Introduction to MapReduce

Louis Jachiet

Example: Counting the occurences of each item in a list

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A	3
B	1
C	2
D	2

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A	3
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A very basic and classical problem in data mining!

e.g. anomaly / spam / bots detection

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nb = dict()
for item in inputList:
  if not item in nb:
    nb[item] = 0
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```

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How to make this program run on many machines?

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Machine A-B
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Machine C-D
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Machine A-B		Machine C-D
A, B, A, A	$\leftarrow$ A, B, A, A	C, C, D, C
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Machine A-B	
A: 6	B:2

Machine C-D	
C: 5	D:3

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What needs to be done for very large data?

- Partition data
- Start computation
- Shuffle data
- Handle failure (data + computation)

Very hard to get right!

The MapReduce Model

Typical Big Data Problem

A typical Big Data problem can be divided into 5 phases

1. Iterate over a large number of records
2. Extract something of interest from each
3. Shuffle and sort intermediate results
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2. Extract something of interest from each –MAP–
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For a MapReduce job, the programmer needs to provide:

- A MAP function: `value` $\rightarrow$ `(key,value)`

  Transforms each record into a (possibly empty) list of key-value pairs

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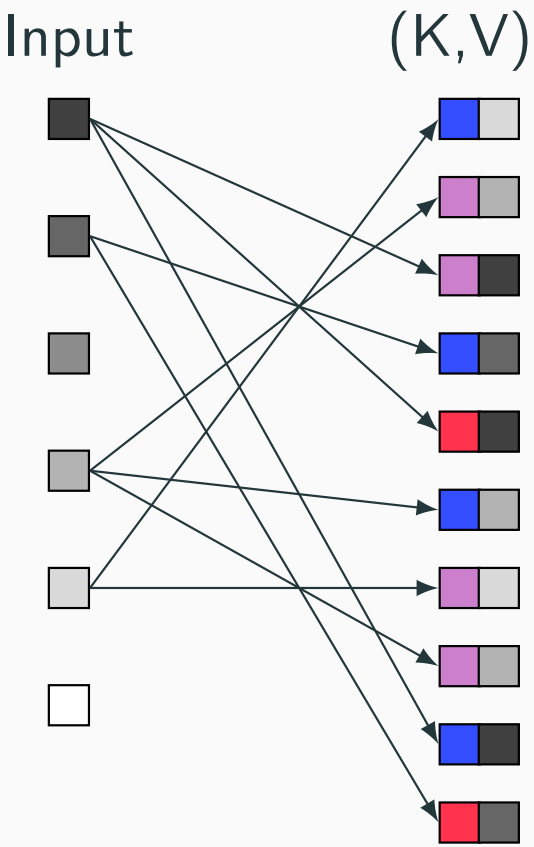
- A REDUCE function: `(key, list of values)` $\rightarrow$ `value`

  Take a key and the list of values with this key

MapReduce Model

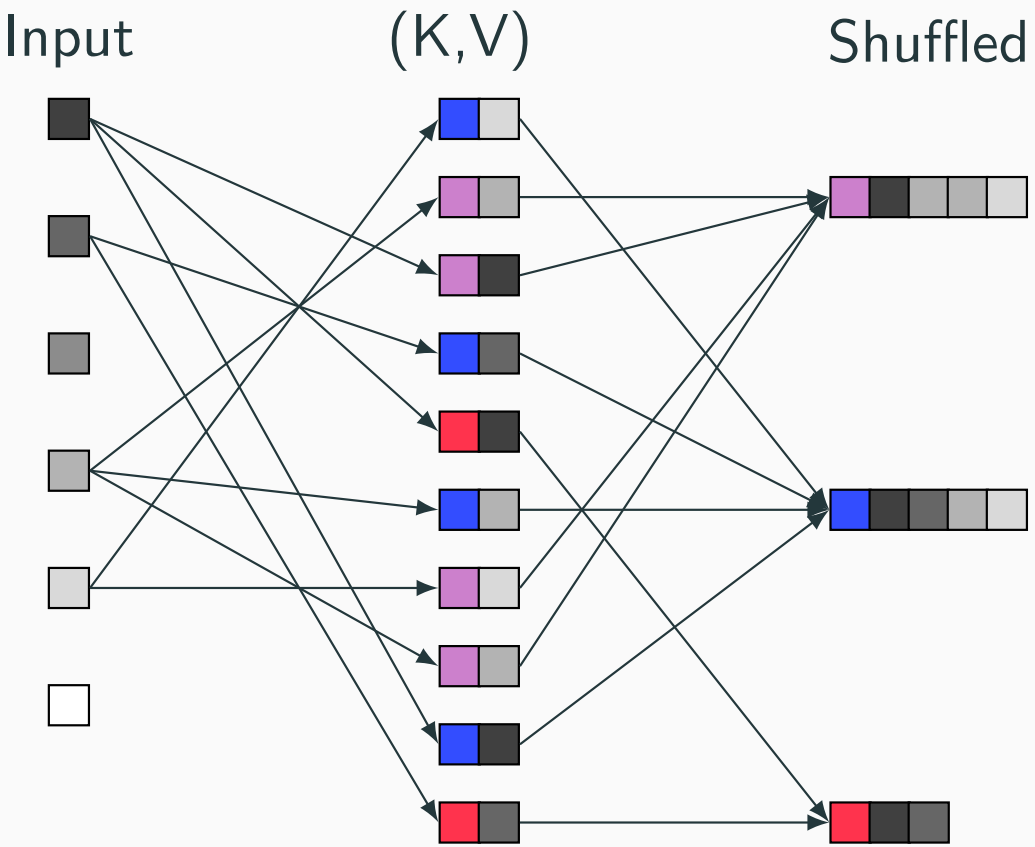
Input

MapReduce Model



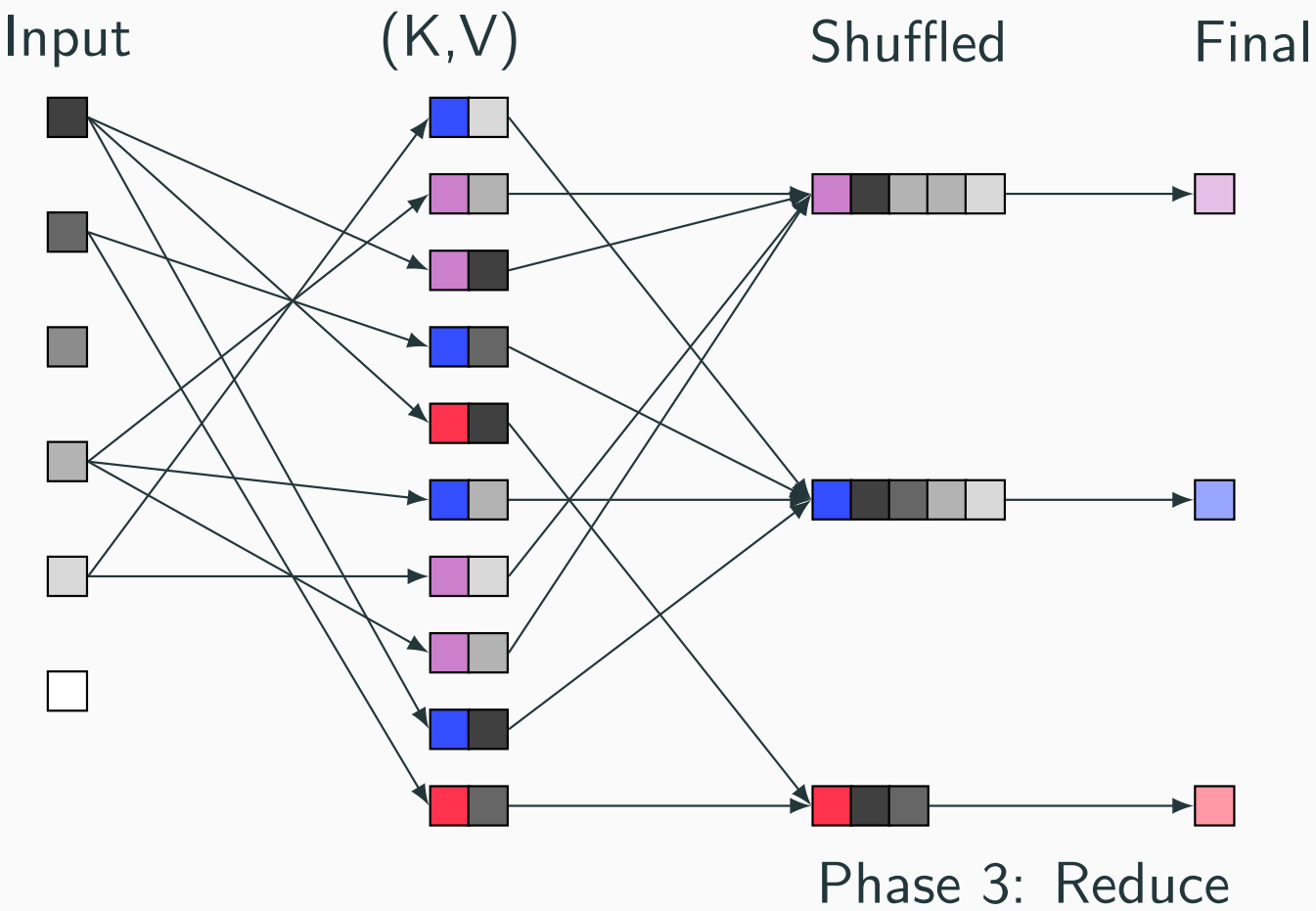
Phase 1: Map

MapReduce Model



Phase 2: Shuffle

MapReduce Model



Example: Counting the occurences of each item in a list

MAP

Each item i is transformed into the singleton list key-value pair $[(i, 1)]$

REDUCE

Given a pair (i, l) where i is an item and l a list, the reducer returns $(i, \texttt{length}(l))$

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MapReduce

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It is possible to use several inputs for a MapReduce job!

Example: Keep distinct items appearing more than twice

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$\downarrow$ MAP: $i \rightarrow [(i, 1)]$ $\downarrow$

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$$\downarrow \text{MAP: } (i, n) \rightarrow \begin{cases} [] & \text{when } n < 2 \\ [(i, n)] & \text{otherwise} \end{cases} \downarrow$$

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A, D, C

Exercise (easy)

Input

You are given a list of pairs (k_i, v_i) where k_i is a string and v_i an integer.

Problem

Compute the average value for each key.

Example

INPUT	
A	42
B	17
A	12
B	99

OUTPUT	
A	$\frac{42+12}{2} = 27$
B	$\frac{17+99}{2} = 58$

Exercise (medium)

Input

You are given two lists of items.

Problem

Compute the list of item appearing in the first one but not in the second.

Example

INPUT 1
A
B
C

INPUT2
A
C
E

OUTPUT
B

Exercise (hard)

Input

You are given the Twitter following list: each record is a pair (A_i, B_i) indicating that account A_i follows B_i.

Problem

Compute the accounts that have more followers than all the accounts that they follow.

Example

INPUT	
A	B
A	D
B	C
B	D
C	E

OUTPUT
E
D
C

Exercise (hardest)

Input

You are given the Twitter following list: each record is a pair (A_i, L_i) indicating that account A_i follows the accounts in the list L_i .

Problem

Compute for each account A the list of accounts that are followed by an account followed by A.

Example

INPUT	
A	B,D
B	C,D
C	E

OUTPUT	
A	C,D
B	E

MapReduce Beyond Map and Reduce

MapReduce extensions: Combiner

Context

Counting the number of times each item appears.

Problem

A few set of words appear very often.

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Problem

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Solution: Combiner

A Combiner is similar to a reduce phase but applied before the shuffle on each local output of mappers.

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You can manually control the partitioning.

MapReduce extensions: Partitioner

```
public class HashPartitioner<K2, V2>
             implements Partitioner<K2, V2> {

    public void configure(JobConf job) {}
    /** Use {@link Object#hashCode()} to partition. */

    public int getPartition(K2 key, V2 value,
                            int numReduceTasks) {
      return (key.hashCode() & Integer.MAX_VALUE)
                               % numReduceTasks;
    }
}
```

Figure 1: Default Partitioner in Hadoop

HADOOP Implementation of MapReduce

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- A Secondary Namenode handles resiliency

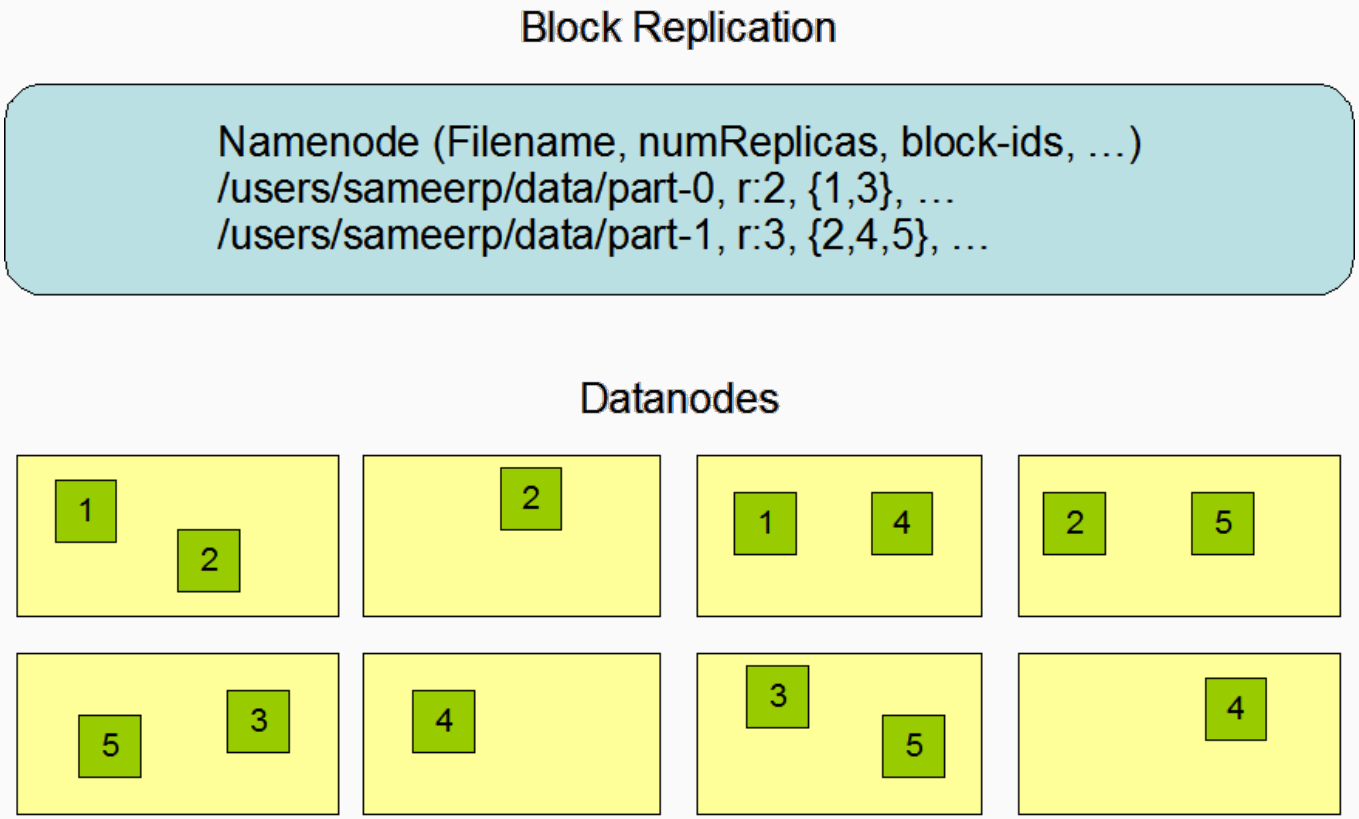

Figure 2: source

`https://hadoop.apache.org/docs/r1.2.1/hdfs_design`

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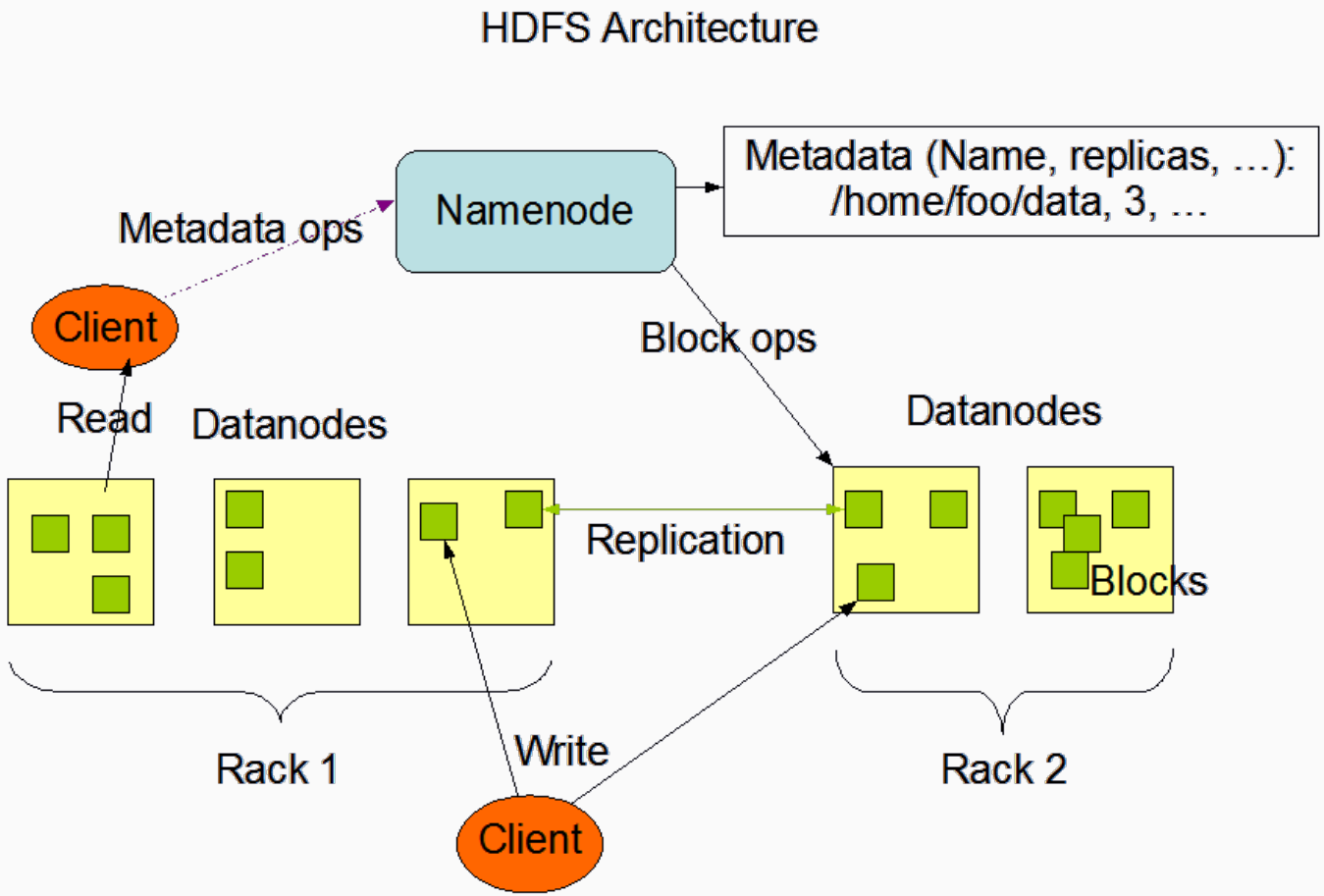

Figure 3: source
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Practical Hadoop

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DEMO

Installing Hadoop

Installing Hadoop 1/3

Requirement

- Optional: a VM for hosting hadoop
- Java
- Create an account that can `ssh localhost` with ssh keys

Get Hadoop

- Download Hadoop 3.2
  `https://www.apache.org/dyn/closer.cgi/hadoop/core`
- Unzip it (e.g. in a Hadoop folder)

Installing Hadoop 2/3

Modify `.bashrc` or `.profile` of the account:

```
export HADOOP_HOME=/path/to/hadoop/folder
export JAVA_HOME=/usr/lib/jvm/default-runtime
alias hls=''fs -ls''
export PATH=$PATH:$HADOOP_HOME/bin
```

Adapt values to your configuration!

Launch Hadoop single node

```
hdfs namenode -format #initialize namenode
cd $HADOOP_HOME/sbin
bash start_all.sh
#don't forget to bash stop_all.sh at the end!
hadoop fs -mkdir /data /out
```

Installing Hadoop 3/3

Putting data on Hadoop:

```
hadoop fs -copyFromLocal /path/to/local /data/filename
```

Getting data from Hadoop:

```
hadoop fs -copyToLocal /data/filename  /path/to/local
```

Explore data on Hadoop:

```
hadoop fs -cat /data/filename
hadoop fs -head /data/filename
hadoop fs -tail /data/filename
```

Hands On: exploring BAN

Problem

The BAN contains addresses and we want to find out the most popular street names.

BAN csv files

What the file look like

```
hadoop fs -head /datasets/ban/ban-01.csv
```

```
id_ban_position;id_ban_adresse;cle_interop;id_ban_group;id_fantoi
```

BAN csv files

```
hadoop fs -head /datasets/ban/ban-01.csv | tr ';' '\n' | nl
     1              id_ban_position
     2        id_ban_adresse
     3        cle_interop
     4        id_ban_group
     5        id_fantoir
     6        numero
     7        suffixe
     8        nom_voie
     9        code_postal
    10        nom_commune
    11        code_insee
    12        nom_complementaire
    13        x
    14        y
    15        lon
    16        lat
    17        typ_loc
```

Counting street name

What is a unique street?

Each street appears multiple times

```
hadoop fs -cat /datasets/ban/ban-75.csv | grep -i barrault
    ban-position-f7b26917d0e7483b81140c9c3abea54e;
    ban-housenumber-927804e4ca734591a257d1fc91771c02;75113_0679_93;
    ban-group-d94295ec4c1a409a893c3aaa21ebcca6;751130679;93;;
    Rue Barrault;75013;Paris 13e Arrondissement;75113;;
    652047.483621478;6858292.61265954;2.346877;48.822911;
    entrance;ign;2018-10-21

    ban-position-cfe9a6c883184b448930656d2a021862;
    ban-housenumber-927804e4ca734591a257d1fc91771c02;75113_0679_93;
    ban-group-d94295ec4c1a409a893c3aaa21ebcca6;751130679;93;;
    Rue Barrault;75013;Paris 13e Arrondissement;75113;;
    652054.959452335;6858290.99409157;2.346979;48.822897;
    parcel;dgfip;2018-10-21

    ban-position-411cce6058474e53bb95ee3aea3466fd;
    ban-housenumber-92d8c6bc6d5c433eb1ed5c310177db3c;75113_0679_94;
```

Counting street name

What is a unique street?

A street is a name and a zip code.

BAN csv files

Columns 8 and 9!

```
 1            id_ban_position
 2        id_ban_adresse
 3        cle_interop
 4        id_ban_group
 5        id_fantoir
 6        numero
 7        suffixe
 8        nom_voie
 9        code_postal
10        nom_commune
11        code_insee
12        nom_complementaire
13        x
14        y
15        lon
16        lat
17        typ_loc
```

Counting occurrences of pairs of (zip code,street name)

Map

record $\rightarrow$ ((street name,zip code),1)

Reduce

Classical word count ($l \rightarrow \mathit{length}(l)$)

Counting occurrences of pairs of (zip code,street name) MAP

```python
#/usr/bin/python

import sys

for myline in sys.stdin:
    myline = myline.strip()
    subs = myline.split(';')
    if len(subs)>8:
        voie = subs[7]
        print('%s %s\t%s' % (subs[8],voie, 1))
```

Counting occurrences of pairs of (zip code,street name) RED

```
from operator import itemgetter
import sys
current_word = ""
current_count = 0
word = ""
for myline in sys.stdin:
   myline = myline.strip()
   subs = myline.split('\t',1)
   if len(subs)>1:
      count = int(str(subs[1]))
      word=subs[0]
      if current_word == word:
         current_count += count
      else:
         if current_word:
            print('%s\t%s' % (current_word, current_count) )
         current_count = count
         current_word = word
if current_word == word:
   print('%s\t%s' % (current_word, current_count))
```

Counting number of zip code for each street name

Map

((street name,zip code),n) $\rightarrow$ (street name,1)

Reduce

Classical word count reducer

Counting occurrences of pairs of (zip code,street name) MAP

```
#/usr/bin/python

import sys

for myline in sys.stdin:
    myline = myline.strip()
    subs = myline.split('\t',1)
    if len(subs)>1:
        subs2 = subs[0].split(' ',1)
        if len(subs2)>1:
            print('%s\t1' % (subs2[1]))
```

Extract the popular street names

Map

$(\text{street name}, n) \rightarrow (\text{street name}, n)$ when $n > 1000$

Reduce

Identity

Counting occurrences of pairs of (zip code,street name) MAP

```python
#/usr/bin/python

import sys

for myline in sys.stdin:
    myline = myline.strip()
    subs = myline.split('\t')
    if len(subs) > 1:
        print('%.9d\t%s' % (int(subs[1]), subs[0]))
```