Calculating Pi - PySpark implementation

CS 570 Big Data Processing

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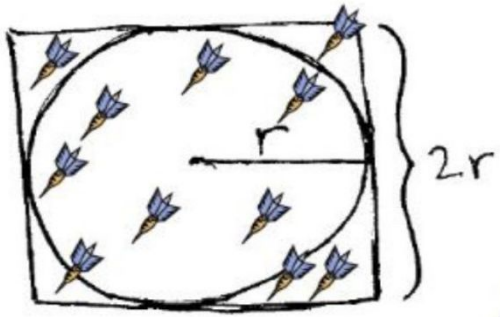
Introduction

- This project utilizes the Google Cloud Platform (GCP) to set up a distributed computing environment.
- Hadoop, an open-source framework, is employed to handle large data sets and perform parallel processing.
- MapReduce, a programming model within Hadoop, is used to efficiently process and generate large data sets.
- Implementation of Pi Calculation using PySpark
- The primary goal is to calculate the value of pi using these technologies.

Theory of Pi Calculation

- Throw N darts on the board. Each dart lands at a random position (x,y) on the board.
  - Note if each dart landed inside the circle or not
    - Check if $x^2+y^2<r$
  - Take the total number of darts that landed in the circle as S



$$4\left(\frac{S}{N}\right)=\pi$$

Formula:

4 * S / N = 4 * (pi * r * r) / (4 * r * r) = pi

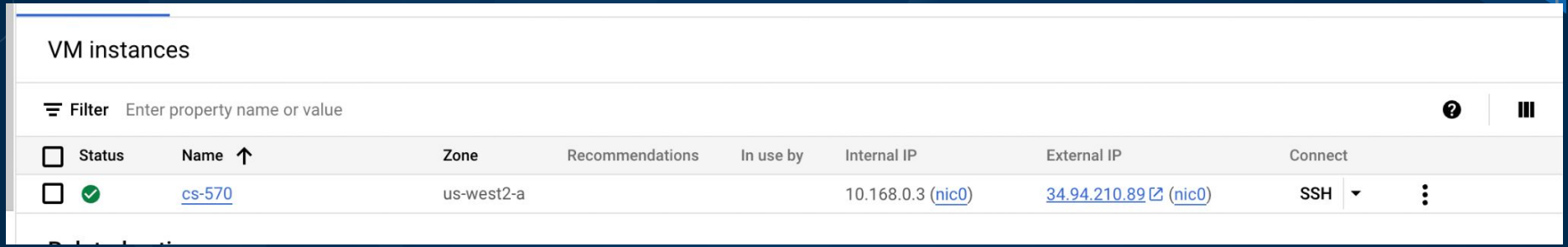
The value of pi can be determined by counting the number of random darts that land inside the circle compared to those that land outside the circle.

Design

Job: Pi										
Map Task								Reduce Task		
map()				combine()				reduce()		
Input (Given)		Output (Program)		Input (Given)		Output (Program)		Input (Given)		Output (Program)
Key	Value (radius=2)	Key	Value (radius=2)	Key	Values	Key	Value	Key	Values	
file1	(0, 1)	Outside	1	Inside	[1]	Inside	1	Inside	[1, 3, 1]	Inside 5
	(1, 3)	Inside	1	Outside	[1, 1]	Outside	2	Outside	[2, 1, 4]	Outside 7
	(4, 3)	Outside	1							
file2	(2, 3)	Inside	1	Inside	[1, 1, 1]	Inside	3			
	(1, 3)	Inside	1	Outside	[1]	Outside	1			
	(1, 4)	Outside	1							
	(3, 2)	Inside	1							
file3	(3, 0)	Outside	1	Inside	[1]	Inside	1			
	(3, 3)	Inside	1	Outside	[1, 1, 1, 1]	Outside	4			
	(3, 4)	Outside	1							
	(0, 0)	Outside	1							
	(4, 4)	Outside	1							

Implementation and Test

1 – Setting up an Ubuntu VM on Google Cloud



2. Hadoop: Setting up a Single Node Cluster

```
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs namenode -format
WARNING: /home/belsabelteklemariam/hadoop-3.4.0/logs does not exist. Creating.
2024-06-05 10:42:06,241 INFO namenode.NameNode: STARTUP_MSG:
/************************************************************
STARTUP_MSG: Starting NameNode
STARTUP_MSG:   host = cs-570/10.168.0.3
STARTUP_MSG:   args = [-format]
STARTUP_MSG:   version = 3.4.0
STARTUP_MSG:   classpath = /home/belsabelteklemariam/hadoop-3.4.0/etc/hadoop:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/kerb-client-2.0.3.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/curator-client-5.2.0.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-resolver-dns-native-macos-4.1.100.Final-osx-aarch_64.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-codec-http-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-codec-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/kerb-util-2.0.3.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jetty-security-9.4.53.v20231009.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jakarta.activation-api-1.2.1.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-codec-stomp-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jetty-server-9.4.53.v20231009.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/kerby-xdr-2.0.3.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-transport-native-unix-common-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-transport-classes-epoll-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-handler-proxy-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/zookeeper-jute-3.8.3.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/commons-text-1.10.0.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jaxb-api-2.2.11.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-handler-ssl-ocsp-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-codec-socks-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jetty-http-9.4.53.v20231009.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-resolver-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/hadoop-shaded-guava-1.2.0.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-transport-native-epoll-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jetty-util-9.4.53.v20231009.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jackson-annotations-2.12.7.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/nimbus-jose-jwt-9.31.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/kerby-pkix-2.0.3.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/gson-2.9.0.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/commons-lang3-3.12.0.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/slf4j-api-1.7.36.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/commons-io-2.14.0.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jetty-util-ajax-9.4.53.v20231009.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/commons-compress-1.24.0.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/animal-sniffer-annotations-1.17.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jersey-server-1.19.4.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/re2j-1.1.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jackson-core-2.12.7.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jsr305-3.0.2.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-codec-mqtt-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/guava-27.0-jre.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/kerb-core-2.0.3.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/checker-qual-2.5.2.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/avro-1.9.2.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/commons-codec-1.15.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/j2objc-annotations-1.1.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/commons-configuration2-2.8.0.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-transport-sctp-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/bcprov-jdk15on-1.70.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/netty-transport-udt-4.1.100.Final.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jsch-0.1.55.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/httpclient-4.5.13.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jcip-annotations-1.0-1.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jsr311-api-1.1.1.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jul-to-slf4j-1.7.36.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/kerby-config-2.0.3.jar:/home/belsabelteklemariam/hadoop-3.4.0/share/hadoop/common/lib/jetty-sslengine-1.5.4.jar:/home/belsabel
```

Start NameNode daemon and DataNode

```
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ sbin/start-dfs.sh
Starting namenodes on [localhost]
Starting datanodes
Starting secondary namenodes [cs-570]
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ wget http://localhost:9870/
--2024-06-05 10:51:47--  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]
--2024-06-05 10:51:47--  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'

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

2024-06-05 10:51:47 (113 MB/s) - 'index.html' saved [1079/1079]
```

Step 1: Creating MapReduce program to calculating Pi

3: PI_on_Mapreduce

```
belsabelteklemariam@cs570:~$ ls
PiProject  hadoop-3.4.0  hadoop-3.4.0.tar.gz
belsabelteklemariam@cs570:~$ cd PiProject
belsabelteklemariam@cs570:~/PiProject$ mkdir input
belsabelteklemariam@cs570:~/PiProject$ ls
CalculatePi.java  CalculatePiMR.java  GenerateDots.java  input
```

CODE--GenerateDots.java

```java
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));
        }
    }
}
```

CODE--CalculatePiMR.java

```
import java.io.IOException; import java.util.*;
import java.lang.Object;

import org.apache.hadoop.fs.Path;
import org.apache.hadoop.conf.*;
import org.apache.hadoop.io.*;
import org.apache.hadoop.mapreduce.*;
import org.apache.hadoop.mapreduce.lib.input.FileInputFormat;
import org.apache.hadoop.mapreduce.lib.input.TextInputFormat;
import org.apache.hadoop.mapreduce.lib.output.FileOutputFormat;
import org.apache.hadoop.mapreduce.lib.output.TextOutputFormat;

public class CalculatePiMR {
   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);
            }

        }
    }
```

CODE--CalculatePi.java

```
import java.io.*;
public class CalculatePi {
        public static void main(String[] args) throws Exception{
                String file = "../hadoop-3.4.0/"+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();
        }
}
```

Compile and run java program to generate dots with radius=5, number = 1000

Output save in ./Input/dots.txt

$ java GenerateDots 5 1000 › ./Input/dots.tx

```
belsabelteklemariam@cs-570:~/PiProject$ java GenerateDots 5 1000 > ./input/dots.txt
belsabelteklemariam@cs-570:~/PiProject$ cat ./input/dots.txt
1.4406666166691517 3.008770756986985 5.0
5.408335796652937 2.9815032546113898 5.0
3.997345429830168 9.946000528287355 5.0
9.295169620361465 9.144400679853685 5.0
0.29292010391042345 7.536568894697078 5.0
5.636436915214842 9.657083087647129 5.0
3.412193157841461 3.4387923740145663 5.0
1.5352840507035648 7.774427946620649 5.0
4.73645982262977 8.725268713969056 5.0
5.635535862527447 3.1061206941878816 5.0
8.378991002057122 7.821445977817709 5.0
8.780879833043716 7.722201445373078 5.0
6.84027626184616 9.101890509383297 5.0
```

Copy file from local to hadoop and check

$ bin/hdfs dfs -mkdir /user/belsabelteklemariam/PiProject/Input

$ bin/hdfs dfs -put ../PiProject/Input/* PiProject/Input

$ bin/hdfs dfs -ls PiProject/Input

```
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs dfs -mkdir -p /user/belsabelteklemariam/PiProject/input
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs dfs -put ../PiProject/input/* PiProject/input
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs dfs -ls PiProject/input
Found 1 items
-rw-r--r--   1 belsabelteklemariam supergroup      40557 2024-06-05 11:34 PiProject/input/dots.txt
```

Compile Mapreduce program in Hadoop with *.class files created

$bin/hadoop jar ~/hadoop-3.4.0/share/hadoop/mapreduce/hadoop-mapreduce-client-core-3.4.0.jar com.sun.tools.javac.Main ~/PiProject/CalculatePiMR.java

```
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hadoop jar ~/hadoop-3.4.0/share/hadoop/mapreduce/hadoop-mapreduce-client-core-3.4.0.jar com.sun.tools.javac.Main ~/PiProject/Calculat
ePiMR.java
Note: /home/belsabelteklemariam/PiProject/CalculatePiMR.java uses or overrides a deprecated API.
Note: Recompile with -Xlint:deprecation for details.
```

Create .jar file with *.class files

$Jar cf pi.jar CalculatePIMR*.class

```
belsabelteklemariam@cs-570:~/PiProject$ ls
 CalculatePi.java  'CalculatePiMR$Map.class'  'CalculatePiMR$Reduce.class'   CalculatePiMR.class   CalculatePiMR.java   GenerateDots.class   GenerateDots.java   input   testing
belsabelteklemariam@cs-570:~/PiProject$ jar cf pi.jar CalculatePiMR*.class
belsabelteklemariam@cs-570:~/PiProject$ cd ..
```

Run MapReduce Program with input file and save result in Output

$ bin/hadoop jar ~/PiProject/pi.jar CalculatePiMR /user/belsabelteklemariam/PiProject/input /user/belsabelteklemariam/PiProject/Output

```
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hadoop jar ~/PiProject/pi.jar CalculatePiMR /user/belsabelteklemariam/PiProject/input /user/belsabelteklemariam/PiProject/Output
2024-06-05 11:55:15,705 INFO impl.MetricsConfig: Loaded properties from hadoop-metrics2.properties
2024-06-05 11:55:15,880 INFO impl.MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
2024-06-05 11:55:15,881 INFO impl.MetricsSystemImpl: JobTracker metrics system started
2024-06-05 11:55:16,249 WARN mapreduce.JobResourceUploader: Hadoop command-line option parsing not performed. Implement the Tool interface and execute your application with ToolRun
ner to remedy this.
2024-06-05 11:55:16,621 INFO input.FileInputFormat: Total input files to process : 1
2024-06-05 11:55:16,666 INFO mapreduce.JobSubmitter: number of splits:1
2024-06-05 11:55:17,036 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_local1814531961_0001
2024-06-05 11:55:17,037 INFO mapreduce.JobSubmitter: Executing with tokens: []
2024-06-05 11:55:17,351 INFO mapreduce.Job: The url to track the job: http://localhost:8080/
2024-06-05 11:55:17,351 INFO mapreduce.Job: Running job: job_local1814531961_0001
2024-06-05 11:55:17,360 INFO mapred.LocalJobRunner: OutputCommitter set in config null
2024-06-05 11:55:17,370 INFO output.PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
2024-06-05 11:55:17,375 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 2
2024-06-05 11:55:17,375 INFO output.FileOutputCommitter: FileOutputCommitter skip cleanup _temporary folders under output directory:false, ignore cleanup failures: false
```

Get output and save to local, the show output

$bin/hdfs dfs -get PiProject/Output Output

Cat Output/*

```
belsabelteklemariam@cs-570:~$ cd hadoop-3.4.0
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ cat Output/*
Inside  781
Outside 219
```

Result

Using the output (local output folder as command line arguments) from MapReduce Program to compile and run java program to get pi value.

```
belsabelteklemariam@cs-570:~/PiProject$ java CalculatePi Output
Inside  781
Outside 219
PI value is: 3.124
```

The pi value calculated is 3.124, and it is quite off from 3.1415926

Enhancement of Pi using Map Reduce

Decrease Radius to get better result

Radius = 1 and number = 1000

```
belsabelteklemariam@cs-570:~/PiProject$ javac GenerateDots.java
belsabelteklemariam@cs-570:~/PiProject$ java GenerateDots 1 1000 > ./input/test1.txt
belsabelteklemariam@cs-570:~/PiProject$ ls ./input
dots.txt  test1.txt
belsabelteklemariam@cs-570:~/PiProject$ cat ./input/test1.txt
1.8058669369195384 0.3490079194216753 1.0
1.7502526423492648 1.7374129161575977 1.0
1.3217944153431407 0.5399359750318693 1.0
1.708214442237073 0.17051646569541457 1.0
0.7039970640417672 0.9806576932362423 1.0
0.8444387559538782 1.4838562777081679 1.0
0.46033178798283814 1.7547635472229284 1.0
0.579020331068921 1.0995519871214199 1.0
1.7754944121527043 1.2643792687603244 1.0
0.2405854132503551 0.9064907521706083 1.0
1.9685267563849158 0.8618356169445511 1.0
1.8407248667789486 1.4997932610301083 1.0
```

```
belsabelteklemariam@cs-570:~$ cd hadoop-3.4.0/
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs dfs -put ../PiProject/input/test1.txt PiProject/input
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs dfs -ls PiProject/input
Found 2 items
-rw-r--r--   1 belsabelteklemariam supergroup      40557 2024-06-05 11:34 PiProject/input/dots.txt
-rw-r--r--   1 belsabelteklemariam supergroup      42052 2024-06-05 12:21 PiProject/input/test1.txt
```

```
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hadoop jar ~/PiProject/pi.jar CalculatePiMR /user/belsabelteklemariam/PiProject/input/test1.txt /user/belsabelteklemariam/PiProject/T
est1
2024-06-05 12:29:01,685 INFO impl.MetricsConfig: Loaded properties from hadoop-metrics2.properties
2024-06-05 12:29:01,850 INFO impl.MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
2024-06-05 12:29:01,850 INFO impl.MetricsSystemImpl: JobTracker metrics system started
2024-06-05 12:29:02,143 WARN mapreduce.JobResourceUploader: Hadoop command-line option parsing not performed. Implement the Tool interface and execute your application with ToolRun
ner to remedy this.
2024-06-05 12:29:02,335 INFO input.FileInputFormat: Total input files to process : 1
2024-06-05 12:29:02,450 INFO mapreduce.JobSubmitter: number of splits:1
2024-06-05 12:29:02,723 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_local1719683798_0001
2024-06-05 12:29:02,723 INFO mapreduce.JobSubmitter: Executing with tokens: []
2024-06-05 12:29:02,969 INFO mapreduce.Job: The url to track the job: http://localhost:8080/
2024-06-05 12:29:02,970 INFO mapreduce.Job: Running job: job_local1719683798_0001
2024-06-05 12:29:02,977 INFO mapred.LocalJobRunner: OutputCommitter set in config null
2024-06-05 12:29:02,988 INFO output.PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
2024-06-05 12:29:02,990 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 2
2024-06-05 12:29:02,990 INFO output.FileOutputCommitter: FileOutputCommitter skip cleanup _temporary folders under output directory:false, ignore cleanup failures: false
2024-06-05 12:29:02,992 INFO mapred.LocalJobRunner: OutputCommitter is org.apache.hadoop.mapreduce.lib.output.FileOutputCommitter
2024-06-05 12:29:03,076 INFO mapred.LocalJobRunner: Waiting for map tasks
2024-06-05 12:29:03,077 INFO mapred.LocalJobRunner: Starting task: attempt_local1719683798_0001_m_000000_0
2024-06-05 12:29:03,117 INFO output.PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
2024-06-05 12:29:03,122 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 2
2024-06-05 12:29:03,122 INFO output.FileOutputCommitter: FileOutputCommitter skip cleanup _temporary folders under output directory:false, ignore cleanup failures: false
```

```
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs dfs  -get PiProject/Test1 Test1
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ cat Test1/*
Inside  775
Outside 225
```

```
belsabelteklemariam@cs-570:~/PiProject$ java CalculatePi Test1
Inside  775
Outside 225
PI value is: 3.1
belsabelteklemariam@cs-570:~/PiProject$
```

Pi value calculated is 3.1 which is a better value to the real pi value

Increase number to get better result

Radius = 5 and number = 1000,000

```
aghebrem423@mapreduce:~/PiProject$ java GenerateDots 5 1000000 > ./input/test2.txt
aghebrem423@mapreduce:~/PiProject$ ls ./input/test2.txt
./input/test2.txt
aghebrem423@mapreduce:~/PiProject$ ls ./input
dots.txt  test1.txt  test2.txt
aghebrem423@mapreduce:~/PiProject$ cat ./input/test2.txt
2.4409513178371336 1.9695968916104478 5.0
6.039596943158905 1.946277459843908 5.0
7.34317341682304 9.64860808775004 5.0
2.6616950654632565 2.589232923294439 5.0
3.495537161083142 8.291024720380582 5.0
6.371800950987319 0.4486674244486122 5.0
9.300473331723488 7.773773117188401 5.0
8.291425720800357 0.9219277488584798 5.0
5.642389490486829 0.0012242655171057493 5.0
6.335145390203549 6.418908354091643 5.0
8.934590875828349 5.823586718904402 5.0
4.601557809759406 0.1391976117294913 5.0
9.090069650570543 4.063996612243868 5.0
2.4441202544231686 6.7298038781988 5.0
4.235313396113073 0.6966038934684193 5.0
5.94434163930047 5.214390014240774 5.0
8.996055945545837 7.243340433171827 5.0
7.1758141315547705 4.516588019987867 5.0
6.00614873233384 8.794951079325372 5.0
2.1260939728793837 2.1441056545946022 5.0
```

```
belsabelteklemariam@cs-570:~/PiProject$ ls ./input/test2.txt
```

```
belsabelteklemariam@cs-570:~/PiProject$ cat ./input/test2.txt
```

```
belsabelteklemariam@cs-570:~$ cd hadoop-3.4.0
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs dfs -put ../PiProject/input/test2.txt PiProject/input
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs dfs -ls PiProject/input
Found 3 items
-rw-r--r--   1 belsabelteklemariam supergroup      40557 2024-06-05 11:34 PiProject/input/dots.txt
-rw-r--r--   1 belsabelteklemariam supergroup      42052 2024-06-05 12:21 PiProject/input/test1.txt
-rw-r--r--   1 belsabelteklemariam supergroup   40539287 2024-06-05 13:11 PiProject/input/test2.txt
```

```
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hadoop jar ~/PiProject/pi.jar CalculatePiMR /user/belsabelteklemariam/PiProject/input/test2.txt /user/belsabelteklemariam/PiProject/T
est2
2024-06-05 13:14:15,623 INFO impl.MetricsConfig: Loaded properties from hadoop-metrics2.properties
2024-06-05 13:14:15,844 INFO impl.MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
2024-06-05 13:14:15,845 INFO impl.MetricsSystemImpl: JobTracker metrics system started
2024-06-05 13:14:16,065 WARN mapreduce.JobResourceUploader: Hadoop command-line option parsing not performed. Implement the Tool interface and execute your application with ToolRun
ner to remedy this.
2024-06-05 13:14:16,302 INFO input.FileInputFormat: Total input files to process : 1
2024-06-05 13:14:16,417 INFO mapreduce.JobSubmitter: number of splits:1
2024-06-05 13:14:16,696 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_local284321300_0001
2024-06-05 13:14:16,697 INFO mapreduce.JobSubmitter: Executing with tokens: []
2024-06-05 13:14:16,961 INFO mapreduce.Job: The url to track the job: http://localhost:8080/
2024-06-05 13:14:16,962 INFO mapreduce.Job: Running job: job_local284321300_0001
2024-06-05 13:14:16,970 INFO mapred.LocalJobRunner: OutputCommitter set in config null
2024-06-05 13:14:16,981 INFO output.PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
2024-06-05 13:14:16,983 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 2
2024-06-05 13:14:16,983 INFO output.FileOutputCommitter: FileOutputCommitter skip cleanup _temporary folders under output directory:false, ignore cleanup failures: false
2024-06-05 13:14:16,985 INFO mapred.LocalJobRunner: OutputCommitter is org.apache.hadoop.mapreduce.lib.output.FileOutputCommitter
2024-06-05 13:14:17,070 INFO mapred.LocalJobRunner: Waiting for map tasks
2024-06-05 13:14:17,071 INFO mapred.LocalJobRunner: Starting task: attempt_local284321300_0001_m_000000_0
2024-06-05 13:14:17,121 INFO output.PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
2024-06-05 13:14:17,126 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 2
2024-06-05 13:14:17,126 INFO output.FileOutputCommitter: FileOutputCommitter skip cleanup _temporary folders under output directory:false, ignore cleanup failures: false
2024-06-05 13:14:17,166 INFO mapred.Task:  Using ResourceCalculatorProcessTree : [ ]
```

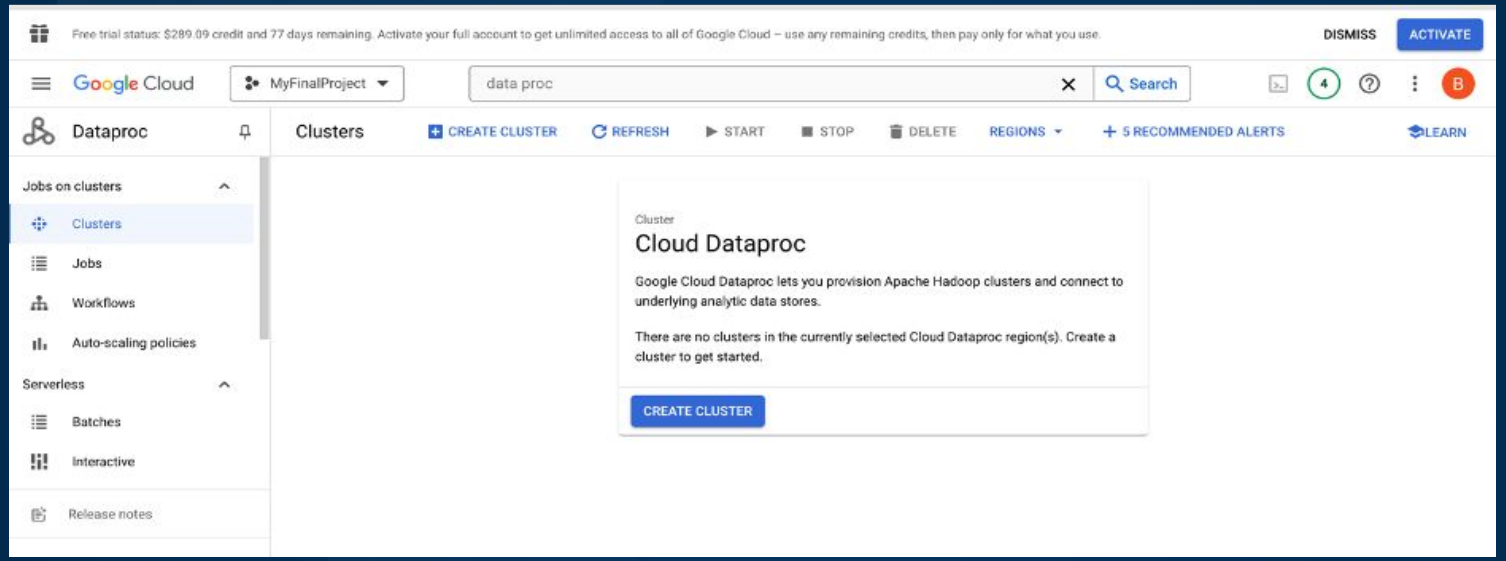
```
                Bytes Written=29
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ bin/hdfs dfs -get PiProject/Test2 Test2
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ cat Test2/*
Inside  785611
Outside 214389
belsabelteklemariam@cs-570:~/hadoop-3.4.0$ cd
belsabelteklemariam@cs-570:~$ cd PiProject
belsabelteklemariam@cs-570:~/PiProject$ java CalculatePi Test2
Inside  785611
Outside 214389
PI value is: 3.142444
belsabelteklemariam@cs-570:~/PiProject$
```

Pi value calculate is 3.142444 which is very close to the real pi value

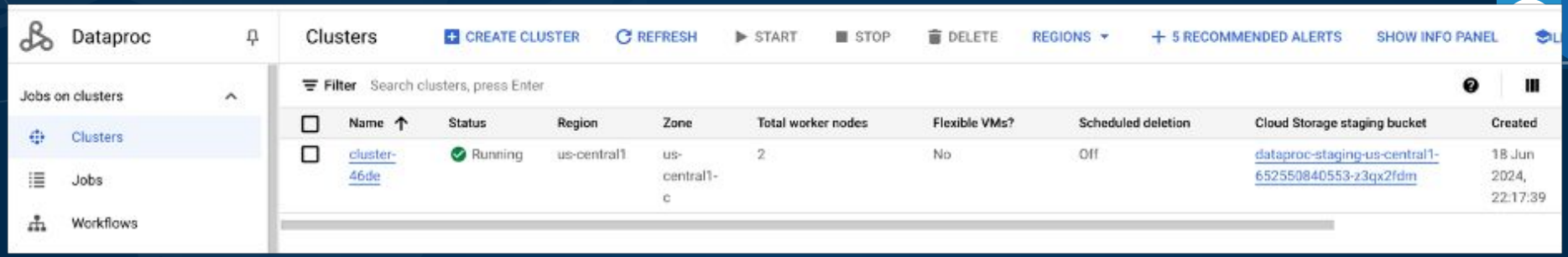
Stop Instance on GCP

Step 2: Pi Calculation using PySpark

1. Create a Dataproc cluster on Compute Engine



2. Cluster is created



3. **Open SSH in Browser**:

- Once you are on the cluster details page, locate the list of instances in the cluster.
- Find the master node (it typically has `-m` in its name).
- Click on the **SSH** button next to the master node.

4. Write the PySpark Script:

```
belsabelteklemariam@cluster-46de-m:~$ nano sparkcalculate_pi.py
```

```
  GNU nano 7.2                                          sparkcalculate_pi.py
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 = 100000 * partitions

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

    with SparkSession.builder.appName("My PyPi").getOrCreate() as spark:
        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)
```

```
if __name__ == "__main__":
    parser = argparse.ArgumentParser()
    parser.add_argument(
        '--partitions', default=2, type=int,
        help="The number of parallel partitions to use when calculating pi.")
    parser.add_argument(
        '--output_uri', help="The URI where output is saved, typically an S3 bucket.")
    args = parser.parse_args()

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

5. Submit the job using gcloud:

gcloud dataproc jobs submit pyspark sparkcalculate_pi.py --cluster=cluster-46de --region=us-central1 -- --partitions=4 --output_uri=gs://belsabel-bucket/pi-calculate-output

```
belsabelteklemariam@cluster-46de-m:~$ gcloud dataproc jobs submit pyspark sparkcalculate_pi.py --cluster=cluster-46de --region=us-central1 -- --partitions=4 --output_uri=gs://belsa
bel-bucket/pi-calculate-output
Job [eabc902125014a04b47a709e0907008e] submitted.
Waiting for job output...
INFO: Calculating pi with a total of 400000 tries in 4 partitions.
24/06/19 19:18:37 INFO SparkEnv: Registering MapOutputTracker
24/06/19 19:18:38 INFO SparkEnv: Registering BlockManagerMaster
24/06/19 19:18:38 INFO SparkEnv: Registering BlockManagerMasterHeartbeat
24/06/19 19:18:38 INFO SparkEnv: Registering OutputCommitCoordinator
24/06/19 19:18:39 INFO DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at cluster-46de-m.us-central1-c.c.myfinalproject-426304.internal./10.128.0.3:8032
24/06/19 19:18:39 INFO AHSProxy: Connecting to Application History server at cluster-46de-m.us-central1-c.c.myfinalproject-426304.internal./10.128.0.3:10200
24/06/19 19:18:41 INFO Configuration: resource-types.xml not found
24/06/19 19:18:41 INFO ResourceUtils: Unable to find 'resource-types.xml'.
24/06/19 19:18:42 INFO YarnClientImpl: Submitted application application_1718774369302_0007
24/06/19 19:18:43 INFO DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at cluster-46de-m.us-central1-c.c.myfinalproject-426304.internal./10.128.0.3:8030
24/06/19 19:18:45 INFO MetricsConfig: Loaded properties from hadoop-metrics2.properties
24/06/19 19:18:45 INFO MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
24/06/19 19:18:45 INFO MetricsSystemImpl: google-hadoop-file-system metrics system started
24/06/19 19:18:46 INFO GoogleCloudStorageImpl: Ignoring exception of type GoogleJsonResponseException; verified object already exists with desired state.
24/06/19 19:18:47 INFO GoogleHadoopOutputStream: hflush(): No-op due to rate limit (RateLimiter[stableRate=0.2qps]): readers will *not* yet see flushed data for gs://dataproc-temp-
us-central1-652550840553-h37js4cc/769804ec-989c-4e0d-a1c9-4801a5bfc450/spark-job-history/application_1718774369302_0007.inprogress [CONTEXT ratelimit_period="1 MINUTES" ]
INFO: 400000 tries and 313596 hits gives pi estimate of 3.13596.
INFO: NumExpr defaulting to 2 threads.
24/06/19 19:19:05 INFO PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
24/06/19 19:19:19 INFO GoogleCloudStorageFileSystemImpl: Successfully repaired 'gs://belsabel-bucket/pi-calculate-output/' directory.
INFO: Closing down clientserver connection
Job [eabc902125014a04b47a709e0907008e] finished successfully.
done: true
```

Result

```
us-central1-652550840553-h37js4cc/769804ec-989c-4e0d-a1c9-4801a5bfc450/spark-job-history/application_171
INFO: 400000 tries and 313596 hits gives pi estimate of 3.13596.
```

INFO: 400000 tries and 313596 hits:

- This part indicates that the algorithm made 400,000 attempts to randomly determine if a point falls within a unit circle.
- Out of these attempts, 313,596 points fell within the circle, which are counted as "hits".

gives pi estimate of 3.13596:

- The algorithm uses the ratio of hits inside the circle to the total number of points attempted to estimate the value of pi.
- The formula used here is $\pi \approx 4 \times 313596/400000 = 3.13596$

Enhancement of Pi using Pyspark

1. Write nano sparkcalculate_pi.py and edit the tries to from 100,000 to 1000000 for

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

tries = 1000000 * partitions

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

2. Change the number of partitions from 4 to to 16

gcloud dataproc jobs submit pyspark sparkcalculate_pi.py --cluster=cluster-46de --region=us-central1 -- --partitions=16 --output_uri=gs://belsabel-bucket/pi-calculate-output

```
belsabelteklemariam@cluster-46de-m:~$ gcloud dataproc jobs submit pyspark sparkcalculate_pi.py --cluster=cluster-46de --region=us-central1 -- --partitions=16 --output_uri=gs://belsabel-bucket/pi-calculate-output
Job [235782ca87b348dca20c80e035c78124] submitted.
Waiting for job output...
INFO: Calculating pi with a total of 16000000 tries in 16 partitions.
24/06/19 20:27:50 INFO SparkEnv: Registering MapOutputTracker
24/06/19 20:27:50 INFO SparkEnv: Registering BlockManagerMaster
24/06/19 20:27:50 INFO SparkEnv: Registering BlockManagerMasterHeartbeat
24/06/19 20:27:50 INFO SparkEnv: Registering OutputCommitCoordinator
24/06/19 20:27:52 INFO DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at cluster-46de-m.us-central1-c.c.myfinalproject-426304.internal./10.128.0.3:8032
24/06/19 20:27:52 INFO AHSProxy: Connecting to Application History server at cluster-46de-m.us-central1-c.c.myfinalproject-426304.internal./10.128.0.3:10200
24/06/19 20:27:54 INFO Configuration: resource-types.xml not found
24/06/19 20:27:54 INFO ResourceUtils: Unable to find 'resource-types.xml'.
24/06/19 20:27:55 INFO YarnClientImpl: Submitted application application_1718774369302_0011
24/06/19 20:27:56 INFO DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at cluster-46de-m.us-central1-c.c.myfinalproject-426304.internal./10.128.0.3:8030
24/06/19 20:27:58 INFO MetricsConfig: Loaded properties from hadoop-metrics2.properties
24/06/19 20:27:58 INFO MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
24/06/19 20:27:58 INFO MetricsSystemImpl: google-hadoop-file-system metrics system started
24/06/19 20:27:59 INFO GoogleCloudStorageImpl: Ignoring exception of type GoogleJsonResponseException; verified object already exists with desired state.
24/06/19 20:28:00 INFO GoogleHadoopOutputStream: hflush(): No-op due to rate limit (RateLimiter[stableRate=0.2qps]): readers will *not* yet see flushed data for gs://dataproc-temp-us-central1-652550840553-h37js4cc/769804ec-989c-4e0d-a1c9-4801a5bfc450/spark-job-history/application_1718774369302_0011.inprogress [CONTEXT ratelimit_period="1 MINUTES" ]
INFO: 16000000 tries and 12561648 hits gives pi estimate of 3.140412.
INFO: NumExpr defaulting to 2 threads.
24/06/19 20:28:28 INFO PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
24/06/19 20:28:40 INFO GoogleCloudStorageFileSystemImpl: Successfully repaired 'gs://belsabel-bucket/pi-calculate-output/' directory.
INFO: Closing down clientserver connection
Job [235782ca87b348dca20c80e035c78124] finished successfully.
done: true
```

Enhanced Result

```
INFO: 16000000 tries and 12561648 hits gives pi estimate of 3.140412.
INFO: NumExpr defaulting to 2 threads.
```

The result of pi has been changed from 3.13596 to 3.140412 which is a better result

Increased `tries`: The number of tries (`1000000 * 16`) is increased to improve the accuracy of the π estimation.

Conclusion

- The MapReduce framework is exceptionally proficient at handling extensive datasets with speed and efficiency, all while requiring minimal memory resources. This makes it particularly well-suited for large-scale data processing tasks.
- Implementing π estimation with PySpark not only harnesses the power of distributed computing but also offers scalability, fault tolerance, and performance optimization. It is well-suited for applications requiring high computational intensity and large-scale simulations. By leveraging PySpark's parallel processing capabilities and integration with cloud platforms, such as Google Cloud Dataproc, organizations can efficiently handle complex mathematical computations and derive meaningful insights from big data.

Reference

Overview of Pi calculation using Map Reduce

How to calculate Pi

Value of Pi

Github link

https://github.com/BelsabelTekle/Cloud_Computing/tree/main/PySpark