

POIR 613: Measurement Models and Statistical Computing

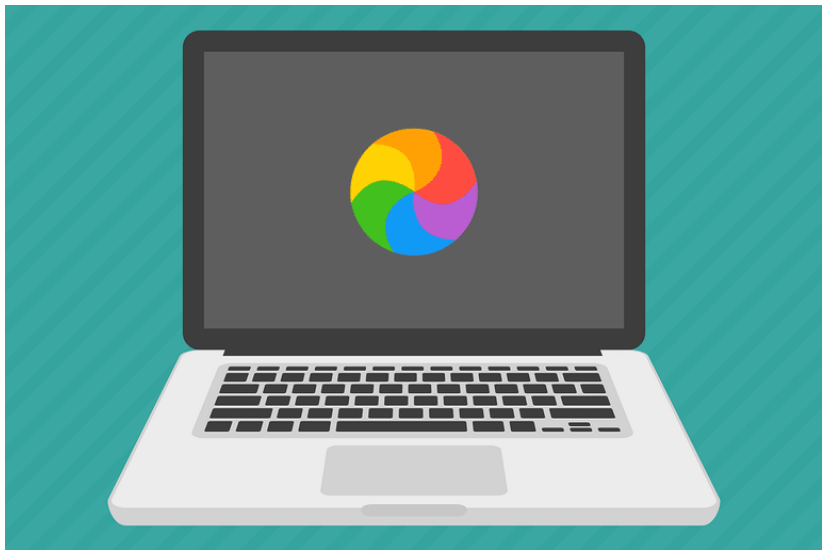
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Course website:

pablobarbera.com/POIR613/

Efficient data analysis with R



Myths about R as programming language

1. R is an **interpreted language**, so it must be slow
 - ▶ Interpreted = executes code directly without compiling
 - ▶ Compiled code = code executed natively on CPU (fast!)
 - ▶ BUT: many functions are written in C and C++ and thus run in fast machine code
 - ▶ Slow code can be written more efficiently
2. All objects in R are **stored in memory**
 - ▶ You cannot open datasets larger than RAM
 - ▶ BUT: most laptops now have 8+ GB of RAM (+virtual mem)
 - ▶ `bigmemory` package: work with files on disk
 - ▶ Easy to work with large databases in the cloud
3. R only uses **one core of your CPU**
 - ▶ Unlike STATA, no multi-core computing out of the box
 - ▶ BUT: many functions and packages now take advantage of multi-core computers
 - ▶ Easy to write your own code to do parallel computing

My data is too big! My code is too slow!

What to do?

1. Buy a better computer or expand RAM memory
2. Write more efficient code
3. Use parallel computing
4. Move your code/data to the cloud
5. Use out-of-memory storage: SQL databases, bigmemory package, Hadoop...

Writing efficient R code (Part I)

- ▶ Conventional wisdom: **avoid for loops at all costs!**
- ▶ But simply rewriting loops will not make code faster
- ▶ Key: use **vectorized** functions instead of loops
See `day1/01-efficient-programming.html`
- ▶ What is slowing our code down?
 - ▶ Additional function calls: `for`, `:`, `[`, `<-`
 - ▶ `sapply` hides explicit loop, but loop is still there, and implemented in R code
- ▶ Why was `+` so fast? Implements vectorization by **vector filtering**
 - ▶ Takes vector as input and return vector as output
 - ▶ Loop is done in machine native code
 - ▶ Other vectorized functions: `ifelse()`, `which()`, `rowSums()`, `colSums()`, `sum()`, `any()`, `rnorm()`...

Writing efficient R code (Part II)

- ▶ A common bottleneck is **memory re-allocation**, e.g.:

```
result <- c()
for (i in 1:n){
  result[i] <- x[i] + y[i]
}
```

- ▶ In iteration, R re-sizes the vector and re-allocates memory
- ▶ For large operations (e.g. data frames), this can make your code **really slow**
- ▶ **Solution**: pre-allocate vector size:

```
result <- rep(NA, n)
for (i in 1:n){
  result[i] <- x[i] + y[i]
}
```

- ▶ **See** day1/01-efficient-programming.html for more examples

Parallel computing

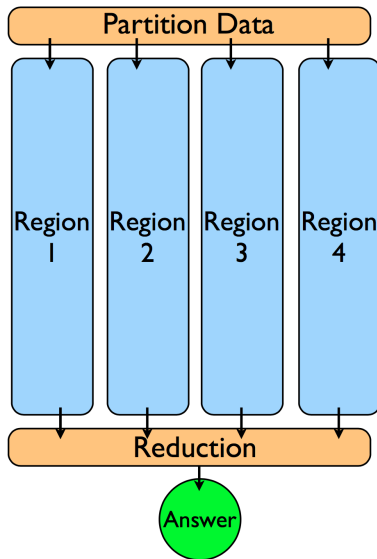
Some hardware terms:

- ▶ **Node**: a single motherboard, with possibly multiple processors
- ▶ **Processor**: silicon containing one or more cores
- ▶ **Core**: unit of computation
- ▶ Most modern CPUs (processors) have multiple cores

Logic of parallel computing

Split-apply-combine framework
(Hadley Wickham and others):

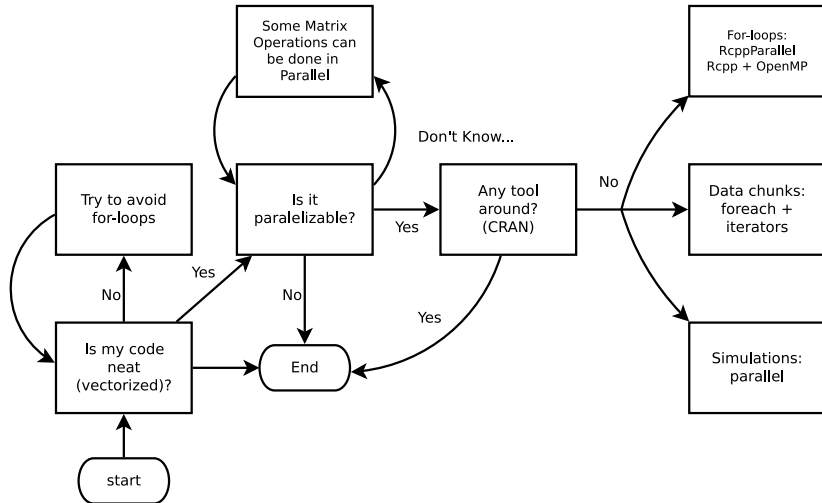
- ▶ **Split** your code and data across multiple nodes/processors/cores
- ▶ **Apply** computation in each region
- ▶ **Combine** the individual results into an aggregate answer



Logic of parallel computing

- ▶ BUT: **overhead** (e.g. splitting and combining data also take some time, no free lunch!)
- ▶ Works best with **embarrassingly parallel** problems:
 - ▶ Statistical simulation using multiple seeds
 - ▶ Word counts in documents
 - ▶ Cross-validation or ensemble learning
 - ▶ **Rule-of-thumb**: can you change the order of the iterations without altering the result?
- ▶ Sometimes problematic: applying on subsets of data, or when full dataset is needed in each node
- ▶ **Not parallelizable**: Markov-Chain Monte-Carlo methods, cumulative sums, etc.

Parallel computing



Source: Vega Yon and Garrett Weaver, 2017

Parallel computing in R

Two main approaches:

1. R packages

- ▶ `parallel`: built-in package with support for parallel computation, including random-number generation (good for statistical simulation)
- ▶ `foreach`: new type of loops that supports parallel execution (good for data analysis)
- ▶ `iterators`: tools for iterating over various R data structures (more advanced)

2. Running C++ code in R:

- ▶ `RcppArmadillo`: interact with C++ linear algebra library
- ▶ `OpenMP`: utility to improve multiprocessing using shared memory; works across all platforms

And **many others** (e.g. Spark, Hadoop, RcppParallel...) we will not cover in this course. See the [High-Performance and Parallel Computing Task View](#)

For more: see [slides+code by Vega Yon and Garrett Weaver](#)