What is Scalable Data Processing?

SCALABLE DATA PROCESSING IN R

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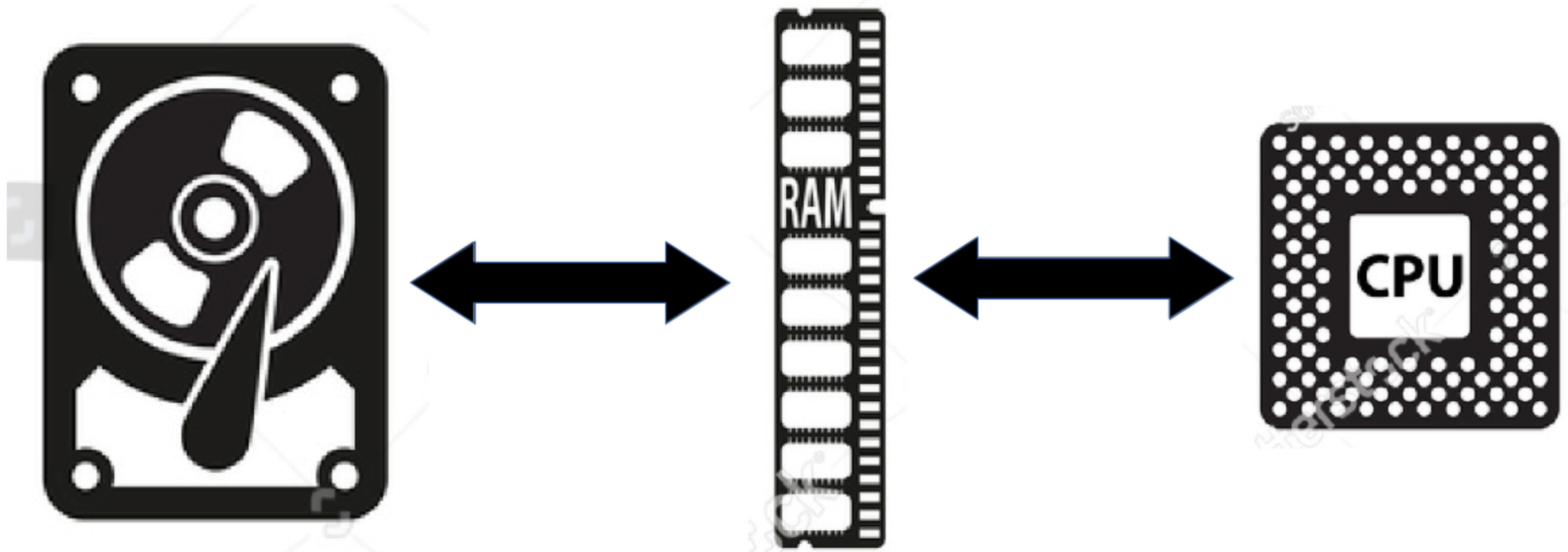
In this course ..

- Work with data that is too large for your computer
- Write Scalable code
- Import and process data in chunks

RAM

> All R objects are stored in RAM

Hardware Architecture Model



Persistent Storage (Hard Drive)

Random Access Memory

Processor(s)

How Big Can Variables Be?

"R is not well-suited for working with data larger than 10-20% of a computer's RAM." - The R Installation and Administration Manual

Swapping is inefficient

- If computer runs out of RAM, data is moved to disk
- Since the disk is much slower than RAM, execution time increases

Scalable solutions

- Move a subset into RAM
- Process the subset
- Keep the result and discard the subset

Why is my code slow?

- Complexity of calculations
- Carefully consider disk operations to write fast, scalable code

Benchmarking Performance

```
library(microbenchmark)
microbenchmark( rnorm(100), rnorm(10000) )
```

```
Unit: microseconds
          expr    min      lq     mean  median      uq     max neval
    rnorm(100)   7.84   8.440   9.5459   8.773   9.355   29.56   100
 rnorm(10000) 679.51 683.706 755.5693 690.876 712.416 2949.03   100
```

Let's practice!

SCALABLE DATA PROCESSING IN R

The Bigmemory Project

SCALABLE DATA PROCESSING IN R

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bigmemory

> `bigmemory` is used to store, manipulate, and process big matrices, that may be larger than a computer's RAM

big.matrix

- Create
- Retrieve
- Subset
- Summarize

What does "out-of-core" mean?

- R objects are kept in RAM
- When you run out of RAM
  - Things get moved to disk
  - Programs keep running (slowly) or crash

You are better off moving data to RAM only when the data are needed for processing.

When to use a big.matrix?

- 20% of the size of RAM
- Dense matrices

An Overview of bigmemory

- bigmemory implements the `big.matrix` data type, which is used to create, store, access, and manipulate matrices stored on the disk
- Data are kept on the disk and moved to RAM implicitly

An Overview of bigmemory

A `big.matrix` object:

- Only needs to be imported once
- "backing" file
- "descriptor" file

An example using bigmemory

```
library(bigmemory)

# Create a new big.matrix object
x <- big.matrix(nrow = 1, ncol = 3, type = "double",
                init = 0,
                backingfile = "hello_big_matrix.bin",
                descriptorfile = "hello_big_matrix.desc")
```

backing and descriptor files

- backing file: binary representation of the matrix on the disk
- descriptor file: holds metadata, such as number of rows, columns, names, etc..

An example using bigmemory

```
# See what's in it
 x[,]
```

```
  0    0    0
```

```
x
```

```
An object of class "big.matrix"
Slot "address":
<pointer: 0x108e2a9a0>
```

Similarities with matrices

```
# Change the value in the first row and column
x[1, 1] <- 3
```

```
# Verify the change has been made
x[,]
```

```
  3   0   0
```

Let's practice!

SCALABLE DATA PROCESSING IN R

References vs. Copies

SCALABLE DATA PROCESSING IN R

Simon Urbanek

Member of R-Core, Lead Inventive Scientist, AT&T Labs Research

Big matrices and matrices - Similarities

- Subset
- Assign

Big matrices and matrices - Differences

- `big.matrix` is stored on the disk
- Persists across R sessions
- Can be shared across R sessions

R usually makes copies during assignment

This creates a copy of `a` and assigns it to `b`.

```
a <- 42
b <- a
a
```

```
42
```

```
b
```

```
42
```

```
a <- 43
a
```

```
43
```

```
b
```

```
42
```

R usually makes copies during assignment

```
a <- 42
foo <- function(a){a <- 43
                   paste("Inside the function a is", a)}
```

```
foo(a)
```

```
"Inside the function a is 43"
```

```
paste("Outside the function a is still", a)
```

```
"Outside the function a is still 42"
```

Not all R objects are copied

This function does change the value of `a` in the global environment

```
foo <- function(a) {a$val <- 43
                    paste("Inside the function a is", a$val)}
a <- environment()
a$val <- 42
foo(a)
```

```
"Inside the function a is 43"
```

```
paste("Outside the function a$val is", a$val)
```

```
"Outside the function a$val is 43"
```

deepcopy()

```
# x is a big matrix
x <- big.matrix(...)

# x_no_copy and x refer to the same object
x_no_copy <- x

# x_copy and x refer to different objects
x_copy <- deepcopy(x)
```

Reference behaviour

R won't make copies implicitly

- Minimize memory usage
- Reduce execution time

Not all R objects are copied

```
library(bigmemory)

x <- big.matrix(nrow = 1, ncol = 3, type = "double",
                init = 0,
                backingfile = "hello-bigmemory.bin",
                descriptorfile = "hello-bigmemory.desc")
```

Not all R objects are copied

```
x_no_copy <- x
x[,]
```

```
0 0 0
```

```
x_no_copy[,]
```

```
0 0 0
```

```
x[,] <- 1
x[,]
```

```
1 1 1
```

```
x_no_copy[,]
```

```
1 1 1
```

Not all R objects are copied

```
x_copy <- deepcopy(x)
x[,]
```

```
1 1 1
```

```
x_copy[,]
```

```
1 1 1
```

```
x[,] <- 2
x[,]
```

```
2 2 2
```

```
x_copy[,]
```

```
1 1 1
```

Let's practice!

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