
# Lecture 8: Apache Spark examples

DAT470 / DIT065 Computational techniques for large-scale data

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2024-04-22

# Estimating pi in Spark

```
import findspark
findspark.init()
```

Locates and sets up the Spark environment

```
import random
from pyspark import SparkContext
sc = SparkContext(master = 'local[16]')

NUM_SAMPLES = 100000000

def inside(p):
    x, y = random.random(), random.random()
    return x*x + y*y < 1

count = sc.parallelize(range(0,NUM_SAMPLES)) \
          .filter(inside).count()

print(f'Pi is roughly {4.0*count/NUM_SAMPLES}')
```

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```

Sets up the spark context: where and how the code is run

The `'local[16]'` bit is just boilerplate that means the code is run locally using 16 cores

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```

Sample *x* and *y*, and return whether it is within the unit circle (or the quarter thereof)
The input argument is ignored

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print(f'Pi is roughly {4.0*count/NUM_SAMPLES}')
```

`range` returns an iterator which is used as a dummy argument for parallelization (`NUM_SAMPLES` arguments)

`filter` selects only those elements that satisfy the predicate

`count` works as if a reducer and counts the number of elements

**Note:** No array is created at any point

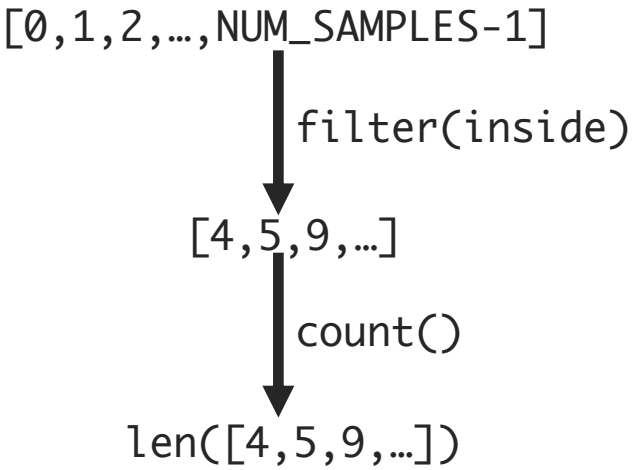
# The Spark programming model

```
sc.parallelize(range(0,NUM_SAMPLES)) \
  .filter(inside).count()
```

A simple corresponding example in serial Python

```
def odd(x):
    return x % 2
```

```
>>> a = [2,3,5,8,9]
>>> b = list(filter(odd,a))
>>> b
[3, 5, 9]
>>> len(b)
3
```




**Note:** arrays are not actually created for intermediate results

# The Spark programming model

```
>>> data = [0,1,2,3,4,5]
>>> distData = sc.parallelize(data)
>>> distData.reduce(lambda a, b: a + b)
15
```

- Spark programs are built around RDDs
- RDDs can be generated by the **driver program**, or they can be obtained from HDFS, or from files on disk, or from other RDDs
- RDDs distribute the data on the nodes, and contain the necessary information to reconstruct them: this makes them fault-tolerant, and effective
- Due to their distributed nature, RDDs can naturally be processed in parallel

# Finding duplicates in PySpark

```
import findspark
findspark.init()
from pyspark import SparkContext
sc = SparkContext(master = 'local[4]')

distFile = sc.textFile('test.data')

counts = distFile.map(lambda l: l.split(',')) \
                 .map(lambda t: (t[0],1)) \
                 .reduceByKey(lambda a,b: a+b) \
                 .filter(lambda t: t[1] > 1)
cc = counts.collect()
print(cc)
```

# Finding duplicates in PySpark

```
distFile = sc.textFile('test.data')
```

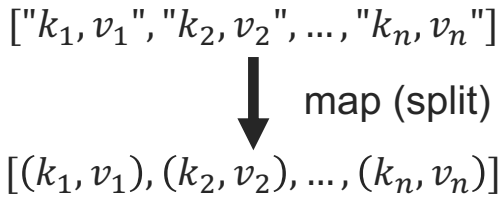
Construct an RDD from a file on the disk

$["k_1, v_1", "k_2, v_2", \ldots, "k_n, v_n"]$

# Finding duplicates in PySpark

Split each key,value string into a (key,value) tuple

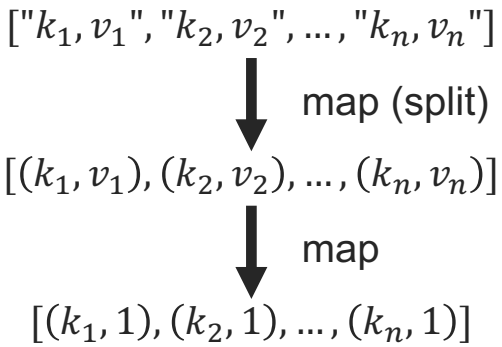
```
distFile.map(lambda l: l.split(',')) \
        .map(lambda t: (t[0],1)) \
        .reduceByKey(lambda a,b: a+b) \
        .filter(lambda t: t[1] > 1)
```



# Finding duplicates in PySpark

Convert the tuples into (key,1) tuples

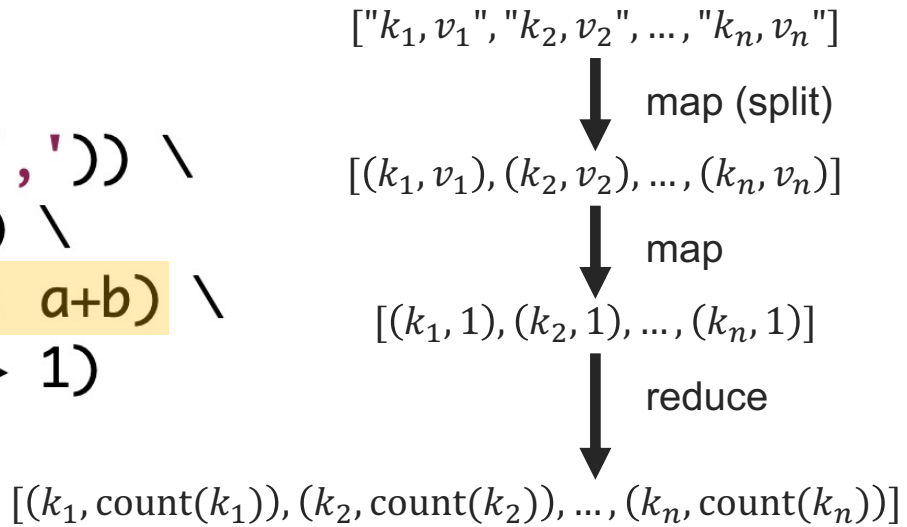
```
distFile.map(lambda l: l.split(',')) \
        .map(lambda t: (t[0],1)) \
        .reduceByKey(lambda a,b: a+b) \
        .filter(lambda t: t[1] > 1)
```



# Finding duplicates in PySpark

Collect tuples by key and reduce

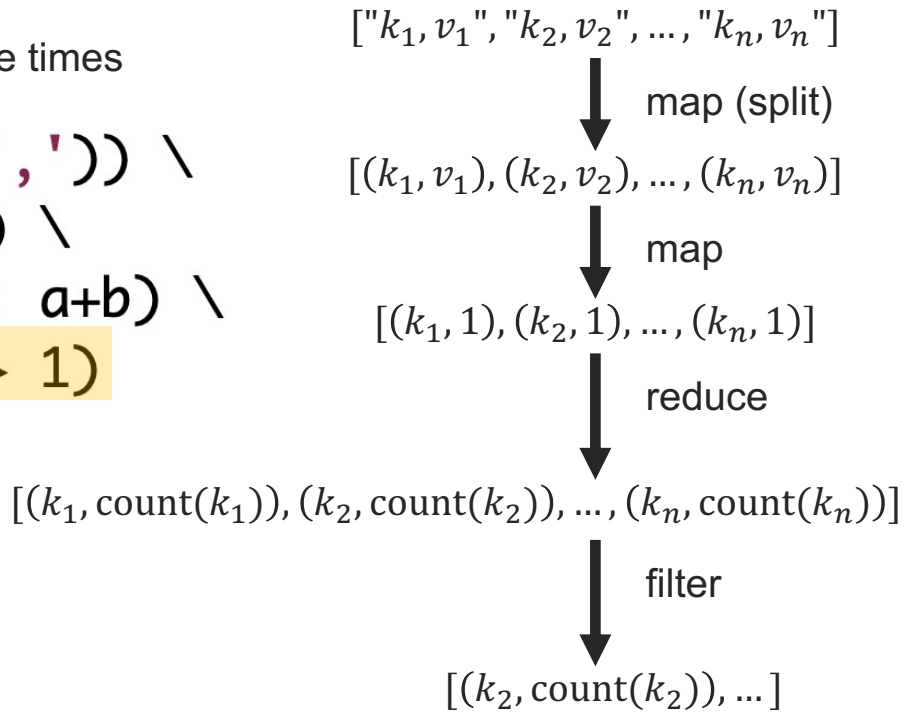
```
distFile.map(lambda l: l.split(',')) \
        .map(lambda t: (t[0],1)) \
        .reduceByKey(lambda a,b: a+b) \
        .filter(lambda t: t[1] > 1)
```



# Finding duplicates in PySpark

Filter only those tuples that occur multiple times

```
distFile.map(lambda l: l.split(',')) \
        .map(lambda t: (t[0],1)) \
        .reduceByKey(lambda a,b: a+b) \
        .filter(lambda t: t[1] > 1)
```



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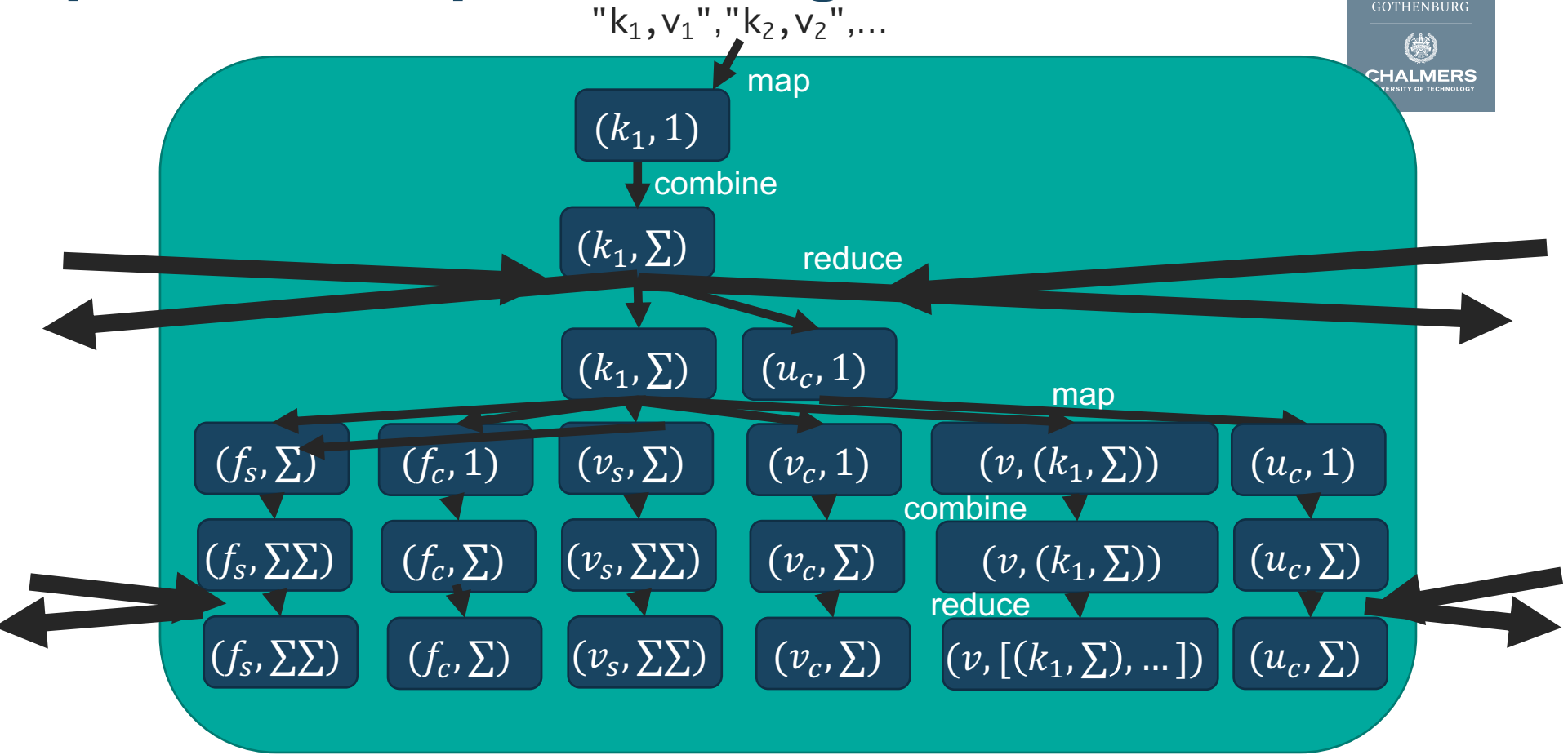
# How do we get this?

```
There are 10 unique keys in the RDD of which 6 appear more than 20 times (sum = 517).
The following keys appear over 100 times (sum = 376).
[('REP', 104), ('LAREM', 272)]
```

- We need to count the number of unique keys
- We need to count the number of occurrences of each key
- We need to filter the number of frequently occurred keys
- We need to also filter the number of very frequently occurred keys
- …and we need to track the most frequent items and store them in a list

# A potential MapReduce algorithm



# Explanation of the algorithm

1. Map each input line into (key,1) tuples
2. Combine such tuples into (key,sum) tuples
3. Reduce such tuples into (key,sum) tuples, and additionally emit a $(u_c, 1)$ tuple for each key for counting unique keys
   - The special key $u_c$ tracks the count of unique keys
   - We now have information about the number of occurrence of each key as (key,sum) tuples
4. In the second step, map the tuples such that $(u_c, 1)$ tuples are preserved, and for other (key,sum) tuples, yield a $(f_c, 1)$ and a $(f_s, \text{sum})$ tuple if they exceed frequency threshold to count the number and sum of frequent elements, and $(v_c, 1)$, $(v_s, \text{sum})$, and $(v, (\text{key}, \text{sum}))$ tuples to count the number and sum of very frequent elements, plus record the actual key-sum pairs
5. Combine the values by summing up $(u_c, 1)$, $(f_c, 1)$, $(v_c, 1)$, $(f_s, \text{sum})$, and $(v_c, \text{sum})$ tuples, and joining the $(v, (\text{key}, \text{sum}))$ tuples as a list
6. Reduce the values by summing up $u_c$, $f_c$, $f_s$, $v_c$, $v_s$ tuples and joining the $v$ tuples as a list
7. We now have all we need to print the description

# Explanation of the algorithm

- Although the algorithm gets everything done, it is long, unwieldy, and ugly
- In such cases, data potentially needs to be duplicated to nodes, and messages passed through the interconnect because the nodes have no access to data
- Same values need to be potentially recomputed
- Spark provides a more flexible interface for such operations

# Potential PySpark implementation

```
import findspark
findspark.init()
from pyspark import SparkContext
sc = SparkContext(master = 'local[4]')
distFile = sc.textFile('test2.data')
keyTuples = distFile.map(lambda l: l.split(',')) \
                    .map(lambda t: (t[0],1))
countsPerKey = keyTuples.reduceByKey(lambda a,b: a+b)
unique_keys_count = countsPerKey.count()
FREQUENT = 20
VERY_FREQUENT = 100
frequent_keys = countsPerKey.filter(lambda t: t[1] > FREQUENT)
frequent_keys_count = frequent_keys.count()
frequent_keys_sum = frequent_keys.values().sum()
very_frequent_keys = frequent_keys.filter(lambda t: t[1] > VERY_FREQUENT)
very_frequent_keys_sum = very_frequent_keys.values().sum()
vfk = very_frequent_keys.collect()
print(f'There are {unique_keys_count} unique keys in the RDD'
      f' of which {frequent_keys_count} appear more than '
      f'{FREQUENT} times (sum = {frequent_keys_sum}).')
print(f'The following keys appear over {VERY_FREQUENT} times '
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print(vfk)
```

Distribute text file contents to nodes

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Map text lines to (key,1) pairs

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Map text lines to (key,1) pairs

Reduce counts by summing, so the RDD contains map from key to the total count

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Reuse the RDD and filter the frequent keys

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Distribute text file contents to nodes

Map text lines to (key,1) pairs

Reduce counts by summing, so the RDD contains map from key to the total count

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Reuse the RDD and filter the frequent keys

Use the same RDD for two different operations: count and sum

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Do the same with very frequent keys

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Count the number of keys

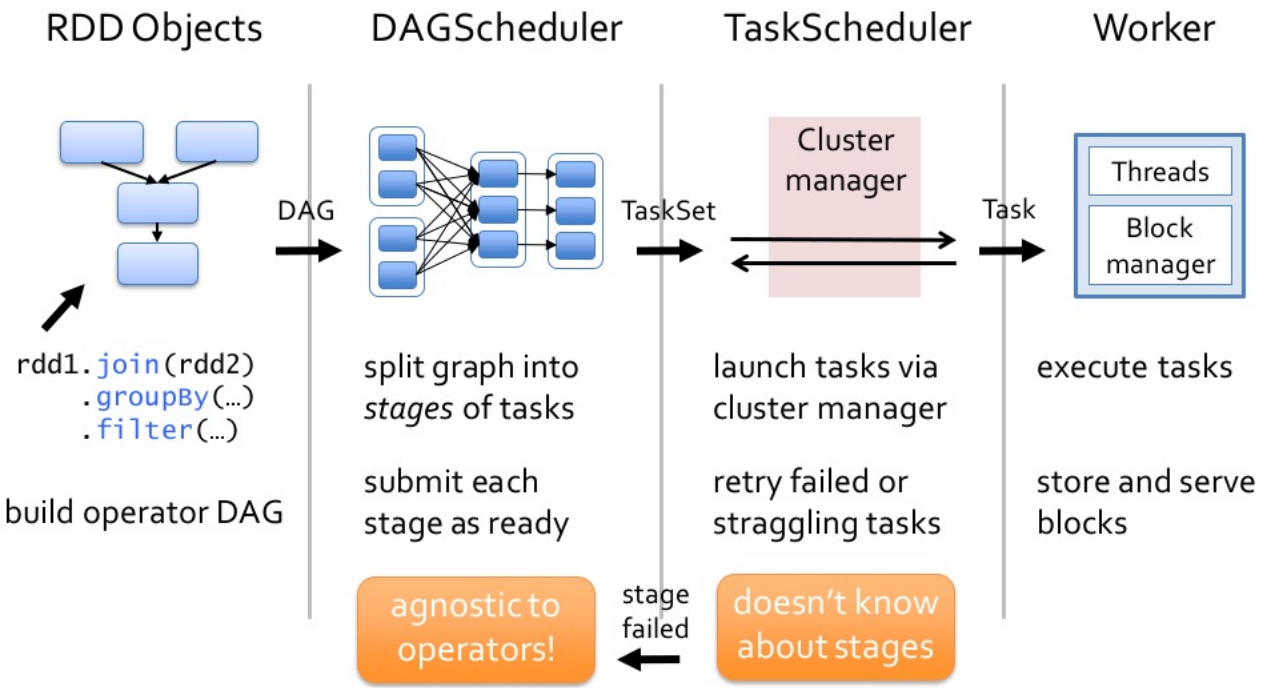
Reuse the RDD and filter the frequent keys

Use the same RDD for two different operations: count and sum

Do the same with very frequent keys

**Collect** the values: copy the values from the distributed filesystem onto the driver node

# Apache Spark under the hood



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# Apache Spark under the hood

- Program flow is managed as a Directed Acyclic Graph (DAG) where nodes are RDDs and edges are transformations
- The transformations are lazy and computation is triggered by actions
- When computation, or a **job**, is requested, the DAG is divided into **stages** of **tasks**; the DAG scheduler tries to optimize the operators in this graph and to exploit data locality, which can lead to many independent operations scheduled in the same stage
- The stages of tasks are passed to the task scheduler that launces them using the cluster manager; the task scheduler is unaware of dependencies among the stages
- Worker executes the task on the node; it only knows of the code passed to it