Spark RDD-based exercises

Ex 30

Exercise #30

- Log filtering
  - Input: a simplified log of a web server (i.e., a textual file)
    - Each line of the file is associated with a URL request
  - Output: the lines containing the word "google"
    - Store the output in an HDFS folder

Exercise #30 - Example

- Input file

```
66.249.69.97 - - [24/Sep/2014:22:25:44 +0000] "GET http://www.google.com/bot.html"
66.249.69.97 - - [24/Sep/2014:22:26:44 +0000] "GET http://www.google.com/how.html"
66.249.69.97 - - [24/Sep/2014:22:28:44 +0000] "GET http://dbdmg.polito.it/course.html"
71.19.157.179 - - [24/Sep/2014:22:30:12 +0000] "GET http://www.google.com/faq.html"
66.249.69.97 - - [24/Sep/2014:31:28:44 +0000] "GET http://dbdmg.polito.it/thesis.html"
```

- Output

```
66.249.69.97 - - [24/Sep/2014:22:25:44 +0000] "GET http://www.google.com/bot.html"
66.249.69.97 - - [24/Sep/2014:22:26:44 +0000] "GET http://www.google.com/how.html"
71.19.157.179 - - [24/Sep/2014:22:30:12 +0000] "GET http://www.google.com/faq.html"
```

```python
from pyspark import SparkConf, SparkContext

# Read the content of the input file
# Each element/string of the logRDD corresponds to one line of the input file
conf = SparkConf().setAppName("Log filtering")

sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex30/data/"
outputPath = "res_out_Ex30/"

# Read the content of the input file
# Each element/string of the logRDD corresponds to one line of the input file
logRDD = sc.textFile(inputPath)

# Only the elements of the RDD satisfying the filter are selected
googleRDD = logRDD.filter(lambda logLine: logLine.lower().find("google") >= 0)

# Store the result in the output folder
googleRDD.saveAsTextFile(outputPath)
```

Ex 31

Exercise #31

- Log analysis
  - Input: log of a web server (i.e., a textual file)
    - Each line of the file is associated with a URL request
  - Output: the list of distinct IP addresses associated with the connections to a google page (i.e., connections to URLs containing the term "www.google.com")
    - Store the output in an HDFS folder

Exercise #31 - Example

- Input file

```
66.249.69.97 - - [24/Sep/2014:22:25:44 +0000] "GET http://www.google.com/bot.html"
66.249.69.97 - - [24/Sep/2014:22:26:44 +0000] "GET http://www.google.com/how.html"
66.249.69.97 - - [24/Sep/2014:22:28:44 +0000] "GET http://dbdmg.polito.it/course.html"
71.19.157.179 - - [24/Sep/2014:22:30:12 +0000] "GET http://www.google.com/faq.html"
66.249.69.95 - - [24/Sep/2014:31:28:44 +0000] "GET http://dbdmg.polito.it/thesis.html"
66.249.69.97 - - [24/Sep/2014:56:26:44 +0000] "GET http://www.google.com/how.html"
56.249.69.97 - - [24/Sep/2014:56:26:44 +0000] "GET http://www.google.com/how.html"
```

- Output

```
66.249.69.97
71.19.157.179
56.249.69.97
```

difference between map() and flatmap()

`map()` and `flatMap()` are both Spark transformations used to apply a function to each element of an RDD, but they behave differently in terms of output structure.

1. map()
   - Transforms each input element into one output element.
   - The result is an RDD where each input element maps to a single transformed element.

   Example:

```
rdd = sc.parallelize(["hello", "world"])

mapped_rdd = rdd.map(lambda x: x.upper())
print(mapped_rdd.collect())

# Output: ['HELLO', 'WORLD']
```

2. flatmap()
   - Transforms each input element into zero or more output elements.
   - The result is a flattened RDD where the transformation function returns an iterable, and Spark automatically expands (flattens) it.
     Example:

```
rdd = sc.parallelize(["hello world", "hi"])

flat_mapped_rdd = rdd.flatMap(lambda x: x.split(" "))
print(flat_mapped_rdd.collect())

# Output: ['hello', 'world', 'hi']
```

- Use map() when each input element should correspond to exactly one output element.

- Use flatMap() when each input element may produce multiple outputs, or when flattening a list structure.

version with map()

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 31")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex31/data/"
outputPath = "res_out_Ex31/"

# Read the content of the input file
# Each element/string of the logRDD corresponds to one line of the input file
logRDD = sc.textFile(inputPath)

# Only the elements of the RDD satisfying the filter are selected
googleRDD = logRDD.filter(lambda logLine:
logLine.lower().find("www.google.com")>=0)

# Use map to select only the IP address. It is the first field before -
IPsRDD = googleRDD.map(lambda logLine: logLine.split('-')[0])

# Remove duplicates
distinctIPsRDD = IPsRDD.distinct()

# Store the result in the output folder
distinctIPsRDD.saveAsTextFile(outputPath)
```

version with flatmap()

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 31")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex31/data/"
outputPath = "res_out_Ex31/"

# Read the content of the input file
# Each element/string of the logRDD corresponds to one line of the input file
logRDD = sc.textFile(inputPath)

def filterAndExtractIP(line):
    # Inizialize the list that will be returned by this function
    listIPs = []
```

```
    # If line contains www.google.com add the IP of this line in the returned
list
    if line.lower().find("www.google.com")>=0:
        IP = line.split('-')[0]
        listIPs.append(IP)

    # return listIPs
    return listIPs

# Only the elements of the RDD satisfying the filter are selected
# and the associated IPs are returned
# Those lines that do not contain "www.google.com" return an empy list.
IPsRDD = logRDD.flatMap(filterAndExtractIP)

# Remove duplicates
distinctIPsRDD = IPsRDD.distinct()

# Store the result in the output folder
distinctIPsRDD.saveAsTextFile(outputPath)
```

Ex 32

Exercise #32

- Maximum value
  - Input: a collection of (structured) textual csv files containing the daily value of PM10 for a set of sensors
    - Each line of the files has the following format
      sensorId,date,PM10 value (µg/m³)\n
  - Output: report the maximum value of PM10
    - Print the result on the standard output

Exercise #32 - Example

- Input file

```
s1,2016-01-01,20.5
s2,2016-01-01,30.1
s1,2016-01-02,60.2
s2,2016-01-02,20.4
s1,2016-01-03,55.5
s2,2016-01-03,52.5
```

- Output 60.2

1. We can use the take `takeOrdered(num)` action → since by default it uses the ascending order, we customize the sorting function by negating the elements. In this way we get the elements in descending order and we only the first one. Keep in mind it returns a list even if there is only one element.
2. We can also use the `top(num)` action → it will retrieve the `num` largest elements in the collection. Of course, we will take only the first one. Same as before: keep in mind it returns a list even if there is only one element.
3. Firstly, with `map()` we retrieve all the values (the same as the examples before) and then with `reduce()` we take only the maximum value.

version with takeOrdered()

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 32")
```

```
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex32/data/"

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Extract the PM10 values
# It can be implemented by using the map transformation
# Split each line and select the third field
# Remember to convert it into a float, otherwise it will be a string
pm10ValuesRDD = readingsRDD.map(lambda PM10Reading:
float(PM10Reading.split(',')[2]))

# Select the maximum PM10 value by using the takeOrdered action. We need to
change the "sort function"
maxPM10Value = pm10ValuesRDD.takeOrdered(1, lambda n: -1*n)[0]

# Print the result on the standard output of the Driver program/notebook
print(maxPM10Value)
```

version with top() action

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 32")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex32/data/"

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Extract the PM10 values
# It can be implemented by using the map transformation
# Split each line and select the third field
pm10ValuesRDD = readingsRDD.map(lambda PM10Reading:
float(PM10Reading.split(',')[2]))

# Select the maximum PM10 value by using the top action
maxPM10Value = pm10ValuesRDD.top(1)[0]

# Print the result on the standard output of the Driver program/notebook
print(maxPM10Value)
```

version with reduce()

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 32")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex32/data/"

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Extract the PM10 values
# It can be implemented by using the map transformation
# Split each line and select the third field
pm10ValuesRDD = readingsRDD.map(lambda PM10Reading:
float(PM10Reading.split(',')[2]))

# Select/compute the maximum PM10 value
# The lambda function is applied in a pairwise fashion to combine the elements
# It compares two values and returns the larger one, progressively reducing the
RDD.
maxPM10Value = pm10ValuesRDD.reduce(lambda value1, value2: max(value1,value2))

# Print the result on the standard output of the Driver program/notebook
print("maxPM10Value")
```

How `reduce()` Works for Finding the Maximum Value

Let's break down how `reduce()` works for finding the **maximum PM10 value**.

```
maxPM10Value = pm10ValuesRDD.reduce(lambda value1, value2: max(value1, value2))
```

Step-by-Step Explanation

1. **Initial Values**:
    - `value1` and `value2` are the two values that are taken from the RDD.
2. **Lambda Function**:
    - The lambda function `lambda value1, value2: max(value1, value2)` compares `value1` and `value2` and returns the larger of the two. This comparison happens iteratively across the entire RDD.

Example with RDD values

If the RDD contains the following values:

```
[35.2, 42.3, 28.7, 50.1, 60.4]
```

Here's how the process works:

1. The first comparison is between `35.2` and `42.3`. The function returns `42.3`.
2. Next, it compares `42.3` and `28.7`. The function returns `42.3`.
3. Then, it compares `42.3` and `50.1`. The function returns `50.1`.
4. Finally, it compares `50.1` and `60.4`. The function returns `60.4`.

Final Result

After applying the `reduce()` function across all elements in the RDD, the maximum PM10 value, `60.4`, is returned.

Ex 33

Exercise #33

- Top-k maximum values
  - Input: a collection of (structured) textual csv files containing the daily value of PM10 for a set of sensors
    - Each line of the files has the following format
      sensorId,date,PM10 value (µg/m³)\n
  - Output: report the top-3 maximum values of PM10
    - Print the result on the standard output

Exercise #33 - Example

- Input file

```
s1,2016-01-01,20.5
s2,2016-01-01,30.1
s1,2016-01-02,60.2
s2,2016-01-02,20.4
s1,2016-01-03,55.5
s2,2016-01-03,52.5
```

- Output

```
60.2
55.5
52.5
```

version with top()

```
# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Extract the PM10 values
# It can be implemented by using the map transformation
# Split each line and select the third field
pm10ValuesRDD = readingsRDD.map(lambda PM10Reading:
float(PM10Reading.split(',')[2]))

# Select the top-3 values
top3PM10Value = pm10ValuesRDD.top(3)

# Print the result on the standard output of the Driver program/notebook
print(top3PM10Value)
```

version with takeOrdered()

```
# Select the top-3 values
top3PM10Value = pm10ValuesRDD.takeOrdered(3, lambda num: -num)
```

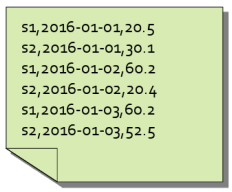
Ex 34

Exercise #34

- Readings associated with the maximum value
  - Input: a collection of (structured) textual csv files containing the daily value of PM10 for a set of sensors
    - Each line of the files has the following format
      sensorId,date,PM10 value (µg/m³)\n
  - Output: the line(s) associated with the maximum value of PM10
    - Store the result in an HDFS folder

Exercise #34 - Example

- Input file



- Output

s1,2016-01-02,60.2
s1,2016-01-03,60.2

1. We first map the values and find the maximum with reduce. We then use this result to select from all the lines only those where the PM10 value is equal to this one (`filter()` action).
   We used the `reduce()` method to find the maximum, but we could have used `top()` or `takeOrdered()` as in the example before without problems.
   Be careful: we can use `takeOrdered()` or `top()` only to select the maximum value, not to select all the lines associated with the maximum value!

version with reduce() and filter()

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 34")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex34/data/"
outputPath = "res_out_Ex34/"

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Extract the PM10 values
# It can be implemented by using the map transformation
# Split each line and select the third field
pm10ValuesRDD = readingsRDD.map(lambda PM10Reading:
float(PM10Reading.split(',')[2]))

# Select/compute the maximum PM10 value
maxPM10Value = pm10ValuesRDD.reduce(lambda value1, value2: max(value1,value2))

# Filter the content of readingsRDD
# Select only the line(s) associated with the maxPM10Value
```

```
selectedRecordsRDD = readingsRDD.filter(lambda PM10Reading:
float(PM10Reading.split(',')[2])==maxPM10Value)

# Store the result in the output folder
selectedRecordsRDD.saveAsTextFile(outputPath)
```

version with takeOrdered()

```
# Select/compute the maximum PM10 value by using takeOrdered
maxPM10Value = pm10ValuesRDD.takeOrdered(1, lambda num: -num)[0]
```

We only select the maximum and then nothing changes with respect to the previous version.

It would have been **WRONG** a solution like this:

```
# Extract the top-1 result by using takeOrdered
# Consider the PM10 value to select the top-1 line
selectedRecords  = readingsRDD.takeOrdered(1, lambda PM10Reading:
-1*float(PM10Reading.split(',')[2]))
# This solution is WRONG because it selects the first line associated with the
maximum PM10 and
# not all the lines (potentially more than one) associated with the maximum
PM10 value

# Transform the local list returned by top in to an RDD
selectedRecordsRDD = sc.parallelize(selectedRecords)
```

Ex 35

Exercise #35

- Dates associated with the maximum value
  - Input: a collection of (structured) textual csv files containing the daily value of PM10 for a set of sensors
    - Each line of the files has the following format
      sensorId,date,PM10 value (µg/m³)\n
  - Output: the date(s) associated with the maximum value of PM10
    - Store the result in an HDFS folder

Exercise #35 - Example

- Input file

```
s1,2016-01-01,20.5
s2,2016-01-01,30.1
s1,2016-01-02,60.2
s2,2016-01-02,20.4
s1,2016-01-03,60.2
s2,2016-01-03,52.5
```

- Output

```
2016-01-02
2016-01-03
```

1. We find the maximum as before
2. We select only the lines with the maximum value
3. We extract the dates from those lines

```python
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 35")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex35/data/"
outputPath = "res_out_Ex35/"

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Extract the PM10 values
# It can be implemented by using the map transformation
# Split each line and select the third field
pm10ValuesRDD = readingsRDD.map(lambda PM10Reading:
float(PM10Reading.split(',')[2]))

# Select/compute the maximum PM10 value
maxPM10Value = pm10ValuesRDD.reduce(lambda value1, value2: max(value1,value2))

# Filter the content of readingsRDD
# Select only the line(s) associated with the maxPM10Value
selectedRecordsRDD = readingsRDD.filter(lambda PM10Reading:
float(PM10Reading.split(',')[2])==maxPM10Value)

# Extract the dates from the selected records (second field of each string)
datesRDD = selectedRecordsRDD.map(lambda PM10Reading: PM10Reading.split(',')
[1])

# Remove duplicates, if any
distinctDatesRDD = datesRDD.distinct()

# Store the result in the output folder
distinctDatesRDD.saveAsTextFile(outputPath)
```

Ex 36

Exercise #36

- Average value
  - Input: a collection of (structured) textual csv files containing the daily value of PM10 for a set of sensors
    - Each line of the files has the following format
      sensorId,date,PM10 value (µg/m³)\n
  - Output: compute the average PM10 value
    - Print the result on the standard output

Exercise #36 - Example

- Input file

```
s1,2016-01-01,20.5
s2,2016-01-01,30.1
s1,2016-01-02,60.2
s2,2016-01-02,20.4
s1,2016-01-03,55.5
s2,2016-01-03,52.5
```

- Output 39.86

Version 1

1. We extract only the PM10Values (`map()`)
2. We sum them (`reduce()`)
3. We find the number of elements (`count()`)
4. We compute the average

Version 2

1. We extract the PM10Values, but this time we return the tuple (PM10 value, 1) (`map()`)
2. We compute the sum of the pm 10 values and the count of the number of lines together (`reduce()`)
3. We use those values to compute the average

Version 3

1. We compute the sum of the PM10 values and the number of input lines by using the aggregate action
2. We compute the average

version 1

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 36")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex36/data/"

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Extract the PM10 values
# It can be implemented by using the map transformation
# Split each line and select the third field
pm10ValuesRDD = readingsRDD.map(lambda PM10Reading:
float(PM10Reading.split(',')[2]))

# Compute the sum of the PM10 values by using the reduce action
sumPM10Values = pm10ValuesRDD.reduce(lambda value1, value2: value1+value2)

# Count the number of lines of the input file
numLines = pm10ValuesRDD.count()

# Compute average
print("Average=", sumPM10Values / numLines)
```

version 2

```
# Extract the PM10 values and return a tuple(PM10 value, 1)
# It can be implemented by using the map transformation
# PM10 is the third field of each input string
pm10ValuesRDD = readingsRDD.map(lambda PM10Reading: (
float(PM10Reading.split(',')[2]), 1) )

# Compute the sum of the PM10 values and the number of input lines (= sum of
onses) by using the reduce action
sumPM10ValuesCountLines = pm10ValuesRDD.reduce(lambda value1, value2:
(value1[0]+value2[0], value1[1]+value2[1]))

# Compute the average PM10 value
# sumPM10ValuesCountLines[0] is equal to the sum of the input PM10 values
# sumPM10ValuesCountLines[1] is equal to the number of input lines/input values
print("Average=", sumPM10ValuesCountLines[0]/sumPM10ValuesCountLines[1])
```

version 3

```
# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Compute the sum of the PM10 values and the number of input lines by using the
aggregate action
sumPM10ValuesCountLines = readingsRDD.aggregate((0,0), \
                                lambda intermediateResult, PM10Reading: \
                                (intermediateResult[0] +
float(PM10Reading.split(',')[2]), intermediateResult[1] + 1), \
                                lambda intermR1, intermR2: (intermR1[0] +
intermR2[0], intermR1[1] + intermR2[1]) )

# Compute the average PM10 value
# sumPM10ValuesCountLines[0] is equal to the sum of the input PM10 values
# sumPM10ValuesCountLines[1] is equal to the number of input lines/input values
print("Average=", sumPM10ValuesCountLines[0]/sumPM10ValuesCountLines[1])
```

version 3, small variation

```
readingsRDD = sc.textFile(inputPath)

pm10ValuesRDD = readingsRDD.map(lambda line: float(line.split(',')[2]))

sumCount = pm10ValuesRDD.aggregate((0, 0), # zero value (sum, count)
                                lambda prev, new: (prev[0] + new, prev[1] +
1), #seqOp
                                lambda p1, p2: (p1[0] + p2[0], p1[1] +
p2[1]) #combop
                                )
```

```
avgPm10 = sumCount[0] / sumCount[1]

print(avgPm10)
```

Ex 37

Exercise #37

- Maximum values
  - Input: a textual csv file containing the daily value of PM10 for a set of sensors
    - Each line of the files has the following format
      sensorId,date,PM10 value (µg/m³)\n
  - Output: the maximum value of PM10 for each sensor
    - Store the result in an HDFS file

Exercise #37 - Example

- Input file

```
s1,2016-01-01,20.5
s2,2016-01-01,30.1
s1,2016-01-02,60.2
s2,2016-01-02,20.4
s1,2016-01-03,55.5
s2,2016-01-03,52.5
```

- Output

```
(s1,60.2)
(s2,52.5)
```

Here, the main point to understand is that we start by creating tuples (sensor_id, pm10Value) using `map()`. Then we use `reduceByKey()` to obtain something like (sensor_id, max pm10 value for that sensor_id). This gives us the desired result. 😊
With `reduceByKey()` we are able to obtain a single-value final result for each key.
Otherwise, if we wanted a list of values for each key → `groupByKey()`

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 37")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex37/data/sensors.txt" #
argv[1]
outputPath = "res_out_Ex37/" # argv[2]

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Extract the PM10 values
# It can be implemented by using the map transformation
# Split each line and select the third field

# Create an RDD of key-value pairs
# Each pair contains a sensorId (key) and a PM10 value (value)
# It can be implemented by using the map transformation.
# The function of the map transformation returns a tuple
sensorsPM10ValuesRDD = readingsRDD.map(lambda PM10Reading:
(PM10Reading.split(',')[0], float(PM10Reading.split(',')[2])) )

# Apply the reduceByKey transformation to compute the maximum PM10 value for
each sensor
```

```
sensorsMaxValuesRDD = sensorsPM10ValuesRDD.reduceByKey(lambda value1, value2:
max(value1, value2))

# Store the result in the output folder
sensorsMaxValuesRDD.saveAsTextFile(outputPath)
```

Ex 38

Exercise #38

- Pollution analysis
  - Input: a textual csv file containing the daily value of PM10 for a set of sensors
    - Each line of the files has the following format
      sensorId,date,PM10 value (µg/m³)\n
  - Output: the sensors with at least 2 readings with a PM10 value greater than the critical threshold 50
    - Store in an HDFS file the sensorIds of the selected sensors and also the number of times each of those sensors is associated with a PM10 value greater than 50

Exercise #38 - Example

- Input file

```
s1,2016-01-01,20.5
s2,2016-01-01,30.1
s1,2016-01-02,60.2
s2,2016-01-02,20.4
s1,2016-01-03,55.5
s2,2016-01-03,52.5
```

- Output (s1,2)

1. We select only the lines where the PM10Value has a value greater than the threshold (`filter()`)
2. We create, with `map()`, an RDD with key-values (sensor_id, 1)
3. With `reduceByKey()` we sum all the '1' values for every sensor_id
4. With `filter()` we select only those that has a value >= 2

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 37")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex38/data/sensors.txt" #
argv[1]
outputPath = "res_out_Ex38/" # argv[2]

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Apply a filter transformation to select only the lines with PM10>50
readingsHighValueRDD = readingsRDD.filter(lambda PM10Reading:
float(PM10Reading.split(',')[2])>50 )

# Create an RDD of key-value pairs
# Each pair contains a sensorId (key) and +1 (value)
# It can be implemented by using the map transformation.
# The function of the map transformation returns a tuple
sensorsPM10CriticalValuesRDD = readingsHighValueRDD.map(lambda PM10Reading:
(PM10Reading.split(',')[0], 1) )

# Count the number of critical values for each sensor by using the reduceByKey
```

```
transformation.
# The used function is the sum of the values (the sum of the ones)
sensorsCountsRDD = sensorsPM10CriticalValuesRDD.reduceByKey(lambda value1,
value2: value1+value2)

# Select only the pairs with a value (number of critical PM10 values) at least
equal to 2
# This is a filter transformation on an RDD of pairs
sensorsCountsCriticalRDD = sensorsCountsRDD.filter(lambda sensorCountPair:
sensorCountPair[1]>=2)

# Store the result in the output folder
sensorsCountsCriticalRDD.saveAsTextFile(outputPath)
```

Ex 39

Exercise #39

- Critical dates analysis
  - Input: a textual csv file containing the daily value of PM10 for a set of sensors
    - Each line of the files has the following format
      sensorId,date,PM10 value (µg/m³)\n
  - Output: an HDFS file containing one line for each sensor
    - Each line contains a sensorId and the list of dates with a PM10 values greater than 50 for that sensor
  - **Consider only the sensors associated at least one time with a PM10 value greater than 50**

Exercise #39 - Example

- Input file

```
s1,2016-01-01,20.5
s2,2016-01-01,30.1
s1,2016-01-02,60.2
s2,2016-01-02,20.4
s1,2016-01-03,55.5
s2,2016-01-03,52.5
```

- Output

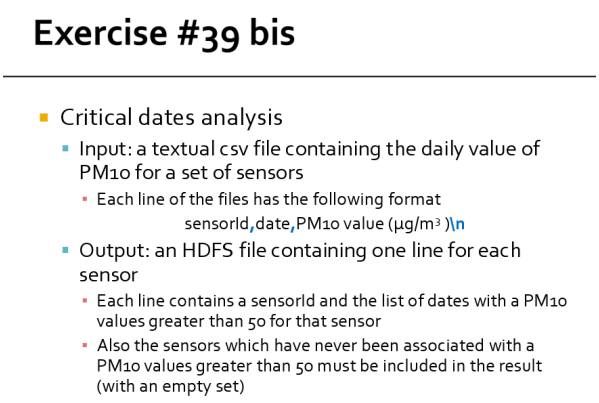
```
(s1, [2016-01-02, 2016-01-03])
(s2, [2016-01-03])
```

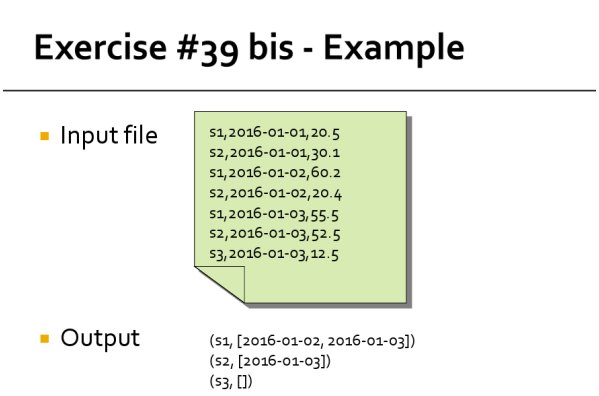
1. We select the sensor_ids where the threshold is > 50 (`filter()`)
2. We create an RDD with pairs (sensor_id, date) (`map()` transformation)
3. We group by key all the values created before (`groupByKey()`)
4. Then we have to transform the content of values into list for correctness

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 39")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex39/data/sensors.txt" #
argv[1]
outputPath = "res_out_Ex39/" # argv[2]

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Apply a filter transformation to select only the lines with PM10>50
readingsHighValueRDD = readingsRDD.filter(lambda PM10Reading:
float(PM10Reading.split(',')[2])>50 )
```

```
# Create an RDD of key-value pairs
# Each pair contains a sensorId (key) and a date (value)
# It can be implemented by using the map transformation.
sensorsCriticalDatesRDD = readingsHighValueRDD.map(lambda PM10Reading:
(PM10Reading.split(',')[0], PM10Reading.split(',')[1]) )

# Create one pair for each sensor (key) with the list of dates associated with
that sensor (value)
# by using the groupByKey transformation
finalSensorCriticalDates = sensorsCriticalDatesRDD.groupByKey()

# The map method is used to transform the content of the iterable over the
values of each key into a list (that can be stored in a readable format)
finalSensorCriticalDateStringFormat = finalSensorCriticalDates.mapValues(lambda
dates : list(dates))

# Store the result in the output folder
finalSensorCriticalDateStringFormat.saveAsTextFile(outputPath)
```

Ex 39 bis





The first part is identical to the previous one.
We have to add the sensor_ids with the empty lists. To do so:

1. We create an RDD for all the sensor_ids
2. We subtract from those the ones with PM10Values > 50
3. We create an RDD with pairs (sensor_id, []) for those
4. We do an union with the previous ones

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 39 bis")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex39bis/data/sensors.txt" #
argv[1]
outputPath = "res_out_Ex39bisv1" # argv[2]
```

```
# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Apply a filter transformation to select only the lines with PM10>50
readingsHighValueRDD = readingsRDD.filter(lambda PM10Reading:
float(PM10Reading.split(',')[2])>50 )

# Create an RDD of key-value pairs
# Each pair contains a sensorId (key) and a date (value)
# It can be implemented by using the map transformation.
sensorsCriticalDatesRDD = readingsHighValueRDD.map(lambda PM10Reading:
(PM10Reading.split(',')[0], PM10Reading.split(',')[1]) )

# Create one pair for each sensor (key) with the list of dates associated with
that sensor (value)
# by using the groupByKey transformation
finalSensorCriticalDates = sensorsCriticalDatesRDD.groupByKey()

# The map method is used to transform the content of the iterable over the
values of each key into a list (that can be stored in a readable format)
finalSensorCriticalDateStringFormat = finalSensorCriticalDates.mapValues(lambda
dates : list(dates))

# All sensors ID from the complete input file
allSensorsRDD = readingsRDD.map(lambda PM10Reading: PM10Reading.split(',')[0])

# Select the identifiers of the sensors that have never been associated with a
PM10 values greater than 50
sensorsNeverHighValueRDD =
allSensorsRDD.subtract(finalSensorCriticalDates.keys())

# Map each sensor that has never been associated with a PM10 values greater
than 50
# to a tuple/pair (sensorId, [])
sensorsNeverHighValueRDDEmptyList = sensorsNeverHighValueRDD.map(lambda
sensorId: (sensorId, []))

# Compute the final result
resultRDD =
finalSensorCriticalDateStringFormat.union(sensorsNeverHighValueRDDEmptyList)
```

Ex 40

Exercise #40

- Order sensors by number of critical days
  - Input: a textual csv file containing the daily value of PM10 for a set of sensors
    - Each line of the files has the following format
      sensorId,date,PM10 value (µg/m³)\n
  - Output: an HDFS file containing the sensors ordered by the number of critical days
    - Each line of the output file contains the number of days with a PM10 values greater than 50 for a sensor s and the sensorId of sensor s
  - **Consider only the sensors associated at least one time with a PM10 value greater than 50**

Exercise #40 - Example

- Input file

```
s1,2016-01-01,20.5
s2,2016-01-01,30.1
s1,2016-01-02,60.2
s2,2016-01-02,20.4
s1,2016-01-03,55.5
s2,2016-01-03,52.5
```

- Output

```
s1,2
s2,1
```

1. We create an RDD with the lines where the PM10Value > 50 (`filter()`)
2. Starting from those we create tuples (sensor_id, 1) (`map()`)
3. We reduce by key making a sum of all values (`reduceByKey()`)
4. We sort them in descending order (`sortBy()` with parameters: value field and False for ascending order)

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 40")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex40/data/sensors.txt" #
argv[1]
outputPath = "res_out_Ex40/" # argv[2]

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Apply a filter transformation to select only the lines with PM10>50
readingsHighValueRDD = readingsRDD.filter(lambda PM10Reading:
float(PM10Reading.split(',')[2])>50 )

# Create an RDD of key-value pairs
# Each pair contains a sensorId (key) and +1 (value)
# It can be implemented by using the map transformation.
# The function of the map transformation returns a tuple
sensorsPM10CriticalValuesRDD = readingsHighValueRDD.map(lambda PM10Reading:
(PM10Reading.split(',')[0], 1) )

# Count the number of critical values for each sensor by using the reduceByKey
transformation.
# The used function is the sum of the values (the sum of the ones)
sensorsCountsRDD = sensorsPM10CriticalValuesRDD.reduceByKey(lambda value1,
value2: value1+value2)

# Sort pairs by number of critical values - descending order
sortedPairs = sensorsCountsRDD.sortBy(lambda pair: pair[1], False)
```

```
# Store the result in the output folder
sortedPairs.saveAsTextFile(outputPath)
```

Ex 41

Exercise #41

- Top-k most critical sensors
  - Input:
    - A textual csv file containing the daily value of PM10 for a set of sensors
      - Each line of the files has the following format

        sensorId,date,PM10 value (µg/m³)\n
    - The value of k
      - It is an argument of the application

Exercise #41

- Top-k most critical sensors
  - Output:
    - An HDFS file containing the top-k critical sensors
      - The "criticality" of a sensor is given by the number of days with a PM10 values greater than 50
      - Each line contains the number of critical days and the sensorId

Exercise #41 - Example

- Input file

  s1,2016-01-01,20.5
  s2,2016-01-01,30.1
  s1,2016-01-02,60.2
  s2,2016-01-02,20.4
  s1,2016-01-03,55.5
  s2,2016-01-03,52.5
  - k = 1
- Output s1,2

Version 1 → use of `top()`

- Pay attention: `top()` is an action → it will return a python local variable, not an RDD (we will create it before saving in the HDFS)

Version 2 → use of `sortBy()` and then `take(k)`

- Same story for `take(k)` → it is an action → doesn't return RDDs

version 1

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 41")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex41/data/sensors.txt" #
argv[1]
outputPath = "res_out_Ex41v1/" # argv[2]
k = 1 # argv[3]

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)
```

```
# Apply a filter transformation to select only the lines with PM10>50
readingsHighValueRDD = readingsRDD.filter(lambda PM10Reading:
float(PM10Reading.split(',')[2])>50 )

# Create an RDD of key-value pairs
# Each pair contains a sensorId (key) and +1 (value)
# It can be implemented by using the map transformation.
# The function of the map transformation returns a tuple
sensorsPM10CriticalValuesRDD = readingsHighValueRDD.map(lambda PM10Reading:
(PM10Reading.split(',')[0], 1) )

# Count the number of critical values for each sensor by using the reduceByKey
transformation.
# The used function is the sum of the values (the sum of the ones)
sensorsCountsRDD = sensorsPM10CriticalValuesRDD.reduceByKey(lambda value1,
value2: value1+value2)

# Use top to select the top k pairs based on the number of critical dates
topKSensorsNumCriticalValues = sensorsCountsRDD.top(k, lambda pair: pair[1])

# top is an action. Hence, topKCriticalSensors is a local Python variable of
the Driver.
# Create an RDD of pairs and store it in HDFS by means of the saveAsTextFile
method
topKSensorsRDD = sc.parallelize(topKSensorsNumCriticalValues)

topKSensorsRDD.saveAsTextFile(outputPath)
```

version 2

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 41")
sc = SparkContext(conf=conf)

inputPath  = "/data/students/bigdata-01QYD/ex_data/Ex41/data/sensors.txt" #
argv[1]
outputPath = "res_out_Ex41v1/" # argv[2]
k = 1 # argv[3]

# Read the content of the input file
readingsRDD = sc.textFile(inputPath)

# Apply a filter transformation to select only the lines with PM10>50
readingsHighValueRDD = readingsRDD.filter(lambda PM10Reading:
float(PM10Reading.split(',')[2])>50 )

# Create an RDD of key-value pairs
# Each pair contains a sensorId (key) and +1 (value)
```

```
# It can be implemented by using the map transformation.
# The function of the map transformation returns a tuple
sensorsPM10CriticalValuesRDD = readingsHighValueRDD.map(lambda PM10Reading:
(PM10Reading.split(',')[0], 1) )

# Count the number of critical values for each sensor by using the reduceByKey
transformation.
# The used function is the sum of the values (the sum of the ones)
sensorsCountsRDD = sensorsPM10CriticalValuesRDD.reduceByKey(lambda value1,
value2: value1+value2)

# Sort pairs by number of critical values - descending order
sortedNumCriticalValuesSensorRDD = sensorsCountsRDD.sortBy(lambda pair:
pair[1], False)

# Select the first k elements of sortedNumCriticalValuesSensorRDD.
# sortedNumCriticalValuesSensorRDD is sorted.
# Hence, the first k elements are the ones we are interested in
topKSensorsNumCriticalValues = sortedNumCriticalValuesSensorRDD.take(k)

# take is an action. Hence, topKCriticalSensors is a local Python variable of
the Driver.
# Create an RDD of pairs and store it in HDFS by means of the saveAsTextFile
method
topKSensorsRDD = sc.parallelize(topKSensorsNumCriticalValues)

topKSensorsRDD.saveAsTextFile(outputPath)
```

Ex 42

Exercise #42

- Mapping Question-Answer(s)
  - Input:
    - A large textual file containing a set of questions
      - Each line contains one question
      - Each line has the format
        - QuestionId,Timestamp,TextOfTheQuestion
    - A large textual file containing a set of answers
      - Each line contains one answer
      - Each line has the format
        - AnswerId,QuestionId,Timestamp,TextOfTheAnswer

Exercise #42

- Output:
  - A file containing one line for each question
  - Each line contains a question and the list of answers to that question
    - QuestionId, TextOfTheQuestion, list of Answers

Exercise #42 - Example

- Questions

```
Q1,2015-01-01,What is ..?
Q2,2015-01-03,Who invented ..
```

- Answers

```
A1,Q1,2015-01-02,It is ..
A2,Q2,2015-01-03,John Smith
A3,Q1,2015-01-05,I think it is ..
```

Exercise #42 - Example

- Output

```
(Q1,([What is ..?],[It is .., I think it is ..]))
(Q2,([Who invented ..],[John Smith]))
```

The strategy here is the following:

1. We create question pairs (question_id, text_of_the_question)
2. We create answer pairs (question_id, text_of_the_answer)
3. We create question-answers pairs with `cogroup()`
   - the 'key' will be *question_id*
   - the 'value' will be a tuple with 2 iterables: one over text_of_the_question and another one over text_of_the_answer
     They will clearly need to be reformatted.

Remember: whenever there is the need to pair keys and list of all values associated with that key → `cogroup()` transformation

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 42")
sc = SparkContext(conf=conf)

inputPathQuestions  = "/data/students/bigdata-
01QYD/ex_data/Ex42/data/questions.txt" # argv[1]
inputPathAnswers = "/data/students/bigdata-01QYD/ex_data/Ex42/data/answers.txt"
# argv[2]
outputPath = "res_out_Ex42/" # argv[3]

# Read the content of the question file
questionsRDD = sc.textFile(inputPathQuestions)

# Create an RDD of pairs with the questionId as key and the question text as
value
```

```
questionsPairRDD = questionsRDD.map(lambda question: (question.split(",")[0] ,
question.split(",")[2]) )

# Read the content of the answer file
answersRDD = sc.textFile(inputPathAnswers)

# Create an RDD of pairs with the questionId as key and the answer text as
value
answersPairRDD = answersRDD.map(lambda answer: (answer.split(",")[1] ,
answer.split(",")[3]) )

# "Cogroup" the two RDDs of pairs
questionsAnswersPairRDD = questionsPairRDD.cogroup(answersPairRDD)

# Use map to transform the two iterables of each pair into a list (reformat
them)
questionsAnswersReformatted = questionsAnswersPairRDD.mapValues(lambda value:
(list(value[0]), list(value[1]) ) )

questionsAnswersReformatted.saveAsTextFile(outputPath)
```

EX 43

Exercise #43 – 1

- Critical bike sharing station analysis
- Input:
  - A textual csv file containing the occupancy of the stations of a bike sharing system
    - The sampling rate is 5 minutes
    - Each line of the file contains one sensor reading/sample has the following format
      stationId,date,hour,minute,num_of_bikes,num_of_free_slots
    - Some readings are missing due to temporarily malfunctions of the stations
      - Hence, the number of samplings is not exactly the same for all stations
  - The number of distinct stations is 100

Exercise #43 – 2

- Input:
  - A second textual csv file containing the list of neighbors of each station
    - Each line of the file has the following format
      $stationId_x$, list of neighbors of $stationId_x$
    - E.g.,
      s1,s2 s3
      means that s2 and s3 are neighbors of s1

Exercise #43 – 3

- Outputs:
  - Compute the percentage of critical situations for each station
    - A station is in a critical situation if the number of free slots is below a user provided threshold (e.g., 3 slots)
    - The percentage of critical situations for a station Si is defined as (number of critical readings associated with Si)/(total number of readings associated with Si)

Exercise #43 – 4

- Store in an HDFS file the stations with a percentage of critical situations higher than 80% (i.e., stations that are almost always in a critical situation and need to be extended)
  - Each line of the output file is associated with one of the selected stations and contains the percentage of critical situations and the stationId
  - Sort the stored stations by percentage of critical situations

Exercise #43 – 5

- Compute the percentage of critical situations for each pair (timeslot, station)
  - Timeslot can assume the following 6 values
    - [0-3]
    - [4-7]
    - [8-11]
    - [12-15]
    - [16-19]
    - [20-23]

Exercise #43 – 6

- Store in an HDFS file the pairs (timeslot, station) with a percentage of critical situations higher than 80% (i.e., stations that need rebalancing operations in specific timeslots)
  - Each line of the output file is associated with one of the selected pairs (timeslot, station) and contains the percentage of critical situations and the pair (timeslot, stationId)
  - Sort the result by percentage of critical situations

Exercise #43 – 7

- Select a reading (i.e., a line) of the first input file if and only if the following constraints are true
  - The line is associated with a full station situation
    - i.e., the station Si associated with the current line has a number of free slots equal to 0
  - All the neighbor stations of the station Si are full in the time stamp associated with the current line
    - i.e., bikers cannot leave the bike at Station Si and also all the neighbor stations are full in the same time stamp
- Store the selected readings/lines in an HDFS file and print on the standard output the total number of such lines

Note on `cache()`:

→ It is used in Pyspark to memorize in the cache an RDD (or a Dataframe).

→ When an RDD or DataFrame is cached, it is stored in memory (RAM) on the cluster nodes, making subsequent operations on it much faster.

→ This is particularly useful when you plan to reuse the same RDD or DataFrame multiple times within a Spark application.

configuration and paths

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 43")
sc = SparkContext(conf=conf)

#inputPathReadings = "/data/students/bigdata-
01QYD/ex_data/Ex43/data/readings.txt"
#inputPathNeighbors = "/data/students/bigdata-
01QYD/ex_data/Ex43/data/neighbors.txt"
#outputPath = "res_out_Ex43/"
#outputPath2 = "res_out_Ex43_2/"
#outputPath3 = "res_out_Ex43_3/"
#thresholdFreeSlots = 3
#thresholdCriticalPercentage = 0.8

inputPathReadings = "data/Ex43/data/readings.txt"
inputPathNeighbors = "data/Ex43/data/neighbors.txt"
outputPath = "res_out_Ex43/"
outputPath2 = "res_out_Ex43_2/"
```

```
outputPath3 = "res_out_Ex43_3/"
thresholdFreeSlots = 3
thresholdCriticalPercentage = 0.8
```

part I

Steps in this part:

1. Identify Critical Situations
   We wrote a function to use for mapping the readings. The mapping is done in this way:
   - takes the reading
   - returns tuple (station_id, (1, isCritical))
     - the first 1 represents one reading (used to count all readings)
     - is_critical is 1 is the situation is critical, 0 otherwise (used to count critical situations)
       Example:

```
Input: "S1,2024-02-10,12,30,5,1"  # Station S1 has 1 free slot
Output: ("S1", (1,1))  # This is a critical situation
```

2. Count Total and Critical Readings per Station
   We use `reduceByKey()` for this purpose, it will group data by station_id (the key) and for each pair of value tuple will compute the sum for both the values:
   - c1[0] + c2[0] → sums up the total number of readings.
   - c1[1] + c2[1] → sums up the number of critical readings.
     Example:

```
Input: [("S1", (1,1)), ("S1", (1,0)), ("S1", (1,1))]
Output: ("S1", (3,2))  # (3 readings in total, 2 of them critical)
```

3. Compute the Percentage of Critical stations
   We use mapValues() for this purpose. The value is a tuple counters = (total_readings, critical_readings).
   So, for each tuple we will return a single value = counters[1] / counters[0]
   Example of application of mapValues result:

```
Input: ("S1", (3,2))  # (3 readings in total, 2 of them critical)
Output: ("S1", 2/3) → ("S1", 0.6667)
```

4. Filter to keep only the pairs with Critical Percentage > 80

5. Sort by Decreasing Percentage

6. Save Results

```
# Solution Ex. 43 - part I
# Selection of the stations with a percentage of critical situations
# greater than 80%

# Read the content of the readings file
readingsRDD = sc.textFile(inputPathReadings).cache()

def criticalSituation(line):
    fields = line.split(",")
    # fields[0] is the station id
    # fields[5] is the number of free slots
    stationId = fields[0]
    numFreeSlots = int(fields[5])

    if  numFreeSlots < thresholdFreeSlots:
        return (stationId, (1, 1))
    else:
        return (stationId, (1, 0))

# Count the number of total and critical readings for each station
# Create an RDD of pairs with
# key: stationId
# value: (numReadings, numCriticalReadings)
# ------- numReadings: 1 for each input line
# --------numCriticalReadings: 0 if the situation is not critical. 1 if it is
critical
stationCountPairRDD = readingsRDD.map(criticalSituation)

# Compute the number of total and critical readings for each station
stationTotalCountPairRDD = stationCountPairRDD\
.reduceByKey(lambda c1, c2: (c1[0]+c2[0], c1[1]+c2[1]) )

# Compute the percentage of critical situations for each station
stationPercentagePairRDD = stationTotalCountPairRDD\
.mapValues(lambda counters: counters[1]/counters[0])

# Select stations with percentage > 80%
selectedStationsPairRDD = stationPercentagePairRDD\
.filter(lambda sensorPerc: sensorPerc[1]>thresholdCriticalPercentage)

# Sort the stored stations by decreasing percentage of critical situations
selectedStationsSortedPairRDD = selectedStationsPairRDD\
.sortBy(lambda sensorPerc: sensorPerc[1], ascending=False)

selectedStationsSortedPairRDD.saveAsTextFile(outputPath)
```

part I , alternative 2 (less efficient, with usage of `join()`)

```
# 1 - compute the percentage of critical situations for each station
# critical_situation -> num_of_free_slots < thresholdFreeSlots
# % critial situations = (critical readings of si) / (number of readings per
si)
# in the output file:
# (station_id, %critial_situations) -> sorted by %critial_situations


# station_id, date, hour, minute, num_of_bikes, num_of_free_slots
readingsRDD = sc.textFile(inputPathReadings).cache()

# filter the readings to retrieve only the lines of the critical ones
criticalReadingsRDD = readingsRDD.filter(lambda line: int(line.split(',')[5]) <
thresholdFreeSlots)

# map to get the pairs (slot_id, 1) for critical readings
criticalStationIdsOnesRDD = criticalReadingsRDD.map(lambda line:
(line.split(',')[0], 1))

# reduce to get the pairs (slot_id, num_critical_readings)
criticalStationIdsNumOfCritialReadingsRDD =
criticalStationIdsOnesRDD.reduceByKey(lambda v1, v2: v1 + v2)

# map to get the pairs (slot_id, 1) for all readings
allStationIdsOnesRDD = readingsRDD.map(lambda line: (line.split(',')[0], 1))

# reduce to get pairs (slot_id, total_readings)
allStationIdsTotalReadingsRDD = allStationIdsOnesRDD.reduceByKey(lambda v1, v2:
v1 + v2)

# we join the tuples of critical stations and all stations
# inner join -> keep only the cases where there is a match between both of the
collections
# result : (station_id, (num_critial_readings, total_readings))
joinCriticalAllRDD =
criticalStationIdsNumOfCritialReadingsRDD.join(allStationIdsTotalReadingsRDD)

# map this rdd to obtain (station_id, num_critial_readings/total_readings)
stationIdPercentagePairsRDD = joinCriticalAllRDD.map(lambda pair: (pair[0],
float(pair[1][0]) / float(pair[1][1])))

# keep only the stations with percentage > thresholdCriticalPercentage
filteredStationIdPercentagePairsRDD = stationIdPercentagePairsRDD.filter(lambda
pair: pair[1] > thresholdCriticalPercentage)

# sort them by percentage value:
sortedStationIdPercentagePairsRDD =
filteredStationIdPercentagePairsRDD.sortBy(lambda pair: pair[1], False)

# save the result
sortedStationIdPercentagePairsRDD.saveAsTextFile(outputPath)
```

part II

Steps in this part:

1. Define the function to categorize readings into timeslots and use it to map the readings
   This function takes the hole line of the input reading and splits it in an array of fields.

   It is used in the map process of the input lines: takes the line and returns:

   - key : (time_slot, station)
   - value: (1, 1) if critical, (1, 0) otherwise

   To calculate the timeslot we consider the hour of the reading (e.g. hour = 5, it falls into [4 - 7])
   The map phase will generate an RDD with pairs:

   ```
   (("ts[4-7]", "Station_12"), (1, 1))
   (("ts[8-11]", "Station_5"), (1, 0))
   (("ts[16-19]", "Station_8"), (1, 1))
   ```

   The first value (`1`) counts the total readings, the second value (`1` or `0`) counts critical readings.

2. Count total and Critcal Readings per (timeslot, station)
   We use `reduceByKey()` to group by (timesolt, station) and sum up values.
   What we obtain is something like this:

   ```
   ("ts[4-7]", "Station_12") -> (10, 7)   # 10 total readings, 7 critical
   ("ts[8-11]", "Station_5") -> (8, 2)    # 8 total readings, 2 critical
   ("ts[16-19]", "Station_8") -> (5, 5)   # 5 total readings, 5 critical
   ```

3. Compute the Percentage of Critical situations
   We use `mapValues()` for this purpose, and we obtain something like this:

   ```
   ("ts[4-7]", "Station_12") -> 7 / 10 = 0.7
   ("ts[8-11]", "Station_5") -> 2 / 8 = 0.25
   ("ts[16-19]", "Station_8") -> 5 / 5 = 1.0
   ```

4. Filter Pairs with Percentage > 80%

5. Sort them by Percentage (Descending)

6. Save the output to HDFS

```
# Solution Ex. 43 - part II
# Selection of the pairs (timeslot, station) with a percentage of
# critical situations greater than 80%
```

```
def criticalSituationTimeslots(line):

    fields = line.split(",")

    # fields[0] is the station id
    # fields[2] is the hour
    # fields[5] is the number of free slots

    stationId = fields[0]
    numFreeSlots = int(fields[5])

    minTimeslotHour = 4 * ( int(fields[2]) // int(4))
    maxTimeslotHour = minTimeslotHour + 3

    timestamp = "ts[" + str(minTimeslotHour) + "-" + str(maxTimeslotHour) + "]"

    key = (timestamp, stationId)

    if  numFreeSlots < thresholdFreeSlots:
        return (key, (1, 1))
    else:
        return (key, (1, 0))

# The input data are already in readingsRDD

# Count the number of total and critical readings for each (timeslot,stationId)
# Create an RDD of pairs with
# key: (timeslot,stationId)
# value: (numReadings, numCriticalReadings)
# ------- numReadings: 1 for each input line
# --------numCriticalReadings: 0 if the situation is not critical. 1 if it is
critical

timestampStationCountPairRDD = readingsRDD.map(criticalSituationTimeslots)

# Compute the number of total and critical readings for each (timeslot,station)
timestampStationTotalCountPairRDD = timestampStationCountPairRDD \
.reduceByKey(lambda c1, c2: (c1[0]+c2[0], c1[1]+c2[1]) )

# Compute the percentage of critical situations for each (timeslot,station)
timestampStationPercentagePairRDD = timestampStationTotalCountPairRDD\
.mapValues(lambda counters: counters[1]/counters[0])

# Select (timeslot,station) pairs with percentage > 80%
selectedTimestampStationsPairRDD = timestampStationPercentagePairRDD\
.filter(lambda sensorPerc: sensorPerc[1]>thresholdCriticalPercentage)

# Sort the stored pairs by decreasing percentage of critical situations
percentageTimestampStationsSortedPairRDD = selectedTimestampStationsPairRDD\
.sortBy(lambda sensorPerc: sensorPerc[1], ascending=False)

percentageTimestampStationsSortedPairRDD.saveAsTextFile(outputPath2)
```

part III

What we want: to select the lines of the readings that are full and at the same time also all the neighboring stations are full in the specific time slot of the selected line.

Steps:

1. Load the Neighbors Data
2. Map Each Line to Station -> Neighbors

```
Example Input: "S1,S2 S3 S4"
Output: ("S1", ["S2", "S3", "S4"])
```

3. Collect Neighbors in a Local Dictionary

```
neighbors = {"S1": ["S2", "S3", "S4"], "S2": ["S1", "S3", "S5"]}
```

4. Filter Full Status Readings (Free Solts = 0)
   This step keeps only the readings where stations are full, which is the starting point for the next filtering steps.
5. Define function to Extract Timestamp
   The timestamp is formed by concatenating date, hour, minute
   It will be used as key to group readings by time
6. Create a Pair RDD with Timestamp and Reading
   - key = the timestamp (from previous step)
   - value = full status reading (station with free slots = 0)

```
Example output: ("2024-02-10 12:30", "S1,2024-02-10,12,30,5,0")
```

7. Group readings by timestamp
   All readings from the same time period are gathered together.

```
Input: [("2024-02-10 12:30", "S1,2024-02-10,12,30,5,0")],[("2024-02-10
12:30", "S2,2024-02-10,12,30,5,0")]
Output: [("2024-02-10 12:30", [list_of_readings])]
```

8. Define the Selection Function
   It iterates over the readings for each timestamp.

   1. Extracts the list of full stations for the current timestamp
   2. Checks if all neighboring stations for each station are also full:
      - For each station in the timestamp, it checks whether every neighbor is present in the list of full stations.
      - If all neighbors are full, the reading is selected
   3. Returns a list of selected readings that satisfy the constraints.

9. Apply the Selection Function and Flatten
   Each selected reading satisfy the constraint that:

   - The station is full
   - All its neighbors are also full at the same timestamp

10. Save the result

```
# Solution Ex. 43 - part III
# Select a reading (i.e., a line) of the first input file if and only if the
following constraints are true
# - The line is associated with a full station situation
# - All the neighbor stations of the station Si are full in the time stamp
associated with the current line

# Read the file containing the list of neighbors for each station
neighborsRDD = sc.textFile(inputPathNeighbors)

# Map each line of the input file to a pair stationid, list of neighbor
stations
nPairRDD = neighborsRDD.map(lambda line: (line.split(",")[0], line.split(",")
[1].split(" ")) )

# Create a local dictionary in the main memory of the driver that will be used
to store the mapping
# stationid -> list of neighbors
# There are only 100 stations. Hence, you can suppose that data about neighbors
can be stored in the main memory
neighbors=nPairRDD.collectAsMap()

# The input data are already in readingsRDD

# Select the lines/readings associated with a full status (number of free slots
equal to 0)
fullStatusLines = readingsRDD.filter(lambda line: int(line.split(",")[5])==0)

def extractTimestamp(reading):
    fields = reading.split(",")
    timestamp = fields[1] + fields[2] + fields[3]

    return timestamp
```

```
# Create an RDD of pairs with key = timestamp and value=reading associated with
that timestamp
# The concatenation of fields[1], fields[2], fields[3] is the timestamp of the
reading
fullLinesPRDD = fullStatusLines.map(lambda reading: (extractTimestamp(reading),
reading))

#  Collapse all the values with the same key in one single pair (timestamp,
reading associated with that timestamp)
fullReadingsPerTimestamp = fullLinesPRDD.groupByKey()

def selectReadingssFunc(pairTimeStampListReadings):
    # Extract the list of stations that appear in the readings
    # associated with the current key
    # (i.e., the list of stations that are full in this timestamp)
    # The list of readings is in the value part of the inpput key-value pair
    stations = []
    for reading in pairTimeStampListReadings[1]:
        # Extract the stationid from each reading
        fields = reading.split(",")
        stationId = fields[0]
        stations.append(stationId)


    # Iterate again over the list of readings to select the readings satistying
the constraint on the
    # full status situation of all neighboors
    selectedReading = []

    for reading in pairTimeStampListReadings[1]:
        # This reading must be selected if all the neighbors of
        # the station of this reading are also in the value of
        # the current key-value pair (i.e., if they are in list stations)
        # Extract the stationid of this reading
        fields = reading.split(",")
        stationId = fields[0]

        # Select the list of neighbors of the current station
        nCurrentStation = neighbors[stationId]

        # Check if all the neighbors of the current station are in value
        # (i.e., the local list stations) of the current key-value pair
        allNeighborsFull = True

        for neighborStation in nCurrentStation:
            if neighborStation not in stations:
                # There is at least one neighbor of th current station
                # that is not in the full status in this timestamp
                allNeighborsFull = False

        if allNeighborsFull == True:
            selectedReading.append(reading)
```

```
    return selectedReading

# Each pair contains a timestamp and the list of readings (with number of free
slots equal to 0)
# associated with that timestamp.
# Check, for each reading in the list, if all the neighbors of the station of
that reading are
# also present in this list of readings
# Emit one "string" for each reading associated with a completely full status
selectedReadingsRDD = fullReadingsPerTimestamp.flatMap(selectReadingssFunc)

# Store the result in HDFS
selectedReadingsRDD.saveAsTextFile(outputPath3)
```

Ex 44

Exercise #44

- Misleading profile selection
- Input:
  - A textual file containing the list of movies watched by the users of a video on demand service
    - Each line of the file contains the information about one visualization
      userid,movieid,start-timestamp,end-timestamp
    - The user with id *userid* watched the movie with id *movieid* from *start-timestamp* to *end-timestamp*

Exercise #44

- Input:
  - A second textual file containing the list of preferences for each user
    - Each line of the file contains the information about one preference
      userid,movie-genre
    - The user with id *userid* liked the movie of type *movie-genre*

Exercise #44

- Input:
  - A third textual file containing the list of movies with the associated information
    - Each line of the file contains the information about one movie
      movieid,title,movie-genre
    - There is only one line for each movie
      - i.e., each movie has one single genre

Exercise #44

- Output:
  - Select the userids of the list of users with a misleading profile
    - A user has a misleading profile if more than threshold% of the movies he/she watched are not associated with a movie genre he/she likes
    - threshold is an argument/parameter of the application and it is specified by the user
  - Store the result in an HDFS file

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 44")
sc = SparkContext(conf=conf)

#inputPathWatched = "/data/students/bigdata-
01QYD/ex_data/Ex44/data/watchedmovies.txt"
#inputPathPreferences = "/data/students/bigdata-
01QYD/ex_data/Ex44/data/preferences.txt"
#inputPathMovies = "/data/students/bigdata-01QYD/ex_data/Ex44/data/movies.txt"
```

```
#outputPath = "res_out_Ex44/"
#threshold = 0.5

inputPathWatched = "data/Ex44/data/watchedmovies.txt"
inputPathPreferences = "data/Ex44/data/preferences.txt"
inputPathMovies = "data/Ex44/data/movies.txt"
outputPath = "res_out_Ex44/"
threshold = 0.5

# Read the content of the watched movies file
watchedRDD = sc.textFile(inputPathWatched)

# Select only userid and movieid
# Define an RDD or pairs with movieid as key and userid as value
movieUserPairRDD = watchedRDD.map(lambda line:  (line.split(",")[1],
line.split(",")[0]))

# Read the content of the movies file
moviesRDD = sc.textFile(inputPathMovies)

# Select only movieid and genre
# Define an RDD of pairs with movieid as key and genre as value
movieGenrePairRDD = moviesRDD.map(lambda line:  (line.split(",")[0],
line.split(",")[2]))

# Join watched movies with movies
joinWatchedGenreRDD = movieUserPairRDD.join(movieGenrePairRDD)

# Select only userid (as key) and genre (as value)
usersWatchedGenresRDD = joinWatchedGenreRDD.map(lambda pair: (pair[1][0],
pair[1][1]))

# Read the content of preferences.txt
preferencesRDD = sc.textFile(inputPathPreferences)

# Define an RDD of pairs with userid as key and genre as value
userLikedGenresRDD = preferencesRDD.map(lambda line: (line.split(",")[0],
line.split(",")[1]))

# Cogroup the lists of watched and liked genres for each user
# There is one pair for each userid
# the value contains the list of genres (with repetitions) of the
# watched movies and the list of liked genres
userWatchedLikedGenres = usersWatchedGenresRDD.cogroup(userLikedGenresRDD)

def misleadingProfileFunc(userWatchedLikedGenresLists):
    # Store in a local list the "small" set of liked genres
    # associated with the current user
    likedGenres = list(userWatchedLikedGenresLists[1][1])

    # Iterate over the watched movies (the genres of the watched movies)and
count
    # - The number of watched movies for this user
```

```
        # - How many of watched movies are associated with a not liked genre
        numWatchedMovies = 0
        notLiked = 0

        for watchedGenre in userWatchedLikedGenresLists[1][0]:
            numWatchedMovies = numWatchedMovies+1
            if watchedGenre not in likedGenres:
                notLiked = notLiked+1

        # Check if the number of watched movies associated with a non-liked genre
        # is greater that threshold%
        if float(notLiked) > threshold * float(numWatchedMovies):
            return True
        else:
            return False

    # Filter the users with a misleading profile
    misleadingUsersListsRDD = userWatchedLikedGenres.filter(misleadingProfileFunc)

    # Select only the userid of the users with a misleading profile
    misleadingUsersRDD = misleadingUsersListsRDD.keys()

    misleadingUsersRDD.saveAsTextFile(outputPath)
```

Ex 45

Exercise #45

- Profile update
- Input:
  - A textual file containing the list of movies watched by the users of a video on demand service
    - Each line of the file contains the information about one visualization
      userid,movieid,start-timestamp,end-timestamp
    - The user with id *userid* watched the movie with id *movieid* from *start-timestamp* to *end-timestamp*

Exercise #45

- Input:
  - A second textual file containing the list of preferences for each user
    - Each line of the file contains the information about one preference
      userid,movie-genre
    - The user with id *userid* liked the movie of type *movie-genre*

Exercise #45

- Input:
  - A third textual file containing the list of movies with the associated information
    - Each line of the file contains the information about one movie
      movieid,title,movie-genre
    - There is only one line for each movie
      - i.e., each movie has one single genre

Exercise #45

- Output:
  - Select for each user with a misleading profile (according to the same definition of Exercise #44) the list of movie genres that are not in his/her preferred genres and are associated with at least 5 movies watched by the user
  - Store the result in an HDFS file
    - Each line of the output file is associated with one pair (user, selected misleading genre) associated with him/her
    - The format is
      userid, selected (misleading) genre
    - Users associated with a list of selected genres are associated with multiple lines of the output file

```
from pyspark import SparkConf, SparkContext

conf = SparkConf().setAppName("Ex 45")
sc = SparkContext(conf=conf)

#inputPathWatched = "/data/students/bigdata-
01QYD/ex_data/Ex45/data/watchedmovies.txt"
#inputPathPreferences = "/data/students/bigdata-
01QYD/ex_data/Ex45/data/preferences.txt"
#inputPathMovies = "/data/students/bigdata-01QYD/ex_data/Ex45/data/movies.txt"
#outputPath = "res_out_Ex45/"
#threshold = 0.5

inputPathWatched = "data/Ex45/data/watchedmovies.txt"
inputPathPreferences = "data/Ex45/data/preferences.txt"
inputPathMovies = "data/Ex45/data/movies.txt"
outputPath = "res_out_Ex45/"
threshold = 0.5

# Read the content of the watched movies file
watchedRDD = sc.textFile(inputPathWatched)

# Select only userid and movieid
# Define an RDD or pairs with movieid as key and userid as value
movieUserPairRDD = watchedRDD.map(lambda line:  (line.split(",")[1],
line.split(",")[0]))

# Read the content of the movies file
moviesRDD = sc.textFile(inputPathMovies)

# Select only movieid and genre
# Define an RDD of pairs with movieid as key and genre as value
movieGenrePairRDD = moviesRDD.map(lambda line:  (line.split(",")[0],
line.split(",")[2]))

# Select only userid (as key) and genre (as value)
usersWatchedGenresRDD = joinWatchedGenreRDD.map(lambda pair: (pair[1][0],
pair[1][1]))

# Read the content of preferences.txt
preferencesRDD = sc.textFile(inputPathPreferences)

# Define an RDD of pairs with userid as key and genre as value
userLikedGenresRDD = preferencesRDD.map(lambda line: (line.split(",")[0],
line.split(",")[1]))

# Cogroup the lists of watched and liked genres for each user
# There is one pair for each userid
# the value contains the list of genres (with repetitions) of the
# watched movies and the list of liked genres
userWatchedLikedGenres = usersWatchedGenresRDD.cogroup(userLikedGenresRDD)
```

```
# This function is used in the next transformation to select users with a
misleading profile
def misleadingProfileFunc(userWatchedLikedGenresLists):
    # Store in a local list the "small" set of liked genres
    # associated with the current user
    likedGenres = list(userWatchedLikedGenresLists[1][1])

    # Iterate over the watched movies (the genres of the watched movies)and
count
    # - The number of watched movies for this user
    # - How many of watched movies are associated with a not liked genre
    numWatchedMovies = 0
    notLiked = 0

    for watchedGenre in userWatchedLikedGenresLists[1][0]:
        numWatchedMovies = numWatchedMovies+1
        if watchedGenre not in likedGenres:
            notLiked = notLiked+1

    # Check if the number of watched movies associated with a non-liked genre
    # is greater that threshold%
    if float(notLiked) > threshold * float(numWatchedMovies):
        return True
    else:
        return False

# Filter the users with a misleading profile
misleadingUsersListsRDD = userWatchedLikedGenres.filter(misleadingProfileFunc)

# This function is used in the next transformation to select the pairs
(userid,misleading genre)
def misleadingGenresFunc(userWatchedLikedGenresLists):
    # Store in a local list the "small" set of liked genres
    # associated with the current user

    userId = userWatchedLikedGenresLists[0]
    likedGenres = list(userWatchedLikedGenresLists[1][1])

    # In this solution I suppose that the number of distinct genres for each
user
    # is small and can be stored in a local variable.
    # The local variable is a dictionary that stores for each non-liked genre
    # also its number of occurrences in the list of watched movies of the
current user
    numGenres = {}


    # Iterate over the watched movies (the genres of the watched movies).
    # Select the watched genres that are not in the liked genres and
    # count their number of occurrences. Store them in the numGenres dictionary
    for watchedGenre in userWatchedLikedGenresLists[1][0]:
        # Check if the genre is not in the liked ones
        if watchedGenre not in likedGenres:
```

```
            # Update the number of times this genre appears
            # in the list of movies watched by the current user
            if watchedGenre in numGenres:
                numGenres[watchedGenre] = numGenres[watchedGenre] + 1
            else:
                numGenres[watchedGenre] = 1

    # Select the genres, which are not in the liked ones,
    # which occur at least 5 times
    selectedGenres = []

    for genre, occurrences in numGenres.items():
        if occurrences>=5:
            selectedGenres.append( (userId, genre) )

    return selectedGenres

# Select the pairs (userid,misleading genre)
misleadingUserGenrePairRDD =
misleadingUsersListsRDD.flatMap(misleadingGenresFunc)

misleadingUserGenrePairRDD.saveAsTextFile(outputPath)
```

Ex 46

Exercise #46

- Time series analysis
- Input:
  - A textual file containing a set of temperature readings
  - Each line of the file contains one timestamp and the associated temperature reading

    timestamp, temperature
    - The format of the timestamp is the Unix timestamp that is defined as the number of seconds that have elapsed since 00:00:00 Coordinated Universal Time (UTC), Thursday, 1 January 1970
  - The sample rate is 1 minute
    - i.e., the difference between the timestamps of two consecutive readings is 60 seconds

Exercise #46

- Output:
  - Consider all the windows containing 3 consecutive temperature readings and
    - Select the windows characterized by an increasing trend
      - A window is characterized by an increasing trend if for all the temperature readings in it temperature(t)>temperature(t-60 seconds)
    - Store the result into an HDFS file

Exercise #46 - Example

- Input file

```
1451606400,12.1
1451606460,12.2
1451606520,13.5
1451606580,14.0
1451606640,14.0
1451606700,15.5
1451606760,15.0
```

- Output file

```
1451606400,12.1,1451606460,12.2,1451606520,13.5
1451606460,12.2,1451606520,13.5,1451606580,14.0
```

```python
from pyspark import SparkConf, SparkContext
import sys

conf = SparkConf().setAppName("Ex 46")
sc = SparkContext(conf=conf)

inputPath = "data/Ex46/data/readings.txt" # "/data/students/bigdata-01QYD/ex_data/Ex46/data/readings.txt"
outputPath = "res_out_Ex46v2/"

# Read the content of the readings
readingsRDD = sc.textFile(inputPath)

# Generate the elements of each window.
# Each reading with start time t belongs to 3 windows with a window size equal to 3:
# - The one starting at time t-120s
# - The one starting at time t-60s
# - The one starting at time t

def windowElementsFunc(reading):
    fields = reading.split(",")

    # Time stamp of this reading
    t = int(fields[0])
    # Temperature
    temperature = float(fields[1])

    # The current reading, associated with time stamp t,
    # is part of the windows starting at time t, t-60s, t-120s

    # pairs is a list containing three pairs (window start timestamp, current reading) associated with
    # the three windows containing this reading
    pairs = []

    # Window starting at time t
    # This reading is the first element of the window starting at time t
    pairs.append((t, reading))

    # Window starting at time t-60
    # This reading is the second element of that window starting at time t-60
    pairs.append((t-60, reading))

    # Window starting at time t-120
    # This reading is the third element of that window starting at time t-120
    pairs.append((t-120, reading))

    return pairs

windowsElementsRDD = readingsRDD.flatMap(windowElementsFunc)
```

```
# Use groupByKey to generate one sequence for each time stamp
timestampsWindowsRDD = windowsElementsRDD.groupByKey()

# This function is used in the next transformation to select the windows with
an incrasing temperature trend
def increasingTrendFunc(pairInitialTimestampWindow):

    # The key of the input pair is the intial timestamp of the current window
    minTimestamp = pairInitialTimestampWindow[0]

    # Store the (at most) 3 elements of the window in a dictionary
    # containing enties time stamp -> temperature
    timestampTemp = {}

    # pairInitialTimestampWindow[1] contains the elements of the current window
    window = pairInitialTimestampWindow[1]


    for timestampTemperature in window:
        fields = timestampTemperature.split(",")
        t = int(fields[0])
        temperature = float(fields[1])

        timestampTemp[t] = temperature


    # Check if the list contains three elements.
    # If the number of elements is not equal to 3 the window is incomplete and
must be discarded
    if len(timestampTemp) != 3:
        increasing = False
    else:
        # Check is the increasing trend is satisfied
        if timestampTemp[minTimestamp]<timestampTemp[minTimestamp+60] and
timestampTemp[minTimestamp+60]<timestampTemp[minTimestamp+120]:
            increasing = True
        else:
            increasing = False

    return increasing

seletedWindowsRDD = timestampsWindowsRDD.filter(increasingTrendFunc)

# The result is in the value part of the returned pairs

# Store the result. Map the iterable associated with each window to a list

seletedWindowsRDD.values().map(lambda window:
list(window)).saveAsTextFile(outputPath)
```