Big Data Applications - Coursework 1

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March, 2022

Question 1

Mapper

For question 1, I'll create a mapper, whose output will be used as input for each reducer I'll develop to calculate the maximum, minimum, mean, median, and variance statistical metrics.

Step 1

For the creation of this mapper, I took the data of April, produced a tiny sample from it (which you can find in the txt file named "example_mapper.txt" in the folder where this report is placed), and tested my Python code in Jupyter Notebook until I was pleased with the outcomes. As a result, I was able to fully understand each line of my code and double-check each line's output until I got my final mapper.

Example of what my mapper sees as input

In [1]:
```
file = open("example_mapper.txt","r")
file = file.readlines()
print(file)
```

```
['Wban Number, YearMonthDay, Time, Station Type, Maintenance Indicator, Sky Conditions, Visibility, Weather Typ
e, Dry Bulb Temp, Dew Point Temp, Wet Bulb Temp, % Relative Humidity, Wind Speed (kt), Wind Direction, Wind Cha
r. Gusts (kt), Val for Wind Char., Station Pressure, Pressure Tendency, Sea Level Pressure, Record Type, Preci
p. Total\n', '03011,20070401,0050,AO2 ,-,SCT055                                  ,10SM   ,-,-,23,28,69  ,
4   ,130,-,0  ,30.13,-,-,AA,-\n', '03011,20070401,0150,AO2 ,-,BKN055                                          ,10S
M   ,-,32,23,28,69  , 4   ,140,-,0  ,30.12,-,-,AA,-\n', '03011,20070401,0250,AO2 ,-,OVC050
...
```

Pseudo code

```
Read the file

for each line in this file:

    Remove beginning and ending spaces then split a string into a list with comma
    as separator

    If you find non-existent values represented by "-" or values equal "Dry Bulb Temp"
    in the "Dry Bulb Temp" column:

        Ignore them and move to the next value/line

    else:

        The key "day" and value "temp" are equal to column "YearMonthDay" and column
        "Dry Bulb Temp" respectively

        Print keys "day" and values "temp"
```

Python code

In [2]:
```
#! /usr/bin/env python3
import sys

for line in sys.stdin:
    val = line.strip().split(",")
    if (val[8] == "-") or (val[8].strip() == "Dry Bulb Temp"):
        continue
    else:
        (day, temp) = (val[1], val[8])
        print ("%s\t%s" % (day, temp))
```

Lines explanation

- if (val[8] == "-") or (val[8].strip() == "Dry Bulb Temp"):

  continue

When looking at my file, I realised that there is some non-existent values represented by "-" in my columns and that I would need to remove headers "Dry Bulb Temp" and "YearMonthDay" from my output values so I set this condition.

Step 2

After I've developed my python code for the mapper using a tiny sample from my original file "200704hourly.txt", I need to test this mapper in my Terminal(Headnote for my entire dataset "200704hourly.txt".

For that I follow some steps:

1. Download data "200704hourly.txt" from VLE to my local machine/computer
2. Open two terminals: one for local computer, one for headnote (dsm1)
3. Tranfer the file "200704hourly.txt" to my headnote
4. Create a diretory on my headnote to have my file "200704hourly.txt", my mapper.py and all my future reducers
5. Run my mapper.py on my file

Code done on both terminals, Local machine and Headnote:

1. #### To access the folder which has the file "200704hourly.txt" - Local machine

cd path

1. #### To log in - Headnote

ssh username@dsm1.doc.gold.ac.uk

1. #### To create directory - Headnote

mkdir coursework_1

1. #### Move to this directory – Headnote

cd coursework_1

1. #### To tranfers my "200704hourly.txt" file from local machine to Headnote - Local machine

scp 200704hourly.txt dsm1.doc.gold.ac.uk:coursework_1/

1. #### To create a file for my mapper - Headnote

touch mapper.py

1. #### To edit the file - Headnote

nano mapper.py

1. #### To give my python scripts the executable permission – Headnote

chmod +x mapper.py

1. #### To run my mapper.py on my file and sort the output - Headnote

cat 200704hourly.txt | ./mapper.py | sort

Note : In step 7, I copy my Python code which is above ("Python code") into it.

Reducers

To build my reducers, I also created a tiny sample example of the output of my mapper (txt file named "example_reducer.txt" in the folder where this report is placed), sorted, which will be the input of my reducers. As I did for my mapper code, I tested my code in the jupyter notebook on my sample until I reached the final reducer for all that I will create: maximum, minimum, average, median and variance.

Example of what all my reducers will sees as input

In [3]:
```
file = open("example_reducer.txt","r")
file = file.readlines()
print(file)
```

```
['20070401\t11\n', '20070401\t12\n', '20070401\t12\n', '20070401\t13\n', '20070401\t14\n', '20070402\t21\n', '2
0070402\t23\n', '20070402\t35\n', '20070402\t36\n', '20070403\t67\n', '20070403\t68\n', '20070403\t79\n']
```

Maximum

Step 1

Pseudo code

```
Read the file

Initialise your key variable "last_key" = None
Initialise your value variable "max_val" = 0

Start loop, for each line in this file:

    Initialise "key" and "val" variables = remove beginning and ending spaces then
    split a string into a list with tab as separator

    If "last_key" and "last_key" differs from current "key":

        First, print current "last_key" and "max_val"

        Update "last_key" and "max_value" with currrent "key" and the integer of "val"
        variable, respectively

    else:

        Update "last_key" and "max_value" with currrent "key" and the maximum between
        current "max_val" and integer of "val" variable, respectively

If "last_key":
    Print keys "last_key" and values "max_val"
```

Python code

In [4]:
```
#! /usr/bin/env python3
import sys

(last_key, max_val) = (None, 0)

for line in sys.stdin:
    (key, val) = line.strip().split("\t")
    if last_key and last_key != key:
        print ("%s\t%s" % (last_key, max_val))
        (last_key, max_val) = (key, int(val))
    else:
        (last_key, max_val) = (key, max(max_val, int(val)))
if last_key:
    print ("%s\t%s" % (last_key, max_val))
```

Lines explanation

When writing this code, I kept in mind that in the mapping process, same keys are grouped together and in a sequential order, such as "AAAAABBBB", so when my for loop stops seing one key, for example, "A", it will never see this key again. In addition, I took into account that the command "cat 200704hourly.txt | ./mapper.py | sort" sorts all data before sending them to the reducer, which is a crucial detail for the median calculation I'll be doing later.

Step 2

Note: this step 2 will be equal for all measurements that follow (minimum, mean, median and variance), the only difference will be the name of the reducer (reducer_min.py, for example).

Code done on Headnote:

1. #### To Move into coursework_1 directory - Headnote

cd coursework_1

1. #### To create a file for my reducer - Headnote

touch reducer_max.py

1. #### To edit my file - Headnote

nano reducer_max.py

1. #### To give my python scripts the executable permission – Headnote

chmod +x mapper.py reducer_max.py

1. #### To run my mapper.py and reducer on my file and sort the output – Headnote

cat 200704hourly.txt | ./mapper.py | sort | ./reducer_max.py

Note : In step 3, I copy my Python code which is above ("Python code") into it.

Minimum

Pseudo code

```
Read the file

Initialise your key variable "last_key" = None
Initialise your value variable "min_val" = 200

Start loop, for each line in this file:

    Initialise "key" and "val" variables = remove beginning and ending spaces then
    split a string into a list with tab as separator

    If "last_key" and "last_key" differs from current "key":

        First, print current "last_key" and "min_val"

        Update "last_key" and "min_value" with currrent "key" and the integer of "val"
        variable, respectively

    else:

        Update "last_key" and "min_value" with currrent "key" and the minimum between
        current "min_val" and integer of "val" variable, respectively

If "last_key":
    Print keys "last_key" and values "min_val"
```

Python code

In [5]:
```
#! /usr/bin/env python3
import sys

(last_key, min_val) = (None, 200)

for line in sys.stdin:
    (key, val) = line.strip().split("\t")
    if last_key and last_key != key:
        print ("%s\t%s" % (last_key, min_val))
        (last_key, min_val) = (key, int(val))
    else:
        (last_key, min_val) = (key, min(min_val, int(val)))
if last_key:
    print ("%s\t%s" % (last_key, min_val))
```

Mean

Pseudo code

```
Read the file

Initialise your key variable "last_key" = None
Initialise your value variable "mean" = 0
Initialise a variable for total number of Observations "count" = 0
Initialise a variable for sum of Observations  "soma" = 0

For each line in this file:

    Initialise "key" and "val" variables = remove beginning and ending spaces then
    split a string into a list with tab as separator

    If "last_key" and "last_key" differs from current "key":

        Print current "last_key" and "mean"

        Reset "count" to zero

        Reset "soma" to zero

        Update "last_key" and "mean" with currrent "key" and the float of "val"
        variable, respectively

        Increment "count"

        Add current "val" to "soma"

    else:

        Increment "count"

        Add current "val" to "soma"

        Update "last_key" and "mean" with currrent "key" and the rounded value
        resulting from dividing "soma" by "count", respectively

If "last_key":
    Print keys "last_key" and values "mean"
```

Python code

In [6]:
```
#! /usr/bin/env python3
import sys

(last_key, mean) = (None, 0)
count = 0
soma = 0

for line in sys.stdin:
    (key, val) = line.strip().split("\t")
    if last_key and last_key != key:
        print ("%s\t%s" % (last_key, mean))
        count = 0
        soma = 0
        (last_key, mean) = (key, float(val))
        count += 1
        soma  += int(val)
    else:
        count += 1
        soma += int(val)
        (last_key, mean) = (key, round(float(soma/count),2))

if last_key:
    print ("%s\t%s" % (last_key, mean))
```

Median

Pseudo code

```
Read the file

Initialise your key variable "last_key" = None
Initialise your value variable "median" = 0

Create and empty list named, for example, "lista", in order for you to be able to store
the values of each key and be able to access them  by their position in
the that list


For each line in this file:

    Initialise "key" and "val" variables = remove beginning and ending spaces then
    split a string into a list with tab as separator

    If "last_key" and "last_key" differs from current "key":

        Print current "last_key" and "median"

        Reset "lista" to an empty list

        Update "last_key" and "median" with currrent "key" and the integer of "val"
        variable, respectively

        Append the current "val" to your list

    else:

        Append the current "val" to your list

        Create a condition for when number of elements belonging to a key is even:

            Update "last_key" and "median" with current "key" and the value
            resulting from dividing the sum of the two middle numbers in the sorted "lista"
            by 2, respectively

        else:

            Update "last_key" and "median" with current "key" and the middle number
            in the sorted "lista", respectively

If "last_key":
    Print keys "last_key" and values "median"
```

Python code

In [7]:
```
#! /usr/bin/env python3
import sys

(last_key, median) = (None, 0)
lista=[]

for line in sys.stdin:
    (key, val) = line.strip().split("\t")
    if last_key and last_key != key:
        print ("%s\t%s" % (last_key, median))
        lista=[]
        (last_key, median) = (key, int(val))
        lista.append(int(val))
    else:
        lista.append(int(val))
        if (len(lista)%2)==0:
            (last_key, median) = (key, (((lista[int(len(lista)/2)])+(lista[int(len(lista)/2)-1]))/2))
        else:
            (last_key, median) = (key,lista[int(len(lista)/2)])

if last_key:
    print ("%s\t%s" % (last_key, median))
```

Variance

Pseudo code

```
Read the file

Initialise your key variable "last_key" = None
Initialise your value variable "variance" = 0
Initialise a variable for total number of Observations "count" = 0
Initialise a variable for sum of Observations  "soma" = 0
Initialise a variable "mean" = 0
Initialise a variable "squared" = 0

For each line in this file:

    Initialise "key" and "val" variables = remove beginning and ending spaces then
    split a string into a list with tab as separator

    If "last_key" and "last_key" differs from current "key":

        Print current "last_key" and "variance"

        Reset "count" to zero

        Reset "soma" to zero

        Reset "mean" to zero

        Reset "squared" to zero

        Update "last_key" and "variance" with currrent "key" and the float of "val"
        variable, respectively

        Increment "count"

        Add current "val" to "soma"

        Add the value resulting from current "val" multiplied by itself to "squared"

        Equal the variable "mean" the float value resulting resulting from dividing
        "soma" by "count"

    else:

        Increment "count"

        Add current "val" to "soma"

        Add to the variable "squared" the value resulting from current "val" multiplied
        by itself

        Equal the variable "mean" the float value resulting resulting from dividing
        "soma" by "count"

        Update "last_key" and "variance" with current "key" and the sum of the squared
        differences between each data point and the mean divided by the number of data
        values, respectively

If "last_key":
    Print keys "last_key" and values "variance"
```

Python code

In [8]:
```
#! /usr/bin/env python3
import sys

(last_key, variance) = (None, 0)
count = 0
soma = 0
mean =0
squared = 0

for line in sys.stdin:
    (key, val) = line.strip().split("\t")
    if last_key and last_key != key:
        print ("%s\t%s" % (last_key, variance))
        count = 0
        soma = 0
        mean = 0
        squared = 0
        (last_key, variance) = (key, float(val))
        count += 1
        soma  += int(val)
        squared += int(val)**2
        mean = float(soma/count)
    else:
        count += 1
        soma += int(val)
        squared += int(val)**2
        mean = float(soma/count)

        (last_key, variance) = (key, round((squared-count*mean**2)/count,2))

if last_key:
    print ("%s\t%s" % (last_key, variance))
```

Hadoop infrastructure

When using Hadoop, we are mainly saying "do this job using multiple nodes/computers".

If we want to run our mapper and reducers using the hadoop infrastructure, we need to follow this steps:

Note: these steps will be equal for all reducers that follow (minimum, mean, median and variance), the only difference will be the name of the reducer (reducer_min.py, for example).

1. #### Log in - Headnote

ssh username@dsm1.doc.gold.ac.uk

1. #### Go to coursework_1 directory

cd coursework_1

1. #### Copy 200704hourly.txt file from Headnote filesystem to HDFS

hadoop fs -copyFromLocal 200704hourly.txt .

1. #### MapReduce in Python with Hadoop Streaming

hadoop jar /usr/local/hadoop-2.6.0/share/hadoop/tools/lib/hadoop-streaming-2.6.0.jar \ -file mapper.py -mapper mapper.py \ -file reducer_max.py -reducer reducer.py \ -input 200704hourly.txt -output output

1. #### Get output and tranfer it from HDFS to Headnote

hadoop fs -copyToLocal output

1. #### Open another terminal (Local machine) and get output file and tranfer it from Headnote to local machine

scp -r username@dsm1.doc.gold.ac.uk:coursework_1/output/ max_output

Question 2

STEP 1

Code done on Terminal

Part 1: Getting data

1. #### Log in to dsm1

ssh username@dsm1.doc.gold.ac.uk

1. #### Create a directory for question 2

mkdir ./docs

1. #### Download our text data

wget http://www.doc.gold.ac.uk/~agero001/data_science/lab_data/western_classics.zip

1. #### Uncompress the data

unzip western_classics.zip

1. #### Copy all the files in the western_classics/british-fiction-corpus/ directory into the docs/ directory

cp ./western_classics/british-fiction-corpus/* ./docs/

1. #### Tranfer the docs directory from the headnote to hadoop

hadoop fs -copyFromLocal ./docs

Part 2: Mahout

1. #### Create sequence files from the raw text using Mahout

mahout seqdirectory -i docs -o docs-seqfiles -c UTF-8 -chunk 5

1. #### Create a sparse (efficient) representation of the vectors using Mahout

mahout seq2sparse -nv -i docs-seqfiles -o docs-vectors

1. #### Generate "canopies", which will help approximate centroids for K-Means

mahout canopy -i docs-vectors/tfidf-vectors -ow -o docs-vectors/docs-canopy-centroids -dm org.apache.mahout.common.distance.CosineDistanceMeasure -t1 0.5 -t2 0.3

1. #### Run the K-Means algorithm with Mahout

mahout kmeans -i docs-vectors/tfidf-vectors -c docs-canopy-centroids -o docs-kmeans-clusters -dm org.apache.mahout.common.distance.CosineDistanceMeasure -cl -cd 0.1 -ow -x 20 -k 3

1. #### Look to find the 'final' iteration's clustering solution

hadoop fs -ls docs-kmeans-clusters

1. #### Evaluate solution

mahout clusterdump -dt sequencefile -d docs-vectors/dictionary.file-* -i docs-kmeans-clusters/clusters-2-final -o clusters.txt -b 100 -p docs-kmeans-clusters/clusteredPoints -n 20 --evaluate

1. #### Look at the end of the clusters.txt file

tail ./clusters.txt

As the coursework demands, I'll need to change the value of k, which is the number of clusters, as well as the distance measurements and loose and tight distances (t1 and t2). In my terminal code, I applied some adjustments in stages 3, 4, 6 (part 2) to do this. For this exercise, I'll test two distance measures: Cosine and Euclidean, for values of k = [3,5,7,10,12,15,18,20]. I chose t1 = 0.5 and t2 = 0.3 for Cosine distance, and t1 = 2000 and t2 = 1500 for Euclidean distance.

STEP 2: Output and graphs

Clustering is the partition of all data into groups, usually referred to as clusters, based on data patterns. We want the distance between points within a cluster (intra cluster distance) to be as small as possible because we want them to be as similar as possible. When the distance between the centroid of a cluster and its points is small, it means the points are close together and the cluster is dense. Different clusters, on the other hand, should be as distinct as possible from one another. The distance between the centroids of two separate clusters is known as inter cluster distance.

Inter-cluster density is defined as the density in the between-cluster areas, so the higher the better. In contrast, the smaller the intra-cluster density the better.

K-means is a distance-based technique in which the distances between points are calculated to allocate a point to a cluster. Each cluster in K-Means is paired with a centroid. Due to its relative ease of implementation and ability to scale well to very big datasets, k-means is one of the most common clustering methods. Because k-means is stochastic, it cannot guarantee the discovery of the global optimum clustering solution. In fact, outliers and noisy data can make the method extremely sensitive, and the ultimate clustering quality can be heavily influenced by the location of the initial cluster centroids. To put it another way, k-means is more likely to find a local minimum than a global one. Even if the original cluster centroids are well-placed, if clusters are not roughly equal in size and density, non-optimal clustering may result.

Output Cosine Distance

In [9]:
```
k = [3,5,7,10,12,15,18]

Inter_Cluster_Density = [0.4451541533194988, 0.49600669221521704, 0.38408398901491614, 0.44024282086510436, 0.3

Intra_Cluster_Density = [0.571138465446429, 0.5544161655101385, 0.5854214453055803, 0.5352731664030042, 0.55505
```

In [10]:
```
Inter_Cluster_Density  = [round(num,4) for num in Inter_Cluster_Density]

Intra_Cluster_Density  = [round(num,4) for num in Intra_Cluster_Density]

print(Inter_Cluster_Density)
print(Intra_Cluster_Density)
```

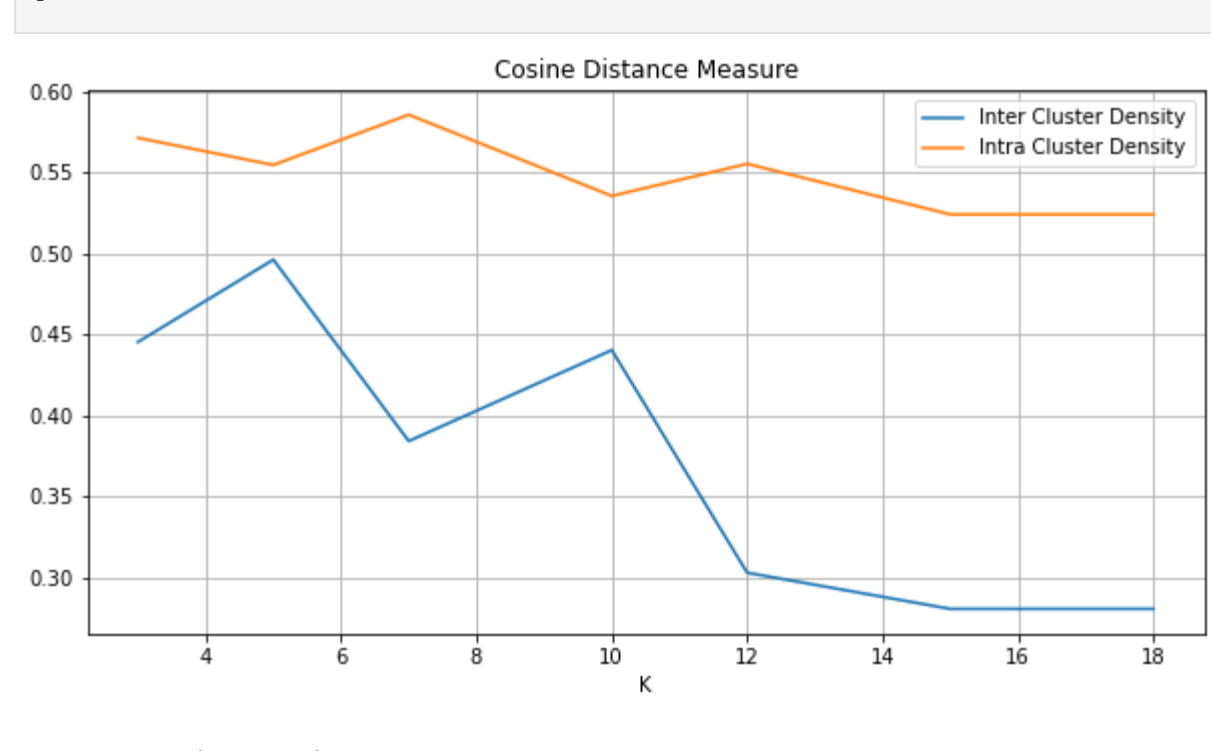
```
[0.4452, 0.496, 0.3841, 0.4402, 0.3029, 0.2806, 0.2806]
[0.5711, 0.5544, 0.5854, 0.5353, 0.5551, 0.5239, 0.5239]
```

In [11]:
```
import pandas as pd

cosine = pd.DataFrame(list(zip(k,Inter_Cluster_Density, Intra_Cluster_Density)),
                     columns =['K','Inter Cluster Density', 'Intra Cluster Density'])

cosine
```

Out[11]:

	K	Inter Cluster Density	Intra Cluster Density
0	3	0.4452	0.5711
1	5	0.4960	0.5544
2	7	0.3841	0.5854
3	10	0.4402	0.5353
4	12	0.3029	0.5551
5	15	0.2806	0.5239
6	18	0.2806	0.5239

In [12]:
```
import matplotlib.pyplot as plt

cosine.plot(x='K', y=['Inter Cluster Density', 'Intra Cluster Density'], figsize=(10,5), grid=True)

plt.title("Cosine Distance Measure")
plt.show()
```



Output Euclidean Distance

In [13]:
```
k = [3,5,7,10,12,15,18]

Inter_Cluster_Density = [0.44235517474526337, 0.43561763349095555, 0.4845228365262356, 0.4892239530039184, 0.45
Intra_Cluster_Density = [0.5891069114004185, 0.5768438483444104, 0.609261366893357, 0.5290949105069825, 0.55688
```

In [14]:
```
Inter_Cluster_Density  = [round(num,4) for num in Inter_Cluster_Density]

Intra_Cluster_Density  = [round(num,4) for num in Intra_Cluster_Density]

print(Inter_Cluster_Density)
print(Intra_Cluster_Density)
```

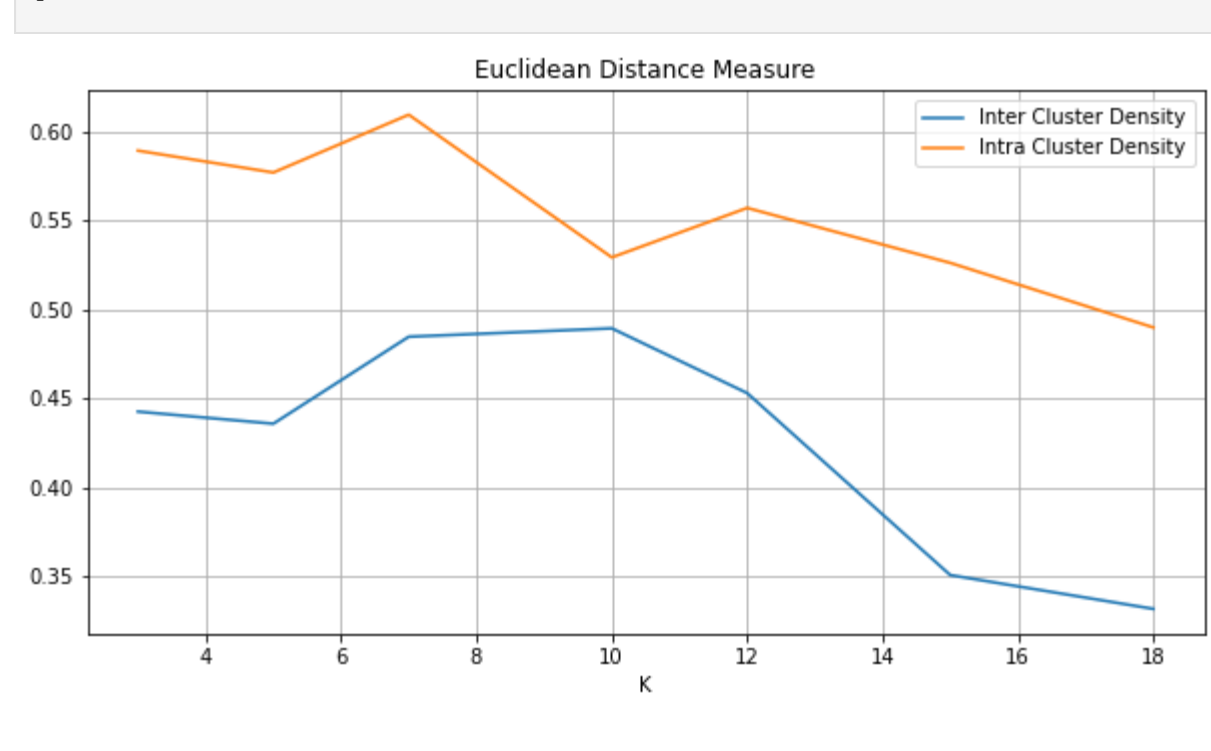
```
[0.4424, 0.4356, 0.4845, 0.4892, 0.4528, 0.3505, 0.3315]
[0.5891, 0.5768, 0.6093, 0.5291, 0.5569, 0.526, 0.4897]
```

In [15]:
```
euclidean = pd.DataFrame(list(zip(k,Inter_Cluster_Density, Intra_Cluster_Density)),
                     columns =['K','Inter Cluster Density', 'Intra Cluster Density'])

euclidean
```

Out[15]:

	K	Inter Cluster Density	Intra Cluster Density
0	3	0.4424	0.5891
1	5	0.4356	0.5768
2	7	0.4845	0.6093
3	10	0.4892	0.5291
4	12	0.4528	0.5569
5	15	0.3505	0.5260
6	18	0.3315	0.4897

In [16]:
```
euclidean.plot(x='K', y=['Inter Cluster Density', 'Intra Cluster Density'], figsize=(10,5), grid=True)

plt.title("Euclidean Distance Measure")
plt.show()
```



Analysis of the two graphs and distance measures

We can see that both graphs present curves with fluctuations, especially between K values between 3 and 10. However, we can also see that for both distance measures, 10 seems the appropriate number of clusters because adding another cluster does not seem to improve much the partition. Additonally, for k=10, we have relatively good inter and intra cluster densities values, 0.4402 and 0.5353 for cosine distance and 0.4892 and 0.5291 for euclidean distance, respectively. We can also say that k<10 may be too few presenting in general numerous long distances from points to the centroid, and k>10 maybe be too many, resulting in little improvements in average distance.

Because cosine distance considers the angle between vectors rather than their weight or magnitude, it is commonly employed as a metric for calculating distance when the magnitude of the vectors is irrelevant. When working with text data represented by word counts, for example, this can happen. Euclidean distance is the length of a line segment between the two points. The distance between any two points is not influenced by the addition of new objects to the study, which may be outliers, which is one advantage of this method.

To summarise, Cosine measure distance and 10 as the number of clusters appear to be the best solution for all of the reasons stated above.

Limitations of MapReduce methodology and Hadoop's MapReduce computing engine

Limitations of MapReduce methodology and Hadoop's MapReduce computing engine Hadoop's MapReduce framework is an open-source software framework that supports distributed storage and processing of huge data sets on computer clusters. Hadoop has its limitations which must be considered when it is to be used along with MapReduce. It struggles to tackle problems that aren't easily recomputable.

Hadoop is designed to process huge volumes of data and writes data to and from disks. The data is read from and written to the disc at each stage of the processing process. Because disc seek requires time, the entire operation takes a long time. Hadoop is optimized more for processing the amounts of data. Large data sets are available to it. Hadoop's performance for real-time processing is limited due to its batch-oriented nature. Hadoop is not suitable for applications that require low latency. For example, HDFS is a good choice for handling huge files but not for handling many small files. The user must wait for real files for HDFS. The user then sends a map-reduce operation using the file as input.

References

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