

Introduction to the Cloud and Apache Spark

Overview

- Introduction to the Cloud
- Context
- Basics of Apache Spark
- Run Apache Spark on the Cloud

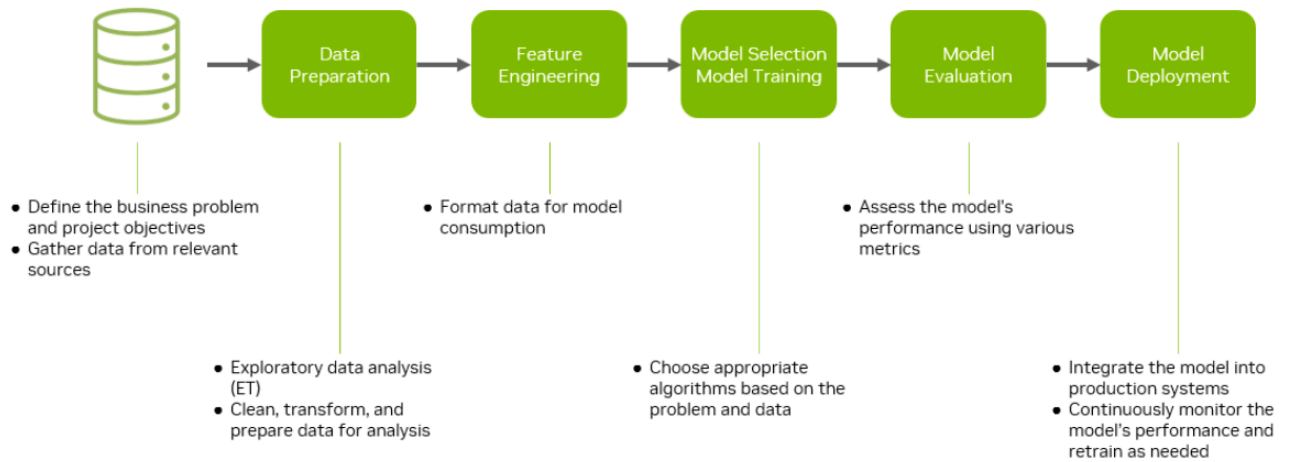
Why would you go with the Cloud?



What is Cloud in the REAL World?

- **“Cloud”** refers to large Internet services running on 10,000s of machines (Amazon, Google, Microsoft, etc)
- **“Cloud computing”** refers to services by these companies that let external customers rent cycles and storage
 - Amazon EC2: virtual machines at 8.5¢/hour (approximated cost)
 - Amazon S3: storage at 21¢/GB/month (approximated cost)
 - Google Cloud AppEngine
 - Windows Azure

Connect the Dots!



Context

Last lecture, we talked about the machine learning modeling process. Now, let's switch gears and discuss our technical infrastructure that can be deployed later to the cloud. You will need Spark installed on your machine in order to run the code snippets in this lecture.

In this class, we will use **Apache Spark** for data preparation, cleaning, and feature engineering. But why Spark?

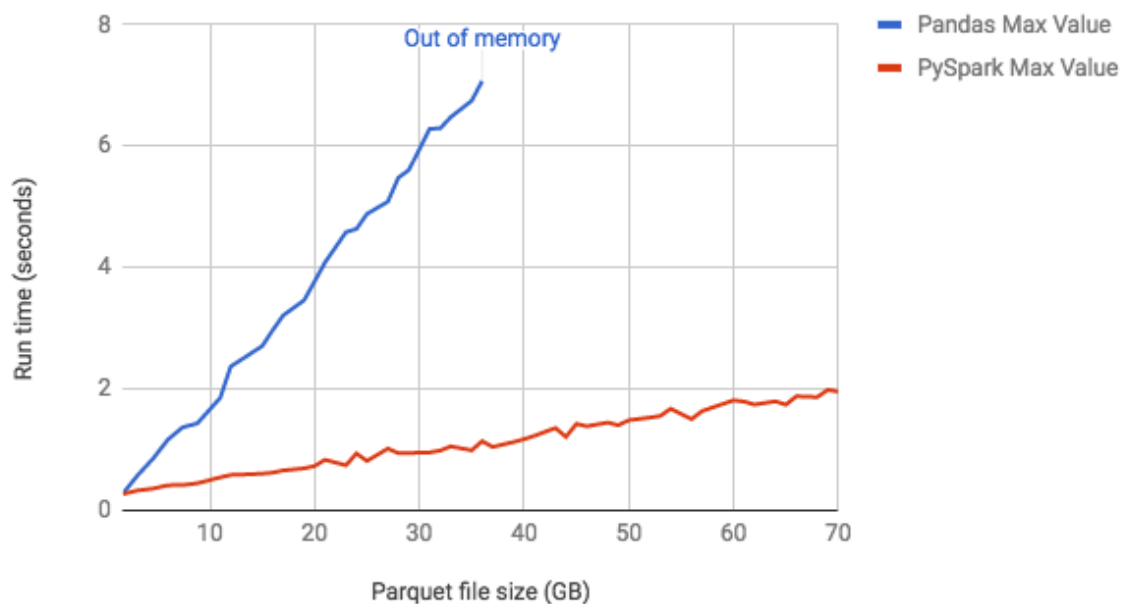
Why Spark?

- Developed in 2009 at UC Berkeley AMPLab, then open sourced in 2010,
- Spark is the next revolution of the popular Hadoop MapReduce framework.
- Gartner, Advanced Analytics and Data Science (2014) "Organizations that are looking at big data challenges – including collection, ETL, storage, exploration and analytics – should consider Spark for its in-memory performance and the breadth of its model. It supports advanced analytics solutions on Hadoop clusters, including the iterative model required for machine learning and graph analysis."

Pandas vs PySpark (Spark developed in Python)

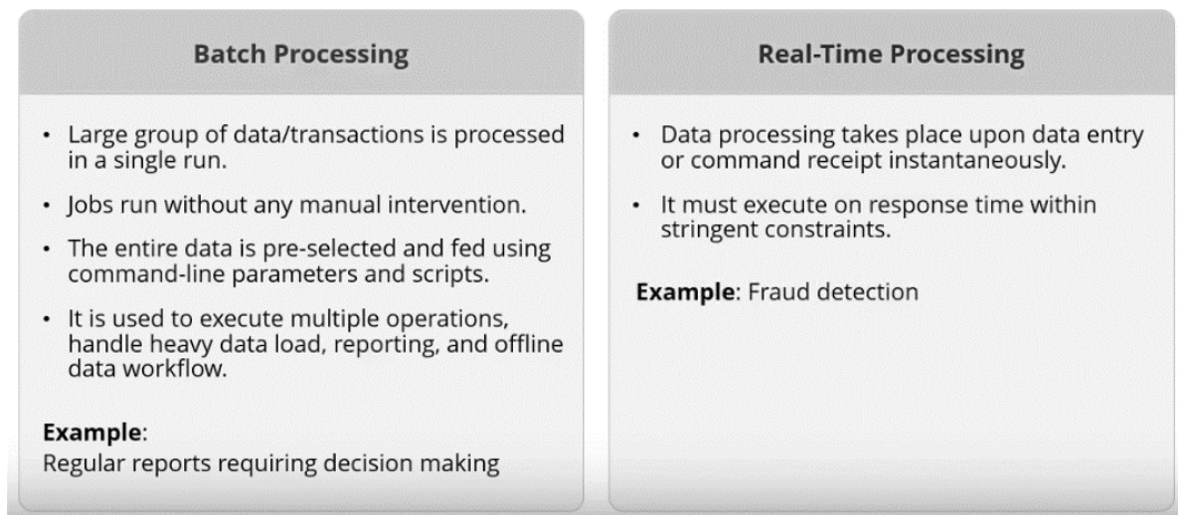
In a research done by Databricks, an industrial leader in the domain of big data storage and processing, PySpark shows superior performance compared to traditional implementations.

Pandas VS PySpark: max value

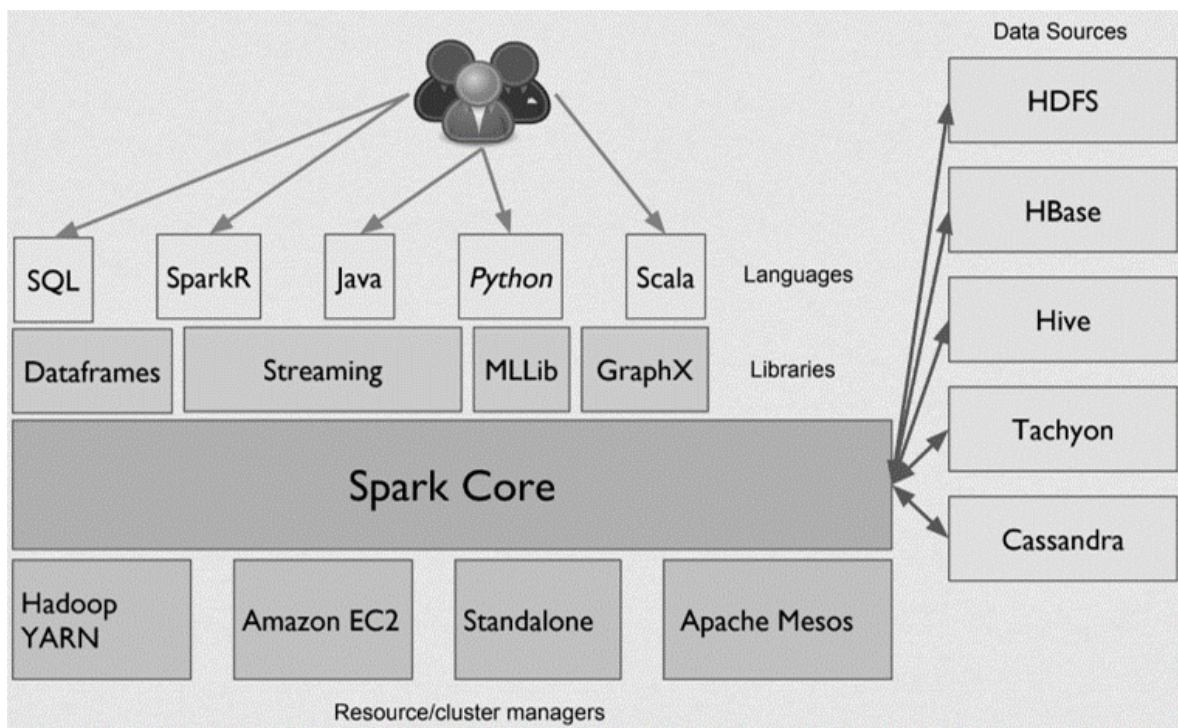


What is Spark?

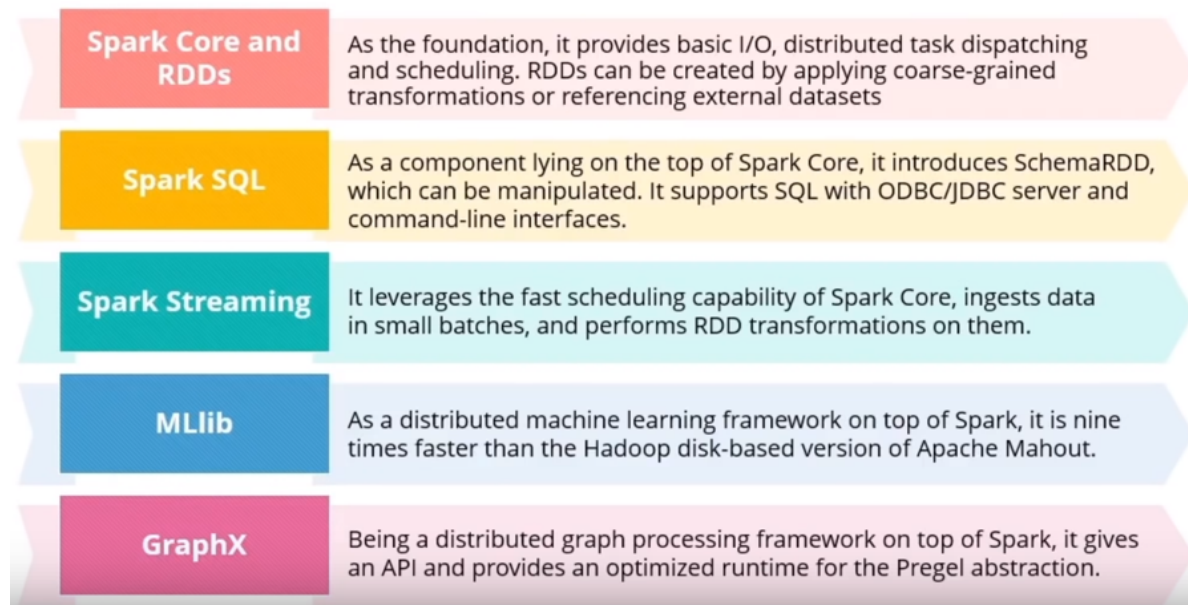
- Apache Spark is a fast and general-purpose cluster computing system for large scale data processing.
- Spark was originally written in Scala, which allows concise function syntax and interactive use.
- Apache Spark provides High-level APIs in Java, Scala, Python (PySpark) and R.
- Apache Spark combines two different modes of processing:
 - **Batch-based Processing** which can be provided via Apache Hadoop MapReduce
 - **Real-time Processing** which can be provided via Apache Storm.



Spark Ecosystem



Spark Componentenets



Spark Core

Spark Core is the general execution engine for the Spark platform that other functionalities are built on top of it. Spark has several advantages:

- Speed: runs programs up to 100x faster than Hadoop MapReduce in memory, or 10x faster on disk
- Ease of Use: Write applications quickly in Java, Scala, Python, R
- Generality: Combine SQL, streaming, and complex analytics
- Runs Everywhere: Spark runs on Hadoop, Mesos, standalone, or in the cloud. It can access diverse data sources including HDFS, Cassandra, HBase, and S3

```
In [ ]: # if you installed Spark on windows,  
# you may need findspark and need to initialize it prior to being able to use pyspark  
  
!pip install findspark
```

```
In [1]: # Uncomment the following lines if you are using Windows!  
import findspark  
findspark.init()  
findspark.find()  
# The above lines are used mostly in Windows only and you don't need them on other platf  
import pyspark  
from pyspark.sql import SparkSession  
  
spark = SparkSession.builder.master("local[*]").appName('SparkTest').getOrCreate()
```

Download Data Files Remotely

```
In [ ]: !pip install wget
```

```
In [5]: # Downloading and preprocessing KDD Train Data
!python -m wget https://www.andrew.cmu.edu/user/mfarag/763/KDDTrain+.txt
```

Saved under KDDTrain+.txt

Cloud Consideration

Your data need to be moved to a special storage server if you are running Spark on the Cloud. This special storage is called HDFS. The following command is used to move your data from your local storage to the special storage server.

```
In [ ]: # Uncomment and Execute this line if you are running your notebook on the Cloud
#!hadoop fs -put KDDTrain+.txt /
```


Spark Dataframes

Inspired by pandas DataFrames in structure, format, and a few specific operations, Spark DataFrames are like distributed in-memory tables with named columns and schemas, where each column has a specific data type: integer, string, array, map, real, date, timestamp, etc. To a human's eye, a Spark DataFrame is like a table

When data are visualized as a structured table, it's not only easy to digest but also easy to work with when it comes to common operations you might want to execute on rows and columns.

Also, DataFrames are immutable and Spark keeps a lineage of all transformations. You can add or change the names and data types of the columns, creating new DataFrames while the previous versions are preserved. A named column in a DataFrame and its associated Spark data type can be declared in the schema.

Let's examine the generic and structured data types available in Spark before we use them to define a schema. Then we'll illustrate how to create a DataFrame with a schema.

Spark's Basic Data Types

Spark supports basic internal data types. These data types can be declared in your Spark application or defined in your schema

Data type	Value assigned in Python	API to instantiate
ByteType	int	DataTypes.ByteType
ShortType	int	DataTypes.ShortType
IntegerType	int	DataTypes.IntegerType
LongType	int	DataTypes.LongType
FloatType	float	DataTypes.FloatType
DoubleType	float	DataTypes.DoubleType
StringType	str	DataTypes.StringType
BooleanType	bool	DataTypes.BooleanType
DecimalType	decimal.Decimal	DecimalType

```
In [2]: # Load data from csv to a dataframe on a local machine.
# header=False means the first row is not a header
# sep=',' means the column are seperated using ','
df = spark.read.csv('KDDTrain+.txt', header=False, sep=",")
# on the Cloud, the files will have to be at the root level. So, the cloud version is:
#df = spark.read.csv('/KDDTrain+.txt', header=False, sep=",")

df.show(5, vertical=True)
```

```
-RECORD 0-----
```

```
_c0 | 0
_c1 | tcp
_c2 | ftp_data
_c3 | SF
_c4 | 491
_c5 | 0
_c6 | 0
_c7 | 0
_c8 | 0
_c9 | 0
_c10 | 0
_c11 | 0
_c12 | 0
_c13 | 0
_c14 | 0
_c15 | 0
_c16 | 0
_c17 | 0
_c18 | 0
_c19 | 0
```



```
_c20 | 0
_c21 | 0
_c22 | 2
_c23 | 2
_c24 | 0.00
_c25 | 0.00
_c26 | 0.00
_c27 | 0.00
_c28 | 1.00
_c29 | 0.00
_c30 | 0.00
_c31 | 150
_c32 | 25
_c33 | 0.17
_c34 | 0.03
_c35 | 0.17
_c36 | 0.00
_c37 | 0.00
_c38 | 0.00
_c39 | 0.05
_c40 | 0.00
_c41 | normal
_c42 | 20
-RECORD 1-----
_c0 | 0
_c1 | udp
_c2 | other
_c3 | SF
_c4 | 146
_c5 | 0
_c6 | 0
_c7 | 0
_c8 | 0
_c9 | 0
_c10 | 0
_c11 | 0
_c12 | 0
_c13 | 0
_c14 | 0
_c15 | 0
_c16 | 0
_c17 | 0
_c18 | 0
_c19 | 0
_c20 | 0
_c21 | 0
_c22 | 13
_c23 | 1
_c24 | 0.00
_c25 | 0.00
_c26 | 0.00
_c27 | 0.00
_c28 | 0.08
_c29 | 0.15
_c30 | 0.00
_c31 | 255
_c32 | 1
_c33 | 0.00
_c34 | 0.60
_c35 | 0.88
_c36 | 0.00
_c37 | 0.00
_c38 | 0.00
_c39 | 0.00
_c40 | 0.00
_c41 | normal
```

```
_c42 | 15
-RECORD 2-----
_c0 | 0
_c1 | tcp
_c2 | private
_c3 | S0
_c4 | 0
_c5 | 0
_c6 | 0
_c7 | 0
_c8 | 0
_c9 | 0
_c10 | 0
_c11 | 0
_c12 | 0
_c13 | 0
_c14 | 0
_c15 | 0
_c16 | 0
_c17 | 0
_c18 | 0
_c19 | 0
_c20 | 0
_c21 | 0
_c22 | 123
_c23 | 6
_c24 | 1.00
_c25 | 1.00
_c26 | 0.00
_c27 | 0.00
_c28 | 0.05
_c29 | 0.07
_c30 | 0.00
_c31 | 255
_c32 | 26
_c33 | 0.10
_c34 | 0.05
_c35 | 0.00
_c36 | 0.00
_c37 | 1.00
_c38 | 1.00
_c39 | 0.00
_c40 | 0.00
_c41 | neptune
_c42 | 19
-RECORD 3-----
_c0 | 0
_c1 | tcp
_c2 | http
_c3 | SF
_c4 | 232
_c5 | 8153
_c6 | 0
_c7 | 0
_c8 | 0
_c9 | 0
_c10 | 0
_c11 | 1
_c12 | 0
_c13 | 0
_c14 | 0
_c15 | 0
_c16 | 0
_c17 | 0
_c18 | 0
_c19 | 0
```

```
_c20 | 0
_c21 | 0
_c22 | 5
_c23 | 5
_c24 | 0.20
_c25 | 0.20
_c26 | 0.00
_c27 | 0.00
_c28 | 1.00
_c29 | 0.00
_c30 | 0.00
_c31 | 30
_c32 | 255
_c33 | 1.00
_c34 | 0.00
_c35 | 0.03
_c36 | 0.04
_c37 | 0.03
_c38 | 0.01
_c39 | 0.00
_c40 | 0.01
_c41 | normal
_c42 | 21
-RECORD 4-----
_c0 | 0
_c1 | tcp
_c2 | http
_c3 | SF
_c4 | 199
_c5 | 420
_c6 | 0
_c7 | 0
_c8 | 0
_c9 | 0
_c10 | 0
_c11 | 1
_c12 | 0
_c13 | 0
_c14 | 0
_c15 | 0
_c16 | 0
_c17 | 0
_c18 | 0
_c19 | 0
_c20 | 0
_c21 | 0
_c22 | 30
_c23 | 32
_c24 | 0.00
_c25 | 0.00
_c26 | 0.00
_c27 | 0.00
_c28 | 1.00
_c29 | 0.00
_c30 | 0.09
_c31 | 255
_c32 | 255
_c33 | 1.00
_c34 | 0.00
_c35 | 0.00
_c36 | 0.00
_c37 | 0.00
_c38 | 0.00
_c39 | 0.00
_c40 | 0.00
_c41 | normal
```

_c42 | 21
only showing top 5 rows

Avoiding Auto-assigned Column Names: Read CSV and Specify the Column Names

```
In [6]: col_names = ["duration", "protocol_type", "service", "flag", "src_bytes",
    "dst_bytes", "land", "wrong_fragment", "urgent", "hot", "num_failed_logins",
    "logged_in", "num_compromised", "root_shell", "su_attempted", "num_root",
    "num_file_creations", "num_shells", "num_access_files", "num_outbound_cmds",
    "is_host_login", "is_guest_login", "count", "srv_count", "serror_rate",
    "srv_serror_rate", "rerror_rate", "srv_rerror_rate", "same_srv_rate",
    "diff_srv_rate", "srv_diff_host_rate", "dst_host_count", "dst_host_srv_count",
    "dst_host_same_srv_rate", "dst_host_diff_srv_rate", "dst_host_same_src_port_rate",
    "dst_host_srv_diff_host_rate", "dst_host_serror_rate", "dst_host_srv_serror_rate",
    "dst_host_rerror_rate", "dst_host_srv_rerror_rate", "classes", "difficulty_level"]

df = spark.read.csv("KDDTrain+.txt", header=False, inferSchema= True).toDF(*col_names)

# on the Cloud, the files will have to be at the root level. So, the cloud version is:
# df = spark.read.csv("/KDDTrain+.txt", header=False, inferSchema= True).toDF(*col_names)

df.show(1, vertical=True)
```

-RECORD 0-----

duration	0
protocol_type	tcp
service	ftp_data
flag	SF
src_bytes	491
dst_bytes	0
land	0
wrong_fragment	0
urgent	0
hot	0
num_failed_logins	0
logged_in	0
num_compromised	0
root_shell	0
su_attempted	0
num_root	0
num_file_creations	0
num_shells	0
num_access_files	0
num_outbound_cmds	0
is_host_login	0
is_guest_login	0
count	2
srv_count	2
serror_rate	0.0
srv_serror_rate	0.0
rerror_rate	0.0
srv_rerror_rate	0.0
same_srv_rate	1.0
diff_srv_rate	0.0
srv_diff_host_rate	0.0
dst_host_count	150
dst_host_srv_count	25
dst_host_same_srv_rate	0.17
dst_host_diff_srv_rate	0.03
dst_host_same_src_port_rate	0.17
dst_host_srv_diff_host_rate	0.0
dst_host_serror_rate	0.0
dst_host_srv_serror_rate	0.0
dst_host_rerror_rate	0.05
dst_host_srv_rerror_rate	0.0

```
classes | normal
difficulty_level | 20
only showing top 1 row
```

More ways to Display Dataframes

1. `df.take(5)` will return a list of five Row objects.
2. `df.collect()` will get all of the data from the entire DataFrame. Be really careful when using it, because if you have a large data set, you can easily crash the driver node.
3. `df.show()` is the most commonly used method to view a dataframe. There are a few parameters we can pass to this method, like the number of rows and truncate. For example, `df.show(5, False)` or `df.show(5, truncate=False)` will show the entire data without any truncation.
4. `df.limit(5)` will **return a new DataFrame** by taking the first n rows. As spark is distributed in nature, there is no guarantee that `df.limit()` will give you the same results each time.

Schemas and Creating DataFrames

You can think about the dataframe as a table. A schema in Spark defines the column names and associated data types for a DataFrame. **Most often, schemas come into play when you are reading structured data from an external data source.** Defining a schema up front as opposed to taking a schema-on-read approach offers three benefits:

- You relieve Spark from the onus of inferring data types.
 - You prevent Spark from creating a separate job just to read a large portion of your file to assert the schema, which for a large data file can be expensive and time-consuming.
 - You can detect errors early if data don't match the schema.
- We will explore the creation of schemas and we want you to leverage them. That said, we will automatically infer the schemas when running the code in the lecture for simplicity.

You may also create your own schema using data field name followed by data type.

```
In [2]: schema = "id INT, firstName STRING, WEBSITE STRING"
data = [[1, "John", "https://tinyurl.1"],
        [2, "Brooke", "https://tinyurl.2"]]

test_df = spark.createDataFrame(data, schema)
test_df.show()
test_df.printSchema()
```

```
+---+-----+-----+
| id|firstName|      WEBSITE|
+---+-----+-----+
|  1|    John|https://tinyurl.1|
|  2|   Brooke|https://tinyurl.2|
+---+-----+-----+

root
 |-- id: integer (nullable = true)
 |-- firstName: string (nullable = true)
 |-- WEBSITE: string (nullable = true)
```

Display Schema Information for Your Dataframe

```
In [7]: df.printSchema() # or df.dtypes

root
 |-- duration: integer (nullable = true)
 |-- protocol_type: string (nullable = true)
 |-- service: string (nullable = true)
 |-- flag: string (nullable = true)
 |-- src_bytes: integer (nullable = true)
 |-- dst_bytes: integer (nullable = true)
 |-- land: integer (nullable = true)
 |-- wrong_fragment: integer (nullable = true)
 |-- urgent: integer (nullable = true)
 |-- hot: integer (nullable = true)
 |-- num_failed_logins: integer (nullable = true)
 |-- logged_in: integer (nullable = true)
 |-- num_compromised: integer (nullable = true)
 |-- root_shell: integer (nullable = true)
 |-- su_attempted: integer (nullable = true)
```



```

|-- num_root: integer (nullable = true)
|-- num_file_creations: integer (nullable = true)
|-- num_shells: integer (nullable = true)
|-- num_access_files: integer (nullable = true)
|-- num_outbound_cmds: integer (nullable = true)
|-- is_host_login: integer (nullable = true)
|-- is_guest_login: integer (nullable = true)
|-- count: integer (nullable = true)
|-- srv_count: integer (nullable = true)
|-- serror_rate: double (nullable = true)
|-- srv_serror_rate: double (nullable = true)
|-- rerror_rate: double (nullable = true)
|-- srv_rerror_rate: double (nullable = true)
|-- same_srv_rate: double (nullable = true)
|-- diff_srv_rate: double (nullable = true)
|-- srv_diff_host_rate: double (nullable = true)
|-- dst_host_count: integer (nullable = true)
|-- dst_host_srv_count: integer (nullable = true)
|-- dst_host_same_srv_rate: double (nullable = true)
|-- dst_host_diff_srv_rate: double (nullable = true)
|-- dst_host_same_src_port_rate: double (nullable = true)
|-- dst_host_srv_diff_host_rate: double (nullable = true)
|-- dst_host_serror_rate: double (nullable = true)
|-- dst_host_srv_serror_rate: double (nullable = true)
|-- dst_host_rerror_rate: double (nullable = true)
|-- dst_host_srv_rerror_rate: double (nullable = true)
|-- classes: string (nullable = true)
|-- difficulty_level: integer (nullable = true)

```

Print Column Names in Your Dataframe

In [5]: `print(df.columns)`

```

['duration', 'protocol_type', 'service', 'flag', 'src_bytes', 'dst_bytes', 'land', 'wrong_fragment', 'urgent', 'hot', 'num_failed_logins', 'logged_in', 'num_compromised', 'root_shell', 'su_attempted', 'num_root', 'num_file_creations', 'num_shells', 'num_access_files', 'num_outbound_cmds', 'is_host_login', 'is_guest_login', 'count', 'srv_count', 'serror_rate', 'srv_serror_rate', 'rerror_rate', 'srv_rerror_rate', 'same_srv_rate', 'diff_srv_rate', 'srv_diff_host_rate', 'dst_host_count', 'dst_host_srv_count', 'dst_host_same_srv_rate', 'dst_host_diff_srv_rate', 'dst_host_same_src_port_rate', 'dst_host_srv_diff_host_rate', 'dst_host_serror_rate', 'dst_host_srv_serror_rate', 'dst_host_rerror_rate', 'dst_host_srv_rerror_rate', 'classes', 'difficulty_level']

```

Print Total Number of Your Records in Your Dataframe

In [7]: `print(df.count())`

```
125973
```

Print Sample Record from Your Dataframe

In [8]: `df.show(1, vertical=True)`

```

-RECORD 0-----
duration          | 0
protocol_type     | tcp
service           | ftp_data
flag              | SF
src_bytes         | 491
dst_bytes         | 0

```

land	0
wrong_fragment	0
urgent	0
hot	0
num_failed_logins	0
logged_in	0
num_compromised	0
root_shell	0
su_attempted	0
num_root	0
num_file_creations	0
num_shells	0
num_access_files	0
num_outbound_cmds	0
is_host_login	0
is_guest_login	0
count	2
srv_count	2
serror_rate	0.0
srv_serror_rate	0.0
rerror_rate	0.0
srv_rerror_rate	0.0
same_srv_rate	1.0
diff_srv_rate	0.0
srv_diff_host_rate	0.0
dst_host_count	150
dst_host_srv_count	25
dst_host_same_srv_rate	0.17
dst_host_diff_srv_rate	0.03
dst_host_same_src_port_rate	0.17
dst_host_srv_diff_host_rate	0.0
dst_host_serror_rate	0.0
dst_host_srv_serror_rate	0.0
dst_host_rerror_rate	0.05
dst_host_srv_rerror_rate	0.0
classes	normal
difficulty_level	20

only showing top 1 row

DataFrame Operations on Columns

1. Selecting Columns & Creating Subset Dataframes
2. Adding New Columns
3. Renaming Columns
4. Removing Columns

Create a Subset Dataframe from Your Dataframe

```
In [9]: small_df = df.select("duration","protocol_type","service","classes","difficulty_level")
small_df.show(5)
```

```
+-----+-----+-----+-----+-----+
|duration|protocol_type| service|classes|difficulty_level|
+-----+-----+-----+-----+-----+
|      0|      tcp|ftp_data| normal|      20|
|      0|      udp|  other| normal|      15|
|      0|      tcp| private|neptune|      19|
|      0|      tcp|  http| normal|      21|
|      0|      tcp|  http| normal|      21|
+-----+-----+-----+-----+-----+
only showing top 5 rows
```

Display Summary Statistics in Your Dataframe

```
In [10]: df.describe().show(vertical=True)
```

```
--RECORD 0-----
summary                | count
duration               | 125973
protocol_type          | 125973
service                | 125973
flag                   | 125973
src_bytes              | 125973
dst_bytes              | 125973
land                   | 125973
wrong_fragment         | 125973
urgent                 | 125973
hot                    | 125973
num_failed_logins      | 125973
logged_in              | 125973
num_compromised        | 125973
root_shell             | 125973
su_attempted           | 125973
num_root               | 125973
num_file_creations     | 125973
num_shells              | 125973
num_access_files       | 125973
num_outbound_cmds      | 125973
is_host_login          | 125973
is_guest_login         | 125973
count                  | 125973
srv_count              | 125973
serror_rate            | 125973
srv_serror_rate        | 125973
rerror_rate            | 125973
srv_rerror_rate        | 125973
same_srv_rate          | 125973
diff_srv_rate          | 125973
srv_diff_host_rate     | 125973
dst_host_count         | 125973
dst_host_srv_count     | 125973
dst_host_same_srv_rate | 125973
dst_host_diff_srv_rate | 125973
dst_host_same_src_port_rate | 125973
dst_host_srv_diff_host_rate | 125973
dst_host_serror_rate   | 125973
dst_host_srv_serror_rate | 125973
```

dst_host_rerror_rate	125973
dst_host_srv_rerror_rate	125973
classes	125973
difficulty_level	125973
-RECORD 1-----	
summary	mean
duration	287.1446500440571
protocol_type	null
service	null
flag	null
src_bytes	45566.74300048423
dst_bytes	19779.114421344257
land	1.984552245322410...
wrong_fragment	0.022687401268525795
urgent	1.111349257380549...
hot	0.20440888126820828
num_failed_logins	0.001222484183118...
logged_in	0.3957355941352512
num_compromised	0.279250315543807
root_shell	0.001341557317837...
su_attempted	0.001103411048399...
num_root	0.30219173949973405
num_file_creations	0.012669381534138267
num_shells	4.127868670270613...
num_access_files	0.004096115834345455
num_outbound_cmds	0.0
is_host_login	7.938208981289641E-6
is_guest_login	0.009422654060790804
count	84.1075547934875
srv_count	27.737888277646796
serror_rate	0.28448453239979987
srv_serror_rate	0.282485373849952
rerror_rate	0.11995848316702792
srv_rerror_rate	0.12118326943075095
same_srv_rate	0.6609276591015695
diff_srv_rate	0.06305263826374652
srv_diff_host_rate	0.09732164828971333
dst_host_count	182.14894461511594
dst_host_srv_count	115.65300500900987
dst_host_same_srv_rate	0.5212416946488765
dst_host_diff_srv_rate	0.08295110857087815
dst_host_same_src_port_rate	0.14837885896185457
dst_host_srv_diff_host_rate	0.03254244957252493
dst_host_serror_rate	0.28445246203552055
dst_host_srv_serror_rate	0.2784845165233873
dst_host_rerror_rate	0.11883181316631444
dst_host_srv_rerror_rate	0.12023989267541528
classes	null
difficulty_level	19.50406039389393
-RECORD 2-----	
summary	stddev
duration	2604.515309867593
protocol_type	null
service	null
flag	null
src_bytes	5870331.181893545
dst_bytes	4021269.151441453
land	0.01408607167151309
wrong_fragment	0.25352998595201326
urgent	0.014366026620154241
hot	2.1499684337047613
num_failed_logins	0.04523913898132976
logged_in	0.48901005300524086
num_compromised	23.942042242794997
root_shell	0.03660284383979861
su_attempted	0.045154383813865565

num_root	24.39961808883742
num_file_creations	0.48393506939604286
num_shells	0.022181128678694186
num_access_files	0.09936955575066152
num_outbound_cmds	0.0
is_host_login	0.002817482738419...
is_guest_login	0.09661232709143097
count	114.50860735418416
srv_count	72.63583964723834
serror_rate	0.4464556243310231
srv_serror_rate	0.44702249836401775
rerror_rate	0.3204355207495169
srv_rerror_rate	0.3236472280054634
same_srv_rate	0.4396228624074803
diff_srv_rate	0.180314407508575
srv_diff_host_rate	0.2598304981211588
dst_host_count	99.20621303459787
dst_host_srv_count	110.70274078086481
dst_host_same_srv_rate	0.4489493637176793
dst_host_diff_srv_rate	0.18892179990461475
dst_host_same_src_port_rate	0.30899713037298815
dst_host_srv_diff_host_rate	0.11256380488118997
dst_host_serror_rate	0.444784050316489
dst_host_srv_serror_rate	0.4456691238860298
dst_host_rerror_rate	0.3065574580251692
dst_host_srv_rerror_rate	0.31945939045523153
classes	null
difficulty_level	2.291502939101359

-RECORD 3-----

summary	min
duration	0
protocol_type	icmp
service	IRC
flag	OTH
src_bytes	0
dst_bytes	0
land	0
wrong_fragment	0
urgent	0
hot	0
num_failed_logins	0
logged_in	0
num_compromised	0
root_shell	0
su_attempted	0
num_root	0
num_file_creations	0
num_shells	0
num_access_files	0
num_outbound_cmds	0
is_host_login	0
is_guest_login	0
count	0
srv_count	0
serror_rate	0.0
srv_serror_rate	0.0
rerror_rate	0.0
srv_rerror_rate	0.0
same_srv_rate	0.0
diff_srv_rate	0.0
srv_diff_host_rate	0.0
dst_host_count	0
dst_host_srv_count	0
dst_host_same_srv_rate	0.0
dst_host_diff_srv_rate	0.0
dst_host_same_src_port_rate	0.0

```

dst_host_srv_diff_host_rate | 0.0
dst_host_serror_rate       | 0.0
dst_host_srv_serror_rate   | 0.0
dst_host_rerror_rate       | 0.0
dst_host_srv_rerror_rate   | 0.0
classes                     | back
difficulty_level           | 0
-RECORD 4-----
summary                     | max
duration                    | 42908
protocol_type               | udp
service                     | whois
flag                        | SH
src_bytes                   | 1379963888
dst_bytes                   | 1309937401
land                        | 1
wrong_fragment              | 3
urgent                      | 3
hot                          | 77
num_failed_logins           | 5
logged_in                   | 1
num_compromised             | 7479
root_shell                  | 1
su_attempted                | 2
num_root                    | 7468
num_file_creations          | 43
num_shells                  | 2
num_access_files            | 9
num_outbound_cmds           | 0
is_host_login               | 1
is_guest_login              | 1
count                       | 511
srv_count                   | 511
serror_rate                 | 1.0
srv_serror_rate             | 1.0
rerror_rate                 | 1.0
srv_rerror_rate             | 1.0
same_srv_rate               | 1.0
diff_srv_rate               | 1.0
srv_diff_host_rate          | 1.0
dst_host_count              | 255
dst_host_srv_count          | 255
dst_host_same_srv_rate      | 1.0
dst_host_diff_srv_rate      | 1.0
dst_host_same_src_port_rate | 1.0
dst_host_srv_diff_host_rate | 1.0
dst_host_serror_rate        | 1.0
dst_host_srv_serror_rate    | 1.0
dst_host_rerror_rate        | 1.0
dst_host_srv_rerror_rate    | 1.0
classes                     | warezmaster
difficulty_level            | 21

```

Display Unique Values from a Column in Your Dataframe

```
In [11]: df.select("classes").distinct().show(40)
```

```

+-----+
|      classes|
+-----+
|      neptune|
|      satan|
|      nmap|

```

```
| portsweep|
| back|
| warezclient|
| guess_passwd|
| normal|
| rootkit|
| perl|
|buffer_overflow|
| multihop|
| ipsweep|
| warezmaster|
| imap|
| teardrop|
| spy|
| land|
| pod|
| ftp_write|
| smurf|
| loadmodule|
| phf|
+-----+
```

Add a Column to Your Dataframe

```
In [12]: # We will add a new column called 'first_column' at the end
from pyspark.sql.functions import lit
df = df.withColumn('first_column',lit(1))
# lit means literal. It populates the row with the literal value given.
# When adding static data / constant values, it is a good practice to use it.
df.show(1,vertical=True)
```

```
-RECORD 0-----
duration                | 0
protocol_type           | tcp
service                 | ftp_data
flag                    | SF
src_bytes                | 491
dst_bytes               | 0
land                    | 0
wrong_fragment          | 0
urgent                  | 0
hot                     | 0
num_failed_logins       | 0
logged_in               | 0
num_compromised         | 0
root_shell              | 0
su_attempted            | 0
num_root                | 0
num_file_creations      | 0
num_shells              | 0
num_access_files        | 0
num_outbound_cmds       | 0
is_host_login           | 0
is_guest_login          | 0
count                   | 2
srv_count               | 2
serror_rate             | 0.0
srv_serror_rate         | 0.0
rerror_rate             | 0.0
srv_rerror_rate         | 0.0
same_srv_rate           | 1.0
diff_srv_rate           | 0.0
srv_diff_host_rate      | 0.0
```



```

dst_host_count          | 150
dst_host_srv_count      | 25
dst_host_same_srv_rate  | 0.17
dst_host_diff_srv_rate  | 0.03
dst_host_same_src_port_rate | 0.17
dst_host_srv_diff_host_rate | 0.0
dst_host_serror_rate    | 0.0
dst_host_srv_serror_rate | 0.0
dst_host_rerror_rate    | 0.05
dst_host_srv_rerror_rate | 0.0
classes                 | normal
difficulty_level        | 20
first_column            | 1
only showing top 1 row

```

Renaming a Column in Your Dataframe

```

In [13]: df = df.withColumnRenamed('first_column', 'new_column_one')

df.printSchema()

```

```

root
|-- duration: integer (nullable = true)
|-- protocol_type: string (nullable = true)
|-- service: string (nullable = true)
|-- flag: string (nullable = true)
|-- src_bytes: integer (nullable = true)
|-- dst_bytes: integer (nullable = true)
|-- land: integer (nullable = true)
|-- wrong_fragment: integer (nullable = true)
|-- urgent: integer (nullable = true)
|-- hot: integer (nullable = true)
|-- num_failed_logins: integer (nullable = true)
|-- logged_in: integer (nullable = true)
|-- num_compromised: integer (nullable = true)
|-- root_shell: integer (nullable = true)
|-- su_attempted: integer (nullable = true)
|-- num_root: integer (nullable = true)
|-- num_file_creations: integer (nullable = true)
|-- num_shells: integer (nullable = true)
|-- num_access_files: integer (nullable = true)
|-- num_outbound_cmds: integer (nullable = true)
|-- is_host_login: integer (nullable = true)
|-- is_guest_login: integer (nullable = true)
|-- count: integer (nullable = true)
|-- srv_count: integer (nullable = true)
|-- serror_rate: double (nullable = true)
|-- srv_serror_rate: double (nullable = true)
|-- rerror_rate: double (nullable = true)
|-- srv_rerror_rate: double (nullable = true)
|-- same_srv_rate: double (nullable = true)
|-- diff_srv_rate: double (nullable = true)
|-- srv_diff_host_rate: double (nullable = true)
|-- dst_host_count: integer (nullable = true)
|-- dst_host_srv_count: integer (nullable = true)
|-- dst_host_same_srv_rate: double (nullable = true)
|-- dst_host_diff_srv_rate: double (nullable = true)
|-- dst_host_same_src_port_rate: double (nullable = true)
|-- dst_host_srv_diff_host_rate: double (nullable = true)
|-- dst_host_serror_rate: double (nullable = true)
|-- dst_host_srv_serror_rate: double (nullable = true)
|-- dst_host_rerror_rate: double (nullable = true)
|-- dst_host_srv_rerror_rate: double (nullable = true)

```

```
|-- classes: string (nullable = true)
|-- difficulty_level: integer (nullable= true)
|-- new_column_one: integer (nullable = false)
```

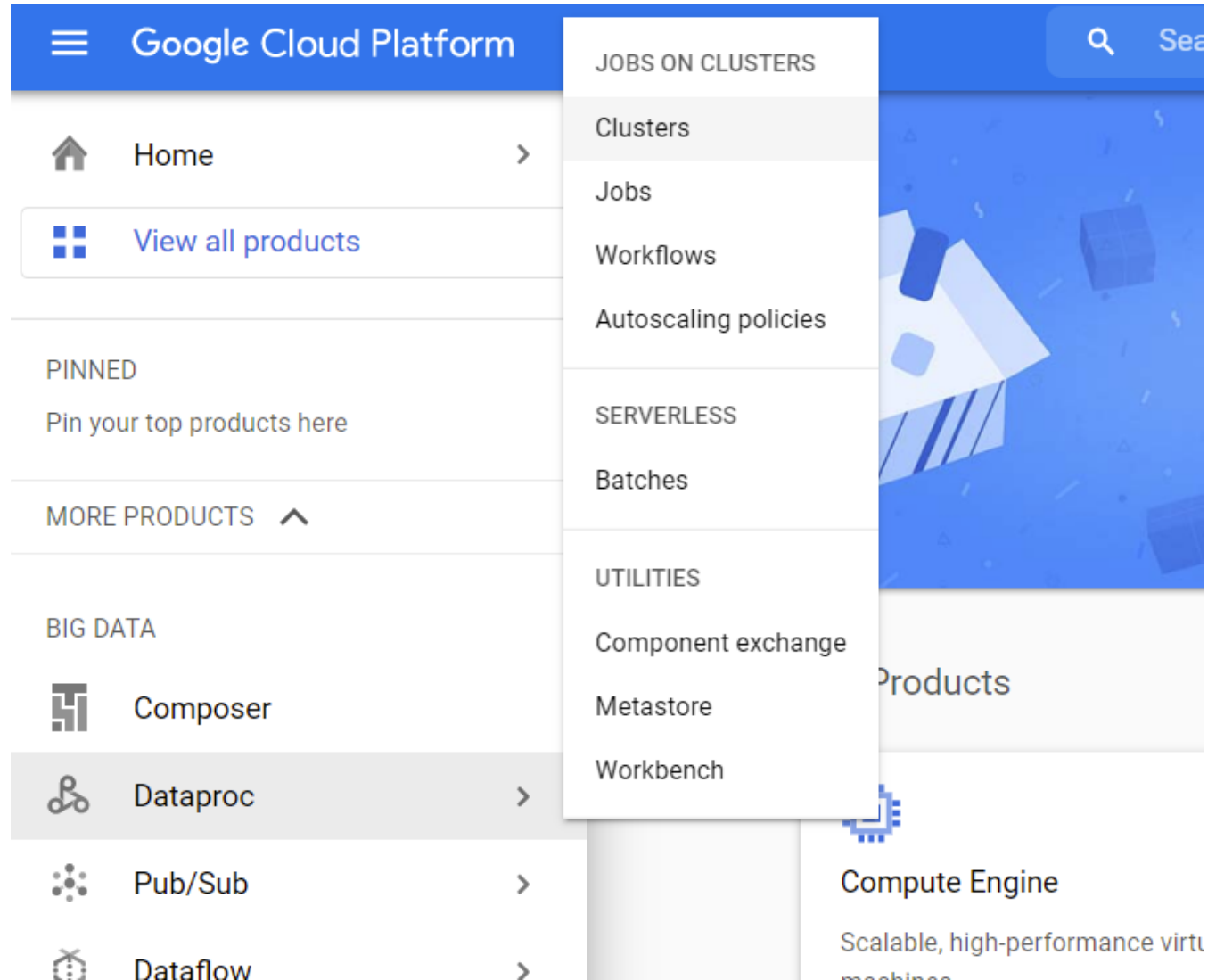
Delete a Column from Your Dataframe

```
In [ ]: df = df.drop('new_column_one')
df.printSchema()
```

Lab: Run Spark on the Cloud

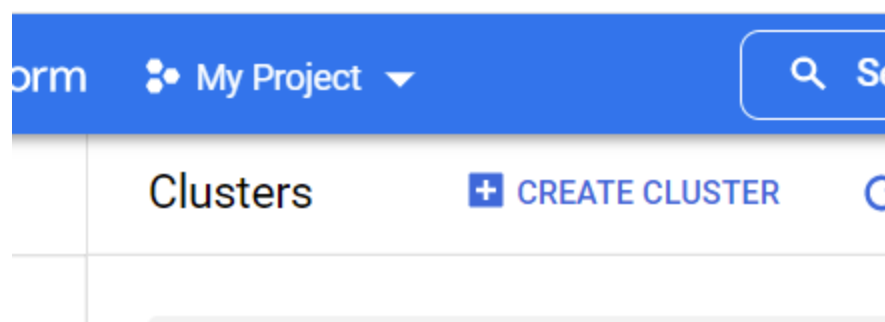
Create Clusters (e.g. Hadoop Clusters)

- A cluster is group of machines, servers, or nodes. It helps providing the sum of the computational power offered by all incorporated machines. It's difficult to build a local machine with 64GB RAM and 20TB of Storage but that is not difficult when you are running on the cloud.
- You may start by navigating to Dataproc and click on the Clusters section



Cluster - Setup

- Next, you need to create your cluster and choose the cluster to use "Google Compute Engine"








Cluster Configuration

Make sure to follow the cluster creation guide posted on Canvas

Running Cluster

Once you click on the create button, Google Cloud will work on creating your own cluster and if it's successful, you will see your cluster running.

<div><div> Filter</div><div>Search clusters, press Enter</div></div> <div><div></div><div></div></div>								
<input type="checkbox"/>	Name 	Status	Region	Zone	Total worker nodes	Scheduled deletion	Cloud Storage staging bucket	Created
<input type="checkbox"/>	cluster-d712	 Running	us-central1	us-central1-f	2	Off	dataproc-staging-us-central1-934687243262-r97j0sab	Jan 26, 2022, 11:43:28 PM

Connect to Your Cluster

From the Web Interfaces, open Jupyter. Upload your Notebook to **GCS** folder and run the cells.