

# CSE 6242 / CX 4242: Data and Visual Analytics | Georgia Tech | Fall 2021

## HW 3: Spark, Docker, DataBricks, AWS and GCP

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## Important Notes

1. Submit your work by this assignment's official **Due** date on the course schedule.
  - a. Every assignment has a 48-hour grace period. You may use it without asking us.
  - b. Before the grace period expires, you may resubmit as many times as you need to.

- c. Submissions during the grace period will display as “late” and will not incur a penalty.
  - d. **We will not accept any submissions after the grace period.**
2. Always use the **most up-to-date assignment** (version number at bottom right of this document).
  3. This advanced course expects students to submit code that runs and is free of syntax errors. Code that does not run successfully will receive **0 credit**.
  4. You may discuss high-level ideas with other students at the “whiteboard” level (e.g., how cross validation works, use HashMap instead of array) and review any relevant materials online. However, **each student must write up and submit the student’s own answers**.
  5. All incidents of suspected dishonesty, plagiarism, or violations of the [Georgia Tech Honor Code](#) will be subject to the institute’s Academic Integrity procedures, directly handled by the [Office of Student Integrity \(OSI\)](#). **Consequences can be severe, e.g., academic probation or dismissal, a 0 grade for assignments concerned, and prohibition from withdrawing from the class.**
  6. Wherever you are asked for a written response, stay within the word limit or you may lose points.

## Submission Instructions

Carefully read and follow the high-level instructions below, and the detailed instructions in each question.

1. **Submit ALL deliverables via Gradescope.** We will not accept submissions via any other channels.
2. Submit all the required files, as specified at the beginning of each question. Any deviations from the specified format (extra files, misnamed files, etc) will cause your submission to not be graded.
3. Each submission and its score will be recorded and saved by Gradescope. **By default, Gradescope uses your last submission for grading.** To use a different submission, **you MUST “activate” it** (click “Submission History” button at bottom toolbar, then “Activate”).

## Grading and Feedback

The maximum possible score for this homework is 100 points.

**We will auto-grade all questions using the Gradescope platform.** Based on our experience, students (you all!) benefit from using Gradescope to obtain feedback as they work on this assignment. **Keep the following important points in mind:**

1. **You can access Gradescope through Canvas.**
2. You may upload your code periodically to Gradescope to obtain feedback for your code. This is accomplished by having Gradescope auto-grade your submission using the **same test cases** that we will use to grade your work. The test cases’ results may help inform you of potential errors and ways to improve your code.
3. You must **not** use Gradescope as the primary way to test your code’s correctness, since it provides only a few test cases, and error messages may not be as informative as local debuggers. Iteratively develop and test your code locally, write more test cases, and [follow good coding practices](#). Use Gradescope mainly as a “final” check.
4. **Gradescope cannot run code that contains syntax errors. If Gradescope is not running your code, before seeking help, verify that:**
  - a. Your code is free of syntax errors (by running it locally)
  - b. All methods have been implemented
  - c. You have submitted the correct file with the correct name
5. When many students use Gradescope simultaneously, it may slow down or fail to communicate with the tester. It can become even slower as the submission deadline approaches. You are responsible for submitting your work on time.

## DO THIS NOW: Create AWS Academy account

Complete step 1 (Create an AWS Academy account) of the [AWS Setup Guide](#) to create your account.

## Download Skeleton and Data Before You Begin

- [HW3 Skeleton](#)
- [Q1 Data](#), [Q2 Data](#), and [Q4 Data](#)

## Homework Overview

Many modern-day datasets are huge and truly exemplify “big data”. For example, the Facebook social graph is petabytes large (over 1M GB); every day, Twitter users generate over 12 terabytes of messages; and the NASA Terra and Aqua satellites each produce over 300 GB of MODIS satellite imagery per day. These raw data are far too large to even fit on the hard drive of an average computer, let alone to process and analyze. Luckily, there are a variety of modern technologies that allow us to process and analyze such large datasets in a reasonable amount of time. For the bulk of this assignment, you will be working with a dataset of over 1 billion individual taxi trips from the New York City Taxi & Limousine Commission (TLC). Further details on this dataset are available [here](#).

In Q1, you will work with a subset of the TLC dataset to get warmed up with PySpark. Apache Spark is a framework for distributed computing, and PySpark is its Python API. You will use this tool to answer questions such as “what are the top 10 most common trips in the dataset”? You will be using your own machine for computation, using an environment defined by a Docker container.

In Q2, you will perform further analysis on a different subset of the TLC dataset using Spark on DataBricks, a platform combining datasets, machine learning models, and cloud compute. This part of the assignment will be completed in the Scala programming language, a modern general-purpose language with a robust support for functional programming. The Spark distributed computing framework is in fact, written using Scala.

In Q3, you will use PySpark on AWS using Elastic MapReduce (EMR), and in Q4 you will use Spark on Google Cloud Platform, to analyze even larger samples from the TLC dataset.

Finally, in Q5 you will use the Microsoft Azure ML Studio to implement a regression model to predict automobile prices using a sample dataset already included in the Azure workspace. A main goal of this assignment is to help students gain exposure to a variety of tools that will be useful in the future (e.g., future project, research, career). The reasoning behind intentionally including AWS, Azure and GCP (most courses use only one), because we want students to be able to try and compare these platforms as they evolve rapidly. This will help the students in the future should they need to select a cloud platform to use, they can make more informed decisions and be able to get started right away.

You will find that a number of computational tasks in this assignment are not very difficult, and there seems to be quite a bit of “setup” to do before getting to the actual “programming” part of the problem. The reasoning behind this design is because for many students, this assignment is the very first time they use *any* cloud services; they are new to the pay-per-use model, and they have never used a cluster of machines. There are over 1000 students in CSE 6242 (campus and online) and CX 4242 combined. This means we have students

coming from a great variety of backgrounds. We wished we could provide every student unlimited AWS credit so that they can try out many services and write programs that are more complex. Over the past offering of this course, we have been gradually increasing the “programming” part and reducing much of the “setup” (e.g., the use of Docker, Databricks and Jupyter notebooks were major improvements). We will continue to further reduce the setup that students need to perform in future offerings of this course.

## Q1 [15 points] Analyzing trips data with PySpark

Technology	PySpark Docker
Allowed Libraries	NA
Max allowed runtime	NA
Deliverables	[Gradescope] <b>q1.ipynb</b> : the notebook for the given question with your code

Follow [these instructions](#) to download and setup a preconfigured Docker image that you will use for this assignment. download and setup a preconfigured Docker image that you will use for this assignment.

**Why use Docker?** In earlier iterations of this course, students installed software on their own machines, and we (both students and instructor team) ran into many issues, which could not be resolved satisfactorily. Docker allows us to distribute a cross-platform, preconfigured image with all the requisite software and correct package versions. Once Docker is installed and the container is running, access Jupyter by browsing to <http://localhost:6242>. There is no need to install any additional Java or PySpark dependencies as they are all bundled as part of the Docker container.

Imagine that your boss gives you a large dataset which contains trip information of New York City Taxi and Limousine Commission (TLC). You are asked to provide summaries for the most common trips, as well as information related to fares and traffic. This information might help in positioning taxis depending on the demand at each location.

You are provided with a Jupyter notebook (q1.ipynb) file which you will complete using PySpark using the provided Docker image. Be sure to save your work often! If you do not see your notebook in Jupyter then double-check that the file is present in the folder and double check that your Docker has been set up correctly. If, after checking both, the file still does not appear in Jupyter then you can still move forward by clicking the “upload” button in the Jupyter notebook and uploading the file – however, if you use this approach then your file will **not** be saved to disk when you save in Jupyter, so you would need to download your work by going to File > Download as... > Notebook (.ipynb), so be sure to download as often as you would normally save!

### Note:

1. Regular PySpark Dataframe Operations and PySpark SQL operations can be used.
2. If you re-run cells, remember to restart the kernel to clear the Spark context, otherwise an existing Spark context may cause errors.

## Tasks

You will use the `yellow_tripdata_2019-01_short.csv` dataset. This dataset is a modified record of the NYC Green Taxi trips and includes information about the pick-up and drop-off dates/times, pick-up and drop-off locations, trip distances, fare amounts, payment types, and driver-reported passenger counts. When processing the data or performing calculations, **do not round any values**.

- a. [1 pt] You will be modifying the function `clean_data` to clean the data. Cast the following columns into the specified data types:
- `passenger_count` - integer
  - `total_amount` - float
  - `tip_amount` - float
  - `trip_distance` - float
  - `fare_amount` - float
  - `tpep_pickup_datetime` - timestamp
  - `tpep_dropoff_datetime` - timestamp
- b. [4 pts] You will be modifying the function `common_pair`. Return the top 10 pickup-dropoff location pairs having the highest number of trips (`count`). The location pairs should be ordered by `count` in descending order. If two or more pairs have the same number of trips, break the tie using the trip amount per distance traveled (`trip_rate`) in descending order. Use columns `total_amount` and `trip_distance` to calculate the trip amount per distance. In certain situations, the pickup and dropoff locations may be the same (include such entries as well).

While calculating `trip_rate`, first get the average `trip_distance` and the average `total_amount` for each pair of `PULocationID` and `DOLocationID` (using group by). Then take their ratio to get the `trip_rate` for a pickup-drop pair.

Example:

PULocationID	DOLocationID	trip_distance	total_amount
1	2	5	10
1	2	0	1
1	2	4	13

$\text{average\_total\_amount} = (10 + 1 + 13) / 3 = 8$   
 $\text{average\_trip\_distance} = (5 + 0 + 4) / 3 = 3$   
 $\text{trip\_rate} = \text{average\_total\_amount} / \text{average\_trip\_distance} = 8 / 3 = 2.6666666$

Sample Output Format (values are examples *only*):

PULocationID	DOLocationID	Count	trip_rate
1	2	23	5.242345
3	3	5	6.61345634

- c. [4 pts] You will be modifying the function `time_of_cheapest_fare`. Divide each day into two periods: Day (from 9am to 8:59:59pm, both inclusive), and Night (from 9pm to 8:59:59am, both inclusive). Calculate the average total amount per unit distance traveled (use column

`total_amount`) for both time periods. Sort the result by `trip_rate` in ascending order to determine when the fare rate is the cheapest. Use `tpep_pickup_datetime` to divide trips into Day and Night.

Output:

day_night	trip_rate
Day	4.2632344561
Night	6.42342882

- d. [4 pts] You will be modifying the function `passenger_count_for_most_tip`. Filter the data for trips having fares (`fare_amount`) greater than \$2 and the number of passengers (`passenger_count`) greater than 0. Calculate the average fare and tip (`tip_amount`) for all passenger group sizes and calculate the tip percent (`tip_amount * 100 / fare_amount`). Sort the result in descending order of tip percent to obtain the group size that tips the most generously.

Output:

passenger_count	tip_percent
2	14.22345234
1	12.523334576
3	12.17345231

- e. [3 pts] You will be modifying the function `day_with_traffic`. Sort the days of the week (using `tpep_pickup_datetime`) in descending order of traffic (day having the highest traffic should be at the top). Calculate traffic for a particular day using the average speed of all taxi trips on that day of the week. Calculate the average speed as the average trip distance divided by the average trip time, as distance per hour. If the `average_speed` is equal for multiple days, order the days alphabetically. A day with low average speed indicates high levels of traffic. The average speed may be 0, indicating very high levels of traffic. Not all days of the week may be present in the data (do not include the missing days of the week in your output). Use `date_format` along with the appropriate [pattern letters](#) to format the day of the week so that it matches the example output below.

Output:

day_of_week	average_speed
Fri	0.953452345
Mon	5.2424622
Tue	9.23345272

**IMPORTANT:** Strictly follow the guidelines below, or your answer may not be graded.

1. Do not add cells to the notebook.
2. Remove out any code you use for testing before submitting it to Gradescope.

## Q2 [30 pts] Analyzing dataset with Spark/Scala on Databricks

Technology	Spark/Scala Databricks
Allowed Libraries	NA
Max allowed runtime	NA
Deliverables	[Gradescope]

	<ul style="list-style-type: none"> <li>• <b>q2_yourGTusername.dbc</b>: Your solution as Scala Notebook archive file (.dbc) exported from Databricks (see Databricks Setup Guide below)</li> <li>• <b>q2_yourGTusername.scala</b>: Your solution as a Scala source file exported from Databricks (see Databricks Setup Guide below)</li> <li>• <b>q2_results.csv</b>: The output results from your Scala code in the Databricks q2 notebook file. You must carefully copy the outputs of the <code>display()/show()</code> function into a file titled <b>q2_results.csv</b> under the relevant sections. Please double check and compare with your actual output with the results you copied.</li> </ul> <p><b>VERY IMPORTANT:</b> Rename your notebook as <b>q2_yourGTusername</b> (e.g., q2_jdoe3) and export your solution in the two formats: .dbc and .scala.</p>
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## Tutorial

Firstly, go over this [Spark on Databricks Tutorial](#), to learn the basics of creating Spark jobs, loading data, and working with data.

You will analyze nyc-tripdata.csv<sup>1</sup> using Spark and [Scala](#) on the Databricks platform. (A short description of how Spark and Scala are related can be found [here](#).) You will also need to use the taxi zone lookup table using taxi\_zone\_lookup.csv that maps the location ID into the actual name of the region in NYC. The nyc-tripdata dataset is a modified record of the NYC Green Taxi trips and includes information about the pick-up and drop-off dates/times, pick-up and drop-off locations, trip distances, fare amounts, payment types, and driver-reported passenger counts.

### VERY IMPORTANT

1. Use only **Firefox, Safari or Chrome** when configuring anything related to Databricks. The setup process has been verified to work on these browsers.
2. **Carefully** follow the instructions in the [Databricks Setup Guide](#) (You should have already downloaded the data needed for this question using the link provided before *Homework Overview*.)
  - a. You **must** choose the Databricks Runtime (DBR) version as “**6.4 (includes Apache Spark 2.4.5, Scala 2.11)**”. We will grade your work using this version.
  - b. You **must not** choose the default DBR version of  $\geq 7.2$
  - c. Note that you do not need to install Scala or spark on your local machine. They are provided with the DBR environment.
3. **You must use only Scala DataFrame operations for this question.** Scala DataFrames are just another name for Spark DataSet of rows. You can use DataSet API in Spark to work on these DataFrames. [Here](#) is a Spark document that will help you get started on working with DataFrames in Spark. **You will lose points if you use SQL queries, Python, or R to manipulate a DataFrame.**
  - a. Refer to this [link](#) to understand how to avoid using other languages. After selecting the default language as SCALA, do not use the language magic `%<language>` with other languages like `%r`, `%python`, `%sql` etc. The language magics are used to override the default language, which you **must not** do for this assignment.
  - b. You **must not** use full SQL queries in lieu of the Spark DataFrame API. That is, you **must not** use functions like `sql()`, which allows you to directly write full SQL queries like `spark.sql`

<sup>1</sup> Graph derived from the [NYC Taxi and Limousine Commission](#)



("SELECT\* FROM col1 WHERE ..."). This should be df.select("") instead.

4. The template Scala notebook *q2.dbc* (in hw3-skeleton) provides you with code that reads a data file *nyc-tripdata.csv*. The input data is loaded into a `DataFrame`, inferring the schema using reflection (Refer to the Databricks Setup Guide above). It also contains code that **filters the data** to only keep the rows where the pickup location is different from the drop location, and the trip distance is strictly greater than 2.0 ( $>2.0$ ).
  - a. All tasks listed below **must** be performed on this filtered `DataFrame`, or you will end up with wrong answers.
  - b. Carefully read the instructions in the notebook, which also provides hints for solving the problems.
5. Some tasks in this question have specified data types for the results that are of lower precision (e.g., float). For these tasks, we will accept relevant higher precision formats (e.g., double). Similarly, we will accept results stored in data types that offer "greater range" (e.g., long, bigint) than what we have specified (e.g., int).

## Tasks

- 1) List the top-5 most popular locations for:
  - a. [2 pts] dropoff based on "DOLocationID", sorted in descending order by popularity. If there is a tie, then one with a lower "DOLocationID" gets listed first.
  - b. [2 pts] pickup based on "PULocationID", sorted in descending order by popularity. If there is a tie, then one with a lower "PULocationID" gets listed first.
- 2) [4 pts] List the top-3 locationID's with the maximum overall activity. Here, overall activity at a LocationID is simply the sum of all pickups and all dropoffs at that LocationID. In case of a tie, the lower LocationID gets listed first.

**Note:** If a taxi picked up 3 passengers at once, we count it as 1 pickup and not 3 pickups.

- 3) [4 pts] List all the boroughs (of NYC: Manhattan, Brooklyn, Queens, Staten Island, Bronx along with "Unknown" and "EWR") and their total number of activities, in descending order of total number of activities. Here, the total number of activities for a borough (e.g., Queens) is the sum of the overall activities (as defined in part 2) of all the LocationIDs that fall in that borough (Queens). An example output is shown below.

Borough total_number_activities	
Bronx	17689
Brooklyn	15785
Unknown	1982
Staten Island	1092
Manhattan	521
EWR	200
Queens	30

- 4) [5 pts] List the top 2 days of week with the largest number of (daily) average pickups, along with the values of the average number of pickups on each of the two days in descending order (no rounding off required). Here, the average pickup is calculated by taking an average of the number of pickups on different dates falling on the same day of the week. For example, 02/01/2021, 02/08/2021 and



02/15/2021 are all Mondays, so the average pickups for these is the sum of the pickups on each date divided by 3. An example output is shown below.

```

+-----+-----+
|day_of_week|avg_count|
+-----+-----+
|    Monday| 17231.82|
|   Saturday| 14901.45|
+-----+-----+

```

**Note:** The day of week should be a string with its full name, for example, "Monday" instead of a number 1 or "Mon". Also, the pickup\_datetime is in this format: yyyy-mm-dd

- 5) [6 pts] For each particular hour of a day (0 to 23, 0 being midnight) — in their order from 0 to 23 (inclusively), find the zone in the Brooklyn borough with the **largest** number of total pickups.

**Note:** All dates for each particular hour should be included.

- 6) [7 pts] Find which 3 different days in the month of January, in Manhattan, that saw the largest positive percentage increase in pickups compared to previous day, in the order from largest percentage increase to smallest percentage increase. An example output is shown below.

```

+---+-----+
|day|percent_change|
+---+-----+
| 15|         45.82|
| 21|         30.45|
|  3|         28.59|
+---+-----+

```

**Note:** All years need to be considered. The change from Dec 31 to Jan 1 can be excluded.

List the results of the above tasks in the provided **q2\_results.csv** file under the relevant sections. **These pre-formatted sections also show you the required output format from your Scala code with the necessary columns — while column names can be different, their resulting values must be correct.**

- You must **manually enter** the output generated into the corresponding sections of the *q2\_results.csv* file, preferably using some spreadsheet software like MS-Excel (but make sure to keep the csv format). For generating the output in the Scala notebook, refer to `show()` and `display()` functions of Scala.
- Note that you can edit this csv file using text editor, but please be mindful about putting the results under designated columns.

**Note:** Do **NOT** modify anything other than filling in those required output values in this csv file. We grade by running the Spark Scala code you write and by looking at your results listed in this file. So, make sure that your output is actually obtained from the Spark Scala code you write.

**Hint:** You may find some of the following DataFrame operations helpful:

`toDF`, `join`, `select`, `groupBy`, `orderBy`, `filter`, `agg`, `Window()`, `partitionBy`, `orderBy`, etc.

### Q3 [35 points] Analyzing Large Amount of Data with PySpark on AWS

Technology	PySpark AWS
Allowed Libraries	NA
Max allowed runtime	NA
Deliverables	<p>[Gradescope]</p> <ul style="list-style-type: none"><li>• <b>submission.py</b>: The python file converted from the PySpark notebook for the question (using the <b>larger</b> data set). Please see instructions for converting Q3.ipynb to submission.py at the end of the Q3 section.</li><li>• <b>output-large.csv</b>: Output (<b>comma-separated</b>) (using the <b>larger</b> data set).</li></ul>

**VERY IMPORTANT:** Use Firefox, Safari or Chrome when configuring anything related to AWS.

You will try out PySpark for processing data on Amazon Web Services (AWS). [Here](#) you can learn more about PySpark and how it can be used for [data analysis](#). You will be completing a task that may be accomplished using a commodity computer (e.g., consumer-grade laptops or desktops). However, we would like you to use this exercise as an opportunity to learn distributed computing on Amazon EC2, and to gain experience that will help you tackle more complex problems.

The services you will primarily be using are Amazon S3 storage, Amazon Elastic Cloud Computing (EC2) virtual servers, and Amazon Elastic MapReduce (EMR) managed Hadoop framework. You will be creating an S3 bucket, running code through EMR, and then storing the output into that S3 bucket.

For this question, you will only use up **a very small fraction of your AWS credit**.

If you have any issues with the AWS credits or educate account, please fill out this [form](#).

#### Setting Up AWS Environment

Go through **all the steps** in the [AWS Setup Guide](#) (You should have already completed Step 1 to create your account) to set up your AWS environment, e.g., setting up billing alert, creating S3 storage bucket, uploading skeleton file, and, **EXTREMELY IMPORTANTLY learning how to terminate all AWS clusters properly, or you will run out of AWS credits and may not be able to complete this question**.

#### Datasets

In this question, you will use a dataset of trip records provided by the New York City Taxi and Limousine Commission (TLC). You will be accessing the dataset directly through AWS via the code outlined in the homework skeleton. Specifically, you will be working with two samples of this dataset, one small, and one much larger. Further details about this dataset are available [here](#) and [here](#), and you may explore the structure of the data via [\[1\]](#) [\[2\]](#).

**EXTREMELY IMPORTANT:** Both the datasets are in the **US East (N. Virginia)** region. Using machines in

other regions for computation will incur data transfer charges. Hence, set your region to **US East (N. Virginia)** in the beginning (not Oregon, which is the default). **This is extremely important, otherwise your code may not work, and you may be charged extra.**

## Goal

You work at NYC TLC, and since the company bought a few new taxis, your boss has asked you to locate potential places where taxi drivers can pick up more passengers. Of course, the more profitable the locations are, the better. Your boss also tells you not to worry about short trips for **any** of your analysis, so only analyze trips which are **2.0 miles or longer**.

First, find the **20** most popular drop off locations in the Manhattan borough by finding which of these destinations had the greatest **passenger count**.

Now, analyze all pickup locations, regardless of borough.

- For each pickup location determine
  - the **average total amount** per trip,
  - the total **count** of all trips that start at that location, and
  - the **count** of all trips that start at that location and end at one of most popular drop off locations.
- Using the above values,
  - determine the **proportion** of trips that end in one of the popular drop off locations (# trips that end in drop off location divided by total # of trips) and
  - multiply that proportion by the **average total amount** to get a **weighted profit value** based on the probability of passengers going to one of the popular destinations.

Bear in mind, your boss is not as savvy with the data as you are and is not interested in location IDs. To make it easy for your boss, provide the **Borough** and **Zone** for each of the top 20 pickup locations you determined.

## Tasks

You are provided with a python notebook (Q3.ipynb) file which you will complete and load into EMR. You are provided with the `load_data()` function, which loads two PySpark DataFrames. The first is **trips** which contains a DataFrame of trip data, where each record refers to one (1) trip. The second is **lookup** which maps a LocationID to its information. It can be linked to either the PULocationID or DOLocationID fields in the trips DataFrame.

The following functions must be completed for full credit.

### VERY IMPORTANT

- Ensure that the parameters for each function remain as defined and the output order and names of the fields in the PySpark DataFrames are maintained.
- Do not import any functions which were not already imported within the skeleton.
- **You must NOT round any numeric values.** Rounding numbers can introduce inaccuracies. Our grader will be checking the first 8 decimal places of each value in the DataFrame.

#### a) [1 pts] `user()`

- i. Returns your GT Username as a string (e.g., gburdell3)

- b) [2 pts] **long\_trips(trips)**
  - i. This function filters trips to keep only trips 2 miles or longer (e.g.,  $\geq 2$ ).
  - ii. Returns PySpark DataFrame with the same schema as **trips**
  - iii. **Note: Parts c, d and e will use the result of this function**
- c) [6 pts] **manhattan\_trips(trips, lookup)**
  - i. This function determines the top 20 locations with a *DOLocationID* in Manhattan by sum of passenger count.
  - ii. Returns a PySpark DataFrame with the schema (*DOLocationID*, *pcount*)
- d) [6 pts] **weighted\_profit(trips, mtrips)**
  - i. This function determines
    - i. the average *total\_amount*,
    - ii. the *total count of trips*, and
    - iii. the *total count of trips ending in the top 20 destinations* and return the *weighted\_profit* as discussed earlier in the homework document.
    - iv. Returns a PySpark DataFrame with the schema (*PULocationID*, *weighted\_profit*) for the *weighted\_profit* as discussed earlier in this homework document.
- e) [5 pts] **final\_output(wp, lookup)**
  - i. This function
    - i. takes the results of *weighted\_profit*,
    - ii. links it to the *borough* and *zone* through the **lookup** data frame, and
    - iii. returns the top 20 locations with the highest *weighted\_profit*.
  - ii. Returns a PySpark DataFrame with the schema (*Zone*, *Borough*, *weighted\_profit*)

**Hint:** Refer to DataFrame commands such as `filter`, `join`, `groupBy`, `agg`, `limit`, `sort`, `withColumnRenamed` and `withColumn`. Documentation for the DataFrame APIs is located [here](#).

Once you have implemented all these functions, run the `main()` function, which is already implemented, and update the line of code to include the name of your output s3 bucket and a location. **This function will fail** if the output directory already exists, so make sure to **change it each time** you run the function.

Example: `final.write.csv('s3://cse6242-bburdell13/output-large3')`

Your output file will appear in a folder in your s3 bucket as a csv file with a name which is similar to *part-0000-4d992f7a-0ad3-48f8-8c72-0022984e4b50-c000.csv*. Download this file and rename it to **output-large.csv** for submission. Do **not** make any other changes to the file.

Once done, use the `notebook2script.py` helper script to convert `Q3.ipynb` to `submission.py`. These are the steps for doing that (also available [here](#) in video format):

- Ensure your notebook file is named `Q3.ipynb`, and both `notebook2script.py` and `Q3.ipynb` files are in the root directory of your JupyterLab console.
- Click on the '+' button at the top of the JupyterLab console to open the launcher. Then, select the 'Terminal' button. A terminal window will open.
- At the command prompt of your terminal window: type the following commands:
  - o `cd /home/notebook/work`
  - o `python notebook2script.py /home/notebook/work/submission`
- When prompted, type 'yes' to agree with the Honor policy (twice).
- There should now be a folder called 'submission' in the console. Inside that folder will be the `submission.py` file that you need to submit in GradeScope.

**IMPORTANT:** Strictly follow the guidelines below, or your answer may not be graded.

1. Double check that you are submitting the correct files --- we only want the script and output from the larger dataset. Also, double check that you are writing the right dataset's output to the right file.
2. You are welcome to store your script's output in any bucket you choose, as long as you can download and submit the correct files.
3. Do not make any manual changes to the output files.
4. Regular Pyspark Dataframe Operations and PySpark SQL operations can be used.
5. Do not import any additional packages, INCLUDING `pyspark.sql.functions`, as this may cause the autograder to work incorrectly.

## Q4 [10 points] Analyzing a Large Dataset using Spark on GCP

Technology	Spark Google Cloud Platform (GCP)
Allowed Libraries	NA
Max allowed runtime	NA
Deliverables	[Gradescope] <b>q4_pyspark-gcp.ipynb</b> : The PySpark notebook for the question.

**VERY IMPORTANT:** Use Firefox, Safari or Chrome when configuring anything related to GCP.

### GCP Guidelines

Instructions to setup GCP Credits, GCP Storage and Dataproc Cluster are provided as video tutorials ([part 1](#), [part 2](#), and [part 3](#)) and as [written instructions](#).

Helpful tips/FAQs for special scenarios:

- a) If GCP service is disabled for your google account, try the steps in this [google support link](#)
- b) If you have any issues with GCP free credits, please fill out this [form](#)

### Goal

The goal of this question is to familiarize you with creating storage buckets/clusters and running [Spark](#) programs on [Google Cloud Platform](#). This question asks you to create a new Google Storage Bucket and load the NYC Taxi & Limousine Commission Dataset. You are also provided with a Jupyter Notebook (`q4_pyspark-gcp.ipynb`) file which you will load and complete in a Google Dataproc Cluster. Inside the notebook, you are provided with the skeleton for the `load_data()` function, which you will complete to load a PySpark DataFrame from the Google Storage Bucket you created as part of this question. Using this PySpark DataFrame, you will complete the following tasks using Spark DataFrame functions or Spark SQL functions.

- You will use the data file `yellow_tripdata09-08-2021.csv`; the preceding link allows you to download the dataset you are required to work with for this question from the course DropBox. Each line represents a single taxi trip consisting of the comma separated columns bulleted below. All columns are of string data type. You must convert the highlighted columns below into decimal data type (**do NOT use float datatype**) inside their respective individual functions when completing this question. Do not convert any datatypes inside within the `load_data` function. While casting to decimal datatype, use a precision of 38 and scale of 10.
- `vendorid`

- tpep\_pickup\_datetime
- tpep\_dropoff\_datetime
- passenger\_count
- **trip\_distance (decimal data type)**
- ratecodeid
- store\_and\_fwd\_flag
- pulocationid
- dolocationid
- payment\_type
- **fare\_amount (decimal data type)**
- extra
- mta\_tax
- **tip\_amount (decimal data type)**
- **tolls\_amount (decimal data type)**
- improvement\_surcharge
- total\_amount

## Tasks

**VERY IMPORTANT:** for this question, you must first perform the task a BEFORE performing task b, c, d, e and f. No points are allocated to task a, but it is essential that you correctly implement the `load_data()` function as the remaining graded tasks depend upon this task and its correct implementation.

- [0 pts - Required]** Function `load_data()` to load data from a Google Storage Bucket into a Spark DataFrame
- [2 pts]** Function `exclude_no_pickuplocations()` to exclude trips with no pickup locations (i.e., pickup location id column is null or is zero. In other words, assume zero is not a valid pickup location id.) in the original data from a.
- [2 pts]** Function `exclude_no_tripdistance()` to exclude trips with no distance (i.e., trip distance column is null or zero) in the dataframe output by `exclude_no_pickuplocations()`. . Note: Cast the trip\_distance column to decimal datatype before filtering.
- [2 pts]** Function `include_fare_range()` to include trips with fare from \$20 (inclusively) to \$60 (inclusively) in the dataframe output by `exclude_no_tripdistance()`. Note: Cast the fare\_amount column to decimal datatype before filtering.
- [2 pts]** Function `get_highest_tip()` to identify the highest tip (rounded to 2 decimal places) in the dataframe output by `include_fare_range()`. Note: Cast the tip\_amount column to decimal datatype before filtering.
- [2 pts]** Function `get_total_toll()` to calculate the total toll amount (rounded to 2 decimal places) in the dataframe output by `include_fare_range()`. Note: Cast the tolls\_amount column to decimal datatype before filtering.

**IMPORTANT:** Strictly follow the guidelines below, or your answer may not be graded.

1. Regular PySpark Dataframe Operations and PySpark SQL operations can be used.
2. Make sure to download the notebook from your GCP cluster **before** deleting the GCP cluster (otherwise, the work will be lost).
3. Do not add new cells to the notebook, as this may break the auto-grader.

4. Remove any code you use for testing before submitting it to Gradescope. Failing to do so may break the auto-grader.

## Q5 [10 points] Regression: Automobile price prediction, using Microsoft Machine Learning Studio

Note: Create and use a free workspace instance on [Microsoft Machine Learning Studio](#). Please use your Georgia Tech username (e.g., jdoe3) to login.

### Goal

Primary purpose of this question is to introduce you to [Microsoft Machine Learning Studio](#), familiarize you to its basic functionalities and typical machine learning workflows. Go through the “[Automobile price prediction](#)” tutorial and create/run ML experiments to complete the following tasks. You will not incur any cost if you save your experiments on Azure till submission. Once you are sure about the results and have reported them, feel free to delete your experiments.

Technology	Microsoft Machine Learning Studio
Allowed Libraries	NA
Max allowed runtime	NA
Deliverables	[Gradescope] <b>q5_results.csv</b> : a csv file containing results for all parts

### Tasks

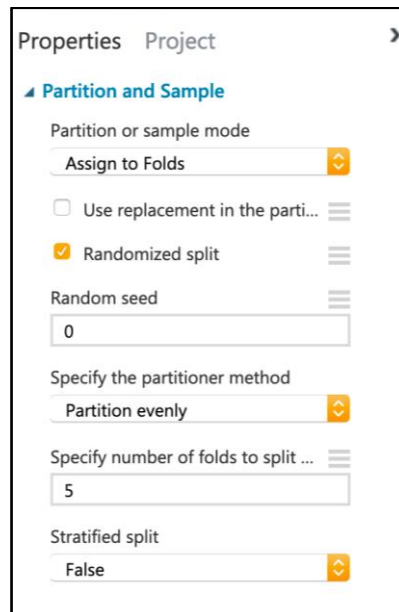
You will manually modify the given file **q5\_results.csv** by adding to it the results from the following tasks (e.g., using a plain text editor). Your solution will be autograded. Hence,

- DO NOT change the order of the questions.
  - Report the exact numerical values that you get in your output, and **DO NOT round any of them**.
  - When manually entering a value into the csv file, append it immediately after a comma, so there will be NO space between the comma and your value, and no trailing spaces or commas after your value.
  - Follow the tutorial and do not change values for L2 regularization. For parts b and c, please select the columns given in the tutorial.
- a) Update your GT username in the q5\_results.csv file to replace gburdell3.
  - b) **[3 pts]** Repeat the experiment described in the tutorial and report values of all metrics as mentioned in the ‘*Evaluate Model*’ section of the tutorial.
  - c) **[3 pts]** Repeat the experiment mentioned in part b with a different value of ‘*Fraction of rows in the first output*’ in the split module. Change the value to 0.8 from the originally set value, 0.75. Report corresponding values of the metrics.
  - d) **[4 pts]** Run a new experiment — evaluate the model using 5-fold cross-validation ([CV](#)). Select parameters in the module ‘*Partition and sample*’ ([Partition and Sample](#)) in accordance with the figure below. Set the column name as “price” for CV. Also, use 0 as a random seed. Report the values of Root Mean Squared Error (RMSE) and Coefficient of Determination for each of the five folds (1st fold corresponds to fold number 0 and so on). Do NOT round the results. Report exact values.



To summarize, for part d, you **MUST** exactly follow each step below to run the experiment:

- A. Import the entire dataset (Automobile Price Data (Raw))
- B. Clean the missing data by dropping rows with missing values (select all columns in the dataset and do not "exclude the normalized losses" from the original tutorial). Leave the maximum missing value ratio to 1.
- C. Partition and sample the data. (**Note**: do not use "Split Data")
- D. Create a new model: Linear Regression (add the default Linear regression, i.e., do not change any values here)
- E. Finally, perform cross validation on the dataset. (**Hint**: use the price column here)
- F. Visualize/report the values.



The image shows a software interface with a 'Properties' tab selected. Under the 'Partition and Sample' section, the following settings are visible:

- Partition or sample mode:** A dropdown menu set to 'Assign to Folds'.
- Use replacement in the parti...:** An unchecked checkbox.
- Randomized split:** A checked checkbox.
- Random seed:** A text input field containing the value '0'.
- Specify the partitioner method:** A dropdown menu set to 'Partition evenly'.
- Specify number of folds to split ...:** A text input field containing the value '5'.
- Stratified split:** A dropdown menu set to 'False'.

Figure: Property Tab of Partition and Sample Module

**Hint:** For part 4, follow each of the outline steps carefully. This should result in 5 blocks in your final workflow (including the Automobile price data (Raw) block).