R Programming under Hadoop

Installation of the Hadoop framework (Cloudera)

Installation and configuration of R and RStudio Server

Mapreduce programming in R

Accessing files in HDFS using R

Topic

The aim of this tutorial is to show the programming of the famous “word count” algorithm from a set of files stored in HDFS file system.

The "word count" is a state-of-the-art example for the programming under Hadoop. It is described everywhere on the web. But, unfortunately, the tutorials which describe the task are often not reproducible. The dataset are not available. The whole process, including the installation of the Hadoop framework, are not described. We do not know how to access to the files stored in the HDFS file system. In short, we cannot run programs and understand in details how they work.

In this tutorial, we describe the whole process. We detail first the installation of a virtual machine which contains a single-node Hadoop cluster. Then we show how to install R and RStudio Server which allows us to write and run a program. Last, we write some programs based on the mapreduce scheme.

The steps, and therefore the source of errors, are numerous. We will use many screenshots to actually understand each operation. This is the reason of this unusual presentation format for a tutorial.

Steps

1. Installation of the single-node Hadoop cluster
2. Installation of R and RStudio Server
3. MapReduce programming in R
4. Accessing files in HDFS using R
5. References

Installation of a virtual machine containing a single-node Apache Hadoop cluster

We can install the Hadoop framework directly on an existing machine. But the operation remains delicate, requiring a certain knowledge about operating system (e.g. installation on Ubuntu Linux).

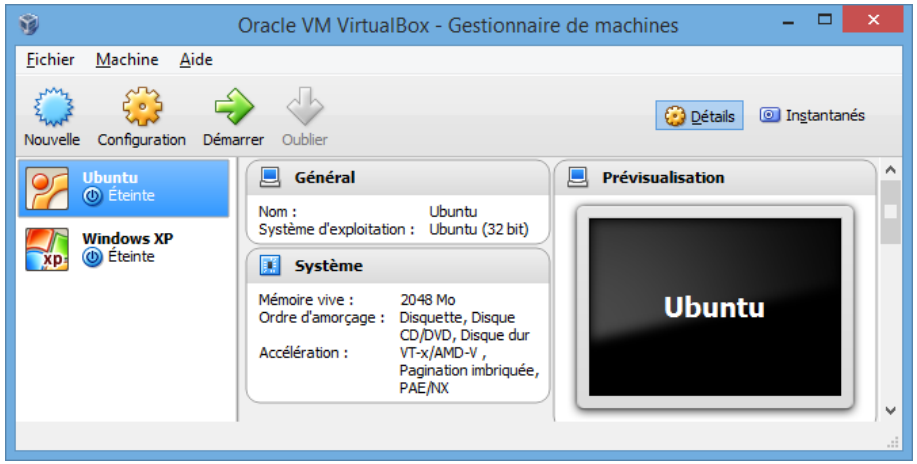
Fortunately, some editors offer turnkey solutions with the creation of a virtual machine - as a single-node cluster - including already correctly configured and functional Hadoop framework. We will use the QuickStart VM of Cloudera based on the CentOS operating system in this tutorial.

Installation of VirtualBox

VirtualBox is a "virtualization" tool i.e. it is a host application that allows to host and run an operating system as a software (guest operating system). Thus, we have a fully functional virtual machine.

VirtualBox is an open source tool.

We can incorporate multiple virtual machines.

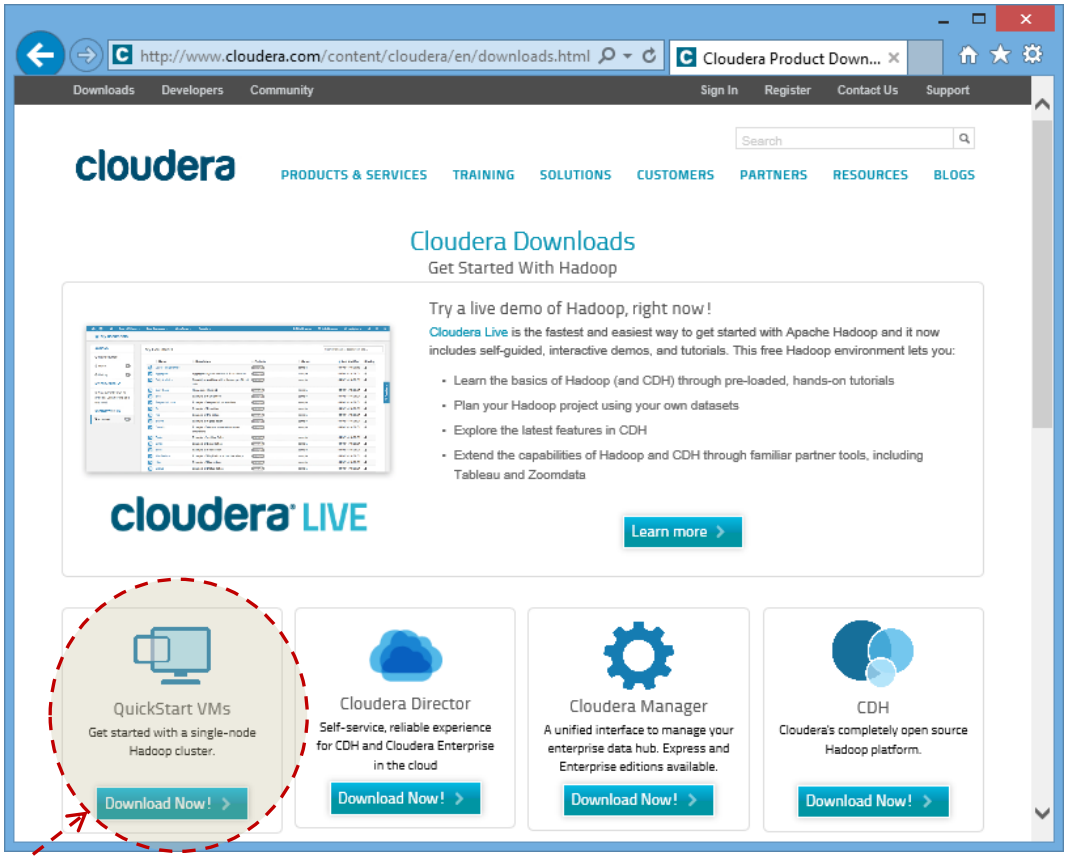


In this screenshot, we see that I have already installed two guests machines into VirtualBox: one running under Ubuntu and the other under Windows XP.

Downloading Cloudera (1/2)

The QuickStart VMs contain a single-node Apache Hadoop cluster, complete with example data, queries, scripts, and Cloudera Manager to manage your cluster.

http://www.cloudera.com/content/cloudera/en/downloads/quickstart_vms/cdh-5-3-x.html

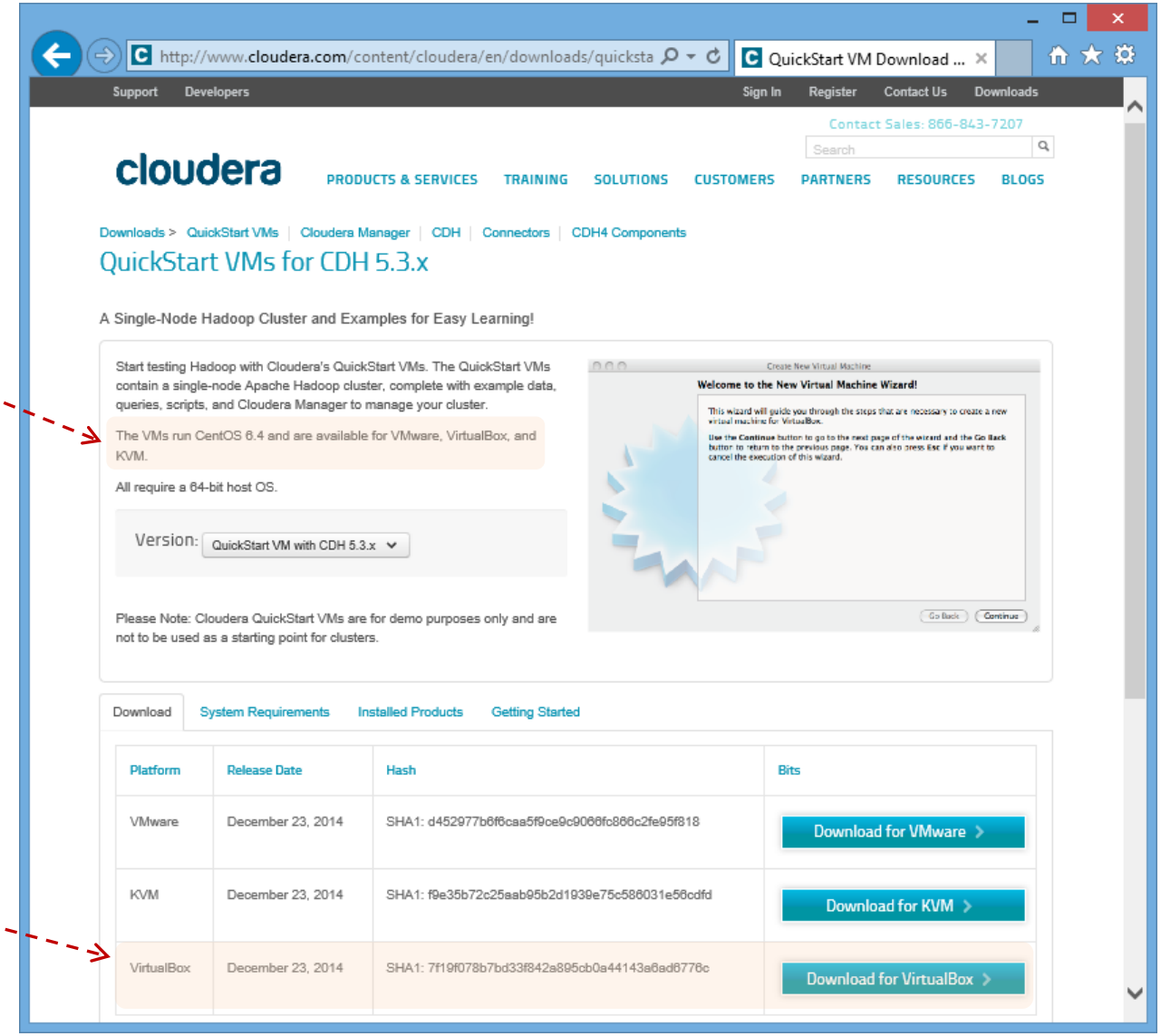


The aim is to create a single-node Hadoop cluster running under a **virtual machine** (VM).

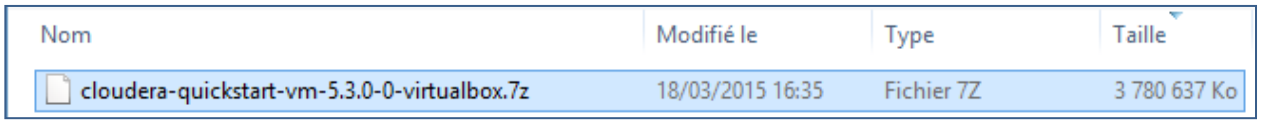
Downloading Cloudera (2/2)

The virtual machine runs CentOS 6.4

We download the machine designed for VirtualBox in this tutorial.

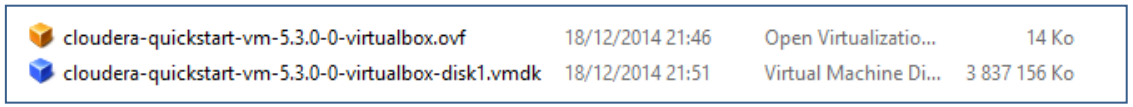


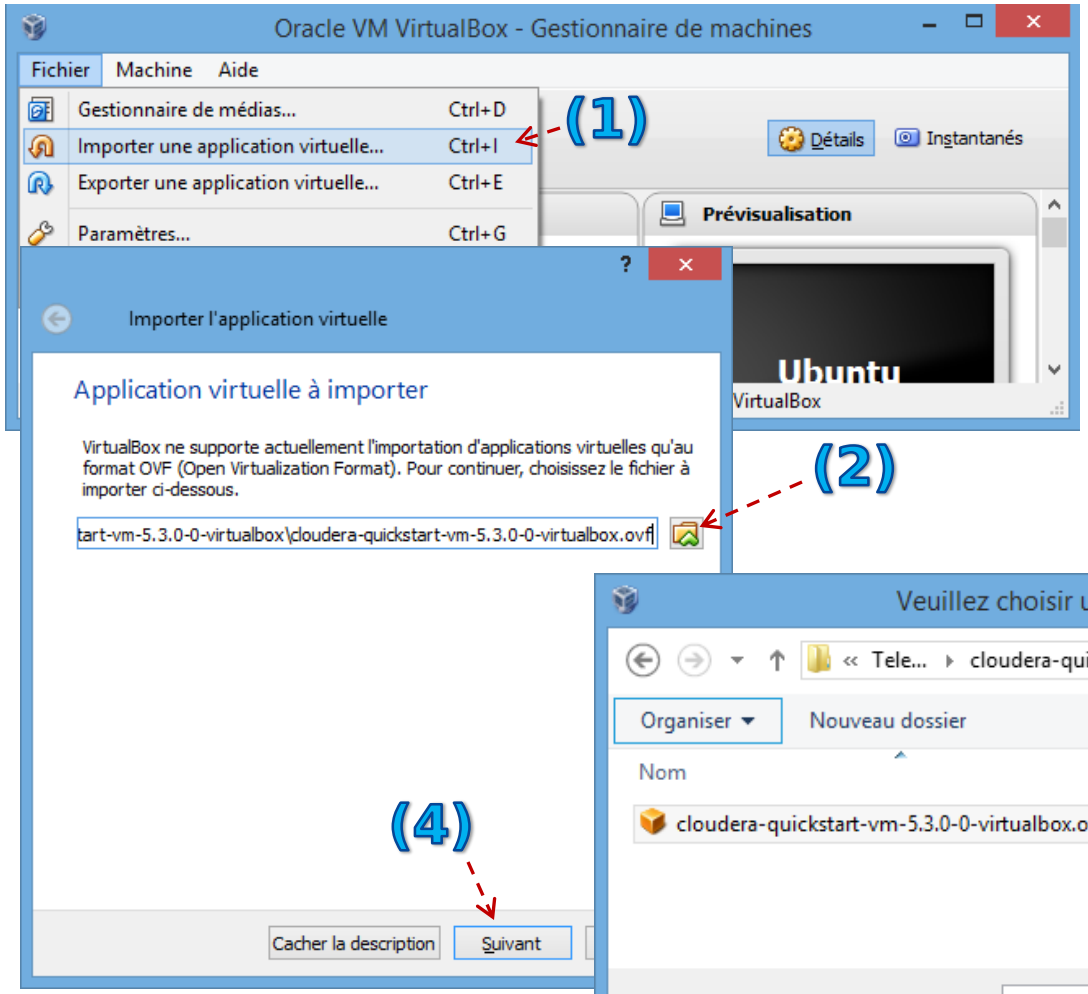
Here is the archive file when it was downloaded.

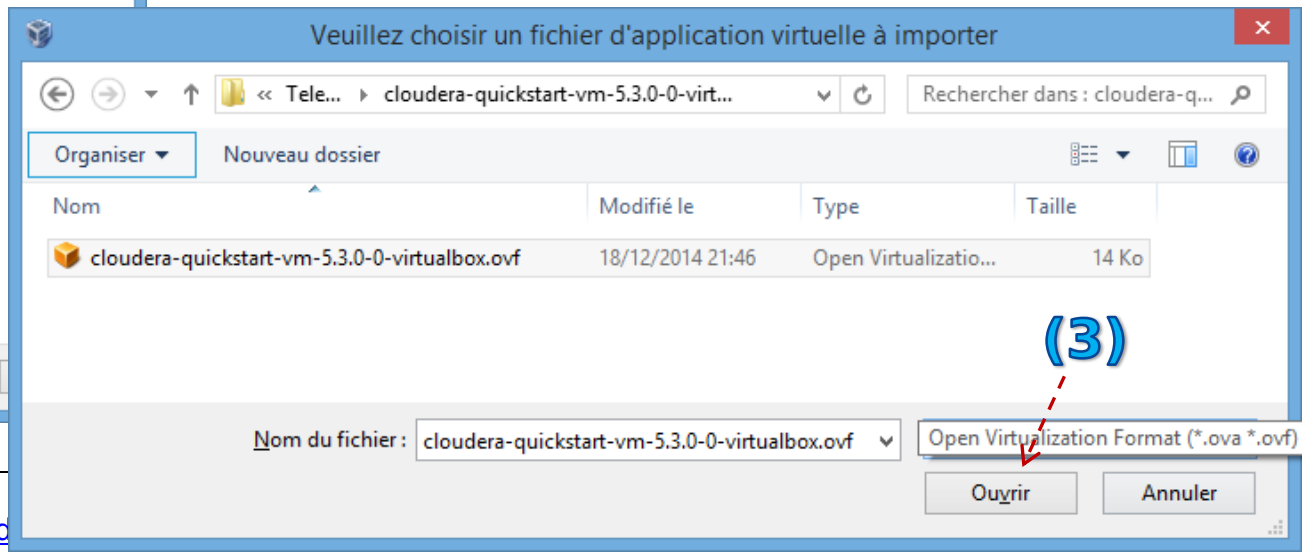


Importing the virtual machine into VirtualBox (1/3)

The archive contains 2 files

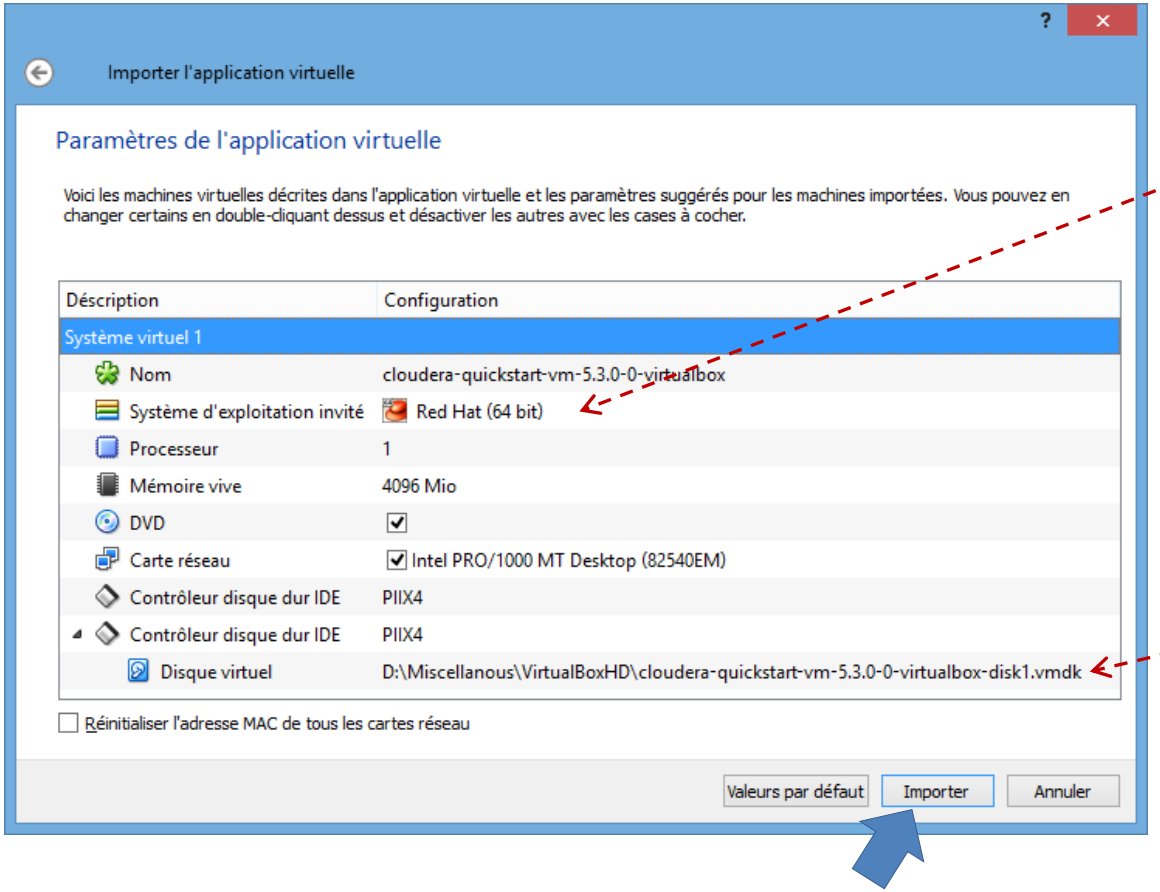






There are several steps in the import process.

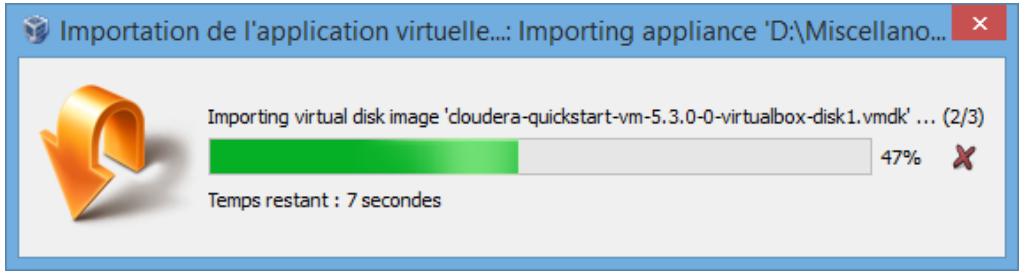
Importing the virtual machine into VirtualBox (2/3)



It seems we can choose, but in reality it is always **CentOS** which is installed.

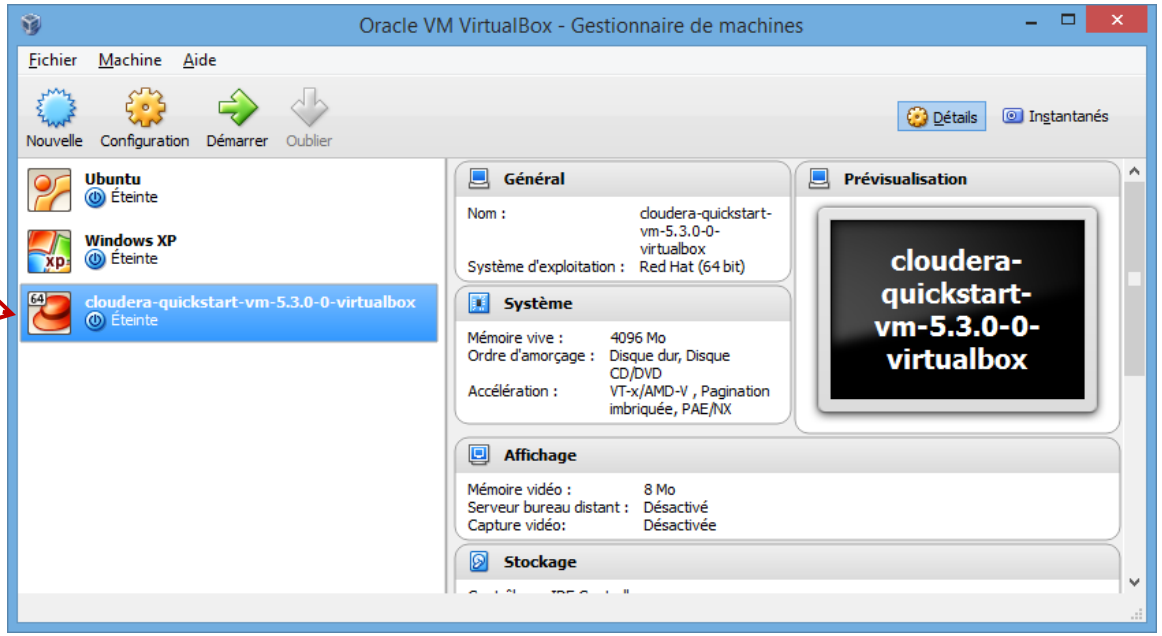
We can choose the destination folder of the file containing the virtual machine. Its size can increase considerably during the operations.

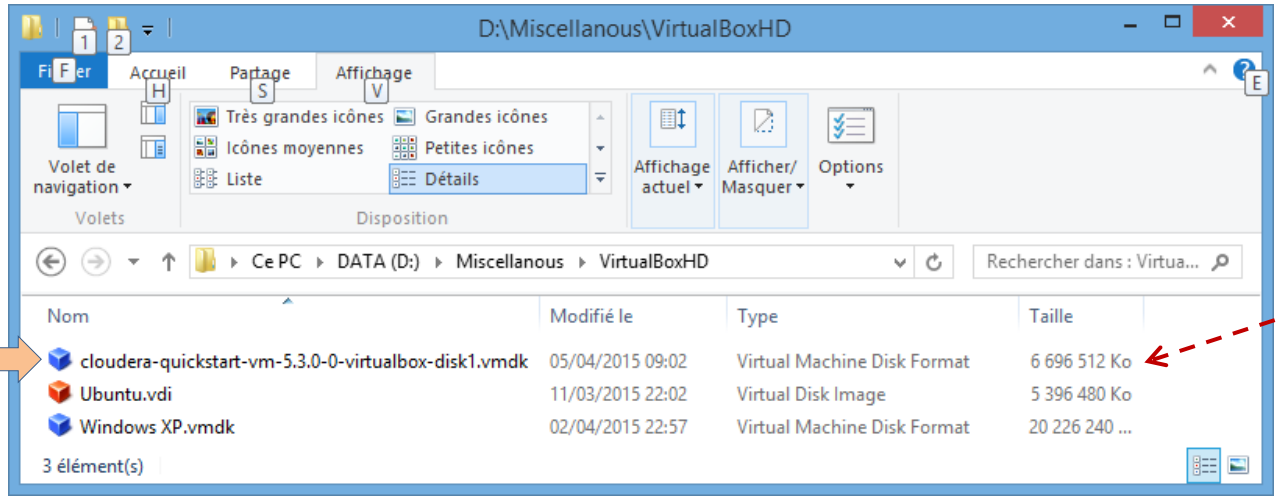
The import process is started when you click on the IMPORT button.



Importing the virtual machine into VirtualBox (3/3)

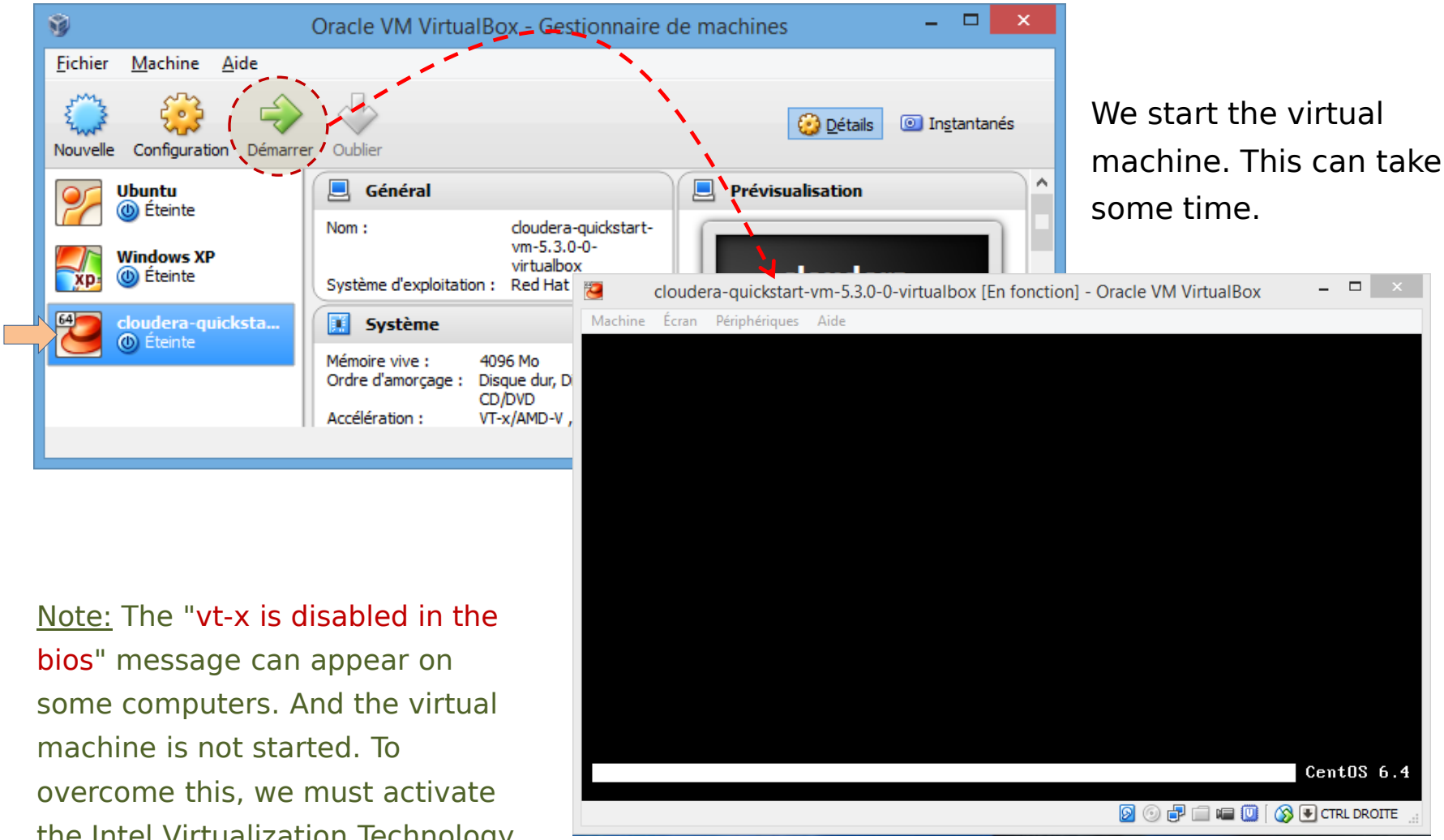
The virtual machine is now available into VirtualBox.





The size of the corresponding file is approximately 6 GB! And this is only the beginning.

Starting the virtual machine (1/3)



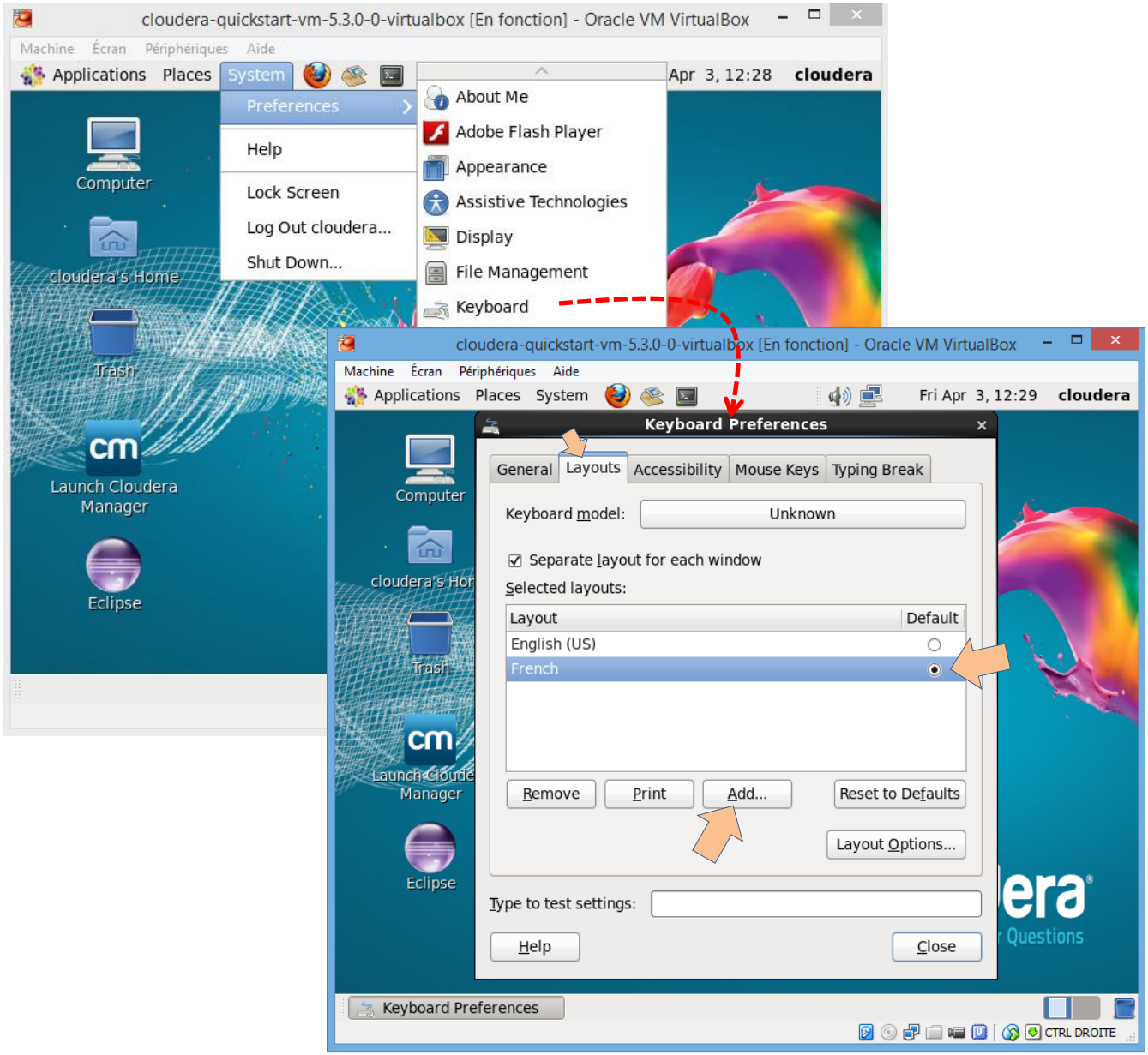
We start the virtual machine. This can take some time.

Note: The "vt-x is disabled in the bios" message can appear on some computers. And the virtual machine is not started. To overcome this, we must activate the Intel Virtualization Technology in the BIOS.

Starting the virtual machine (2/3)

Hadoop is already functional when the virtual machine is started. There are no specific operations to do at this step.

Starting the virtual machine (3/3)



If necessary, we must install the keyboard layout for our country.

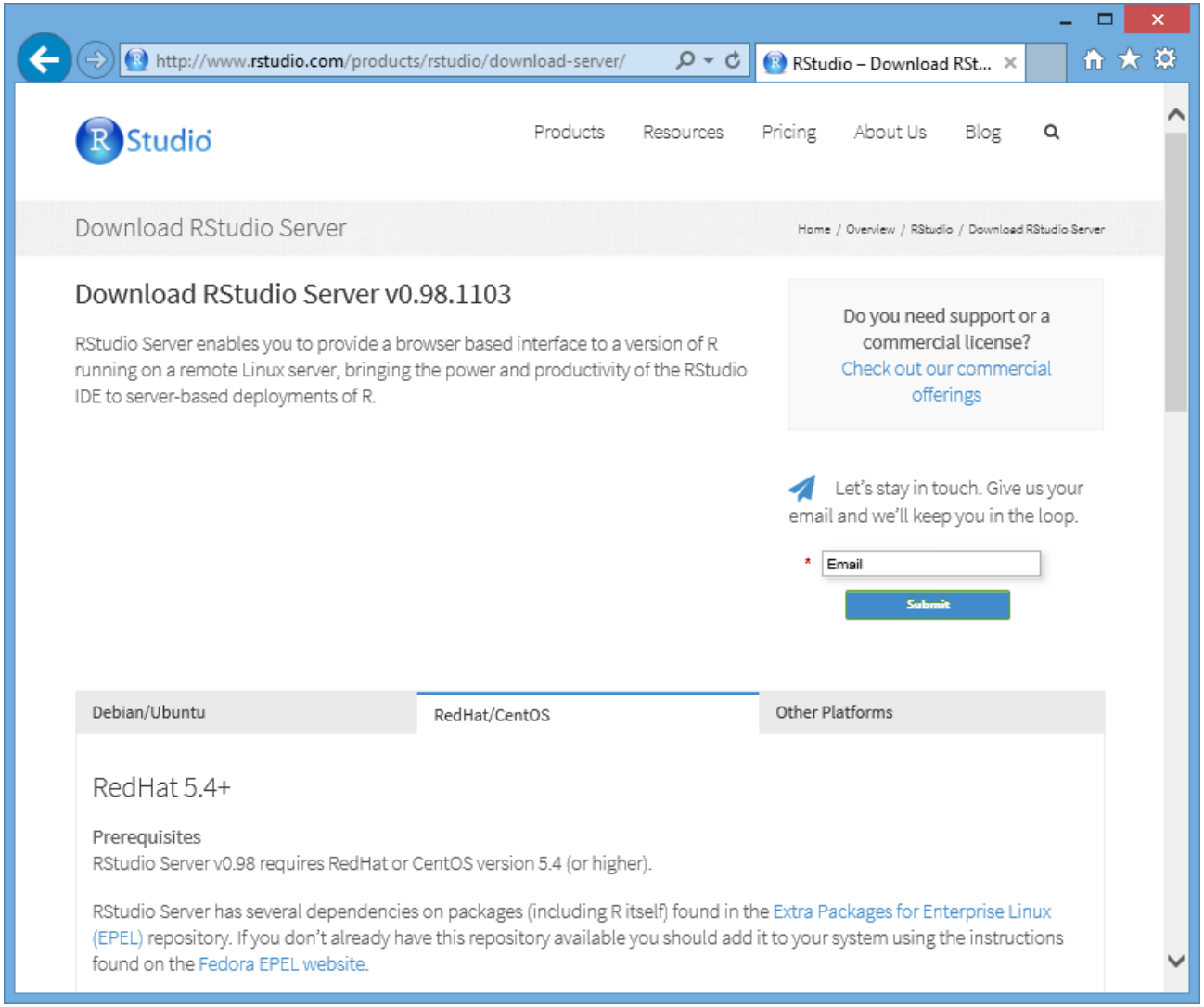
Here, I install the French keyboard for me. I set it as the default keyboard.

Installation of R and RStudio Server

The R tool allows to execute our programs.

RStudio Server enables to provide a browser based interface to a version of R running on a remote Linux server. In our case, the same computer is the client and the server, we use 127.0.0.1 as IP address (local host). But the approach can be applied generally to remote access using a properly configured server.

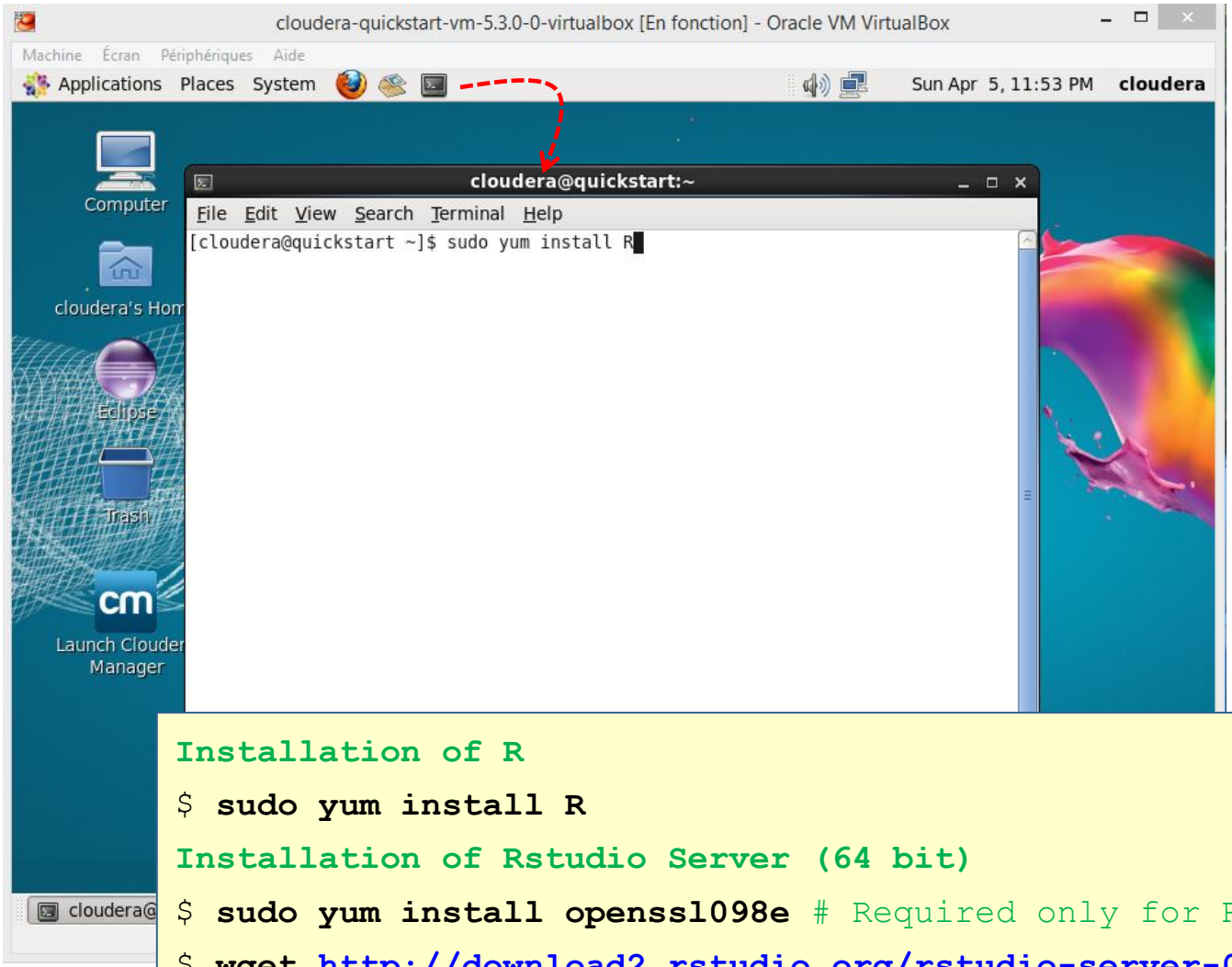
Installation of R and RStudio Server (1/2)



All appropriate instructions are described on the website of RSTUDIO. We choose CentOS because this is the operating system that has been installed with our virtual machine.

http://www.rstudio.com/products/rstudio/download-server/

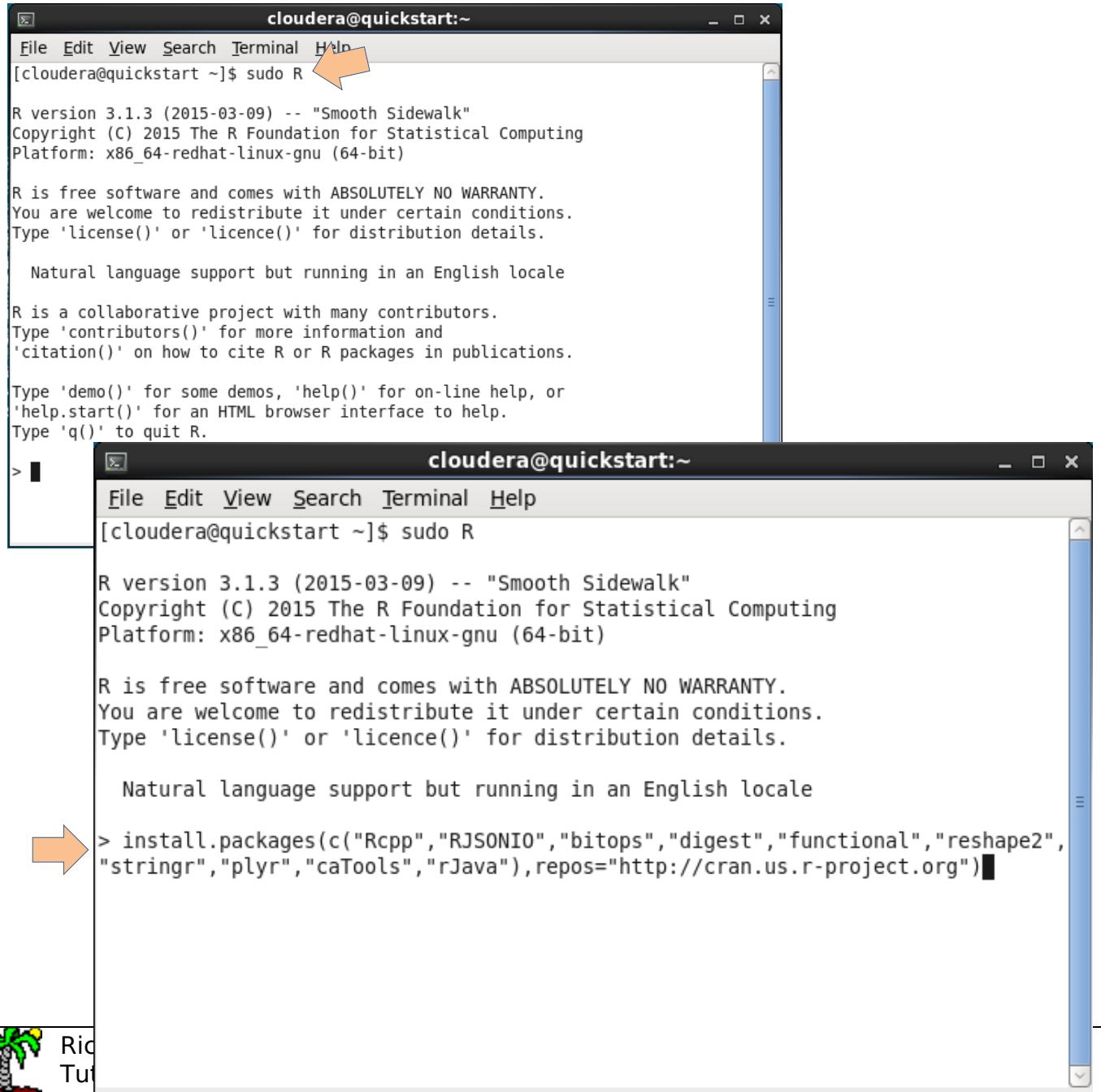
Installation of R and RStudio Server (2/2)



We open a terminal and we set the commands below.

```
Installation of R
$ sudo yum install R
Installation of Rstudio Server (64 bit)
$ sudo yum install openssl098e # Required only for RedHat/CentOS 6 and 7
$ wget http://download2.rstudio.org/rstudio-server-0.98.1103-x86_64.rpm
$ sudo yum install --nogpgcheck rstudio-server-0.98.1103-x86_64.rpm
```

Installation of packages available on the CRAN server

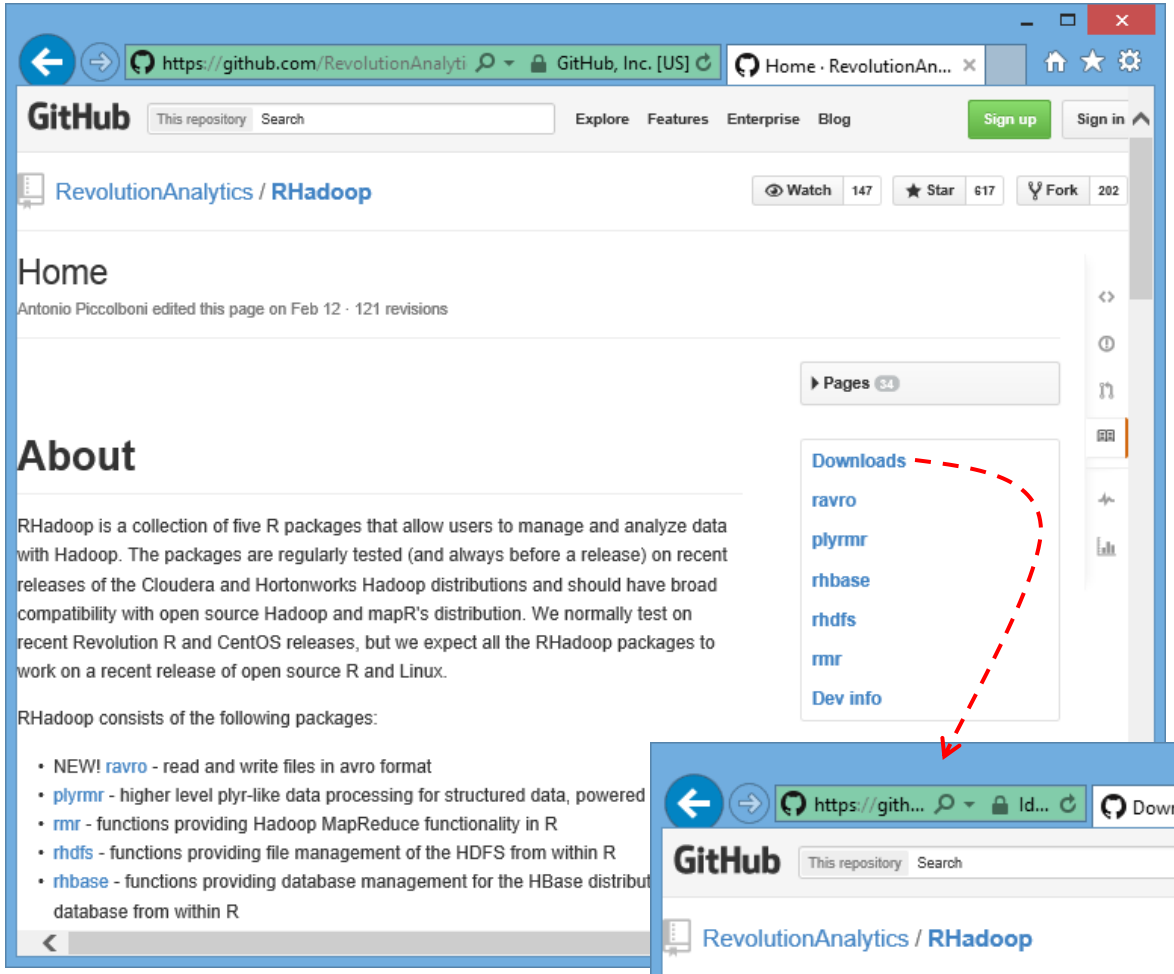


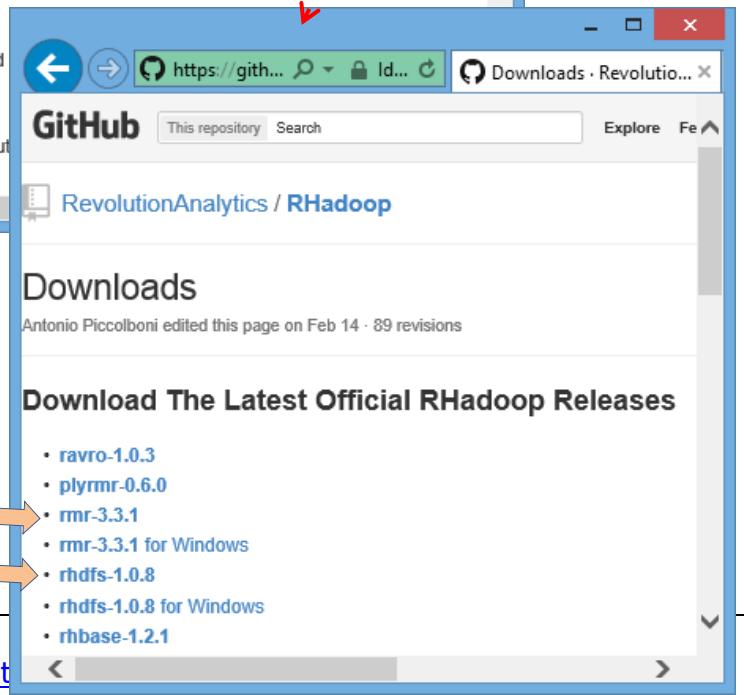
To use the RHadoop packages for programming with Hadoop, we need first to install some packages available on the CRAN server.

We launch R in the administrator mode from a terminal i.e. using the command **$sudo R**

Then, inside R terminal, we use the **install.packages()** command by specifying a repository (repos).

Installation of the RHadoop packages (1/3)





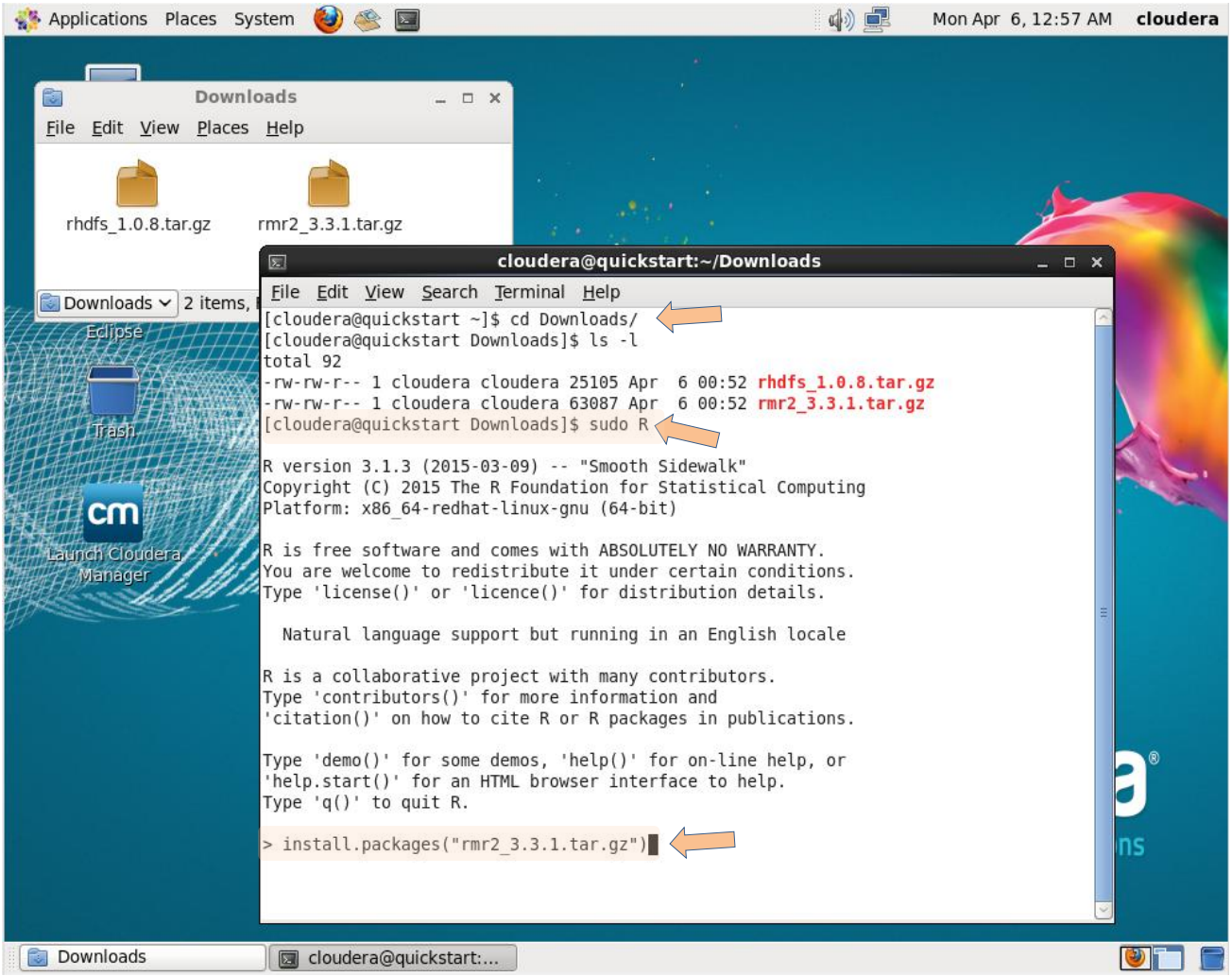
We want to use two packages from the RHadoop collection.

rmr which provides **MAPREDUCE** functionality in R.

rhdfs which provides functions for file management of the **HDFS** from within R.

We download these two files into the "Downloads" directory

Installation of the RHadoop packages (2/3)

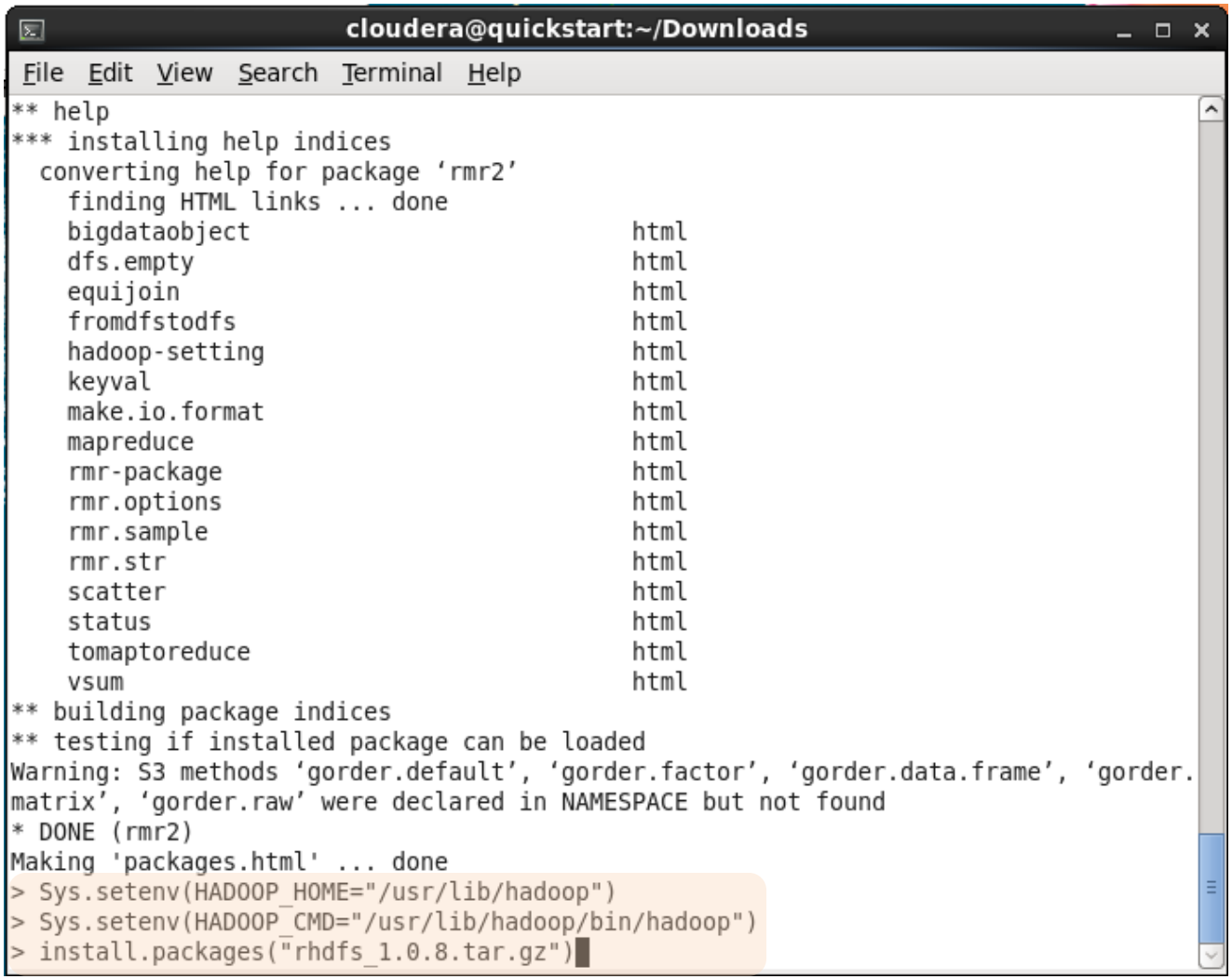


We open a terminal.

We change the current directory and we launch R in the administrative mode.

install.packages() allows also to install packages from local files.

Installation of the RHadoop packages (3/3)



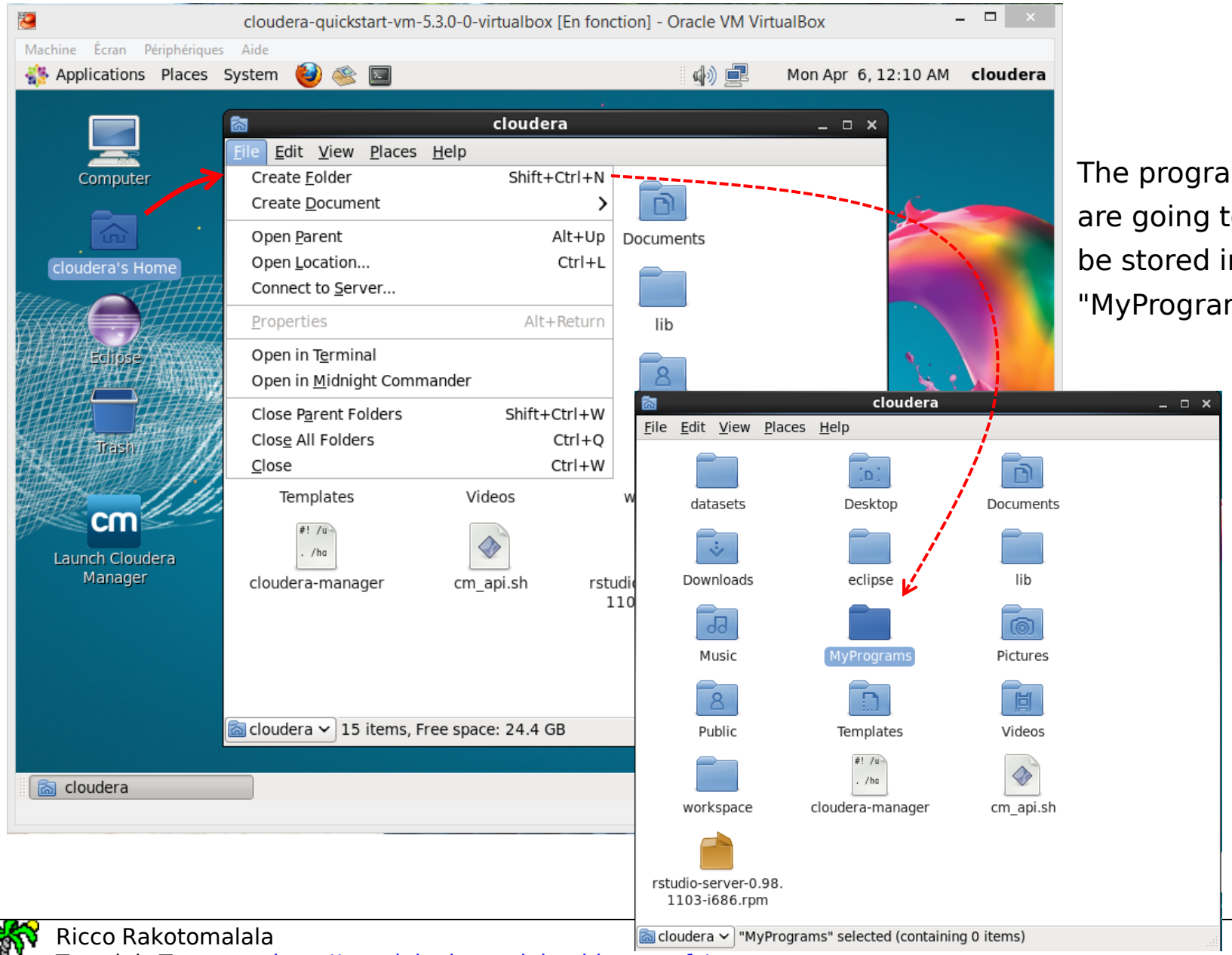
For the "rmr" packages, we must define first some environment variables for the HADOOP system.

We use the Sys.setenv() command under R.

R programming under Hadoop (1)
MapReduce functionalities in R

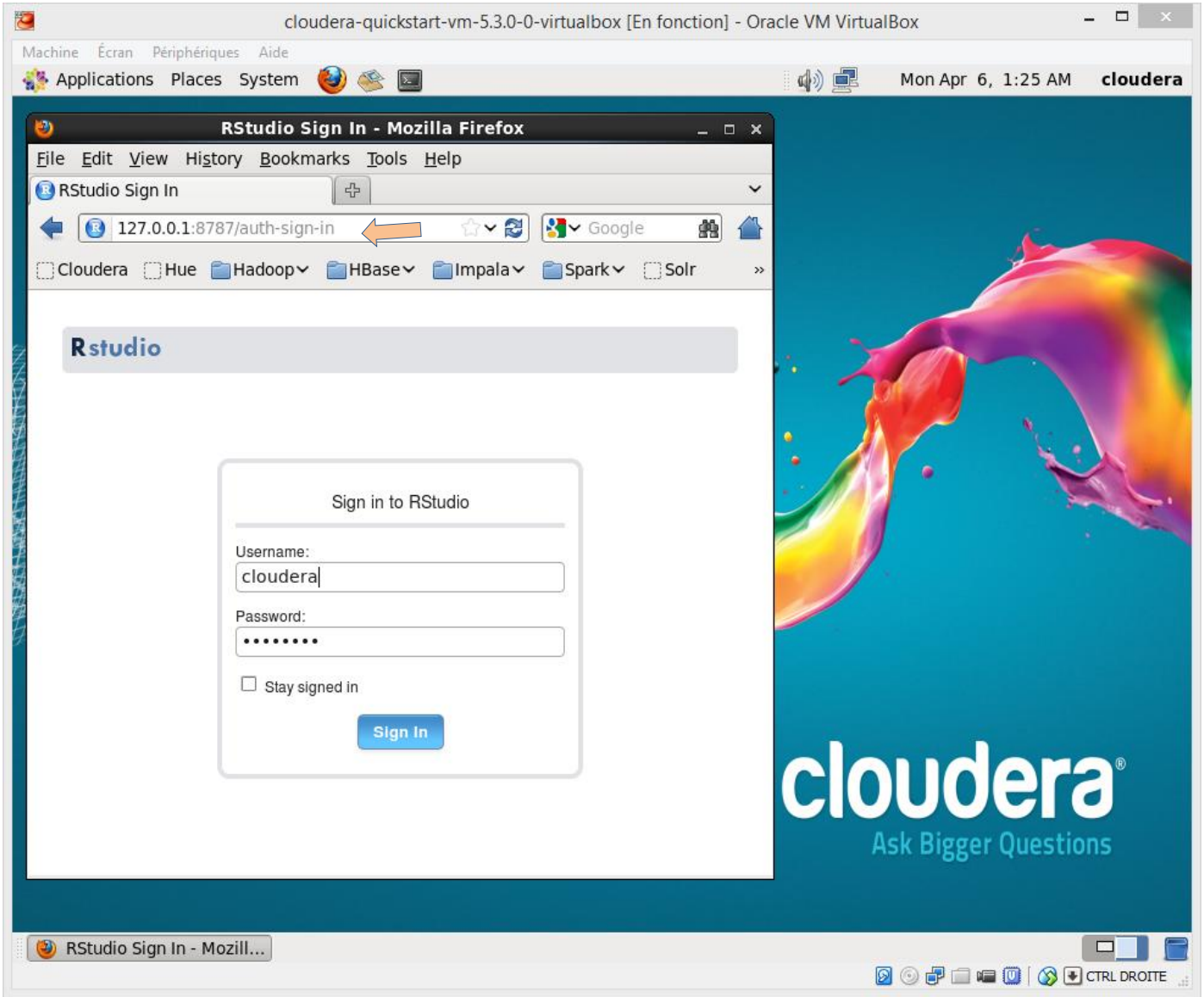
In this first example, a vector of words is generated in memory. It is stored in a temporary file and then the mapreduce() function from the “rmr2” package is called. This function calls internally the map() and reduce() functions that we have coded before.

Creating a directory for our programs



The programs that we are going to write will be stored in the "MyPrograms" folder.

Accessing to RStudio using a web browser (1/2)



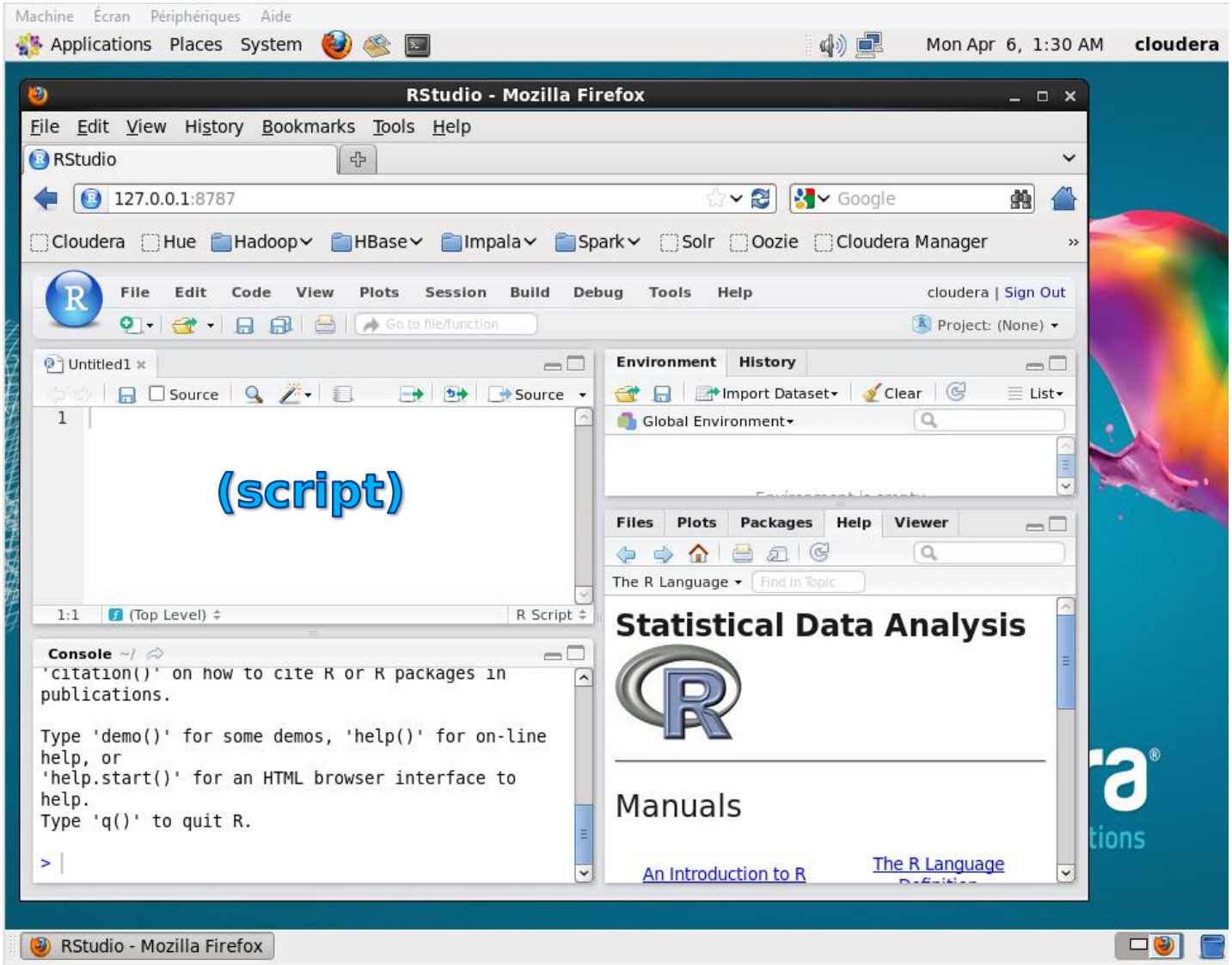
The same machine is client and server. We use the local host IP address: 127.0.0.1

The port is 8787

The standard login is username : cloudera password : cloudera

See https://support.rstudio.com/hc/en-us/articles/200552306-Getting-Started

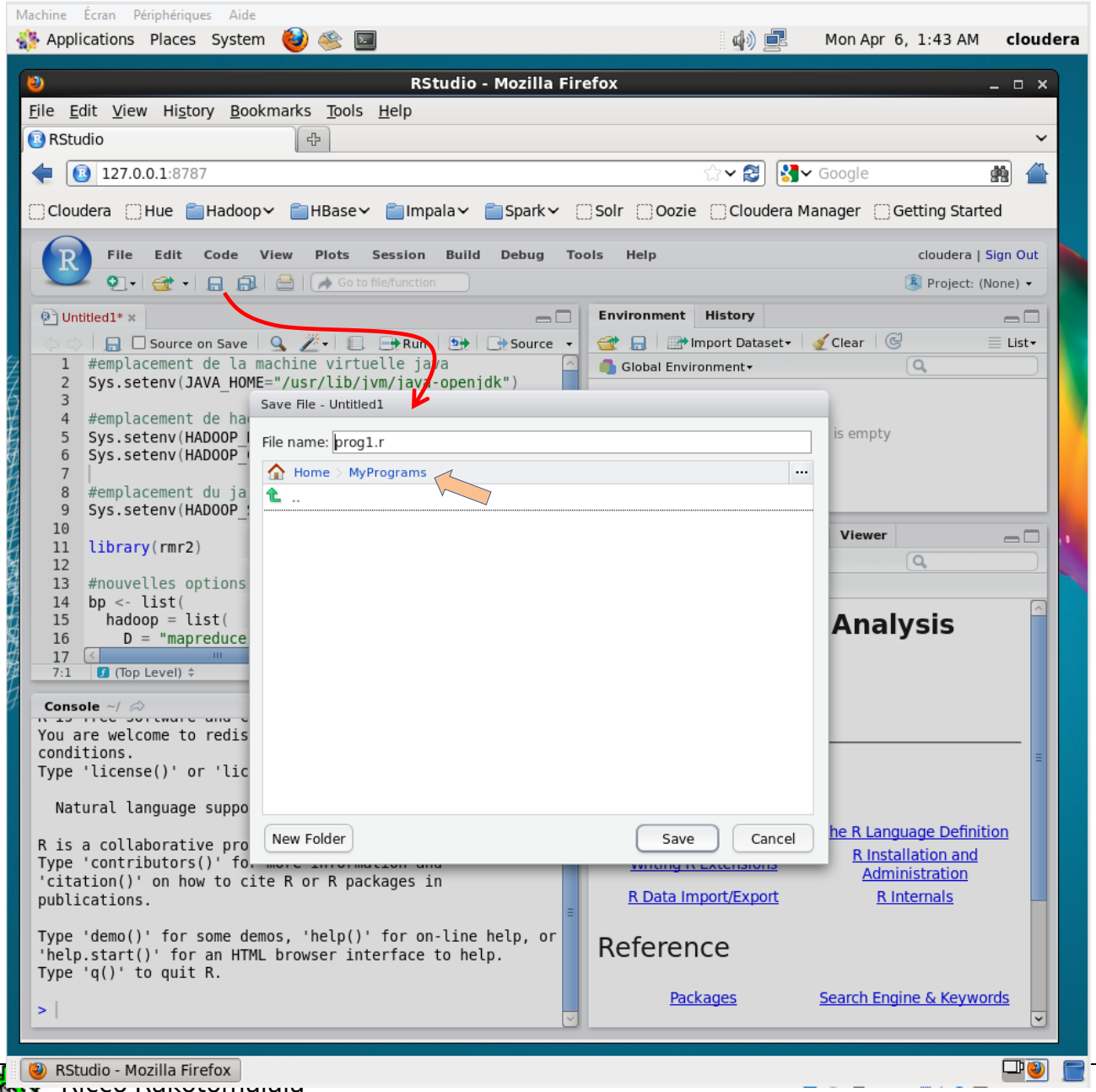
Accessing to RStudio using a web browser (2/2)



We have the usual RStudio development environment.

To write a new R script, we click on the FILE / NEW FILE / R SCRIPT menu.

Mapreduce in R (1/4)



The program is stored in the "MyPrograms" directory.

MapReduce in R (2/4) – Setting the options

```
#directory of the JAVA virtual machine
Sys.setenv(JAVA_HOME="/usr/lib/jvm/java-openjdk")

#directory of the hadoop system
Sys.setenv(HADOOP_HOME="/usr/lib/hadoop")
Sys.setenv(HADOOP_CMD="/usr/lib/hadoop/bin/hadoop")

#directory of the utility which allows to create and run mapreduce jobs
Sys.setenv(HADOOP_STREAMING="/usr/lib/hadoop-mapreduce/hadoop-streaming-2.5.0-cdh5.3.0.jar")

#loading the "rmr2" package
library(rmr2)

#options for the memory management
#otherwise, the error message "Java heap space" interrupts the execution of the program
bp <- list(
  hadoop = list(
    D = "mapreduce.map.java.opts=-Xmx1024M",
    D = "mapreduce.reduce.java.opts=-Xmx2048M",
    D = "mapreduce.map.memory.mb=1280",
    D = "mapreduce.reduce.memory.mb=2560"
  )
)

#modification of the settings
rmr.options(backend.parameters = bp)

#hadoop mode
rmr.options(backend="hadoop")
```

MapReduce in R (3/4) – Writing the map() and reduce() functions. Handling a vector of words.

```
#map function
mymap <- function(k,v){
  keyval(v,1)
}

#reduce function
myreduce <- function(k,v){
  n <- length(v)
  keyval(k,n)
}

#vector of words
b <- c("one","two","one","one","two")

#transformed and copied in a temporary file on HDFS
a <- to.dfs(b)

#launching the mapreduce function
sortie <- mapreduce(input=a, map=mymap, reduce=myreduce)

#retrieving the output from a temporary file on HDFS
# printing the results
print(from.dfs(sortie))
```

After the calling of the map() function

key	value
one	1
two	1
one	1
one	1
two	1

Splitting based on the key

Key = one	1	1	1
Key = two	1	1	

Calling of REDUCE (Wikipedia [EN] : The framework calls the application's **Reduce** function once for each unique key in the sorted order)

After the calling of REDUCE

Key = one	3
Key = two	2

MapReduce in R (4/4) – Reading the R terminal output

```
Console ~/
> #jeu de données créé en mémoire
> b <- c("one","two","one","one","two")
>
> #copié temporairement sur le système HDFS
> a <- to.dfs(b)
15/04/06 05:06:02 INFO zlib.ZlibFactory: Successfully loaded & initialized
native-zlib library
15/04/06 05:06:02 INFO compress.CodecPool: Got brand-new compressor [.deflate]
>
> #lancement
> sortie <- mapreduce(input=a, map=mymap, reduce=myreduce)
packageJobJar: [] [/usr/lib/hadoop-mapreduce/hadoop-streaming-2.5.0-
cdh5.3.0.jar] /tmp/streamjob5719859679609417903.jar tmpDir=null
15/04/06 05:06:04 INFO client.RMProxy: Connecting to ResourceManager at
/0.0.0.0:8032
15/04/06 05:06:05 INFO client.RMProxy: Connecting to ResourceManager at
/0.0.0.0:8032
15/04/06 05:06:05 INFO mapred.FileInputFormat: Total input paths to process : 1
15/04/06 05:06:05 INFO mapreduce.JobSubmitter: number of splits:2
15/04/06 05:06:05 INFO mapreduce.JobSubmitter: Submitting tokens for job:
job_1428320419241_0002
15/04/06 05:06:06 INFO impl.YarnClientImpl: Submitted application
application_1428320419241_0002
15/04/06 05:06:06 INFO mapreduce.Job: The url to track the job:
http://quickstart.cloudera:8088/proxy/application_1428320419241_0002/
15/04/06 05:06:06 INFO mapreduce.Job: Running job: job_1428320419241_0002
15/04/06 05:06:13 INFO mapreduce.Job: Job job_1428320419241_0002 running in
uber mode : false
15/04/06 05:06:13 INFO mapreduce.Job:  map 0% reduce 0%
```

The vector of words is created into the R memory

This vector is copied into a temporary file in HDFS file system. This file will be the input of the **mapreduce**() function of "rmr2".

Initialization of the execution. Then the map() and reduce() functions are called internally.

```
Console ~/
                Total committed heap usage (bytes)=391979008
        Shuffle Errors
                BAD_ID=0
                CONNECTION=0
                IO_ERROR=0
                WRONG_LENGTH=0
                WRONG_MAP=0
                WRONG_REDUCE=0
        File Input Format Counters
                Bytes Read=776
        File Output Format Counters
                Bytes Written=744
        rmr
                reduce calls=2
15/04/06 05:06:30 INFO streaming.StreamJob: Output directory:
/tmp/file178076b50cbe




> print(from.dfs(sortie))
$key
[1] "one" "two"

$val
[1] 3 2

>
```

At the end of the execution, the output is copied into another temporary file on HDFS

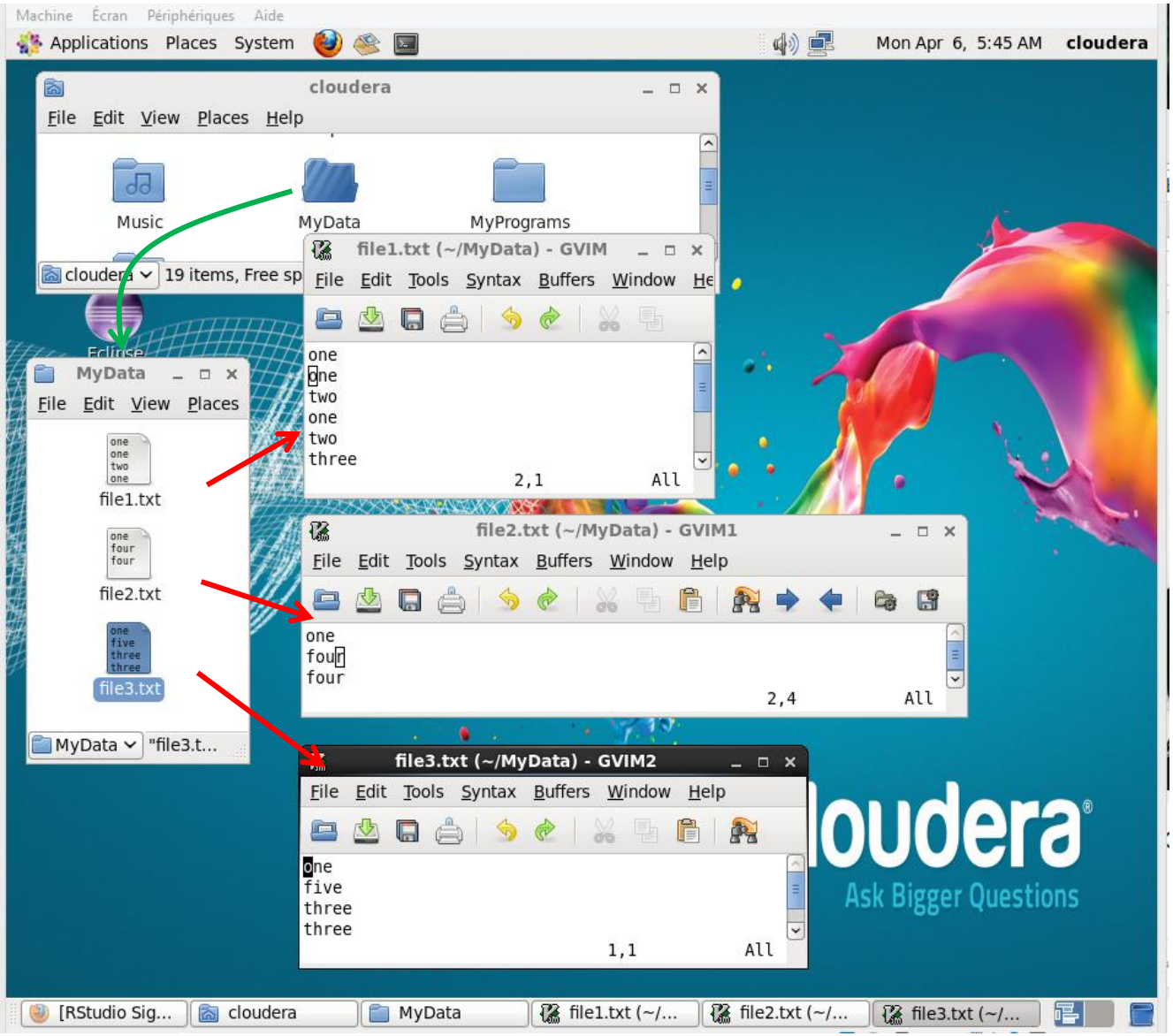
We can retrieve the object in memory and print it.

R programming under Hadoop (2)
Accessing files in HDFS

In more realistic perspective, we will access to a set of files stored into a folder in the HDFS file system.

We first detail the format and the contents of these files, then we show how we copy them into a folder specially created for this purpose in HDFS. Finally, we modify our program in order to process these files.

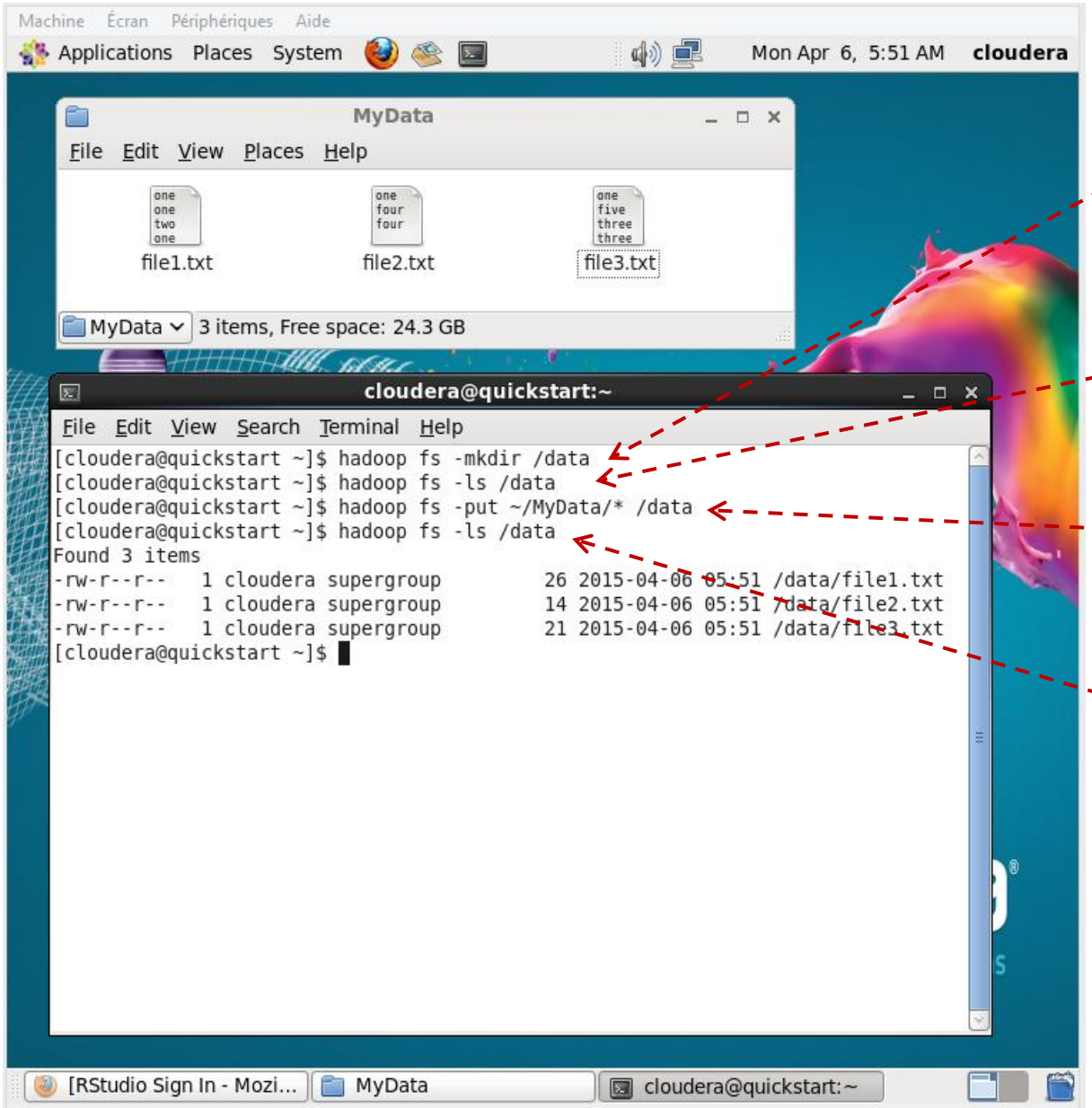
Creating 3 files (text format)



3 files are created in the "MyData" directory: file1.txt, file2.txt, file3. txt

Each file contains a list of words that we can see in the screen shot.

Copying the files from the local directory to HDFS



We create the directory **"/data"** on HDFS. The command is valid regardless the number of nodes on the cluster.

The directory is empty for the moment.

We copy the files from the local directory to HDFS.

The files are visible into the directory **"/data"** now.

R program to handle files in HDFS

The global settings, the functions map() and reduce() are the same as before.

The input parameter now allows to scan the files in the /data directory in HDFS

```
#we need the rhdfs package here
library(rhdfs)

#initializing the access to hdfs
hdfs.init()

#displaying the content of the /data directory
hdfs.ls("/data")

#calling the mapreduce() function by reading the content of /data in HDFS
sortie.bis <- mapreduce(input="/data", input.format="text", map=mymap, reduce=myreduce)
print(from.dfs(sortie.bis))
```

The files are in the text file format. We do not need to create a temporary file using the **to.dfs()** procedure here.

Output of the program (1/2)

```
Console ~/
> #afficher le contenu du dossier data
> hdfs.ls("/data")
  permission    owner      group size          modtime            file
1 -rw-r--r-- cloudera supergroup   26 2015-04-06 05:51 /data/file1.txt
2 -rw-r--r-- cloudera supergroup   14 2015-04-06 05:51 /data/file2.txt
3 -rw-r--r-- cloudera supergroup   21 2015-04-06 05:51 /data/file3.txt
>
> #programmation en accédant aux fichiers contenu dans le dossier /data
> sortie.bis <- mapreduce(input="/data", input.format="text", map=mymap, reduce=myreduce)
packageJobJar: [] [/usr/lib/hadoop-mapreduce/hadoop-streaming-2.5.0-cdh5.3.0.jar]
/tmp/streamjob7113339506246022660.jar tmpDir=null
15/04/06 06:09:13 INFO client.RMProxy: Connecting to ResourceManager at /0.0.0.0:8032
15/04/06 06:09:13 INFO client.RMProxy: Connecting to ResourceManager at /0.0.0.0:8032
15/04/06 06:09:14 INFO mapred.FileInputFormat: Total input paths to process : 3
15/04/06 06:09:14 INFO mapreduce.JobSubmitter: number of splits:3
15/04/06 06:09:14 INFO mapreduce.JobSubmitter: Submitting tokens for job:
job_1428320419241_0003
15/04/06 06:09:14 INFO impl.YarnClientImpl: Submitted application
application_1428320419241_0003
15/04/06 06:09:14 INFO mapreduce.Job: The url to track the job:
http://quickstart.cloudera:8088/proxy/application_1428320419241_0003/
15/04/06 06:09:14 INFO mapreduce.Job: Running job: job_1428320419241_0003
15/04/06 06:09:23 INFO mapreduce.Job: Job job_1428320419241_0003 running in uber mode : false
15/04/06 06:09:23 INFO mapreduce.Job:  map 0% reduce 0%
```

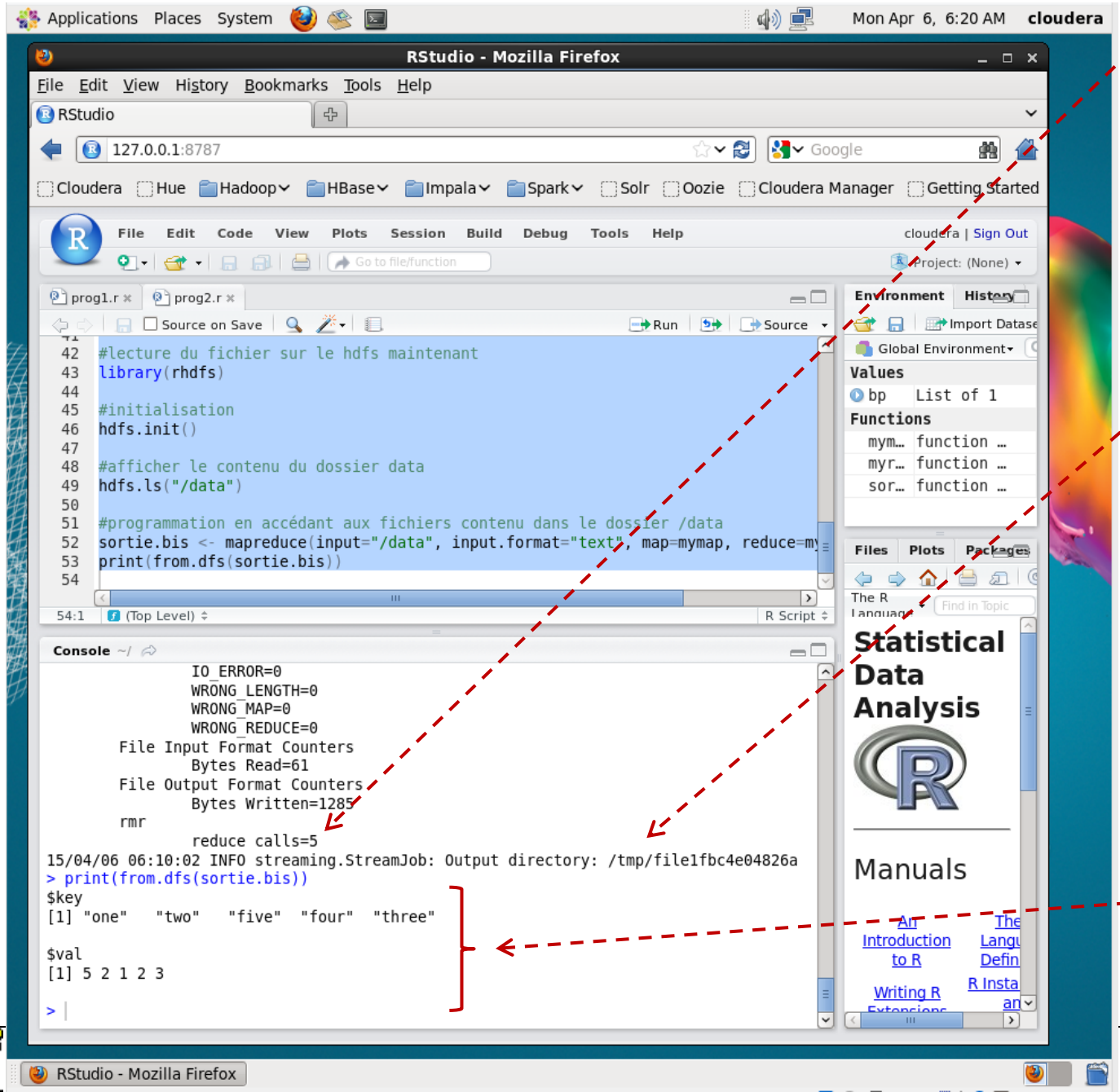
The 3 files in the **/data** directory are visible.

And they will be processed.

We can observe the steps of the processing.

```
Console ~/
15/04/06 06:09:14 INFO impl.YarnClientImpl: Submitted application
application_1428320419241_0003
15/04/06 06:09:14 INFO mapreduce.Job: The url to track the job:
http://quickstart.cloudera:8088/proxy/application_1428320419241_0003/
15/04/06 06:09:14 INFO mapreduce.Job: Running job: job_1428320419241_0003
15/04/06 06:09:23 INFO mapreduce.Job: Job job_1428320419241_0003 running in uber mode : false
15/04/06 06:09:23 INFO mapreduce.Job:  map 0% reduce 0%
15/04/06 06:09:41 INFO mapreduce.Job:  map 22% reduce 0%
15/04/06 06:09:48 INFO mapreduce.Job:  map 33% reduce 0%
15/04/06 06:09:51 INFO mapreduce.Job:  map 78% reduce 0%
15/04/06 06:09:53 INFO mapreduce.Job:  map 100% reduce 0%
15/04/06 06:10:01 INFO mapreduce.Job:  map 100% reduce 100%
15/04/06 06:10:02 INFO mapreduce.Job: Job job_1428320419241_0003 completed successfully
15/04/06 06:10:02 INFO mapreduce.Job: Counters: 50
        File System Counters
                FILE: Number of bytes read=1797
                FILE: Number of bytes written=447123
                FILE: Number of read operations=0
                FILE: Number of large read operations=0
                FILE: Number of write operations=0
                HDFS: Number of bytes read=355
                HDFS: Number of bytes written=1285
                HDFS: Number of read operations=12
                HDFS: Number of large read operations=0
                HDFS: Number of write operations=2
        Job Counters
```

Output of the program (2/2)



reduce() is called 5 times because there are 5 distinct values of key.

The results are stored in a temporary file because we have not specified the output parameter.

And we obtain the counting of the words for the three files: file1.txt, file2.txt et file3.txt !

References

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