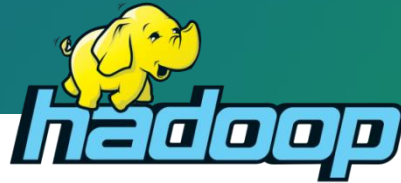


# k-means algorithm implementation on Hadoop



**Athens University of Economics and Business**

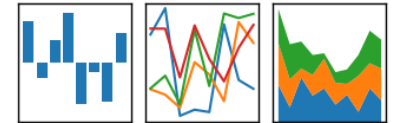
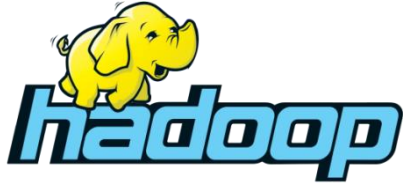
Dpt. Of Management Science and Technology

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# Tools



# Running Hadoop on Ubuntu Linux (Single-Node Cluster) [1]

## Prerequisites



- jdk-8uversion-linux-x64.tar.gz (Download)
- Directory modification
- % tar zxvf jdk-8uversion-linux-x64.tar.gz

### Hadoop system user

```
$ sudo addgroup hadoop $ sudo adduser --ingroup hadoop  
hduser
```

### Disabling IPv6

```
/etc/sysctl.conf { net.ipv6.conf.all.disable_ipv6 = 1  
net.ipv6.conf.default.disable_ipv6 = 1  
net.ipv6.conf.lo.disable_ipv6 = 1
```

References: [1], [2]

## Configuring SSH

### Generate an SSH key for the hduser

```
$ sudo mkdir -p /app/hadoop/tmp  
$ sudo chown hduser:hadoop /app/hadoop/tmp  
$ sudo chmod 750 /app/hadoop/tmp  
  
$ ssh-keygen -t rsa -P ""  
$ cat $HOME/.ssh/id_rsa.pub >> $HOME/.ssh/authorized_keys  
$ ssh localhost
```

### Create an RSA key pair with an empty password

```
hduser@ubuntu:~$ cat $HOME/.ssh/id_rsa.pub >>  
$HOME/.ssh/authorized_keys
```

# Running Hadoop on Ubuntu Linux (Single-Node Cluster) [2]

## Hadoop configuration



```
$ cd /usr/local
$ sudo tar xzf hadoop-2.7.3.tar.gz
$ sudo mv hadoop-2.7.3 hadoop
$ sudo chown -R hduser:hadoop hadoop
```

### hadoop-env.sh

```
export JAVA_HOME="/usr/lib/jvm/java-8-openjdk-amd64"
```

## Configuration

### ownerships and permissions

```
$ sudo mkdir -p /app/hadoop/tmp
$ sudo chown hduser:hadoop /app/hadoop/tmp
$ sudo chmod 750 /app/hadoop/tmp
```

References: [1], [2]

### conf/core-site.xml

```
<configuration>
<property>
  <name>hadoop.tmp.dir</name>
  <value>/app/hadoop/tmp</value>
</property>
<property>
  <name>fs.defaultFS</name>
  <value>hdfs://localhost:9000</value>
</property>
</configuration>
```

### conf/mapred-site.xml

```
<configuration>
<property>
<name>mapreduce.framework.name</name>
  <value>yarn</value>
</property>
</configuration>
```

# Running Hadoop on Ubuntu Linux (Single-Node Cluster) [3]

## yarn-site.xml

```
<configuration>
<property>
  <name>yarn.scheduler.minimum-allocation-mb</name>
  <value>128</value>
</property>
<property>
  <name>yarn.scheduler.maximum-allocation-mb</name>
  <value>2048</value>
</property>
<property>
  <name>yarn.scheduler.minimum-allocation-vcores</name>
  <value>1</value>
</property>
<property>
  <name>yarn.scheduler.maximum-allocation-vcores</name>
  <value>2</value>
</property>
<property>
  <name>yarn.nodemanager.resource.memory-mb</name>
  <value>4096</value>
</property>
<property>
  <name>yarn.nodemanager.resource.cpu-vcores</name>
  <value>4</value>
</property>
<property>
  <name>yarn.nodemanager.aux-services</name>
  <value>mapreduce_shuffle</value>
</property>
</configuration>
```

## hdfs-site.xml

```
<configuration>
<property>
  <name>dfs.replication</name>
  <value>1</value>
  <description>Default block replication.
    The actual number of replications can be specified when
    the file is created.
    The default is used if replication is not specified in create
    time.
  </description>
</property>
<property>
  <name>hadoop.tmp.dir</name>
  <value>/app/hadoop/tmp</value>
  <description>A base for other temporary
    directories.</description>
</property>
</configuration>
```

# Running Hadoop on Ubuntu Linux (Single-Node Cluster) [4]

## conf/hdfs-site.xml

```
<configuration>
<property>
  <name>dfs.replication</name>
  <value>1</value>
</property>
<property>
  <name>hadoop.tmp.dir</name>
  <value>/app/hadoop/tmp</value>
</property>
</configuration>
```

## Formatting the HDFS filesystem via the NameNode

```
hduser@ubuntu:~$ /usr/local/hadoop/bin/hadoop
namenode -format
```

## Starting your single-node cluster

```
hduser@ubuntu:~$ /usr/local/hadoop/bin/start-
all.sh
```

## Stopping your single-node cluster

```
hduser@ubuntu:~$ /usr/local/hadoop/bin/stop-all.sh
```

# Setting up a Single Node Cluster - Hadoop Distributed File System (HDFS)

To access Hadoop WEB UI , we need to type `http://localhost:50070/` though our `core-site.xml` that has as value the `http://localhost:9000`.

## Summary

Security is off.  
Safemode is off.  
120 files and directories, 83 blocks = 203 total filesystem object(s).  
Heap Memory used 48.39 MB of 250.5 MB Heap Memory. Max Heap Memory is 889 MB.  
Non Heap Memory used 58.3 MB of 59.59 MB Committed Non Heap Memory. Max Non Heap Memory is -1 B.

Configured Capacity:	47.2 GB
DFS Used:	5.14 MB (0.01%)
Non DFS Used:	14.39 GB
DFS Remaining:	32.8 GB (69.5%)
Block Pool Used:	5.14 MB (0.01%)
DataNodes usages% (Min/Median/Max/stdDev):	0.01% / 0.01% / 0.01% / 0.00%
Live Nodes	1 (Decommissioned: 0)

## NameNode Storage

Storage Directory	Type	State
/app/hadoop/tmp/dfs/name	IMAGE_AND_EDITS	Active

## Overview 'localhost:9000' (active)

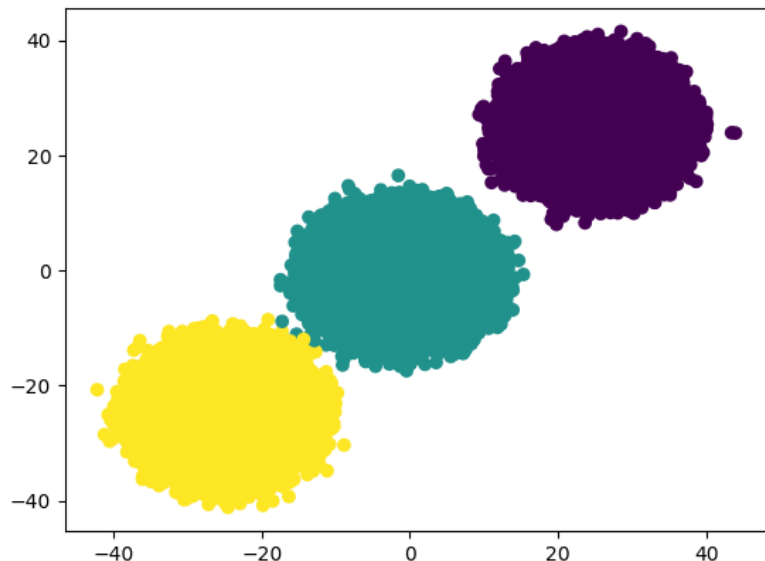
Started:	Sat Mar 25 19:30:22 EET 2017
Version:	2.7.3, rbaa91f7c6bc9cb92be5982de4719c1c8af91ccff
Compiled:	2016-08-18T01:41Z by root from branch-2.7.3
Cluster ID:	CID-b411faf1-1b6a-4a0b-9596-335707ba9cae
Block Pool ID:	BP-1093431230-127.0.1.1-1490463017525

Our HDFS cluster consists of a single **NameNode**, a master server that manages the file system namespace and regulates access to files by clients. In addition, there are a number of **DataNodes**, usually one per node in the cluster, which manage storage attached to the nodes that they run on.

## From hardware/software to algorithms

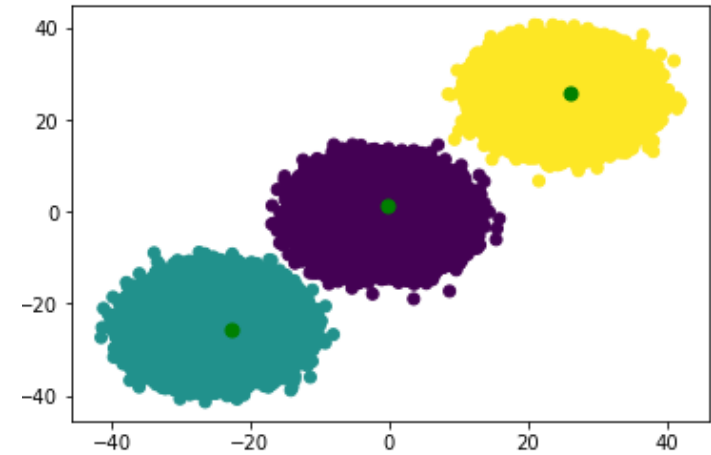
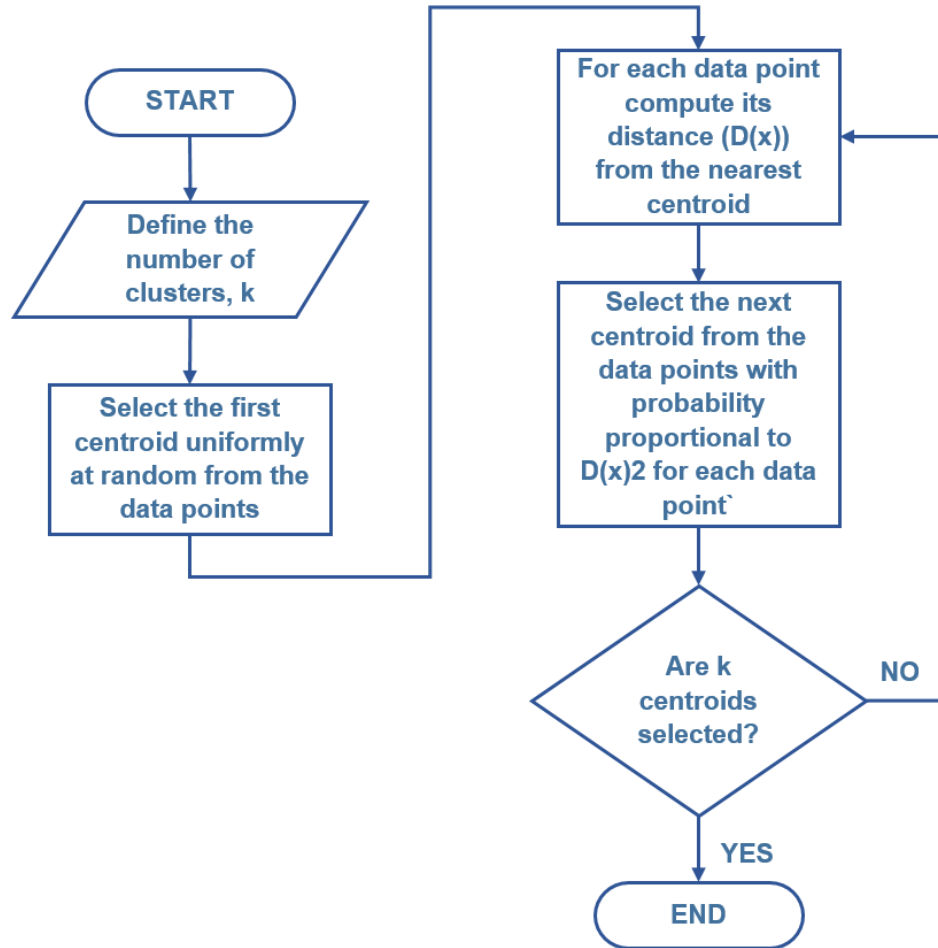


# Data Generation

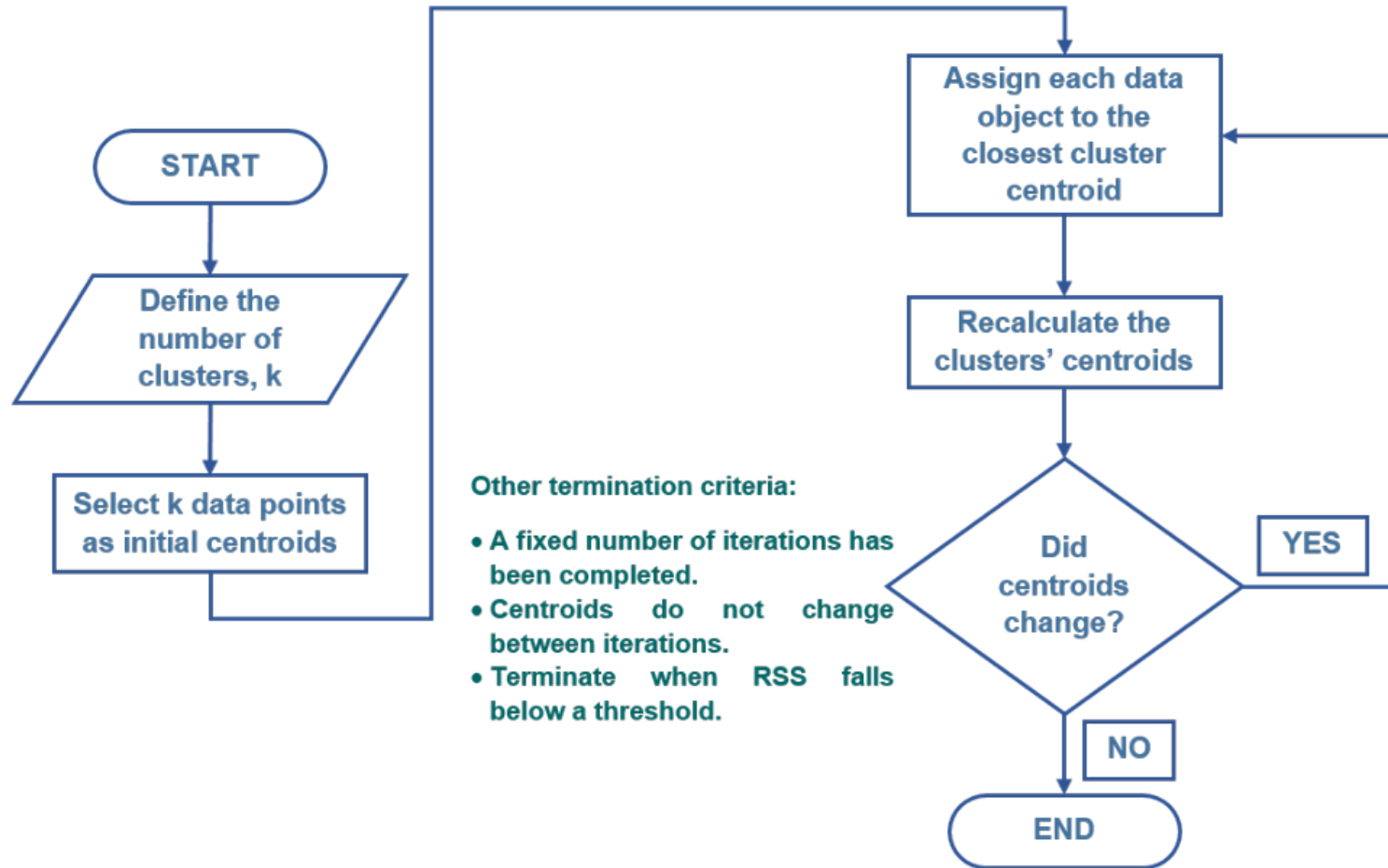


- **Isotropic Gaussian blobs**
- **2.000.000 points**
- **centers = [[25, 25], [-1, -1], [-25, -25]]**
- **cluster\_std = 3.5**

# K-means++ : Calculation of initial centroids



# K-means : Clustering algorithm



# K-means using Map Reduce

**Do**

**Map**

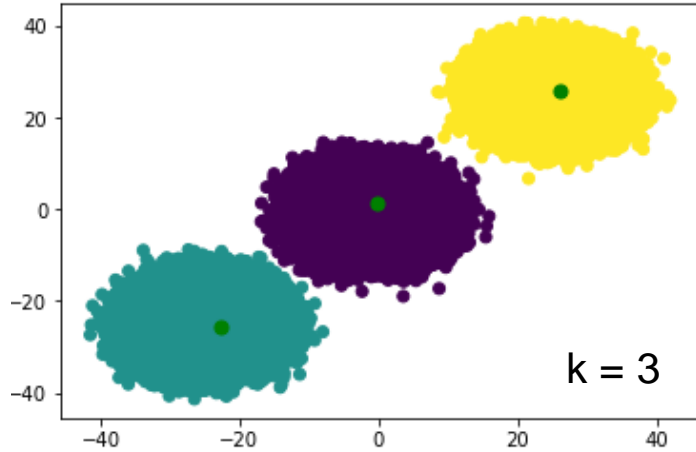
Input is a data point and k centers are broadcasted  
Finds the closest center among k centers for the input point

**Reduce**

Input is one of k centers and all data points having this center as their closest center.  
Calculates the new center using data points

**Until** all of new centers are not changed

# K-means using Map Reduce [1]



Centroids are broadcasted to  
every map function

Reference: [6]

Mapper

map

map

⋮

map

key

value

[centroid1, point1]

[centroid2, point3]

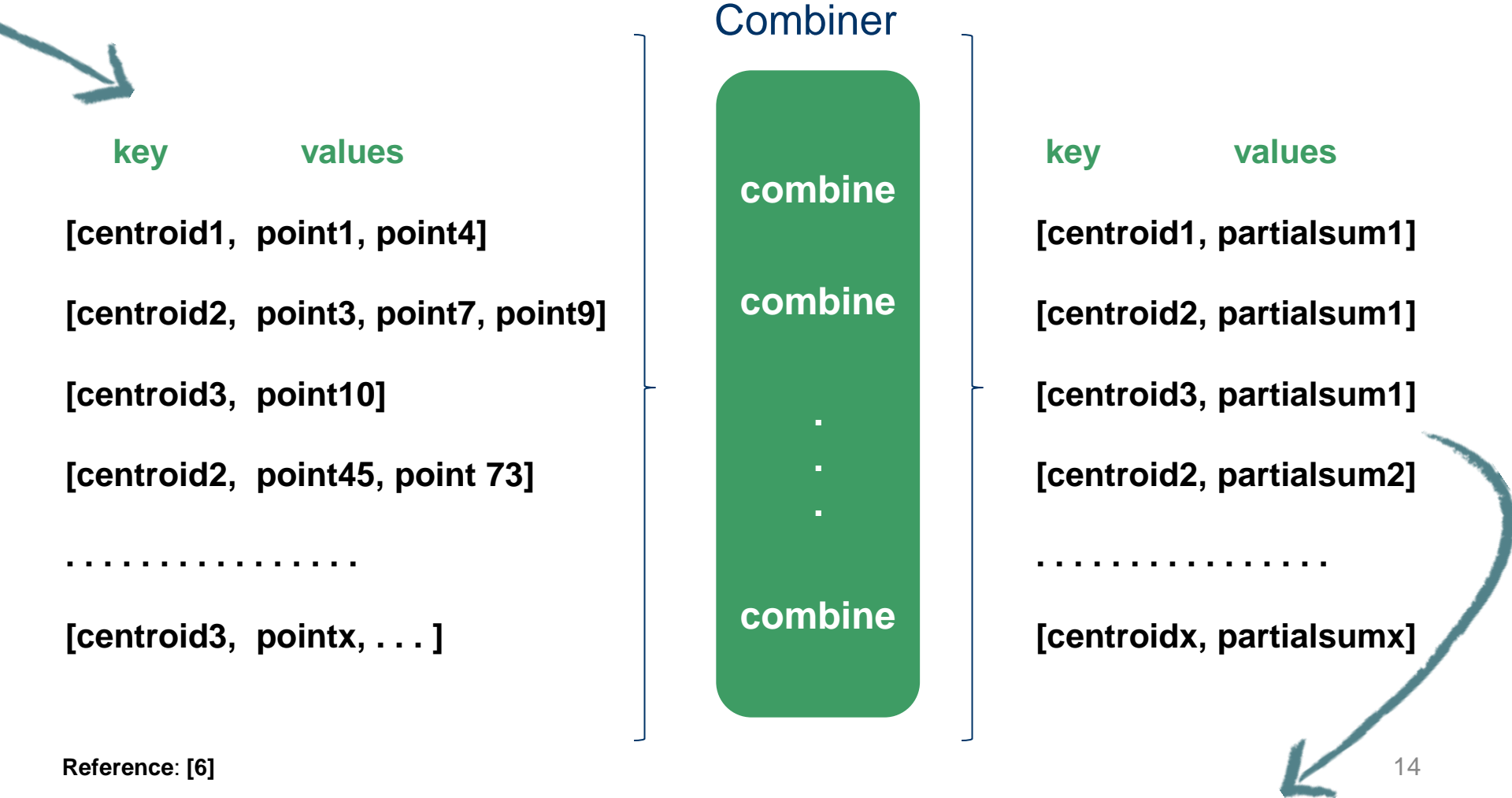
[centroid3, point10]

[centroid2, point45]

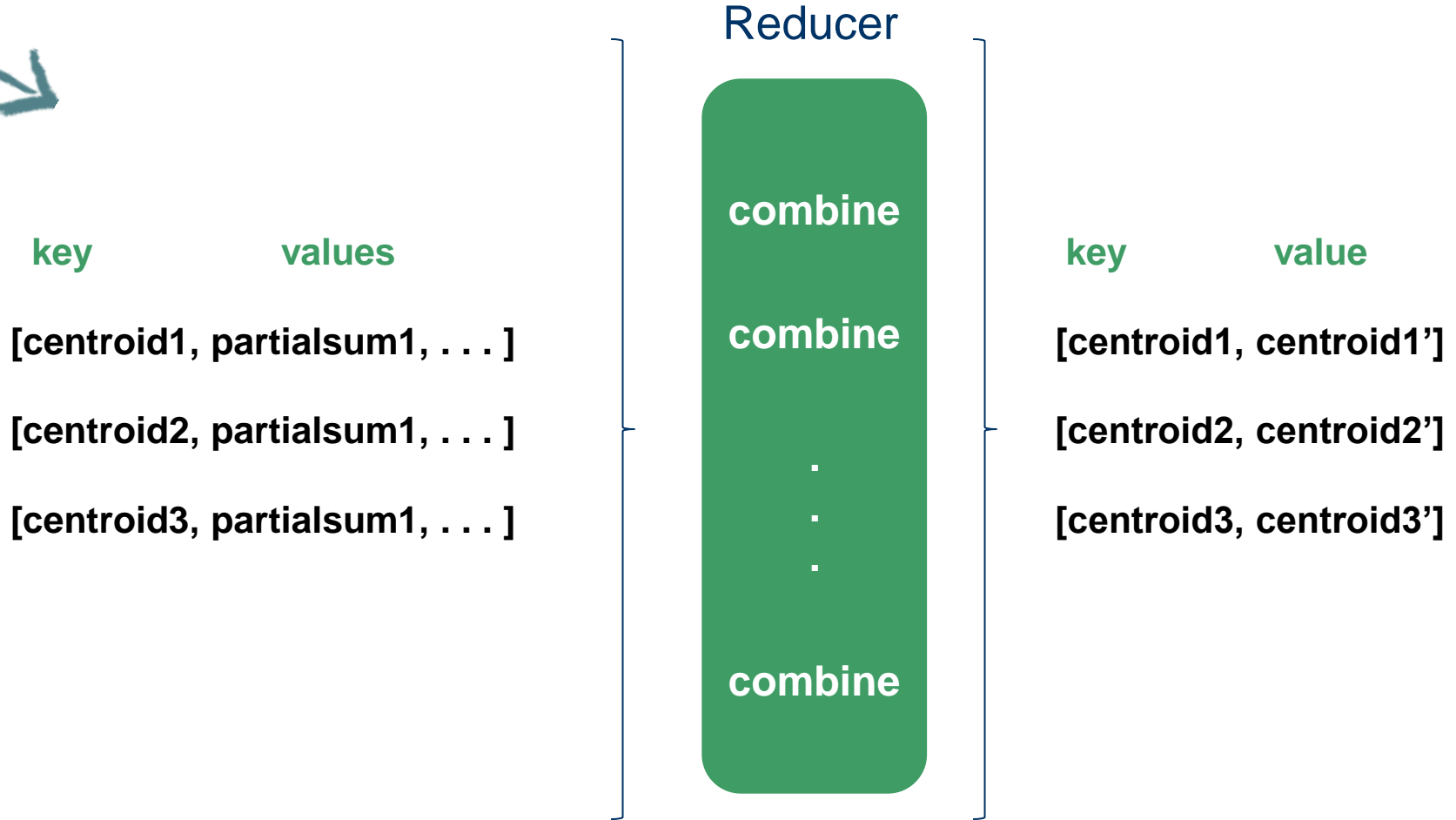
.....

[centroidx, pointx]

# K-means using Map Reduce [2]



# K-means using Map Reduce [3]



## From **algorithms** to **coding**



# Python Coding [1]



createDataPoints

The initial task of the project is to generate **a set of more than one million data points** to be used later as an input for the k-means clustering algorithm. Using this python script three **isotropic Gaussian blobs** for clustering are generated. More specifically, the centers are the following data points **[25, 25], [-1, -1], [-25, -25]**.



plotSilhouetteScore

The silhouette score constitutes a useful criterion for determining **the proper number of clusters**. A silhouette close to 1 implies the datum is in an appropriate cluster, while a silhouette close to -1 implies the datum is in the wrong cluster. The specific python script calculates the silhouette score for different numbers of clusters ranging from 2 to 6.



This python script calls the **k-means algorithm** implemented on hadoop. However, before implementing k-means the initial centroids are computed using the **k-means++ algorithm** proposed in 2007 by Arthur and Vassilvitskii.



In order to implement k-means algorithm on hadoop **mrjob** is used. Mrjob is a python package, which allows to write multi-step MapReduce jobs in pure Python and run them on a hadoop cluster. In our case mrjob run on a single-node cluster.

- The mapper function returns each data point and the cluster, to which it belongs.
- The combiner function returns partial sums of batches of data points belonging to the same cluster.
- The reducer returns the new centroids of each cluster.
- If the centroids remain unchanged the algorithm terminates. Otherwise, the steps are repeated from the beginning.

# Coding Running [1]

```
hduser@stratosg-Lenovo-YOGA-700-14ISK:~/Downloads/hadoop$ python kmeans.py -h
usage: kmeans.py [-h] inputFile centroids

k-means algorithm implementation on Hadoop

positional arguments:
  inputFile  Input data points for the clustering algorithm.
  centroids  Number of clusters.

optional arguments:
  -h, --help  show this help message and exit

Go ahead and try it!
```

# Coding Running [2]

## kmeans

```
hduser@stratosg-Lenovo-YOGA-700-14ISK:~/Downloads/hadoop$ python kmeans.py input data.txt 3
k-means iteration #1
No configs found; falling back on auto-configuration
Looking for hadoop binary in /home/hduser/Downloads/hadoop/bin...
Found hadoop binary: /home/hduser/Downloads/hadoop/bin/hadoop
Using Hadoop version 2.7.3
Looking for Hadoop streaming jar in /home/hduser/Downloads/hadoop/...
Found Hadoop streaming jar: /home/hduser/Downloads/hadoop/share/hadoop/tools/lib/hadoop-streaming-2.7.3.jar
Creating temp directory /tmp/kmeansAlgorithm.hduser.20170330.162921.120232
reading from STDIN
Copying local files to hdfs:///user/hduser/tmp/mrjob/kmeansAlgorithm.hduser.20170330.162921.120232/files/...
Running step 1 of 1...
packageJobJar: [/tmp/hadoop-unjar4040366256055210692/] [] /tmp/streamjob7394773186967757379.jar tmpDir=null
Connecting to ResourceManager at /0.0.0.0:8032
Connecting to ResourceManager at /0.0.0.0:8032
Total input paths to process : 1
number of splits:2
Submitting tokens for job: job_1490890691442_0008
Submitted application application_1490890691442_0008
The url to track the job: http://stratosg-Lenovo-YOGA-700-14ISK:8088/proxy/application_1490890691442_0008/
Running job: job_1490890691442_0008
Job job_1490890691442_0008 running in uber mode : false
map 0% reduce 0%
map 100% reduce 0%
map 100% reduce 100%
Job job_1490890691442_0008 completed successfully
Output directory: hdfs:///user/hduser/tmp/mrjob/kmeansAlgorithm.hduser.20170330.162921.120232/output
Counters: 49
```

# Coding Running [3]

```
Running step 1 of 1...
packageJobJar: [/tmp/hadoop-unjar2251983163613915235/] [] /tmp/streamjob4331642045348544338.ja
Connecting to ResourceManager at /0.0.0.0:8032
Connecting to ResourceManager at /0.0.0.0:8032
Total input paths to process : 1
number of splits:2
Submitting tokens for job: job_1490463036897_0008
Submitted application application_1490463036897_0008
The url to track the job: http://stratosg-Lenovo-YOGA-700-1415K:8088/proxy/application_1490463036897_0008
Running job: job_1490463036897_0008
Job job_1490463036897_0008 running in uber mode : false
  map 0% reduce 0%
  map 100% reduce 0%
  map 100% reduce 100%
Job job_1490463036897_0008 completed successfully
Output directory: hdfs:///user/hduser/tmp/nrjob/kmeans_centroid_updater.hduser.20170325.174201
Counters: 49
  File Input Format Counters
    Bytes Read=573
  File Output Format Counters
    Bytes Written=128
  File System Counters
    FILE: Number of bytes read=215
    FILE: Number of bytes written=371793
    FILE: Number of large read operations=0
    FILE: Number of read operations=0
    FILE: Number of write operations=0
    HDFS: Number of bytes read=895
    HDFS: Number of bytes written=128
    HDFS: Number of large read operations=0
    HDFS: Number of read operations=9
    HDFS: Number of write operations=2
  Job Counters
    Data-local map tasks=2
    Launched map tasks=2
    Launched reduce tasks=1
    Total megabyte-milliseconds taken by all map tasks=6896640
    Total megabyte-milliseconds taken by all reduce tasks=2209792
    Total time spent by all map tasks (ms)=6735
    Total time spent by all maps in occupied slots (ms)=53880
    Total time spent by all reduce tasks (ms)=2158
    Total time spent by all reduces in occupied slots (ms)=17264
    Total vcore-milliseconds taken by all map tasks=6735
    Total vcore-milliseconds taken by all reduce tasks=2158
  Map-Reduce Framework
    CPU time spent (ms)=2080
    Combine input records=13
    Combine output records=5
    Failed 5shuffles=0
    GC time elapsed (ms)=193
    Input split bytes=322
    Map input records=13
```

```
Submitted application application_1490463036897_0014
The url to track the job: http://stratosg-Lenovo-YOGA-700
Running job: job_1490463036897_0014
Job job_1490463036897_0014 running in uber mode : false
  map 0% reduce 0%
  map 6% reduce 0%
  map 10% reduce 0%
  map 13% reduce 0%
  map 17% reduce 0%
  map 20% reduce 0%
  map 24% reduce 0%
  map 28% reduce 0%
  map 31% reduce 0%
  map 35% reduce 0%
  map 38% reduce 0%
  map 40% reduce 0%
  map 42% reduce 0%
  map 44% reduce 0%
  map 46% reduce 0%
  map 47% reduce 0%
  map 49% reduce 0%
  map 51% reduce 0%
  map 53% reduce 0%
  map 55% reduce 0%
  map 56% reduce 0%
  map 58% reduce 0%
  map 60% reduce 0%
  map 62% reduce 0%
  map 64% reduce 0%
  map 65% reduce 0%
  map 67% reduce 0%
  map 83% reduce 0%
  map 100% reduce 0%
  map 100% reduce 100%
Job job_1490463036897_0014 completed successfully
```

# References

- [1]: Noll, M. *Running Hadoop On Ubuntu Linux (Single-Node Cluster)* - Michael G. Noll. [online]  
Available at: <http://www.michael-noll.com/tutorials/running-hadoop-on-ubuntu-linux-single-node-cluster/> [Accessed 29 Mar. 2017].
- [2]: Stackoverflow.com. (2017). *Error launching job using mrjob on Hadoop*. [online]  
Available at: <http://stackoverflow.com/questions/25358793/error-launching-job-using-mrjob-on-hadoop> [Accessed 29 Mar. 2017].
- [3]: David Arthur, and Sergei Vassilvitskii, (2007). *k-means++: the advantages of careful seeding* - Proceedings of the eighteenth annual ACM-SIAM Symposium on Discrete Algorithms, New Orleans, LA, January 7-9, 2007. 1st ed. New York: ACM, pp.1027–1035.
- [4]: Nlp.stanford.edu. *K-means*. Available at: <http://nlp.stanford.edu/IR-book/html/htmledition/k-means-1.html> [Accessed 15 Mar. 2017]
- [5]: Home.deib.polimi.it. (n.d.). *Clustering - K-means*. [online] Available at:  
[http://home.deib.polimi.it/matteucc/Clustering/tutorial\\_html/kmeans.html](http://home.deib.polimi.it/matteucc/Clustering/tutorial_html/kmeans.html) [Accessed 8 Mar. 2017].
- [6]: Kyuseok Shim, "MapReduce Algorithms for Big Data Analysis", VLDB Conference, 2012