General principle: Memory allocation

WRITING EFFICIENT R CODE

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CALL
bpt

If we programmed in C...

WE'RE IN CHARGE OF MEMORY ALLOCATION

```
// C code: request memory for a number
x = (double *) malloc(sizeof(double));

// Free the memory
free(x);
```

- In R, memory allocation happens automatically
- R allocates memory in RAM to store variables
- Minimize variable assignment for speed

Example: Sequence of integers

$$1, 2, \ldots, n$$

The obvious and best way

```
## Method 1
x <- 1:n
```

Not so bad

```
## Method 2
x <- vector("numeric", n) # length n
for(i in 1:n)
    x[i] <- i
```

Don't ever do this!

```
## Method 3
x <- NULL # Length zero
for(i in 1:n)
    x <- c(x, i)
```

Benchmarking

- Method 1: `1:n`
- Method 2: Preallocate
- Method 3: Growing

TIME IN SECONDS

n	1	2	3
10^5	0.00	0.02	0.2
10^6	0.00	0.2	30
10^7	0.00	2	3800

Welcome to R club!

The first rule of R club: never, ever grow a vector.

Let's practice!

WRITING EFFICIENT R CODE

The importance of vectorizing your code

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General rule

- Calling an R function eventually leads to C or FORTRAN code
  - This code is *very* heavily optimized

Goal

- Access the underlying C or FORTRAN code as quickly as possible; the fewer functions call the better.

Vectorized functions

- Many R functions are vectorized
  - Single number but return a vector

```
rnorm(4)
```

```
-0.7247  0.2502  0.3510  0.6919
```

- Vector as input

```
mean(c(36, 48))
```

```
42
```

Generating random numbers

```
library(microbenchmark)
n <- 1e6
x <- vector("numeric", n)
microbenchmark(
    x <- rnorm(n),
    {
        for(i in seq_along(x))
            x[i] <- rnorm(1)
        },
    times = 10
)
```

```
# Unit: milliseconds
# expr        lq mean    uq  cld
# rnorm(n)    60   70    80  a
# Looping   2600 2700  2800   b

## Output trimmed for presentation
```

Compare

```
x <- vector("numeric", n)
for(i in seq_along(x))
    x[i] <- rnorm(1)
```

to

```
x <- rnorm(n)
```

Why is the loop slow?

LOOPING

```
x <- vector("numeric", n)
for(i in seq_along(x))
    x[i] <- rnorm(1)
```

ALLOCATION

```
x <- vector("numeric", n)
```

- *Loop*: One-off cost
- *Vectorized*: Comparable

GENERATION

- *Loop*: one million calls to `rnorm()`
- *Vectorized*: a single call to `rnorm()`

ASSIGNMENT

- *Loop*: One million calls to the assignment method
- *Vectorized*: a single assignment

R club

The second rule of R club: use a vectorized solution wherever possible.

Let's practice!

WRITING EFFICIENT R CODE

Data frames and matrices

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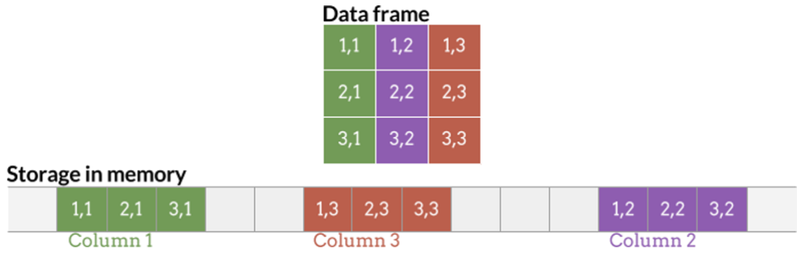
The data frame

- Key data structure in R
  - Copied in other languages
    - Python: pandas data frame
    - If you can't beat them, join them!

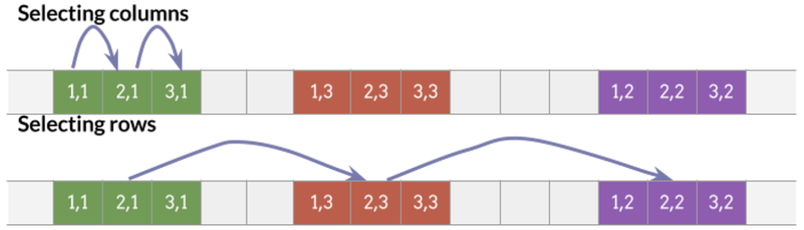
Data frames

- Tabular structure: rows and colums
  - `read.csv()` and friends returns a data frame
    - Columns
  - Data must be the same type
    - Rows
  - Different type

STORAGE



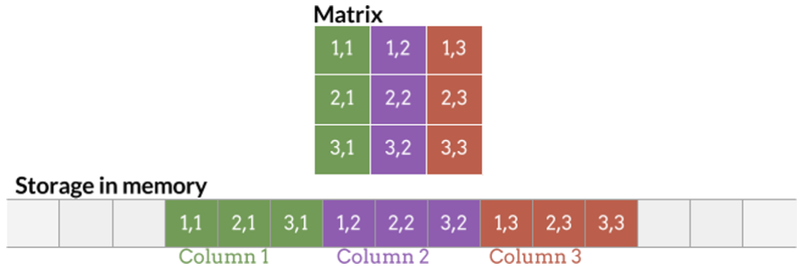
SELECTION



Matrices

- It's a rectangular data structure
  - You can perform usual subsetting and extracting operations
  - BUT - every element must be the same data type

STORAGE



SELECTION

R club

The third rule of R club: Use a matrix whenever appropriate.

Let's practice!

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