Big Data Analytics (2CS702)

Practical 7	
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Aim: To implement KMeans Clustering using MapReduce by handling larger datasets in main memory.

Code:

Results:

KMeans.java

```
package kmeans;



import java.io.BufferedReader;
import java.io.BufferedWriter;
import java.io.FileNotFoundException;
import java.io.IOException;
import java.io.InputStreamReader;
import java.io.OutputStreamWriter;
import java.util.ArrayList;
import java.util.Collections;
import java.util.List;
import java.util.Random;


import org.apache.hadoop.conf.Configuration;
import org.apache.hadoop.fs.FSDataInputStream;
import org.apache.hadoop.fs.FSDataOutputStream;
import org.apache.hadoop.fs.FileStatus;
import org.apache.hadoop.fs.FileSystem;
import org.apache.hadoop.fs.Path;
```

```
import org.apache.hadoop.mapreduce.Job;

import org.apache.hadoop.util.GenericOptionsParser;



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;



import kmeans.Point;



public class KMeans {



   private static boolean stoppingCriterion(Point[] oldCentroids, Point[]

newCentroids, int distance, float threshold) {

       boolean check = true;

       for(int i = 0; i < oldCentroids.length; i ) {

check = oldCentroids[i].distance(newCentroids[i], distance)                 threshold;

           if(!check) {

               return false;

           }

       }

       return true;
```

```
   }


   private static Point[] centroidsInit(Configuration conf, String pathString, int k,
int dataSetSize)
     throws IOException {
       Point[] points = new Point[k];
```

```
        Create a sorted list of positions without duplicates
        Positions are the line index of the random selected centroids
        List<Integer> positions = new ArrayList<Integer>();
        Random random = new Random();
        int pos;
        while(positions.size() < k) {
            pos = random.nextInt(dataSetSize);
            if(!positions.contains(pos)) {
                positions.add(pos);
            }
        }
        Collections.sort(positions);


        File reading utils
        Path path = new Path(pathString);
        FileSystem hdfs = FileSystem.get(conf);
        FSDataInputStream in = hdfs.open(path);
        BufferedReader br = new BufferedReader(new InputStreamReader(in));


        Get centroids from the file
        int row = 0;
        int i = 0;
        int position;
        while(i < positions.size()) {
            position = positions.get(i);
            String point = br.readLine();
            if(row    position) {
                points[i] = new Point(point.split(","));
                i ;
            }
            row ;
        }
        br.close();


        return points;
    }


    private static Point[] readCentroids(Configuration conf, int k, String pathString)
      throws IOException, FileNotFoundException {
        Point[] points = new Point[k];
        FileSystem hdfs = FileSystem.get(conf);
        FileStatus[] status = hdfs.listStatus(new Path(pathString));


        for (int i = 0; i < status.length; i ) {
            Read the centroids from the hdfs
            if(!status[i].getPath().toString().endsWith("_SUCCESS")) {
```

```
                BufferedReader br = new BufferedReader(new
InputStreamReader(hdfs.open(status[i].getPath())));
```

```
                String[] keyValueSplit = br.readLine().split("\t"); Split line in K,V
                int centroidId = Integer.parseInt(keyValueSplit[0]);
                String[] point = keyValueSplit[1].split(",");
                points[centroidId] = new Point(point);
                br.close();
            }
        }
        Delete temp directory
        hdfs.delete(new Path(pathString), true);


        return points;
    }


    private static void finalize(Configuration conf, Point[] centroids, String output)
throws IOException {
        FileSystem hdfs = FileSystem.get(conf);
        FSDataOutputStream dos = hdfs.create(new Path(output + "/centroids.txt"),
true);
        BufferedWriter br = new BufferedWriter(new OutputStreamWriter(dos));


        Write the result in a unique file
        for(int i = 0; i < centroids.length; i ) {
            br.write(centroids[i].toString());
            br.newLine();
        }


        br.close();
        hdfs.close();
    }


    public static void main(String[] args) throws Exception {
        long start = 0;
        long end = 0;
        long startIC = 0;
        long endIC = 0;


        start = System.currentTimeMillis();
        Configuration conf = new Configuration();
        conf.addResource(new Path("config.xml")); Configuration file for the
parameters


        String[] otherArgs = new GenericOptionsParser(conf, args).getRemainingArgs();


        if (otherArgs.length    2) {
            System.err.println("Usage: <input> <output>");
            System.exit(1);
        }
```

```
      Parameters setting
      final String INPUT = otherArgs[0];
      final String OUTPUT = otherArgs[1] + "/temp";
       Hard-coded values.
```

```
final int DATASET_SIZE = 3;
final int DISTANCE = 5;
final int K = 2;
final float THRESHOLD = 0.0001f;
final int MAX_ITERATIONS = 10;


Point[] oldCentroids = new Point[K];
Point[] newCentroids = new Point[K];


Initial centroids
startIC = System.currentTimeMillis();
newCentroids = centroidsInit(conf, INPUT, K, DATASET_SIZE);
endIC = System.currentTimeMillis();
for(int i = 0; i < K; i ) {
    conf.set("centroid." + i, newCentroids[i].toString());
}


MapReduce workflow
boolean stop = false;
boolean succeded = true;
int i = 0;
while(!stop) {
    i ;


    Job configuration
    Job iteration = Job.getInstance(conf, "iter_" + i);
    iteration.setJarByClass(KMeans.class);
    iteration.setMapperClass(KMeansMapper.class);
    iteration.setCombinerClass(KMeansCombiner.class);
    iteration.setReducerClass(KMeansReducer.class);
    iteration.setNumReduceTasks(K); one task each centroid
    iteration.setOutputKeyClass(IntWritable.class);
    iteration.setOutputValueClass(Point.class);
    FileInputFormat.addInputPath(iteration, new Path(INPUT));
    FileOutputFormat.setOutputPath(iteration, new Path(OUTPUT));
    iteration.setInputFormatClass(TextInputFormat.class);
    iteration.setOutputFormatClass(TextOutputFormat.class);


    succeded = iteration.waitForCompletion(true);


    If the job fails the application will be closed.
```

```
    if(!succeded) {
        System.err.println("Iteration" + i + "failed.");
        System.exit(1);
    }


    Save old centroids and read new centroids
    for(int id = 0; id < K; id ) {
        oldCentroids[id] = Point.copy(newCentroids[id]);
    }
    newCentroids = readCentroids(conf, K, OUTPUT);


    Check if centroids are changed
            stop = stoppingCriterion(oldCentroids, newCentroids, DISTANCE, THRESHOLD);


           if(stop    i    (MAX_ITERATIONS -1)) {
               finalize(conf, newCentroids, otherArgs[1]);
           } else {
               Set the new centroids in the configuration
               for(int d = 0; d < K; d ) {
                   conf.unset("centroid." + d);
                   conf.set("centroid." + d, newCentroids[d].toString());
               }
           }
       }


       end = System.currentTimeMillis();


       end -= start;
       endIC -= startIC;


       System.out.println("execution time: " + end + " ms");
       System.out.println("init centroid execution: " + endIC + " ms");
       System.out.println("n_iter: " + i);


       System.exit(0);
   }


}
```

KMeansReducer.java

```
package kmeans;


import java.io.IOException;


import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.LongWritable;
```

```java
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapreduce.Mapper;


import kmeans.Point;


public class KMeansMapper extends Mapper<LongWritable, Text, IntWritable, Point> {


   private Point[] centroids;
   private int p;
   private final Point point = new Point();
   private final IntWritable centroid = new IntWritable();


   public void setup(Context context) {
       int k = Integer.parseInt(context.getConfiguration().get("k"));
       this.p = Integer.parseInt(context.getConfiguration().get("distance"));


       this.centroids = new Point[k];
       for(int i = 0; i < k; i ) {
           String[] centroid = context.getConfiguration().getStrings("centroid." + i);
           this.centroids[i] = new Point(centroid);
       }
   }


   public void map(LongWritable key, Text value, Context context)
    throws IOException, InterruptedException {


        Contruct the point
       String[] pointString = value.toString().split(",");
       point.set(pointString);


        Initialize variables
       float minDist = Float.POSITIVE_INFINITY;
       float distance = 0.0f;
       int nearest = -1;


        Find the closest centroid
       for (int i = 0; i < centroids.length; i ) {
           distance = point.distance(centroids[i], p);
           if(distance < minDist) {
               nearest = i;
               minDist = distance;
           }
       }


       centroid.set(nearest);
```

```
        context.write(centroid, point);
    }
}
```

KMeansCombiner.java

```
package kmeans;


import java.io.IOException;


import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.mapreduce.Reducer;


 import kmeans.Point;


public class KMeansCombiner extends Reducer<IntWritable, Point, IntWritable, Point> {


    public void reduce(IntWritable centroid, Iterable<Point> points, Context context)
        throws IOException, InterruptedException {


        Sum the points
        Point sum = Point.copy(points.iterator().next());
        while (points.iterator().hasNext()) {
            sum.sum(points.iterator().next());
        }


        context.write(centroid, sum);
    }
}
```

KMeansReducer.java

```
package kmeans;


import java.io.IOException;


import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapreduce.Reducer;


 import kmeans.Point;


public class KMeansReducer extends Reducer<IntWritable, Point, Text, Text> {


    private final Text centroidId = new Text();
    private final Text centroidValue = new Text();
```

```
   public void reduce(IntWritable centroid, Iterable<Point> partialSums, Context
context)
       throws IOException, InterruptedException {


       Sum the partial sums
       Point sum = Point.copy(partialSums.iterator().next());
       while (partialSums.iterator().hasNext()) {
           sum.sum(partialSums.iterator().next());
       }
       Calculate the new centroid
       sum.average();


       centroidId.set(centroid.toString());
       centroidValue.set(sum.toString());
       context.write(centroidId, centroidValue);
   }
}
```

Point.java

```
package kmeans;


import java.io.DataInput;
import java.io.DataOutput;
import java.io.IOException;


import org.apache.hadoop.io.Writable;


public class Point implements Writable {


   private float[] components = null;
   private int dim;
   private int numPoints; For partial sums


   public Point() {
       this.dim = 0;
   }
```

```
   public Point(final float[] c) {
       this.set(c);
   }


   public Point(final String[] s) {
       this.set(s);
   }
```

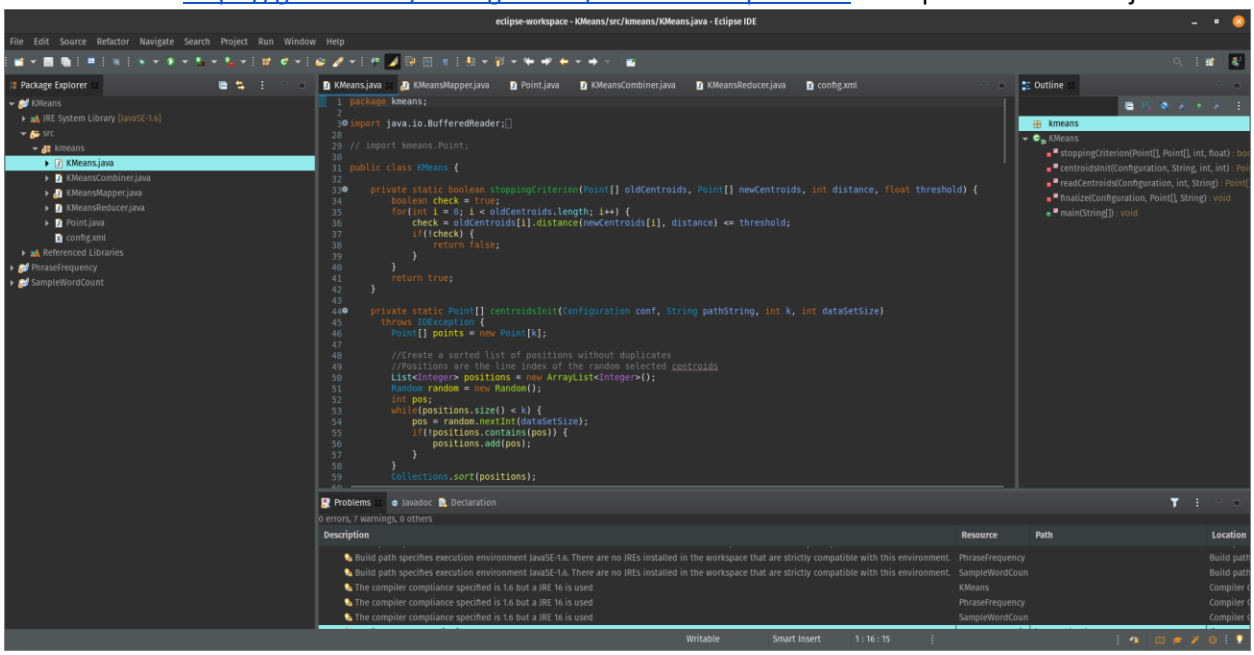
```
public static Point copy(final Point p) {
    Point ret = new Point(p.components);
    ret.numPoints = p.numPoints;
    return ret;
}


public void set(final float[] c) {
    this.components = c;
    this.dim = c.length;
    this.numPoints = 1;
}


public void set(final String[] s) {
    this.components = new float[s.length];
    this.dim = s.length;
    this.numPoints = 1;
    for (int i = 0; i < s.length; i ) {
        this.components[i] = Float.parseFloat(s[i]);
    }
}


@Override
public void readFields(final DataInput in) throws IOException {
    this.dim = in.readInt();
    this.numPoints = in.readInt();
    this.components = new float[this.dim];


    for(int i = 0; i < this.dim; i ) {
        this.components[i] = in.readFloat();
    }
}


@Override
public void write(final DataOutput out) throws IOException {
    out.writeInt(this.dim);
    out.writeInt(this.numPoints);


    for(int i = 0; i < this.dim; i ) {
        out.writeFloat(this.components[i]);
    }
}


@Override
public String toString() {
    StringBuilder point = new StringBuilder();
```

```
        for (int i = 0; i < this.dim; i ) {
            point.append(Float.toString(this.components[i]));
            if(i    dim - 1) {
                point.append(",");
            }
        }
        return point.toString();
    }


    public void sum(Point p) {
        for (int i = 0; i < this.dim; i ) {
            this.components[i] += p.components[i];
        }
        this.numPoints += p.numPoints;
    }


    public float distance(Point p, int h){
        if (h < 0) {
             Consider only metric distances
            h = 2;
        }


        if (h    0) {
             Chebyshev
            float max = -1f;
            float diff = 0.0f;
            for (int i = 0; i < this.dim; i ) {
                diff = Math.abs(this.components[i] - p.components[i]);
                if (diff > max) {
                    max = diff;
                }
            }
            return max;


        } else {
             Manhattan, Euclidean, Minkowsky
            float dist = 0.0f;
            for (int i = 0; i < this.dim; i ) {
                dist += Math.pow(Math.abs(this.components[i] - p.components[i]), h);
            }
            dist = (float)Math.round(Math.pow(dist, 1f/h)*100000)/100000.0f;
            return dist;
        }
    }


    public void average() {
        for (int i = 0; i < this.dim; i ) {
            float temp = this.components[i] / this.numPoints;
            this.components[i] = (float)Math.round(temp*100000)/100000.0f;
```

```
        }
        this.numPoints = 1;
    }
}
```

Results:

Add code from https://github.com/seraogianluca/k-means-mapreduce to Eclipse and create a .jar file.



Configure the properties like maximum iterations, number of centroids, dataset dimensions, etc either by hard-coding it on KMeans.java (like below) or by using the config.xml provided in the repository and placing it in the Hadoop configuration folder.

```
//Parameters setting
final String INPUT = otherArgs[0];
final String OUTPUT = otherArgs[1] + "/temp";
// Hard-coded values.
final int DATASET_SIZE = 3;
final int DISTANCE = 5;
final int K = 2;
final float THRESHOLD = 0.0001f;
final int MAX_ITERATIONS = 10;
```

Download the dataset from the aforementioned GitHub repository and copy it to HDFS. The dataset contains 1000 points. Run the MapReduce job. The MapReduce job runs with multiple iterations:

ID	User	Name	Application Type	Queue	Application Priority	StartTime	LaunchTime	FinishTime	State	FinalStatus	Running Containers	Allocated CPU VCores	Allocated Memory MB	Reserved CPU VCores	Reserved Memory MB	% of Queue	% of Cluster	Progress	Tracking UI
application_1633427255694_0023	hduser	iter_10	MAPREDUCE	default	0	Tue Oct 26 11:34:27 +0400 2021	Tue Oct 26 11:34:32 +0400 2021	Tue Oct 26 11:34:45 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History
application_1633427255694_0022	hduser	iter_9	MAPREDUCE	default	0	Tue Oct 26 11:34:05 +0400 2021	Tue Oct 26 11:34:11 +0400 2021	Tue Oct 26 11:34:25 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History
application_1633427255694_0021	hduser	iter_8	MAPREDUCE	default	0	Tue Oct 26 11:33:44 +0400 2021	Tue Oct 26 11:33:50 +0400 2021	Tue Oct 26 11:34:03 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History
application_1633427255694_0020	hduser	iter_7	MAPREDUCE	default	0	Tue Oct 26 11:33:23 +0400 2021	Tue Oct 26 11:33:28 +0400 2021	Tue Oct 26 11:33:43 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History
application_1633427255694_0019	hduser	iter_6	MAPREDUCE	default	0	Tue Oct 26 11:33:00 +0400 2021	Tue Oct 26 11:33:06 +0400 2021	Tue Oct 26 11:33:20 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History
application_1633427255694_0018	hduser	iter_5	MAPREDUCE	default	0	Tue Oct 26 11:32:41 +0400 2021	Tue Oct 26 11:32:46 +0400 2021	Tue Oct 26 11:32:59 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History
application_1633427255694_0017	hduser	iter_4	MAPREDUCE	default	0	Tue Oct 26 11:32:19 +0400 2021	Tue Oct 26 11:32:25 +0400 2021	Tue Oct 26 11:32:39 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History
application_1633427255694_0016	hduser	iter_3	MAPREDUCE	default	0	Tue Oct 26 11:31:58 +0400 2021	Tue Oct 26 11:32:04 +0400 2021	Tue Oct 26 11:32:18 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History
application_1633427255694_0015	hduser	iter_2	MAPREDUCE	default	0	Tue Oct 26 11:31:37 +0400 2021	Tue Oct 26 11:31:42 +0400 2021	Tue Oct 26 11:31:56 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History
application_1633427255694_0014	hduser	iter_1	MAPREDUCE	default	0	Tue Oct 26 11:31:21 +0400 2021	Tue Oct 26 11:31:22 +0400 2021	Tue Oct 26 11:31:35 +0400 2021	FINISHED	SUCCEEDED	N/A	N/A	N/A	N/A	N/A	0.0	0.0		History

After the iterations are complete, we get the centroids: