Calculating Pi using MapReduce and PySpark

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Agenda

- Introduction to Pi
- Design
- Implementation using MapReduce
- Test
- Enhancement
- Implementation using PySpark
- Conclusion
- References

Process

01

Prepare Input File

Write a Java program to generate numbers of random pairs of point(x,y) with given radius

02

Code for MapReduce

Write MapReduce program in Java Language to count number of points inside and outside of the circle with given radius

03

Execute Mapreduce on GCP

Using the input file to run MapReduce program

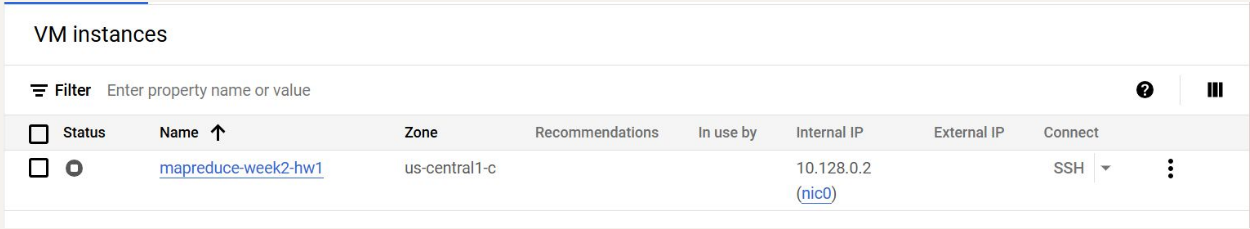
04

Calculate Pi

Write Java Program to calculate pi value using the output from step 3

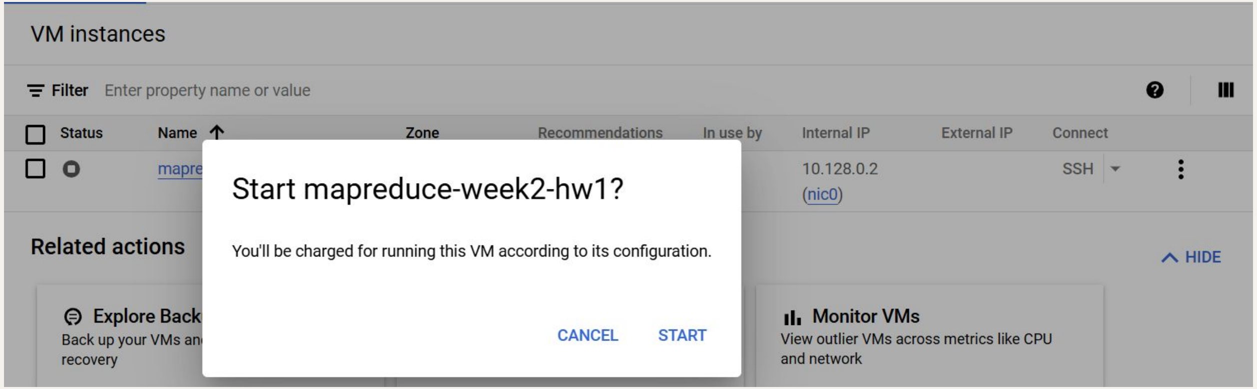
Setup

- Create a Ubuntu VM instance on Google Cloud Platform



VM instances

□	Status	Name ↑	Zone	Recommendations	In use by	Internal IP	External IP	Connect
□	⊙	mapreduce-week2-hw1	us-central1-c			10.128.0.2 (nic0)		SSH ▾ ⋮



VM instances

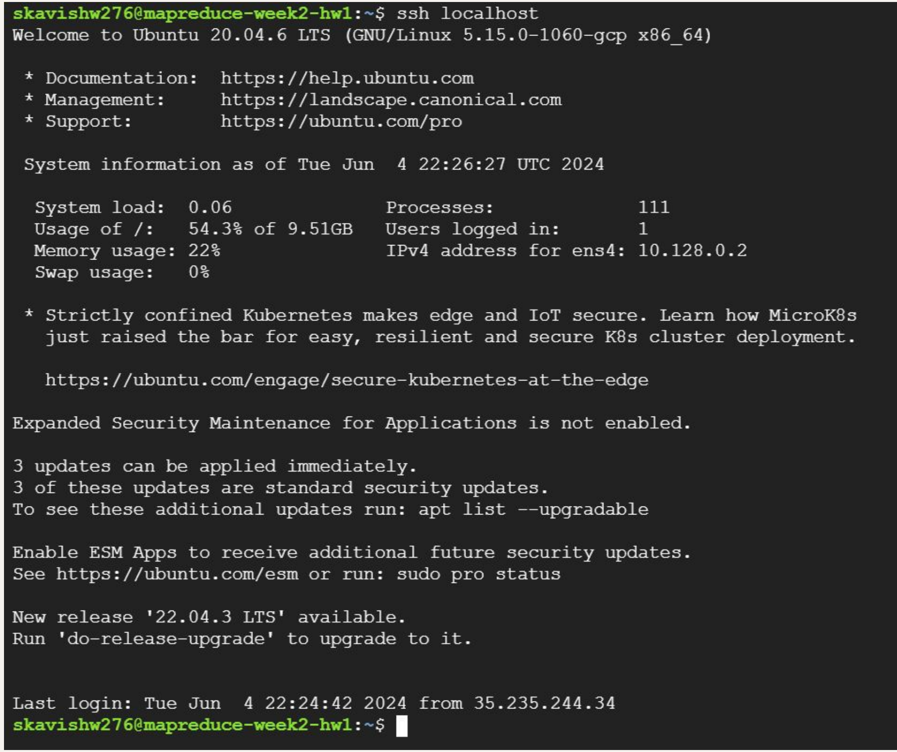
□	Status	Name ↑	Zone	Recommendations	In use by	Internal IP	External IP	Connect
□	⊙	mapre				10.128.0.2 (nic0)		SSH ▾ ⋮

Start mapreduce-week2-hw1?

You'll be charged for running this VM according to its configuration.

Setup

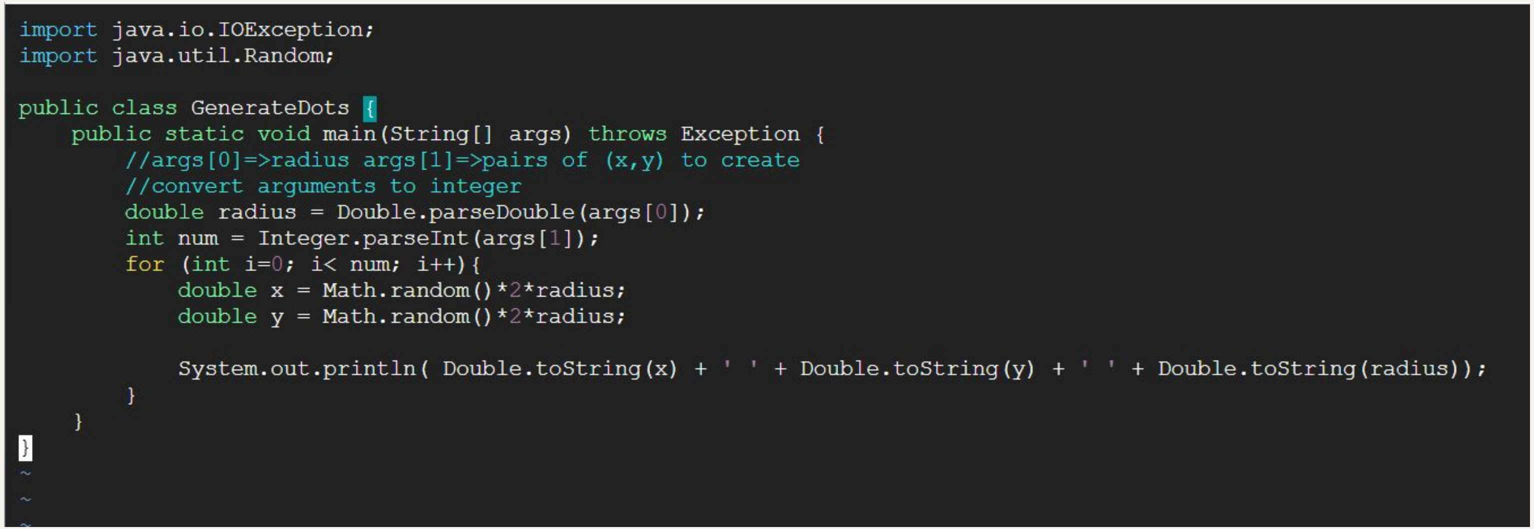
- Connect VM through SSH
- Connect to the localhost after the instance is up and running..



```
skavishw276@mapreduce-week2-hw1:~$ ssh localhost
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-1060-gcp x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/pro

 System information as of Tue Jun  4 22:26:27 UTC 2024

  System load:  0.06               Processes:             111
  Usage of /:   54.3% of 9.51GB    Users logged in:       1
  Memory usage: 22%                IPv4 address for ens4: 10.128.0.2
  Swap usage:   0%

 * Strictly confined Kubernetes makes edge and IoT secure. Learn how MicroK8s
   just raised the bar for easy, resilient and secure K8s cluster deployment.

   https://ubuntu.com/engage/secure-kubernetes-at-the-edge

Expanded Security Maintenance for Applications is not enabled.

3 updates can be applied immediately.
3 of these updates are standard security updates.
To see these additional updates run: apt list --upgradable

Enable ESM Apps to receive additional future security updates.
See https://ubuntu.com/esm or run: sudo pro status

New release '22.04.3 LTS' available.
Run 'do-release-upgrade' to upgrade to it.


Last login: Tue Jun  4 22:24:42 2024 from 35.235.244.34
skavishw276@mapreduce-week2-hw1:~$ 
```

Setup

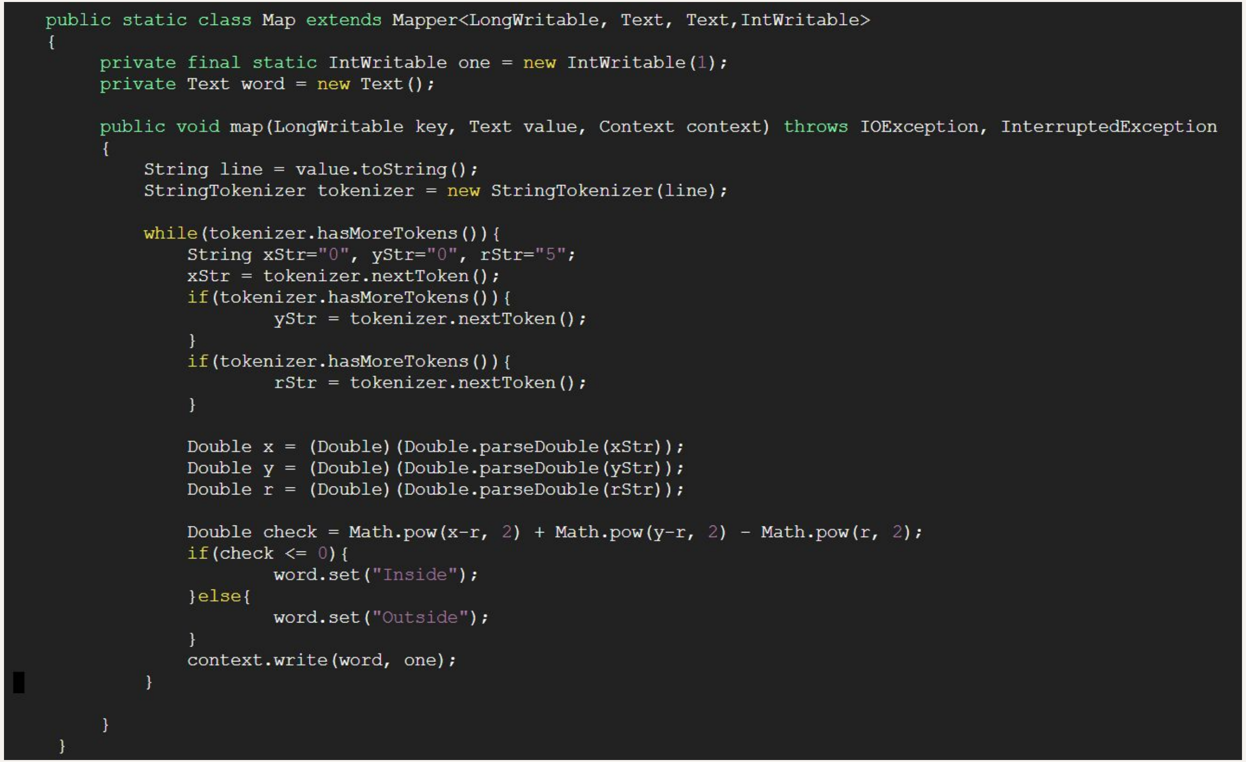
- Code to generate random dot pairs with command line argument taken in as radius and number of pairs. Output will be x y radius



```
import java.io.IOException;
import java.util.Random;

public class GenerateDots {
    public static void main(String[] args) throws Exception {
        //args[0]=>radius args[1]=>pairs of (x,y) to create
        //convert arguments to integer
        double radius = Double.parseDouble(args[0]);
        int num = Integer.parseInt(args[1]);
        for (int i=0; i< num; i++){
            double x = Math.random()*2*radius;
            double y = Math.random()*2*radius;

            System.out.println( Double.toString(x) + ' ' + Double.toString(y) + ' ' + Double.toString(radius));
        }
    }
}
~
~
~
```

Setup

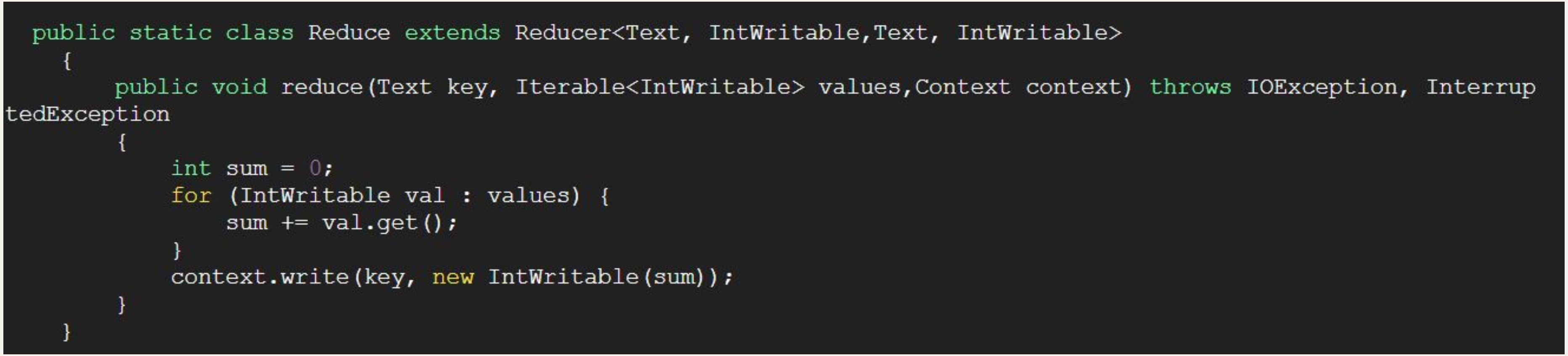
- Map() for MapReduce



```
public static class Map extends Mapper<LongWritable, Text, Text,IntWritable>
{
     private final static IntWritable one = new IntWritable(1);
     private Text word = new Text();

     public void map(LongWritable key, Text value, Context context) throws IOException, InterruptedException
     {
         String line = value.toString();
         StringTokenizer tokenizer = new StringTokenizer(line);

         while(tokenizer.hasMoreTokens()){
             String xStr="0", yStr="0", rStr="5";
             xStr = tokenizer.nextToken();
             if(tokenizer.hasMoreTokens()){
                     yStr = tokenizer.nextToken();
             }
             if(tokenizer.hasMoreTokens()){
                     rStr = tokenizer.nextToken();
             }

             Double x = (Double)(Double.parseDouble(xStr));
             Double y = (Double)(Double.parseDouble(yStr));
             Double r = (Double)(Double.parseDouble(rStr));

             Double check = Math.pow(x-r, 2) + Math.pow(y-r, 2) - Math.pow(r, 2);
             if(check <= 0){
                     word.set("Inside");
             }else{
                     word.set("Outside");
             }
             context.write(word, one);
         }

     }
 }
```

Setup

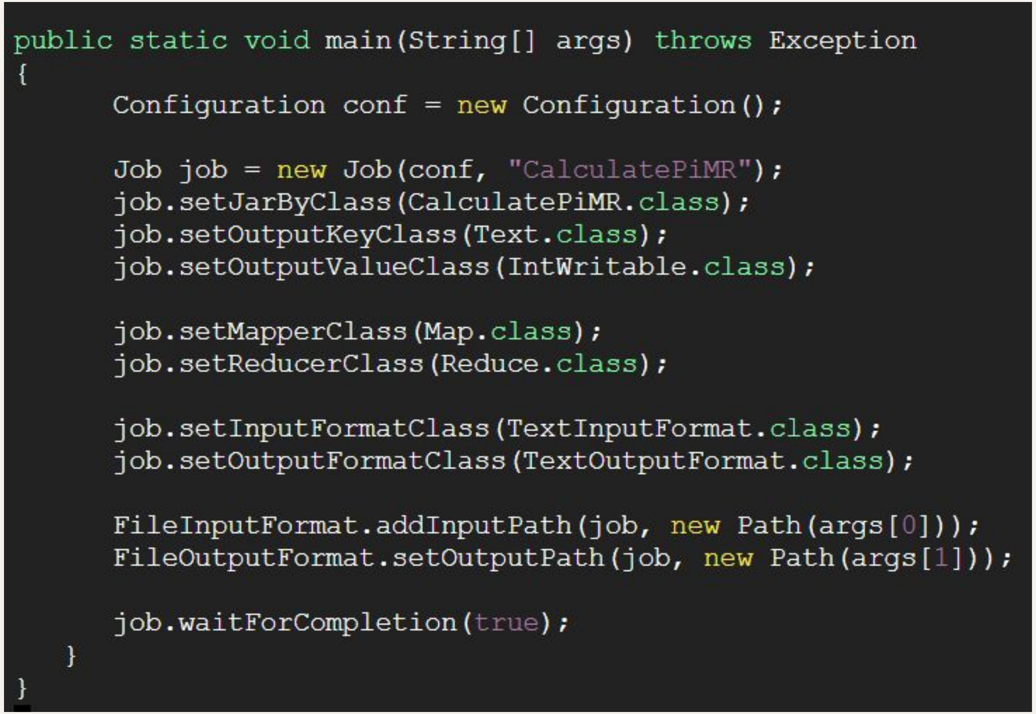
- Reduce() for MapReduce



```
  public static class Reduce extends Reducer<Text, IntWritable,Text, IntWritable>
    {
        public void reduce(Text key, Iterable<IntWritable> values,Context context) throws IOException, Interrup
tedException
        {
            int sum = 0;
            for (IntWritable val : values) {
                sum += val.get();
            }
            context.write(key, new IntWritable(sum));
        }
    }
```

Setup

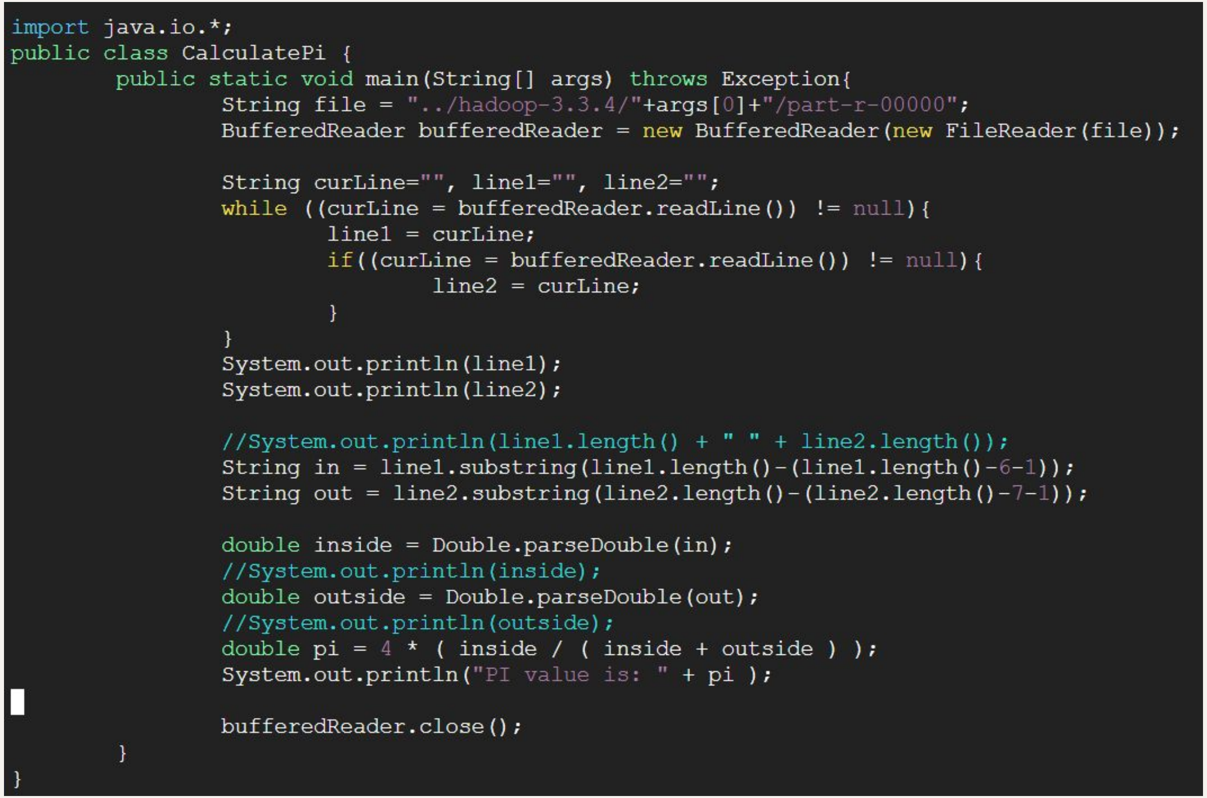
- main() for MapReduce



```
public static void main(String[] args) throws Exception
{
      Configuration conf = new Configuration();

      Job job = new Job(conf, "CalculatePiMR");
      job.setJarByClass(CalculatePiMR.class);
      job.setOutputKeyClass(Text.class);
      job.setOutputValueClass(IntWritable.class);

      job.setMapperClass(Map.class);
      job.setReducerClass(Reduce.class);

      job.setInputFormatClass(TextInputFormat.class);
      job.setOutputFormatClass(TextOutputFormat.class);

      FileInputFormat.addInputPath(job, new Path(args[0]));
      FileOutputFormat.setOutputPath(job, new Path(args[1]));

      job.waitForCompletion(true);
   }
}
```

Setup

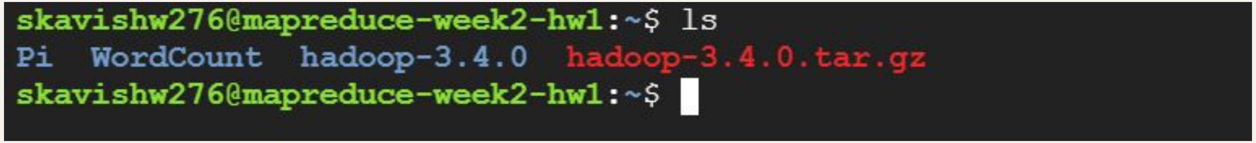
- Java code to calculate pi value with MapReduce result taken in by reading the file



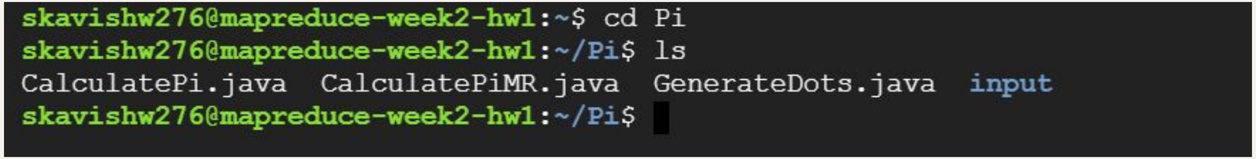
```java
import java.io.*;
public class CalculatePi {
        public static void main(String[] args) throws Exception{
                String file = "../hadoop-3.3.4/"+args[0]+"/part-r-00000";
                BufferedReader bufferedReader = new BufferedReader(new FileReader(file));

                String curLine="", line1="", line2="";
                while ((curLine = bufferedReader.readLine()) != null){
                        line1 = curLine;
                        if((curLine = bufferedReader.readLine()) != null){
                                line2 = curLine;
                        }
                }
                System.out.println(line1);
                System.out.println(line2);

                //System.out.println(line1.length() + " " + line2.length());
                String in = line1.substring(line1.length()-(line1.length()-6-1));
                String out = line2.substring(line2.length()-(line2.length()-7-1));

                double inside = Double.parseDouble(in);
                //System.out.println(inside);
                double outside = Double.parseDouble(out);
                //System.out.println(outside);
                double pi = 4 * ( inside / ( inside + outside ) );
                System.out.println("PI value is: " + pi );

                bufferedReader.close();
        }
}
```

Code Structure

Pi Directory and content of the Pi directory with the input file and code files created



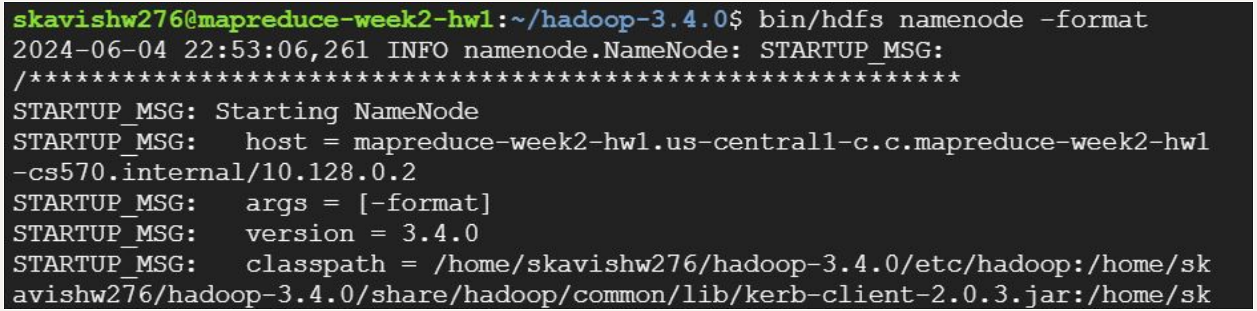
```
skavishw276@mapreduce-week2-hwl:~$ ls
Pi  WordCount  hadoop-3.4.0  hadoop-3.4.0.tar.gz
skavishw276@mapreduce-week2-hwl:~$ 
```



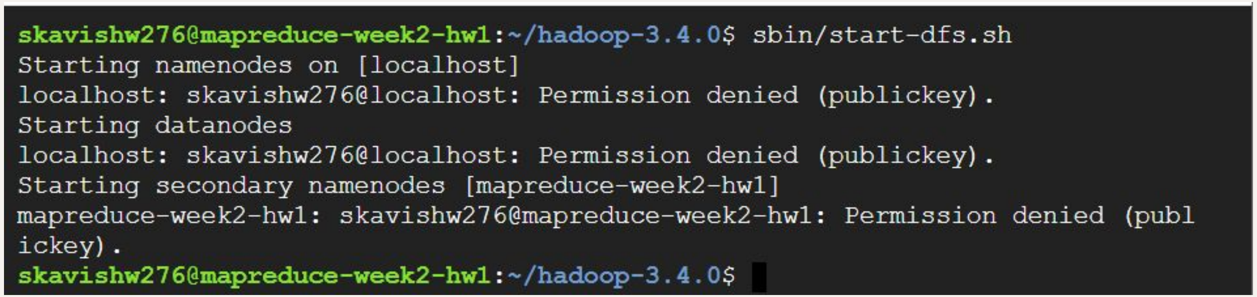
```
skavishw276@mapreduce-week2-hwl:~$ cd Pi
skavishw276@mapreduce-week2-hwl:~/Pi$ ls
CalculatePi.java  CalculatePiMR.java  GenerateDots.java  input
skavishw276@mapreduce-week2-hwl:~/Pi$ 
```

Test

Start the Cluster and start the namenode and datanode services



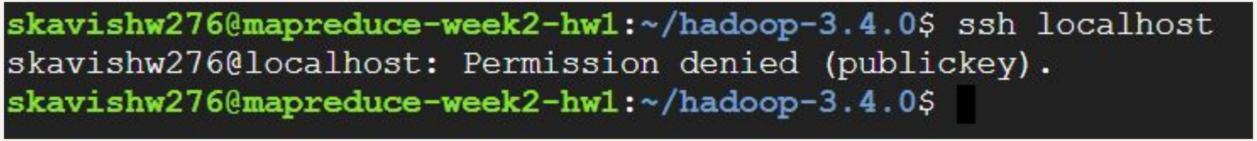
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs namenode -format
2024-06-04 22:53:06,261 INFO namenode.NameNode: STARTUP_MSG:
/*************************************************************
STARTUP_MSG: Starting NameNode
STARTUP_MSG:   host = mapreduce-week2-hw1.us-central1-c.c.mapreduce-week2-hw1
-cs570.internal/10.128.0.2
STARTUP_MSG:   args = [-format]
STARTUP_MSG:   version = 3.4.0
STARTUP_MSG:   classpath = /home/skavishw276/hadoop-3.4.0/etc/hadoop:/home/sk
avishw276/hadoop-3.4.0/share/hadoop/common/lib/kerb-client-2.0.3.jar:/home/sk
```



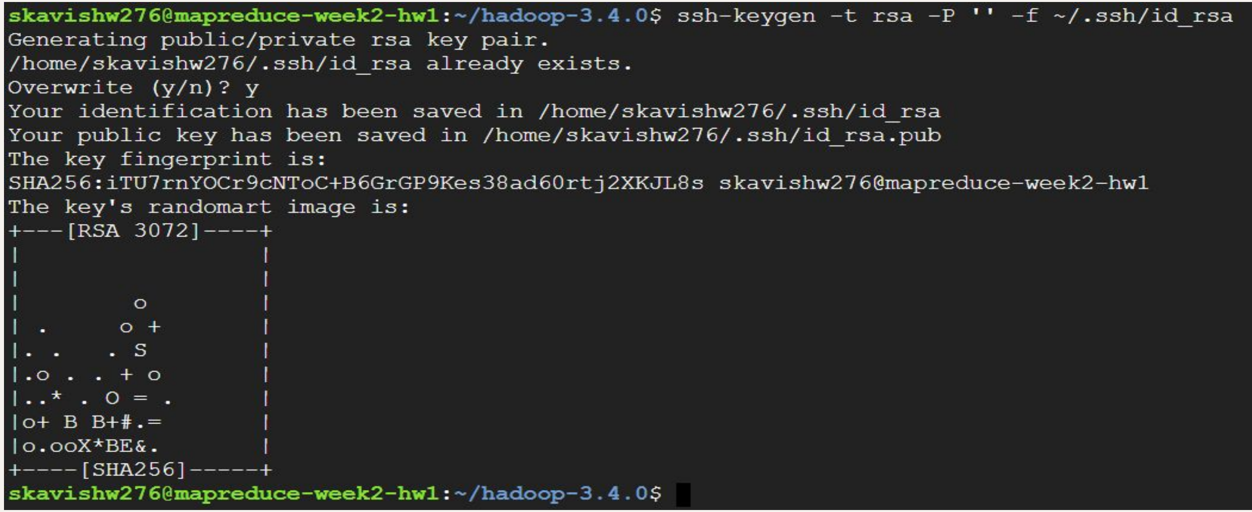
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ sbin/start-dfs.sh
Starting namenodes on [localhost]
localhost: skavishw276@localhost: Permission denied (publickey).
Starting datanodes
localhost: skavishw276@localhost: Permission denied (publickey).
Starting secondary namenodes [mapreduce-week2-hw1]
mapreduce-week2-hw1: skavishw276@mapreduce-week2-hw1: Permission denied (publ
ickey).
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```

Test

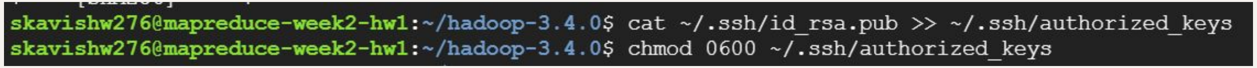
Permission denied error ssh to localhost again



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ ssh localhost
skavishw276@localhost: Permission denied (publickey).
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```



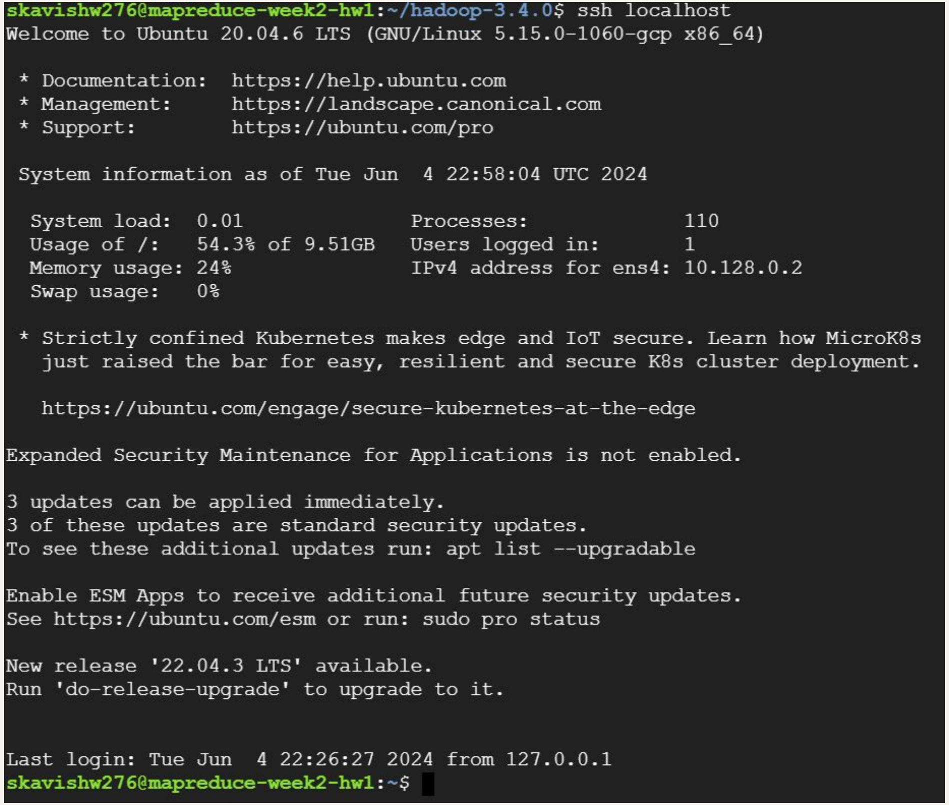
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ ssh-keygen -t rsa -P '' -f ~/.ssh/id_rsa
Generating public/private rsa key pair.
/home/skavishw276/.ssh/id_rsa already exists.
Overwrite (y/n)? y
Your identification has been saved in /home/skavishw276/.ssh/id_rsa
Your public key has been saved in /home/skavishw276/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:iTU7rnYOCr9cNToC+B6GrGP9Kes38ad60rtj2XKJL8s skavishw276@mapreduce-week2-hw1
The key's randomart image is:
+---[RSA 3072]----+
|                 |
|                 |
|        o        |
| .      o +      |
|. .    . S       |
|.o . . + o       |
|..* . O = .      |
|o+ B B+#.=       |
|o.ooX*BE&.       |
+----[SHA256]-----+
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ chmod 0600 ~/.ssh/authorized_keys
```

Test

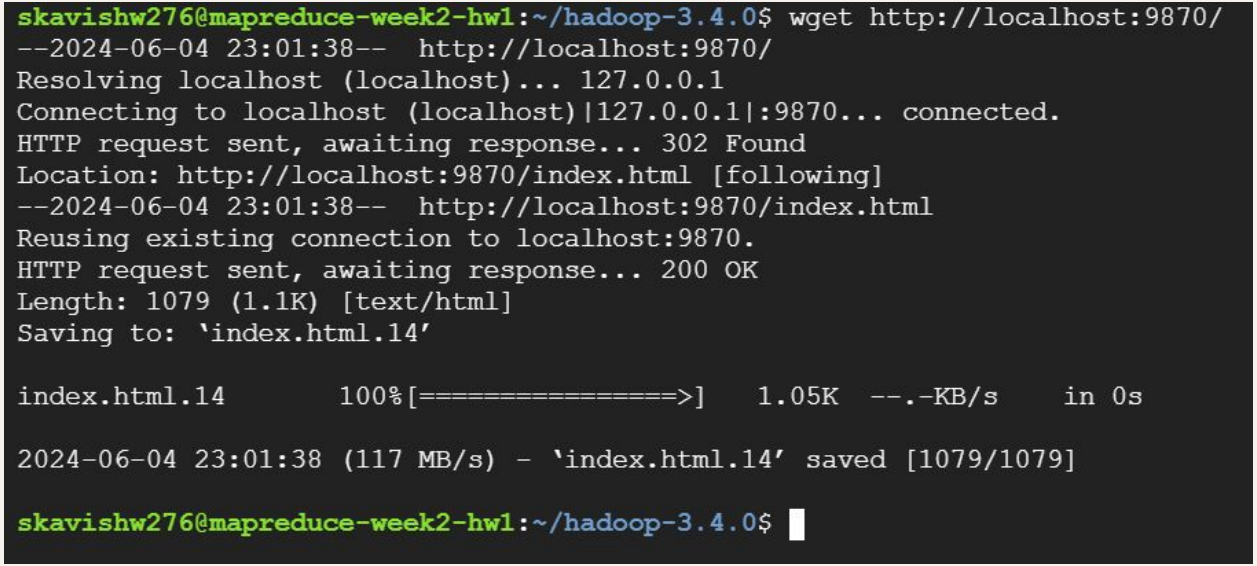
- Connect to the localhost it should work now



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ ssh localhost
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-1060-gcp x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/pro

 System information as of Tue Jun  4 22:58:04 UTC 2024

  System load:  0.01               Processes:             110
  Usage of /:   54.3% of 9.51GB    Users logged in:       1
  Memory usage: 24%                IPv4 address for ens4: 10.128.0.2
  Swap usage:   0%

 * Strictly confined Kubernetes makes edge and IoT secure. Learn how MicroK8s
   just raised the bar for easy, resilient and secure K8s cluster deployment.

   https://ubuntu.com/engage/secure-kubernetes-at-the-edge

Expanded Security Maintenance for Applications is not enabled.

3 updates can be applied immediately.
3 of these updates are standard security updates.
To see these additional updates run: apt list --upgradable

Enable ESM Apps to receive additional future security updates.
See https://ubuntu.com/esm or run: sudo pro status

New release '22.04.3 LTS' available.
Run 'do-release-upgrade' to upgrade to it.


Last login: Tue Jun  4 22:26:27 2024 from 127.0.0.1
skavishw276@mapreduce-week2-hw1:~$ 
```

Test

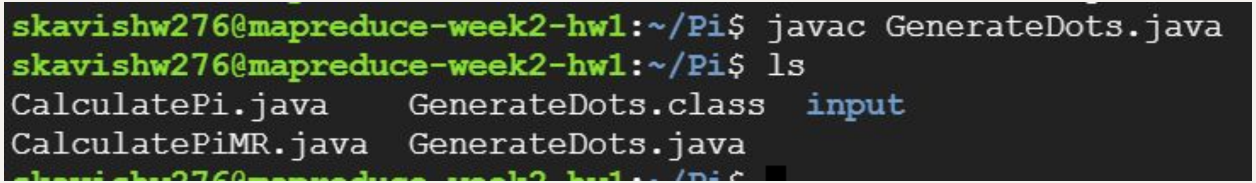
- Continue to start the cluster and start the services. Test connection with localhost.



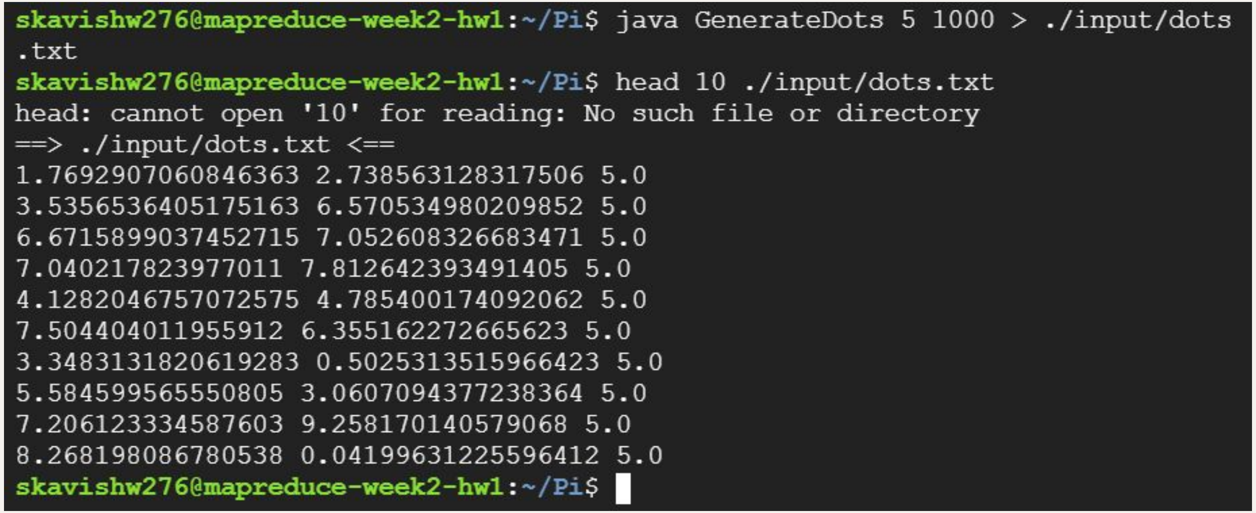
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ wget http://localhost:9870/
--2024-06-04 23:01:38--  http://localhost:9870/
Resolving localhost (localhost)... 127.0.0.1
Connecting to localhost (localhost)|127.0.0.1|:9870... connected.
HTTP request sent, awaiting response... 302 Found
Location: http://localhost:9870/index.html [following]
--2024-06-04 23:01:38--  http://localhost:9870/index.html
Reusing existing connection to localhost:9870.
HTTP request sent, awaiting response... 200 OK
Length: 1079 (1.1K) [text/html]
Saving to: ‘index.html.14’

index.html.14       100%[================>]   1.05K  --.-KB/s    in 0s

2024-06-04 23:01:38 (117 MB/s) - ‘index.html.14’ saved [1079/1079]

skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ 
```

Test

- Compile the GenerateDots.java
- Run the java code with radius 5 and 1000 random numbers



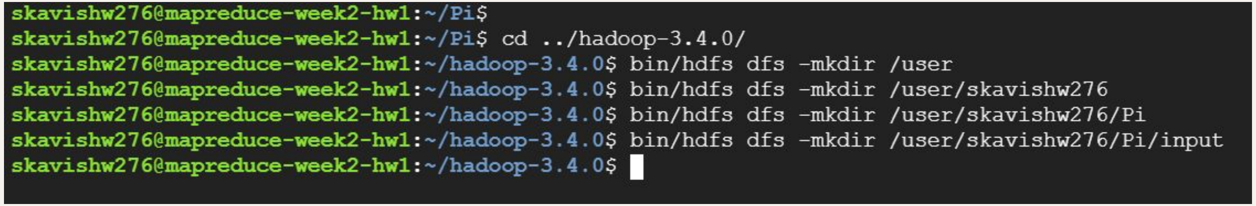
```
skavishw276@mapreduce-week2-hw1:~/Pi$ javac GenerateDots.java
skavishw276@mapreduce-week2-hw1:~/Pi$ ls
CalculatePi.java    GenerateDots.class  input
CalculatePiMR.java  GenerateDots.java
skavishw276@mapreduce-week2-hw1:~/Pi$
```



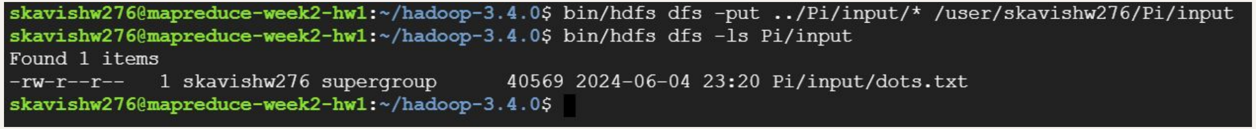
```
skavishw276@mapreduce-week2-hw1:~/Pi$ java GenerateDots 5 1000 > ./input/dots
.txt
skavishw276@mapreduce-week2-hw1:~/Pi$ head 10 ./input/dots.txt
head: cannot open '10' for reading: No such file or directory
==> ./input/dots.txt <==
1.7692907060846363 2.738563128317506 5.0
3.5356536405175163 6.570534980209852 5.0
6.6715899037452715 7.052608326683471 5.0
7.040217823977011 7.812642393491405 5.0
4.1282046757072575 4.785400174092062 5.0
7.504404011955912 6.355162272665623 5.0
3.3483131820619283 0.5025313515966423 5.0
5.584599565550805 3.0607094377238364 5.0
7.206123334587603 9.258170140579068 5.0
8.268198086780538 0.04199631225596412 5.0
skavishw276@mapreduce-week2-hw1:~/Pi$
```

Test

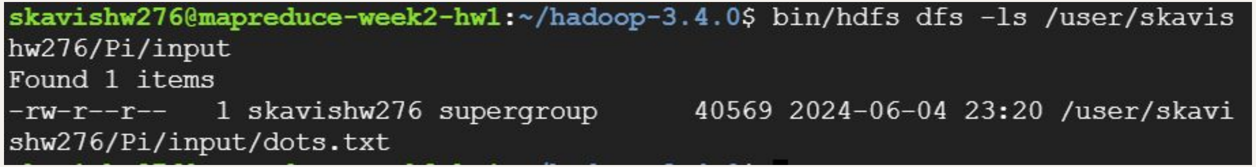
- Create following directories
- Copy file from local machine to hadoop
- Compile in hadoop



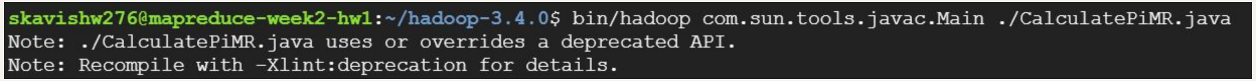
```
skavishw276@mapreduce-week2-hw1:~/Pi$
skavishw276@mapreduce-week2-hw1:~/Pi$ cd ../hadoop-3.4.0/
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -mkdir /user
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -mkdir /user/skavishw276
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -mkdir /user/skavishw276/Pi
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -mkdir /user/skavishw276/Pi/input
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -put ../Pi/input/* /user/skavishw276/Pi/input
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -ls Pi/input
Found 1 items
-rw-r--r--   1 skavishw276 supergroup      40569 2024-06-04 23:20 Pi/input/dots.txt
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```



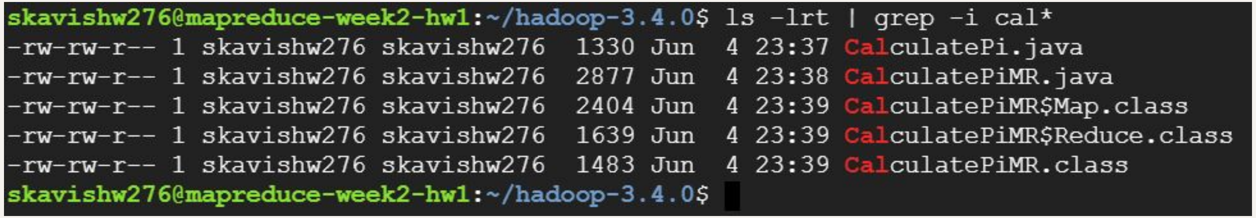
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -ls /user/skavis
hw276/Pi/input
Found 1 items
-rw-r--r--   1 skavishw276 supergroup      40569 2024-06-04 23:20 /user/skavi
shw276/Pi/input/dots.txt
```



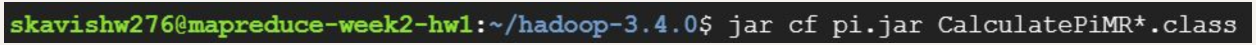
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hadoop com.sun.tools.javac.Main ./CalculatePiMR.java
Note: ./CalculatePiMR.java uses or overrides a deprecated API.
Note: Recompile with -Xlint:deprecation for details.
```

Test

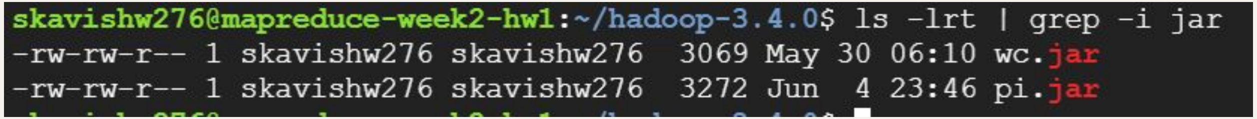
- Maper and reduce files are created after compiling



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ ls -lrt | grep -i cal*
-rw-rw-r-- 1 skavishw276 skavishw276  1330 Jun  4 23:37 CalculatePi.java
-rw-rw-r-- 1 skavishw276 skavishw276  2877 Jun  4 23:38 CalculatePiMR.java
-rw-rw-r-- 1 skavishw276 skavishw276  2404 Jun  4 23:39 CalculatePiMR$Map.class
-rw-rw-r-- 1 skavishw276 skavishw276  1639 Jun  4 23:39 CalculatePiMR$Reduce.class
-rw-rw-r-- 1 skavishw276 skavishw276  1483 Jun  4 23:39 CalculatePiMR.class
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```



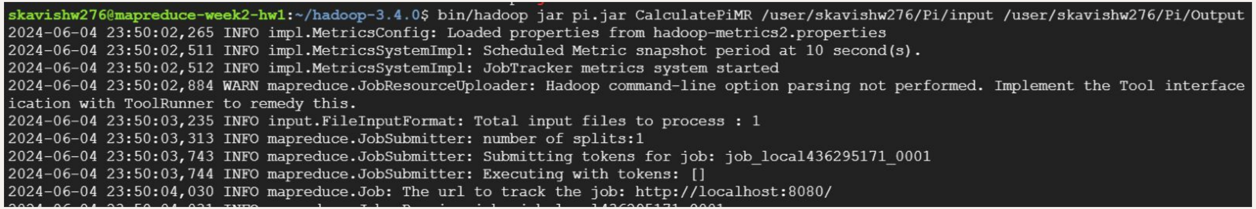
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ jar cf pi.jar CalculatePiMR*.class
```



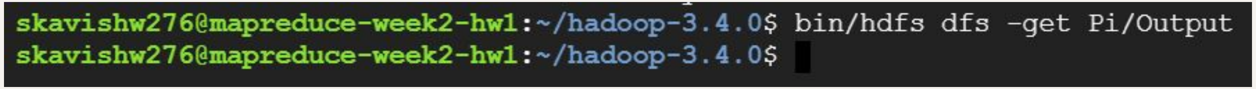
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ ls -lrt | grep -i jar
-rw-rw-r-- 1 skavishw276 skavishw276  3069 May 30 06:10 wc.jar
-rw-rw-r-- 1 skavishw276 skavishw276  3272 Jun  4 23:46 pi.jar
```

Test

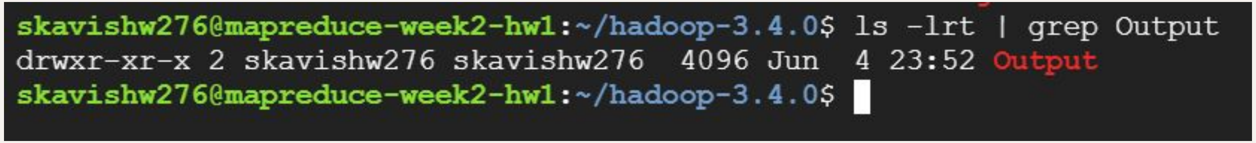
- Run MapReduce program with input file and save the output file
- Get command on hdfs filesystem to get the output and save the file to local machine



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hadoop jar pi.jar CalculatePiMR /user/skavishw276/Pi/input /user/skavishw276/Pi/Output
2024-06-04 23:50:02,265 INFO impl.MetricsConfig: Loaded properties from hadoop-metrics2.properties
2024-06-04 23:50:02,511 INFO impl.MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
2024-06-04 23:50:02,512 INFO impl.MetricsSystemImpl: JobTracker metrics system started
2024-06-04 23:50:02,884 WARN mapreduce.JobResourceUploader: Hadoop command-line option parsing not performed. Implement the Tool interface
ication with ToolRunner to remedy this.
2024-06-04 23:50:03,235 INFO input.FileInputFormat: Total input files to process : 1
2024-06-04 23:50:03,313 INFO mapreduce.JobSubmitter: number of splits:1
2024-06-04 23:50:03,743 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_local436295171_0001
2024-06-04 23:50:03,744 INFO mapreduce.JobSubmitter: Executing with tokens: []
2024-06-04 23:50:04,030 INFO mapreduce.Job: The url to track the job: http://localhost:8080/
```



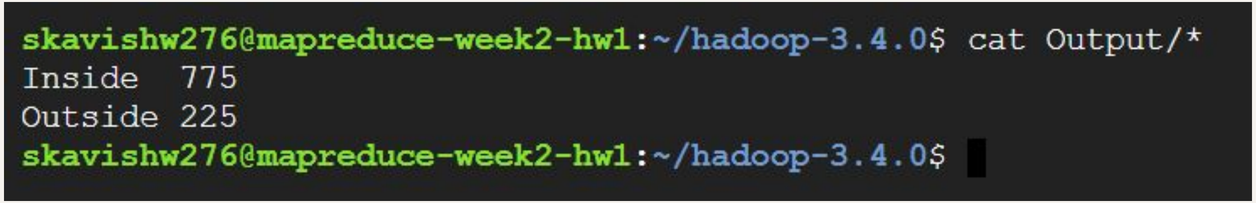
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -get Pi/Output
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ ls -lrt | grep Output
drwxr-xr-x 2 skavishw276 skavishw276  4096 Jun  4 23:52 Output
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```

Test

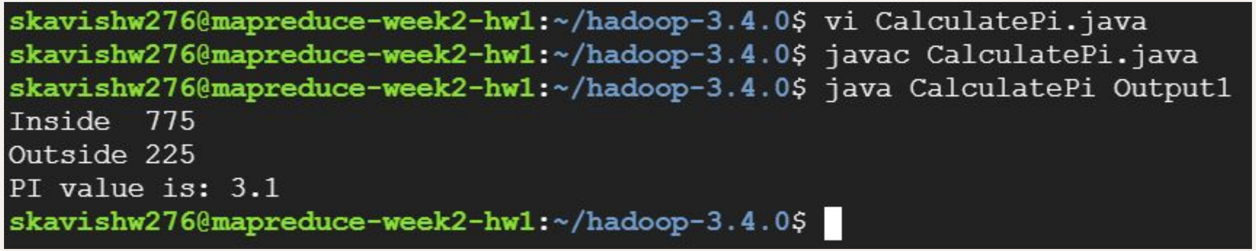
- Number of inside and outside points



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ cat Output/*
Inside  775
Outside 225
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ 
```

Result

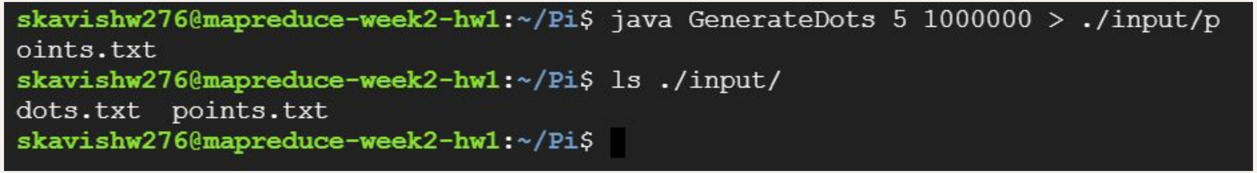
- Number of inside and outside points
- The value of Pi = 3.1 which is pretty close to the actual value of Pi



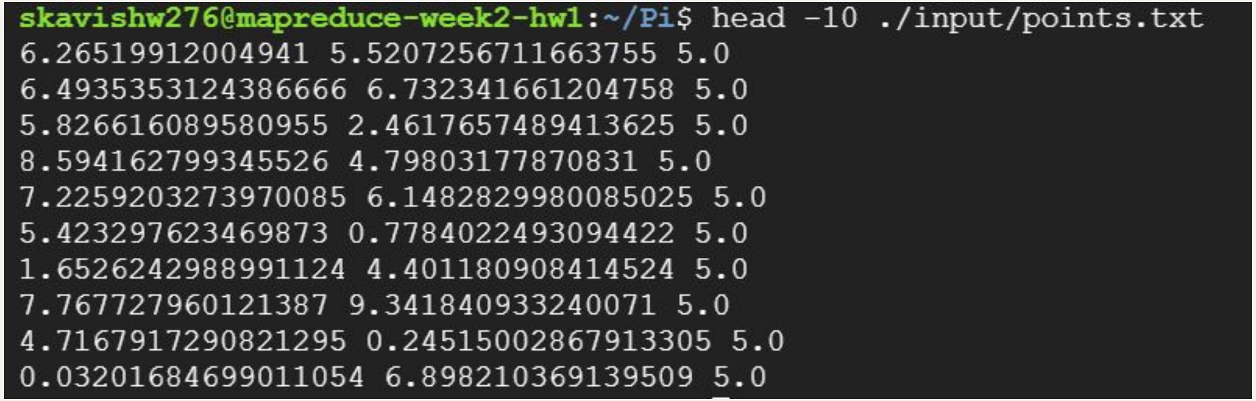
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ vi CalculatePi.java
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ javac CalculatePi.java
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ java CalculatePi Output1
Inside  775
Outside 225
PI value is: 3.1
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```

Enhanced Result

- Increase the number of dots to 1000000. As we increase the number of dots the accuracy tends to increase.



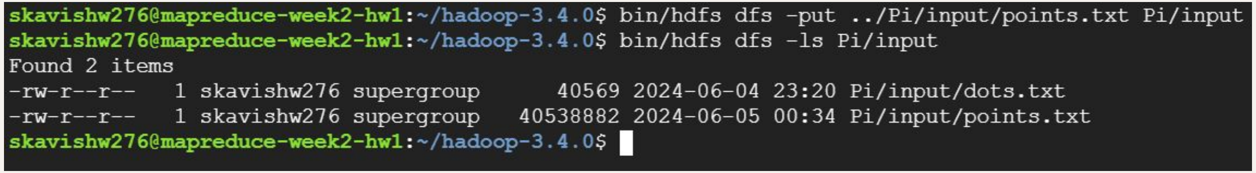
```
skavishw276@mapreduce-week2-hw1:~/Pi$ java GenerateDots 5 1000000 > ./input/p
oints.txt
skavishw276@mapreduce-week2-hw1:~/Pi$ ls ./input/
dots.txt  points.txt
skavishw276@mapreduce-week2-hw1:~/Pi$ 
```



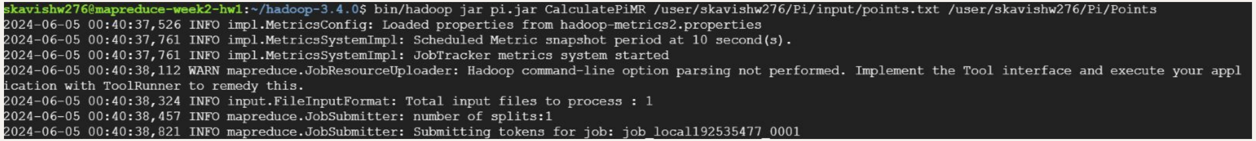
```
skavishw276@mapreduce-week2-hw1:~/Pi$ head -10 ./input/points.txt
6.26519912004941 5.5207256711663755 5.0
6.4935353124386666 6.732341661204758 5.0
5.826616089580955 2.4617657489413625 5.0
8.594162799345526 4.79803177870831 5.0
7.2259203273970085 6.1482829980085025 5.0
5.423297623469873 0.7784022493094422 5.0
1.6526242988991124 4.401180908414524 5.0
7.767727960121387 9.341840933240071 5.0
4.7167917290821295 0.24515002867913305 5.0
0.03201684699011054 6.898210369139509 5.0
```

Enhanced Result

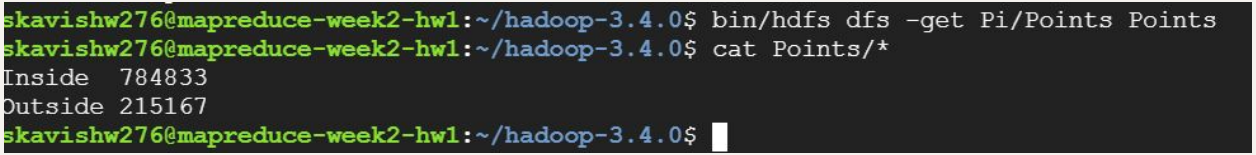
- Copy points input file to hdfs



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -put ../Pi/input/points.txt Pi/input
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -ls Pi/input
Found 2 items
-rw-r--r--   1 skavishw276 supergroup      40569 2024-06-04 23:20 Pi/input/dots.txt
-rw-r--r--   1 skavishw276 supergroup   40538882 2024-06-05 00:34 Pi/input/points.txt
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```



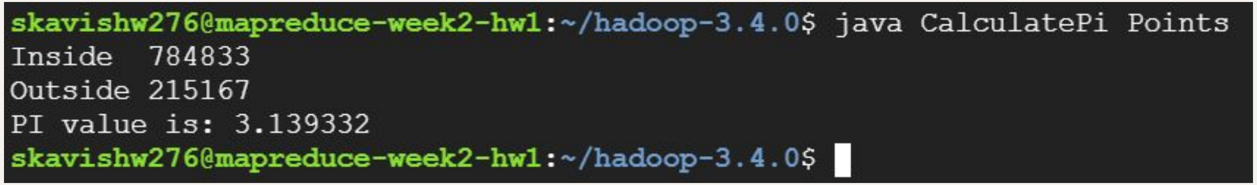
```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hadoop jar pi.jar CalculatePiMR /user/skavishw276/Pi/input/points.txt /user/skavishw276/Pi/Points
2024-06-05 00:40:37,526 INFO impl.MetricsConfig: Loaded properties from hadoop-metrics2.properties
2024-06-05 00:40:37,761 INFO impl.MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
2024-06-05 00:40:37,761 INFO impl.MetricsSystemImpl: JobTracker metrics system started
2024-06-05 00:40:38,112 WARN mapreduce.JobResourceUploader: Hadoop command-line option parsing not performed. Implement the Tool interface and execute your appl
ication with ToolRunner to remedy this.
2024-06-05 00:40:38,324 INFO input.FileInputFormat: Total input files to process : 1
2024-06-05 00:40:38,457 INFO mapreduce.JobSubmitter: number of splits:1
2024-06-05 00:40:38,821 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_local192535477_0001
```



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ bin/hdfs dfs -get Pi/Points Points
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ cat Points/*
Inside  784833
Outside 215167
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```

Final Result

- The value of Pi = 3.139332 when the generated dots were 1M.



```
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$ java CalculatePi Points
Inside  784833
Outside 215167
PI value is: 3.139332
skavishw276@mapreduce-week2-hw1:~/hadoop-3.4.0$
```

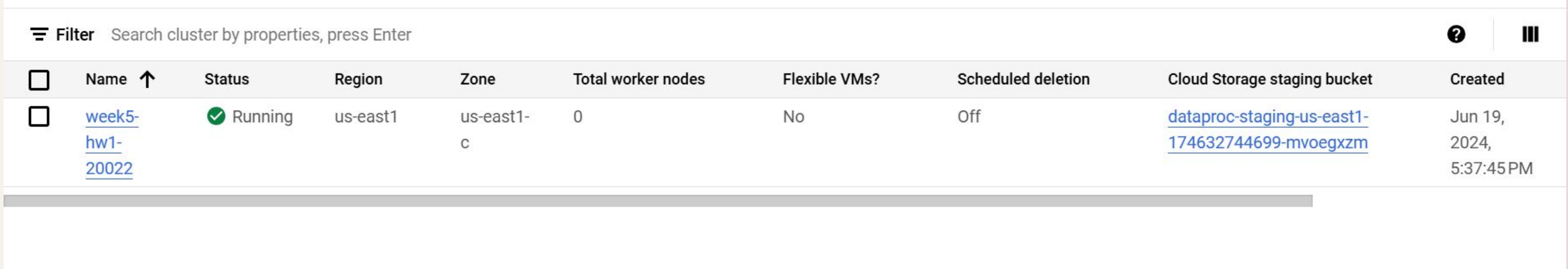
Conclusion

- The accuracy of value of Pi increases as the number of generated points increases.

Implementation Using PySpark

Setup

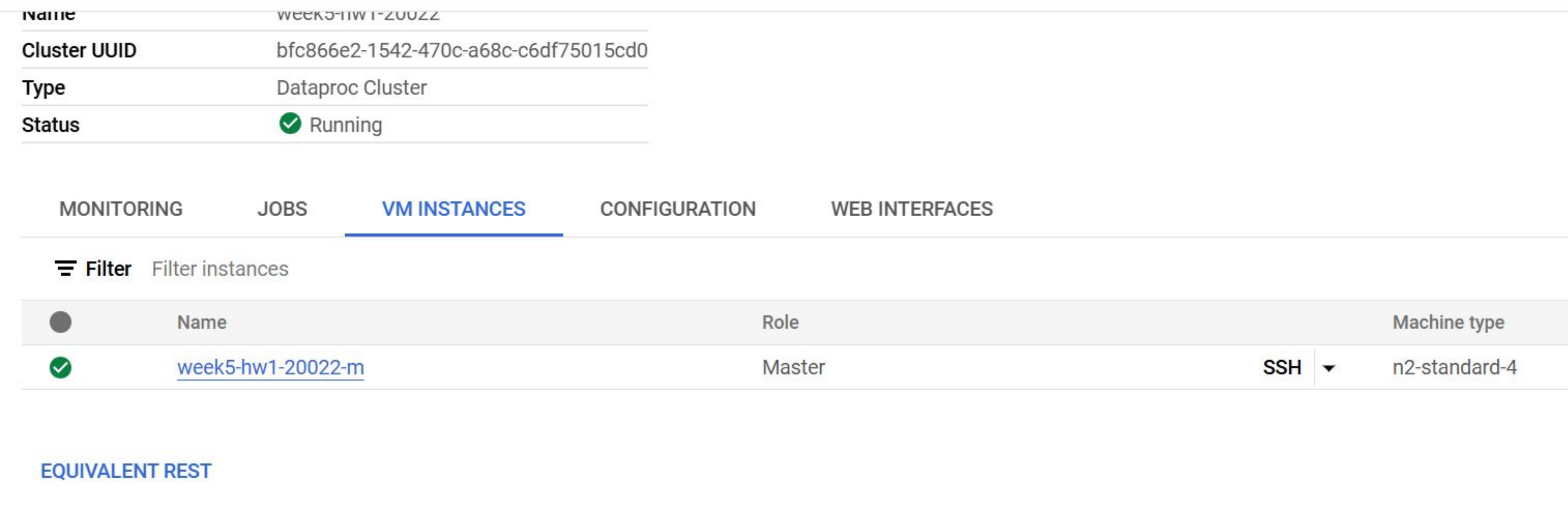
- Create a DataProc Cluster in your GCP console



☐	Name ↑	Status	Region	Zone	Total worker nodes	Flexible VMs?	Scheduled deletion	Cloud Storage staging bucket	Created
☐	week5-hw1-20022	✓ Running	us-east1	us-east1-c	0	No	Off	dataproc-staging-us-east1-174632744699-mvoegxzm	Jun 19, 2024, 5:37:45 PM

Setup

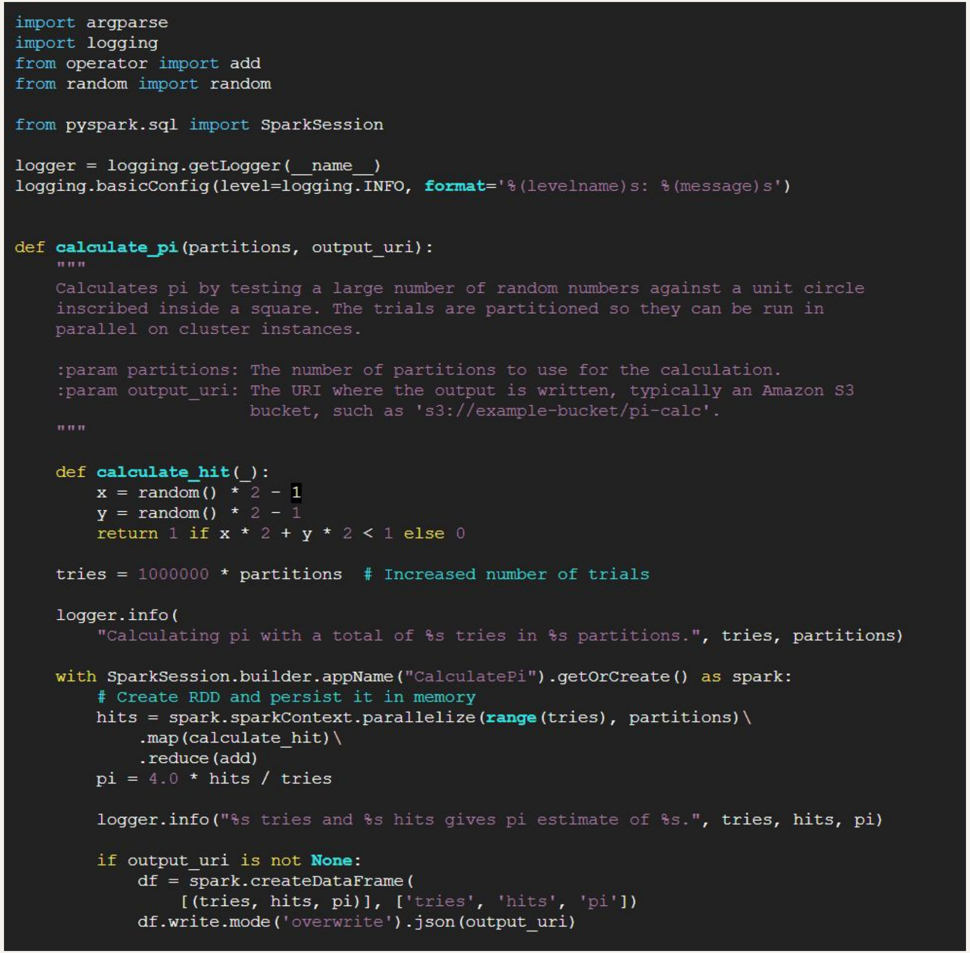
- Find the Master Node in the VM instances in the created DataProc cluster
- SSH to the VM instance



Name	week5-hw1-20022
Cluster UUID	bfc866e2-1542-470c-a68c-c6df75015cd0
Type	Dataproc Cluster
Status	✓ Running

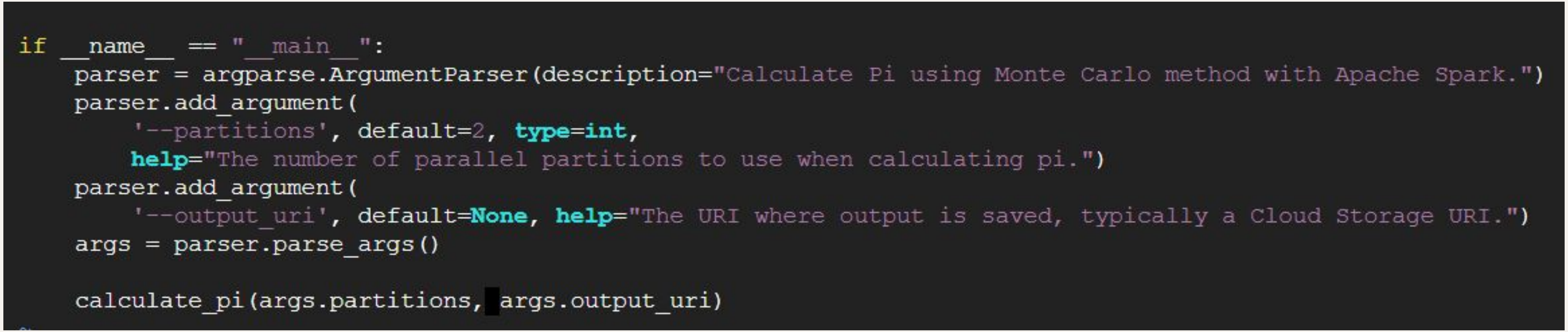
●	Name	Role		Machine type
✓	week5-hw1-20022-m	Master	SSH ▾	n2-standard-4

Code Structure



```
import argparse
import logging
from operator import add
from random import random

from pyspark.sql import SparkSession

logger = logging.getLogger(__name__)
logging.basicConfig(level=logging.INFO, format='%(levelname)s: %(message)s')


def calculate_pi(partitions, output_uri):
    """
    Calculates pi by testing a large number of random numbers against a unit circle
    inscribed inside a square. The trials are partitioned so they can be run in
    parallel on cluster instances.

    :param partitions: The number of partitions to use for the calculation.
    :param output_uri: The URI where the output is written, typically an Amazon S3
                       bucket, such as 's3://example-bucket/pi-calc'.
    """

    def calculate_hit(_):
        x = random() * 2 - 1
        y = random() * 2 - 1
        return 1 if x * 2 + y * 2 < 1 else 0

    tries = 1000000 * partitions  # Increased number of trials

    logger.info(
        "Calculating pi with a total of %s tries in %s partitions.", tries, partitions)

    with SparkSession.builder.appName("CalculatePi").getOrCreate() as spark:
        # Create RDD and persist it in memory
        hits = spark.sparkContext.parallelize(range(tries), partitions)\
            .map(calculate_hit)\
            .reduce(add)
        pi = 4.0 * hits / tries

        logger.info("%s tries and %s hits gives pi estimate of %s.", tries, hits, pi)

        if output_uri is not None:
            df = spark.createDataFrame(
                [(tries, hits, pi)], ['tries', 'hits', 'pi'])
            df.write.mode('overwrite').json(output_uri)
```

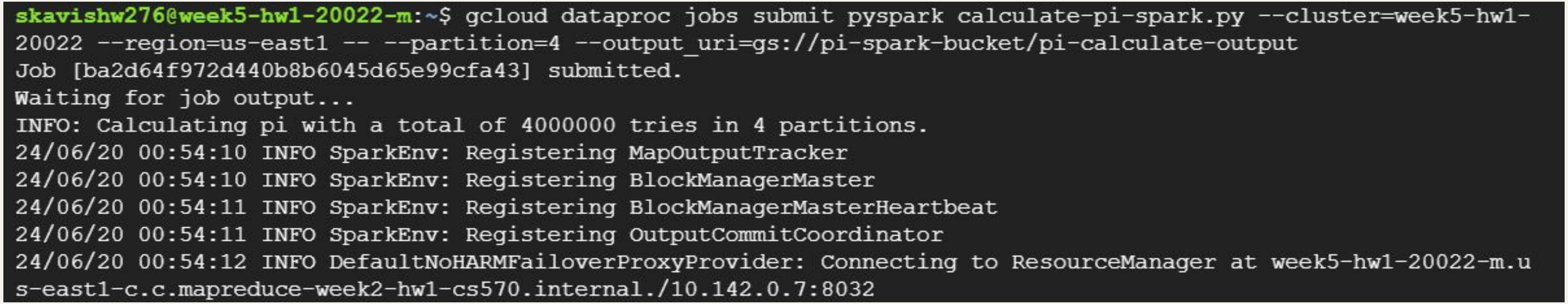
Code Structure



```python
if __name__ == "__main__":
    parser = argparse.ArgumentParser(description="Calculate Pi using Monte Carlo method with Apache Spark.")
    parser.add_argument(
        '--partitions', default=2, type=int,
        help="The number of parallel partitions to use when calculating pi.")
    parser.add_argument(
        '--output_uri', default=None, help="The URI where output is saved, typically a Cloud Storage URI.")
    args = parser.parse_args()

    calculate_pi(args.partitions, args.output_uri)
```

Test

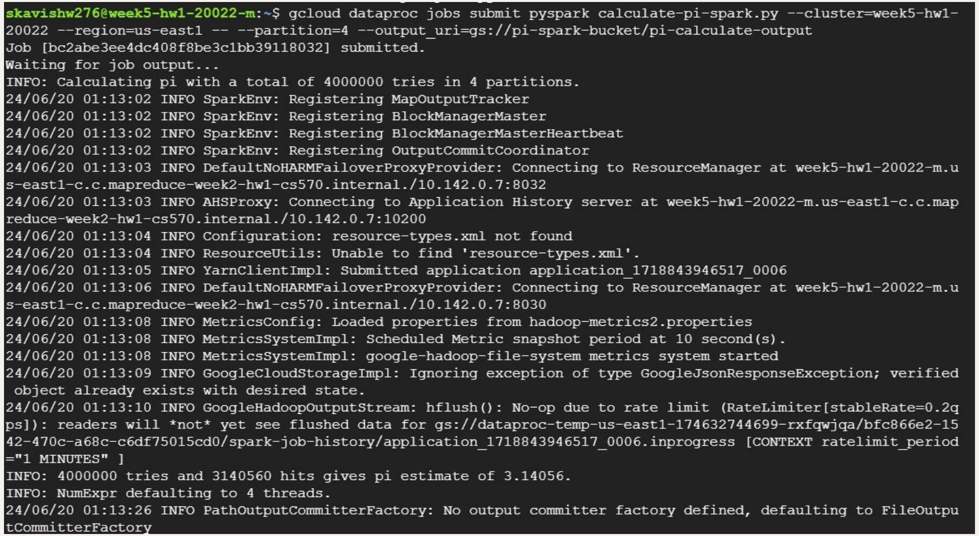
- $ gcloud dataproc jobs submit pyspark calculate-pi-spark.py --cluster=week5-hw1-20022 --region=us-east1 -- --partition=4 --output_uri=gs://pi-spark-bucket/pi-calculate-output



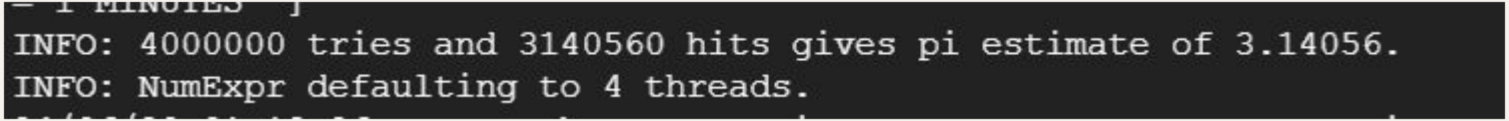
```
skavishw276@week5-hw1-20022-m:~$ gcloud dataproc jobs submit pyspark calculate-pi-spark.py --cluster=week5-hw1-
20022 --region=us-east1 -- --partition=4 --output_uri=gs://pi-spark-bucket/pi-calculate-output
Job [ba2d64f972d440b8b6045d65e99cfa43] submitted.
Waiting for job output...
INFO: Calculating pi with a total of 4000000 tries in 4 partitions.
24/06/20 00:54:10 INFO SparkEnv: Registering MapOutputTracker
24/06/20 00:54:10 INFO SparkEnv: Registering BlockManagerMaster
24/06/20 00:54:11 INFO SparkEnv: Registering BlockManagerMasterHeartbeat
24/06/20 00:54:11 INFO SparkEnv: Registering OutputCommitCoordinator
24/06/20 00:54:12 INFO DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at week5-hw1-20022-m.u
s-east1-c.c.mapreduce-week2-hw1-cs570.internal./10.142.0.7:8032
```

Result

- The Pi value is 3.14056 in 4000000 attempts to determine if the point falls inside a unit circle



```
skavishw276@week5-hw1-20022-m:~$ gcloud dataproc jobs submit pyspark calculate-pi-spark.py --cluster=week5-hw1-
20022 --region=us-east1 -- --partition=4 --output_uri=gs://pi-spark-bucket/pi-calculate-output
Job [bc2abe3ee4dc408f8be3c1bb39118032] submitted.
Waiting for job output...
INFO: Calculating pi with a total of 4000000 tries in 4 partitions.
24/06/20 01:13:02 INFO SparkEnv: Registering MapOutputTracker
24/06/20 01:13:02 INFO SparkEnv: Registering BlockManagerMaster
24/06/20 01:13:02 INFO SparkEnv: Registering BlockManagerMasterHeartbeat
24/06/20 01:13:02 INFO SparkEnv: Registering OutputCommitCoordinator
24/06/20 01:13:03 INFO DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at week5-hw1-20022-m.u
s-east1-c.c.mapreduce-week2-hw1-cs570.internal./10.142.0.7:8032
24/06/20 01:13:03 INFO AHSProxy: Connecting to Application History server at week5-hw1-20022-m.us-east1-c.c.map
reduce-week2-hw1-cs570.internal./10.142.0.7:10200
24/06/20 01:13:04 INFO Configuration: resource-types.xml not found
24/06/20 01:13:04 INFO ResourceUtils: Unable to find 'resource-types.xml'.
24/06/20 01:13:05 INFO YarnClientImpl: Submitted application application_1718843946517_0006
24/06/20 01:13:06 INFO DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at week5-hw1-20022-m.u
s-east1-c.c.mapreduce-week2-hw1-cs570.internal./10.142.0.7:8030
24/06/20 01:13:08 INFO MetricsConfig: Loaded properties from hadoop-metrics2.properties
24/06/20 01:13:08 INFO MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
24/06/20 01:13:08 INFO MetricsSystemImpl: google-hadoop-file-system metrics system started
24/06/20 01:13:09 INFO GoogleCloudStorageImpl: Ignoring exception of type GoogleJsonResponseException; verified
 object already exists with desired state.
24/06/20 01:13:10 INFO GoogleHadoopOutputStream: hflush(): No-op due to rate limit (RateLimiter[stableRate=0.2q
ps]): readers will *not* yet see flushed data for gs://dataproc-temp-us-east1-174632744699-rxfqwjqa/bfc866e2-15
42-470c-a68c-c6df75015cd0/spark-job-history/application_1718843946517_0006.inprogress [CONTEXT ratelimit_period
="1 MINUTES" ]
INFO: 4000000 tries and 3140560 hits gives pi estimate of 3.14056.
INFO: NumExpr defaulting to 4 threads.
24/06/20 01:13:26 INFO PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutpu
tCommitterFactory
```



```
INFO: 4000000 tries and 3140560 hits gives pi estimate of 3.14056.
INFO: NumExpr defaulting to 4 threads.
```

Conclusion

- With correctly set value of partition and the number of attempts to calculate if a point lies inside the circle the value of Pi can be calculated near to the actual value.