PAGERANK_SPARK

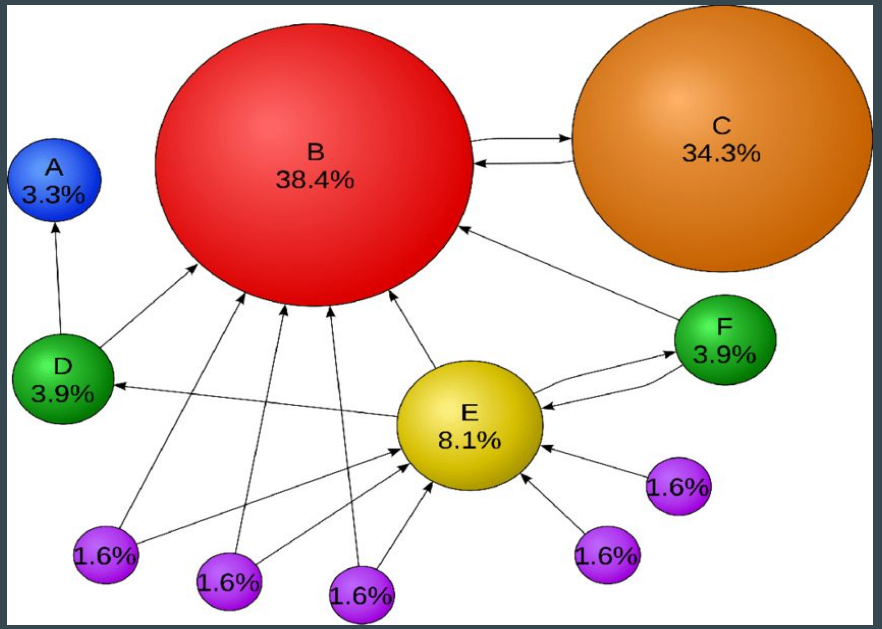
FATEMA_NAGORI

TABLE OF CONTENT

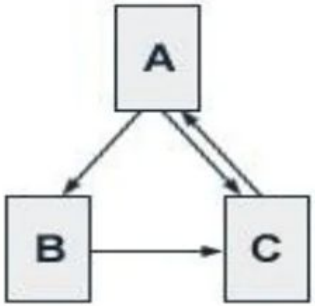
INTRODUCTION

- PageRank (PR) is an algorithm used by Google Search to rank web pages in their search engine results.

- PageRank is a way of measuring the importance of website pages.



DESIGN



Consider an imaginary web of 3 web pages.
And the inbound and outbound link structure is as shown in the figure. The calculations can be done by following method :

PR(A) = 0.5 + 0.5 PR(C)
= 0.5 + (0.5*1)
= 1

PR(B) = 0.5 + 0.5 (PR(A) / 2)
= 0.5 + 0.5 (1/2)
= 0.5 + (0.5 * 0.5)
= 0.5 + 0.25
= 0.75

PR(C) = 0.5 + 0.5 ((PR(A) / 2)+ PR (B))
= 0.5 + 0.5 (1/2 + 0.75)
= 0.5 + 0.5 (1.25)
= 0.5 + 0.625
= 1.125

DESIGN

A web page does not have input will have:

constant PageRank: 1-d

the smallest PageRank Input Web Pages' impact to the PageRank of a web page:

The more Input Web Pages the better.

The higher PageRank of an Input Web Page the better..

An iterative algorithm that performs many joins, so it is a good use case for RDD partitioning.

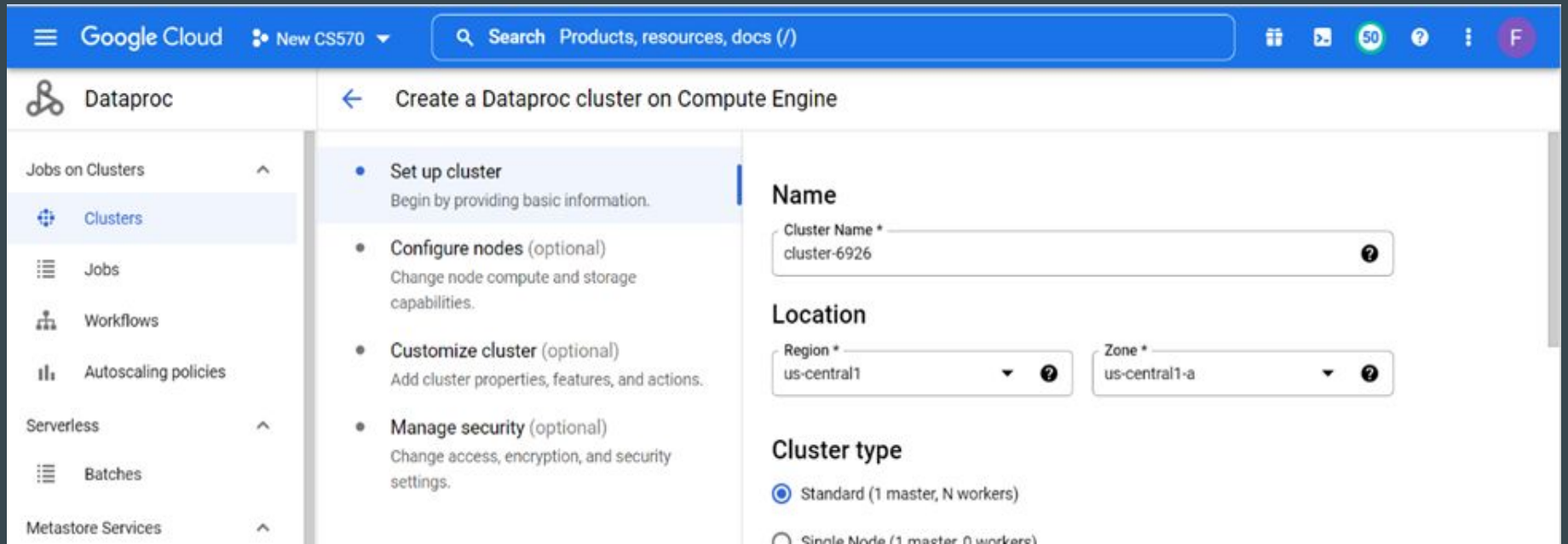
The algorithm maintains two datasets:

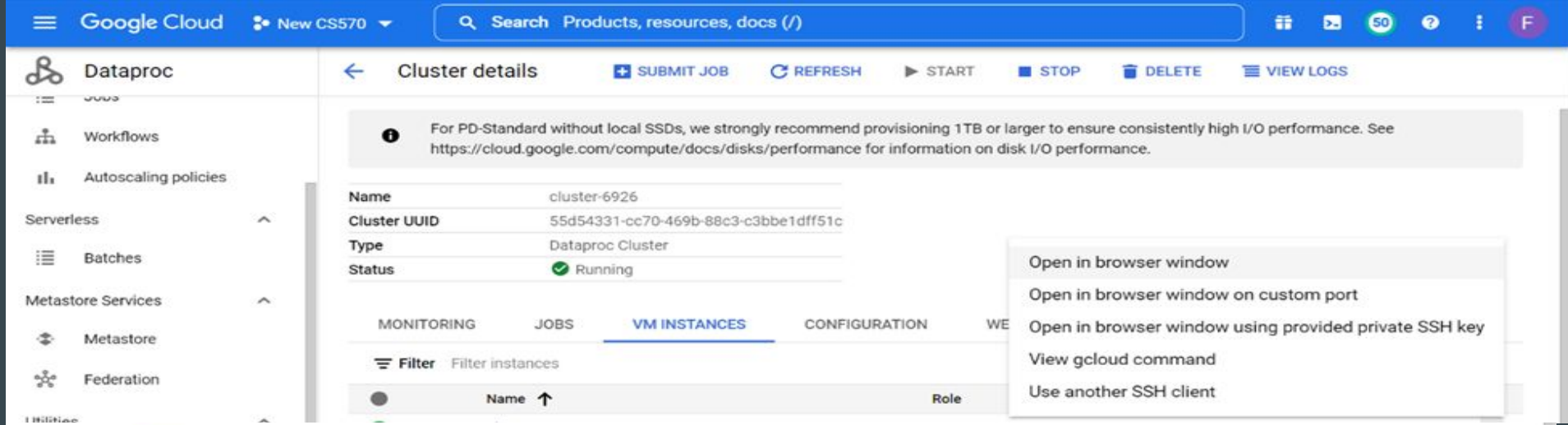
(pageID, link List) elements containing the list of neighbors of each page,

(pageID, rank) elements containing the current rank for each page.

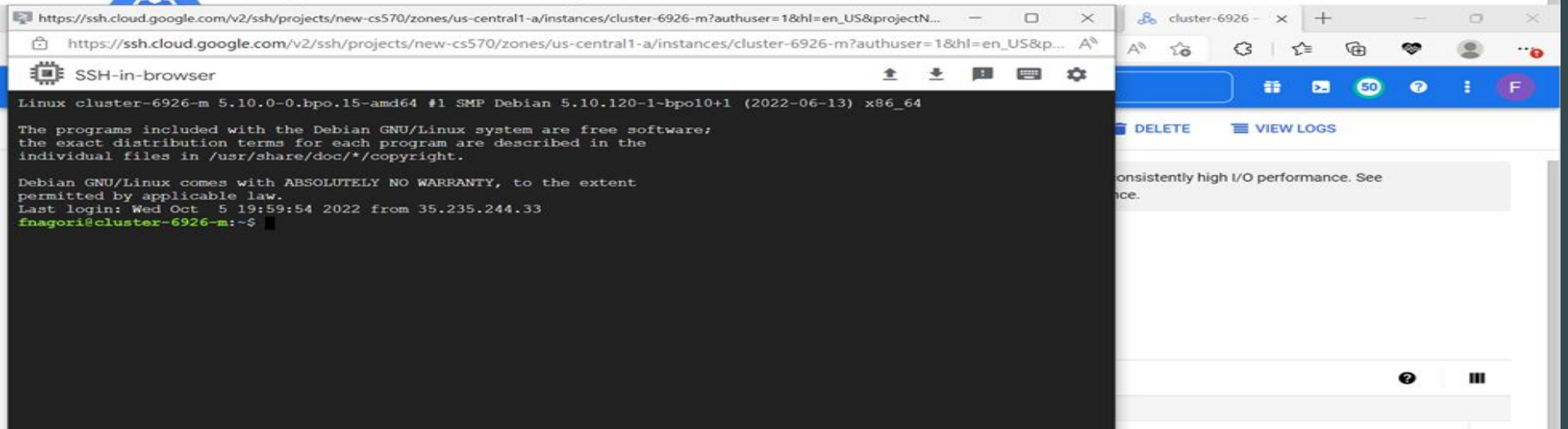
SETUP GCP

- Enable the Google Cloud Compute Engine API
- Create, Configure and Launch a Google Cloud Dataproc cluster
- Connecting to the Master Node using Secure Shell (ssh)





Google Cloud Data Catalog API



Launch Spark shell at GCP

```
fnagori@cluster-6926-m:~$ pyspark
Python 3.8.13 | packaged by conda-forge | (default, Mar 25 2022, 06:04:10)
[GCC 10.3.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use setLogLevel(newLevel).
22/10/05 20:09:02 INFO org.apache.spark.SparkEnv: Registering MapOutputTracker
22/10/05 20:09:02 INFO org.apache.spark.SparkEnv: Registering BlockManagerMaster
22/10/05 20:09:02 INFO org.apache.spark.SparkEnv: Registering BlockManagerMasterHeartbeat
22/10/05 20:09:02 INFO org.apache.spark.SparkEnv: Registering OutputCommitCoordinator
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 3.1.3
      /_/

Using Python version 3.8.13 (default, Mar 25 2022 06:04:10)
Spark context Web UI available at http://cluster-6926-m.us-central1-a.c.new-cs570.internal:34509
Spark context available as 'sc' (master = yarn, app id = application_1664999425862_0001).
SparkSession available as 'spark'.
>>> # The SparkContext 'sc' is already defined.
>>> # Set the Logging Level to ERROR only
>>> sc.setLogLevel("ERROR")
>>> # Set the Logging Level to ERROR only
>>> sc.setLogLevel("ERROR")
```

Implementation-PageRank_PySpark_GCP

STEP:

- Prepare Data:vi pagerank_data.txt
- Create a directory (folder) to store the data: hdfs dfs -mkdir hdfs:///mydata
- Copy the date to HDFS: hdfs dfs -put pagerank_data.txt hdfs:///mydata
- Prepare the program: vi pagerank.py
- Running the program with Pyspark: spark-submit pagerank.py hdfs:///mydata/pagerank_input.txt 1

INPUT FILE FORMAT

A B
A C
B C
C A

TEST-PageRank_PySpark_GCP (1st-iteration)

```
nagorifatma1@cluster-5854-m-0:~$ hdfs dfs -put pagerank_input.txt hdfs:///mydata
nagorifatma1@cluster-5854-m-0:~$ spark-submit pagerank.py hdfs:///mydata/pagerank_input.txt 1
WARN: This is a naive implementation of PageRank and is given as an example!
Please refer to PageRank implementation provided by graphx
22/11/01 21:29:35 INFO org.apache.spark.SparkEnv: Registering MapOutputTracker
22/11/01 21:29:35 INFO org.apache.spark.SparkEnv: Registering BlockManagerMaster
22/11/01 21:29:35 INFO org.apache.spark.SparkEnv: Registering BlockManagerMasterHeartbeat
22/11/01 21:29:35 INFO org.apache.spark.SparkEnv: Registering OutputCommitCoordinator
22/11/01 21:29:35 INFO org.sparkproject.jetty.util.log: Logging initialized @3688ms to org.sparkproject.jetty.util.log.Slf4jLog
22/11/01 21:29:35 INFO org.sparkproject.jetty.server.Server: jetty-9.4.40.v20210413; built: 2021-04-13T20:42:42.668Z; git: b881a572662e1943a14ae12e7e1207989f218
b74; jvm 1.8.0_345-b01
22/11/01 21:29:35 INFO org.sparkproject.jetty.server.Server: Started @3846ms
22/11/01 21:29:36 INFO org.sparkproject.jetty.server.AbstractConnector: Started ServerConnector@24e81266{HTTP/1.1, (http/1.1)}{0.0.0.0:44567}
22/11/01 21:29:37 INFO org.apache.hadoop.yarn.client.AHSProxy: Connecting to Application History server at cluster-5854-m-0.us-central1-b.c.new-cs570.internal./
10.128.0.18:10200
22/11/01 21:29:37 INFO org.apache.hadoop.yarn.client.ConfiguredRMFailoverProxyProvider: Failing over to rm1
22/11/01 21:29:37 INFO org.apache.hadoop.io.retry.RetryInvocationHandler: java.net.ConnectException: Call From cluster-5854-m-0/10.128.0.18 to cluster-5854-m-1.
us-central1-b.c.new-cs570.internal.:8032 failed on connection exception: java.net.ConnectException: Connection refused; For more details see:  http://wiki.apach
e.org/hadoop/ConnectionRefused, while invoking ApplicationClientProtocolPBClientImpl.getNewApplication over rm1 after 1 failover attempts. Trying to failover af
ter sleeping for 764ms.
22/11/01 21:29:37 INFO org.apache.hadoop.yarn.client.ConfiguredRMFailoverProxyProvider: Failing over to rm2
22/11/01 21:29:39 INFO org.apache.hadoop.conf.Configuration: resource-types.xml not found
22/11/01 21:29:39 INFO org.apache.hadoop.yarn.util.resource.ResourceUtils: Unable to find 'resource-types.xml'.
22/11/01 21:29:40 INFO org.apache.hadoop.yarn.client.api.impl.YarnClientImpl: Submitted application application_1667337547764_0002
22/11/01 21:29:41 INFO org.apache.hadoop.yarn.client.ConfiguredRMFailoverProxyProvider: Failing over to rm1
22/11/01 21:29:41 INFO org.apache.hadoop.io.retry.RetryInvocationHandler: java.net.ConnectException: Call From cluster-5854-m-0/10.128.0.18 to cluster-5854-m-1.
us-central1-b.c.new-cs570.internal.:8030 failed on connection exception: java.net.ConnectException: Connection refused; For more details see:  http://wiki.apach
e.org/hadoop/ConnectionRefused, while invoking ApplicationMasterProtocolPBClientImpl.registerApplicationMaster over rm1 after 1 failover attempts. Trying to fai
lover after sleeping for 693ms.
22/11/01 21:29:41 INFO org.apache.hadoop.yarn.client.ConfiguredRMFailoverProxyProvider: Failing over to rm2
22/11/01 21:29:43 INFO com.google.cloud.hadoop.repackaged.gcs.com.google.cloud.hadoop.gcsio.GoogleCloudStorageImpl: Ignoring exception of type GoogleJsonRespons
eException; verified object already exists with desired state.
C has rank: 1.4249999999999998.
A has rank: 1.0.
B has rank: 0.575.
22/11/01 21:29:56 INFO org.sparkproject.jetty.server.AbstractConnector: Stopped Spark@24e81266{HTTP/1.1, (http/1.1)}{0.0.0.0:0}
nagorifatma1@cluster-5854-m-0:~$
```

TEST-PageRank_PySpark_GCP (10th-iteration)

```
22/11/01 21:31:39 INFO org.sparkproject.jetty.server.AbstractConnector: Stopped Spark@3babe07{HTTP/1.1, (http/1.1)}{0.0.0.0:0}
nagorifatma1@cluster-5854-m-0:~$ spark-submit pagerank.py hdfs:///mydata/pagerank_input.txt 10
WARN: This is a naive implementation of PageRank and is given as an example!
Please refer to PageRank implementation provided by graphx
22/11/01 21:32:13 INFO org.apache.spark.SparkEnv: Registering MapOutputTracker
22/11/01 21:32:13 INFO org.apache.spark.SparkEnv: Registering BlockManagerMaster
22/11/01 21:32:13 INFO org.apache.spark.SparkEnv: Registering BlockManagerMasterHeartbeat
22/11/01 21:32:13 INFO org.apache.spark.SparkEnv: Registering OutputCommitCoordinator
22/11/01 21:32:13 INFO org.sparkproject.jetty.util.log: Logging initialized @3781ms to org.sparkproject.jetty.util.log.Slf4jLog
22/11/01 21:32:13 INFO org.sparkproject.jetty.server.Server: jetty-9.4.40.v20210413; built: 2021-04-13T20:42:42.668Z; git: b881a572662e1943a14ae12e7e1207989f218
b74; jvm 1.8.0_345-b01
22/11/01 21:32:13 INFO org.sparkproject.jetty.server.Server: Started @3932ms
22/11/01 21:32:13 INFO org.sparkproject.jetty.server.AbstractConnector: Started ServerConnector@ab57f85{HTTP/1.1, (http/1.1)}{0.0.0.0:42679}
22/11/01 21:32:14 INFO org.apache.hadoop.yarn.client.AHSProxy: Connecting to Application History server at cluster-5854-m-0.us-central1-b.c.new-cs570.internal./
10.128.0.18:10200
22/11/01 21:32:14 INFO org.apache.hadoop.yarn.client.ConfiguredRMFailoverProxyProvider: Failing over to rm1
22/11/01 21:32:14 INFO org.apache.hadoop.io.retry.RetryInvocationHandler: java.net.ConnectException: Call From cluster-5854-m-0/10.128.0.18 to cluster-5854-m-1.
us-central1-b.c.new-cs570.internal.:8032 failed on connection exception: java.net.ConnectException: Connection refused; For more details see:  http://wiki.apach
e.org/hadoop/ConnectionRefused, while invoking ApplicationClientProtocolPBClientImpl.getNewApplication over rm1 after 1 failover attempts. Trying to failover af
ter sleeping for 1312ms.
22/11/01 21:32:16 INFO org.apache.hadoop.yarn.client.ConfiguredRMFailoverProxyProvider: Failing over to rm2
22/11/01 21:32:17 INFO org.apache.hadoop.conf.Configuration: resource-types.xml not found
22/11/01 21:32:17 INFO org.apache.hadoop.yarn.util.resource.ResourceUtils: Unable to find 'resource-types.xml'.
22/11/01 21:32:18 INFO org.apache.hadoop.yarn.client.api.impl.YarnClientImpl: Submitted application application_1667337547764_0004
22/11/01 21:32:19 INFO org.apache.hadoop.yarn.client.ConfiguredRMFailoverProxyProvider: Failing over to rm1
22/11/01 21:32:19 INFO org.apache.hadoop.io.retry.RetryInvocationHandler: java.net.ConnectException: Call From cluster-5854-m-0/10.128.0.18 to cluster-5854-m-1.
us-central1-b.c.new-cs570.internal.:8030 failed on connection exception: java.net.ConnectException: Connection refused; For more details see:  http://wiki.apach
e.org/hadoop/ConnectionRefused, while invoking ApplicationMasterProtocolPBClientImpl.registerApplicationMaster over rm1 after 1 failover attempts. Trying to fai
lover after sleeping for 1249ms.
22/11/01 21:32:20 INFO org.apache.hadoop.yarn.client.ConfiguredRMFailoverProxyProvider: Failing over to rm2
22/11/01 21:32:22 INFO com.google.cloud.hadoop.repackaged.gcs.com.google.cloud.hadoop.gcsio.GoogleCloudStorageImpl: Ignoring exception of type GoogleJsonRespons
eException; verified object already exists with desired state.
A has rank: 1.1667391764027368.
B has rank: 0.6432494117885129.
C has rank: 1.1900114118087488.
22/11/01 21:32:37 INFO org.sparkproject.jetty.server.AbstractConnector: Stopped Spark@ab57f85{HTTP/1.1, (http/1.1)}{0.0.0.0:0}
nagorifatma1@cluster-5854-m-0:~$
```

Implementation-PageRank_Scala_GCP

SETUP Scala Environment at GCP

- Create a Cloud Storage bucket
- Create a Dataproc cluster
- Connecting to the Master Node using Secure Shell (ssh)
- install scala

- $ export SCALA_HOME=/usr/local/share/scala
- $ export PATH=$PATH:$SCALA_HOME/

Scala program:

- 1.Prepare data: vi pagerank_data.txt
- 2.create a directory (folder) to store the data:
  - hdfs dfs -mkdir hdfs:///mydata
  - hdfs dfs -put pagerank_data.txt hdfs:///mydata
  - hdfs dfs -ls hdfs:///mydata
- spark-shell

Launch Scala on GCP

```
fnagori@cluster-0386-m:~$ export PATH=$PATH:$SCALA_HOME/
fnagori@cluster-0386-m:~$ scala
Welcome to Scala 2.12.14 (OpenJDK 64-Bit Server VM, Java 1.8.0_332).
Type in expressions for evaluation. Or try :help.
```

Implementation-PageRank_Scala_GCP

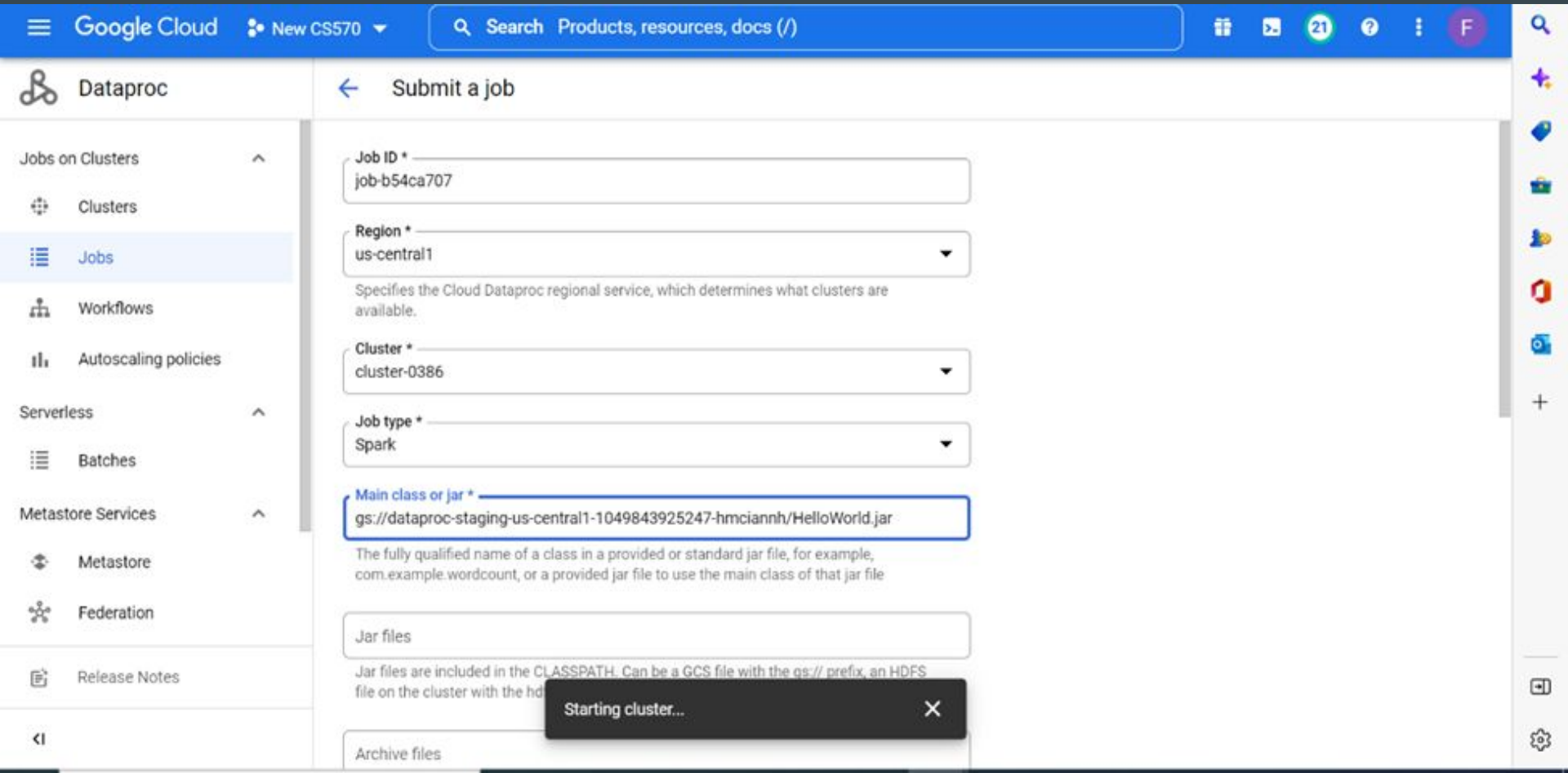
COMMANDS:

```
val lines = sc.textFile("hdfs:///mydata/pagerank_data.txt")

val links = lines.map{ s =>
   val parts = s.split("\\s+")
   (parts(0), parts(1))
}.distinct().groupByKey().cache()

var ranks = links.mapValues(v => 1.0)

for (i <- 1 to 10) {
   val contribs = links.join(ranks).values.flatMap{ case (urls, rank) =>
   val size = urls.size
   urls.map(url => (url, rank / size))
   }

   ranks = contribs.reduceByKey(_ + _).mapValues(0.15 + 0.85 * _)
}
val output = ranks.collect()
output.foreach(tup => println(tup._1 + " has rank: " + tup._2 + "."))

ctx.stop()
```

INPUT FILE FORMAT

A B
A C
B C
C A

SUBMIT JOB AT GCP



TEST-PageRank_Scala_GCP (1ST iteration)

```
scala> for (i <- 1 to 10) {
         val contribs = links.join(ranks).values.flatMap{ case (urls, rank) =>
         val size = urls.size
         urls.map(url => (url, rank / size))
         }
         ranks = contribs.reduceByKey(_ + _).mapValues(0.15 + 0.85 * _)

       }

scala> for (i <- 1 to 1) {
         val contribs = links.join(ranks).values.flatMap{ case (urls, rank) =>
         val size = urls.size
         urls.map(url => (url, rank / size))
         }
         ranks = contribs.reduceByKey(_ + _).mapValues(0.15 + 0.85 * _)
       }

scala>

scala> val output = ranks.collect()
output: Array[(String, Double)] = Array((B,0.644434510492888), (A,1.1633753188067952), (C,1.1921901707003153))

scala> output.foreach(tup => println(tup._1 + " has rank: " + tup._2 + "."))
B has rank: 0.644434510492888.
A has rank: 1.1633753188067952.
C has rank: 1.1921901707003153.
```

TEST-PageRank_Scala_GCP (2nd iteration)

```
scala>

scala> val output = ranks.collect()
output: Array[(String, Double)] = Array((B,0.644434510492888), (A,1.1633753188067952), (C,1.1921901707003153))

scala> output.foreach(tup => println(tup._1 + " has rank: " + tup._2 + "."))
B has rank: 0.644434510492888.
A has rank: 1.1633753188067952.
C has rank: 1.1921901707003153.

scala> for (i <- 1 to 2) {
     |     val contribs = links.join(ranks).values.flatMap{ case (urls, rank) =>
     |     val size = urls.size
     |     urls.map(url => (url, rank / size))
     |     }
     |     ranks = contribs.reduceByKey(_ + _).mapValues(0.15 + 0.85 * _)
     | }

scala>

scala> val output = ranks.collect()
output: Array[(String, Double)] = Array((B,0.6444286991654888), (A,1.163373267750066), (C,1.1921980330844435))

scala>  output.foreach(tup => println(tup._1 + " has rank: " + tup._2 + "."))
B has rank: 0.6444286991654888.
A has rank: 1.163373267750066.
C has rank: 1.1921980330844435.
```

TEST-PageRank_Scala_GCP (10 iteration)

```
scala> val lines = sc.textFile("hdfs:///mydata/pagerank_input.txt")
lines: org.apache.spark.rdd.RDD[String] = hdfs:///mydata/pagerank_input.txt MapPartitionsRDD[1] at textFile at <console>:23

scala> val links = lines.map{ s =>
     |     val parts = s.split("\\s+")
     |     (parts(0), parts(1))
     | }.distinct().groupByKey().cache()
links: org.apache.spark.rdd.RDD[(String, Iterable[String])] = ShuffledRDD[6] at groupByKey at <console>:26

scala>

scala> var ranks = links.mapValues(v => 1.0)
ranks: org.apache.spark.rdd.RDD[(String, Double)] = MapPartitionsRDD[7] at mapValues at <console>:23

scala>

scala> for (i <- 1 to 10) {
     |     val contribs = links.join(ranks).values.flatMap{ case (urls, rank) =>
     |     val size = urls.size
     |     urls.map(url => (url, rank / size))
     |     }
     |     ranks = contribs.reduceByKey(_ + _).mapValues(0.15 + 0.85 * _)
     | }

scala> val output = ranks.collect()
[Stage 0:>                                                          (0 + 2)[Stage 1:>                                                          (0 + 2)
                                                                    output: Array[(String, Double)] = Array((B,0.6432494117885129), (A,1.1667391764027368), (C,1.19
00114118087488))

scala> output.foreach(tup => println(tup._1 + " has rank: " + tup._2 + "."))
B has rank: 0.6432494117885129.
A has rank: 1.1667391764027368.
C has rank: 1.1900114118087488.
```

Enhancement Ideas

1. Performance
2. Simplicity
3. Concurrency
4. Type Safety
5. Productivity and Ease of Use
6. Advanced Features

CONCLUSION:

Both the program results for Scala and Python was same like manual result.

From a more personal point of view, I consider PySpark easier to learn and read, however for production Scala is a much "prettier" programming language. For this reason, many people program in PySpark and when all the code is validated, they go to production in Scala.

REFERENCES

PAGE RANK EXAMPLES

SCALA AT GCP

PYTHON AT GCP

EXAMPLES OF THEORY


THANK
YOU