming forums such as **StackOverflow**. As far as going to the web and using Google, we will apply the **”two-line rule”**. Go to any web page you like and do any search that you like. But you cannot take more than two lines of code from an external resource and actually include it in your assignment in any form. Note that changing variable names or otherwise transforming or obfuscating code you found on the web does not render the

”two-line rule” inapplicable. It is still a violation to obtain more than two lines of code from an external resource and turn it in, whatever you do to those two lines after you first obtain them.

Furthermore, you should cite your sources. Add a comment to your code that includes the URL(s) that you consulted when constructing your solution. This turns out to be very helpful when you’re looking at something you wrote a while ago, and you need to remind yourself what you were thinking.

5.3 Turnin

1. Fill in the results in the provided template.
2. For each task and for each Spark job you ran, include a screenshot of the Spark History. **To demonstrate that you did execute your code on the cloud, it is important to include URLs in the screenshots. Otherwise, there is no way for us to verify if the code was executed in your cloud account.**



Spark Jobs (?)

Scheduling Mode: FIFO
Completed Jobs: 1

Completed Jobs (1)

Job Id	Description	Submitted	Duration	Stages: Succeeded/Total	Tasks (for all stages): Succeeded/Total
0	reduce at it.py:17	2015/10/21 04:36:12	1 s	1/1	2/2

Figure 1: Screenshot of Spark History

3. Please zip up all of your code and your document (use .zip only, please!), or attach each piece of code and your document to your submission individually.
4. Please have the latest version of your code on GitHub. Zip the GitHub files and submit your latest version of the assignment work to Blackboard. We will consider the latest version on Blackboard, but it should exactly match your code on GitHub.
5. **Remember to delete your cluster after the calculation is finished!!!**