Lecture 4: Grouping, Control Structures + Loops, and Big O

James Balamuta

June 19, 2016

On the Agenda

- Effective Groups (Inspired by Prof. Brian Bailey)
  - Why groups?
  - Stages of Group Development
  - Group Norms
- Control Structures
  - `if/else`, `if/elseif/else`, `switch`
  - Ternary Operator
  - While
  - Do-While
  - For
- Big O
  - Notation
  - Examples
  - Drawbacks

Grouping Brainstorming

Form a group of 2-3 people around you.
Take three minutes to answer the following:

- What was your *best* group experience?
- What do you like the most about group work?
- What techniques worked well for groups?

Take (another) three minutes to answer the following:

- What was your *wurst* group experience?
- What do you *dislike* the most about group work?

Did you introduce yourself?

- When you started to talk with those around you, did you **introduce** yourself first?
- Or did you just jump into the task?
- **Always introduce yourself *before* starting the task!**

Why Group?

- Exposure to *new* viewpoints from different fields and life experiences
- Improves creativity and overall work quality (4 eyes vs. 2 eyes)
- Constructive dialog and increased internal group motivation
- Personal accountability to the team
- Friendship
- Prepares you for a team-environment in the workplace or a research group.

Statistics **is** a group effort

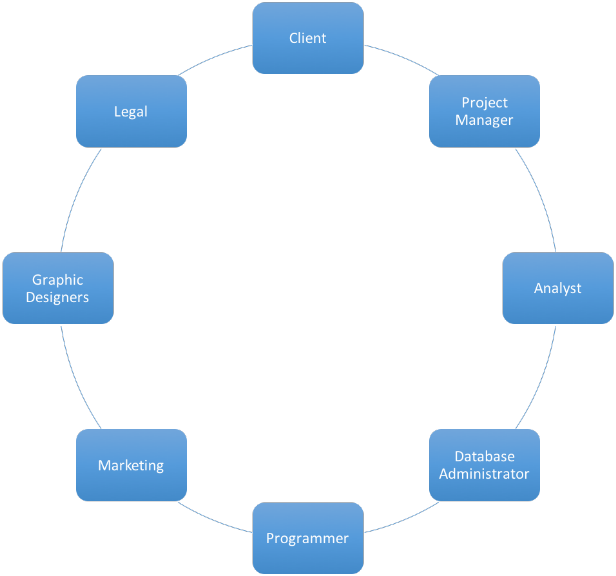


Figure 1: Process of an Analysis

Stages of Group Development (Tuckman and Jensen 2010)

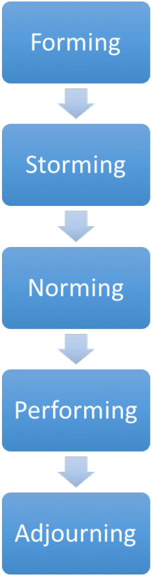


Figure 2: Small Group Development

Forming (Honeymoon Stage)

- **Excitement**
  - New experiences and people
- **Eagerness**
  - Working on a common new task
- **High Expectations**
  - We will be able to get a good grade.
  - We can use *this*
- **Anxiety**
  - Will I fit in?
  - Am I able to contribute?

Forming (Honeymoon Stage)

Combat the **anxiety** with an ice-breaker activity:

- Try to come up with a team name
- Talk about the weather
- Fact or Fiction
    - Write 2 facts and 1 fictional item
    - The group guesses the fictional item.

Storming (Internal Strife)

- As you begin to work, group structure will form to ensure goals are met
  - Who is the leader? Who can write well? Who is able to program? And so on...
- Watch out for **conflict** due to group structure disagreements on roles and processes.
  - Form a consensus on different roles and processes.
- Some groups may skip this stage and jump to **norming**.

Norming (Resolution)

- Conflicts in **Storming** are resolved due to a formed consensus.
  - Team member idiosyncrasy are accepted or corrected.
- Team members begins focusing on the goal as group members take on their responsibilities.
- Overall, the team is ready to collaborate together toward a common goal.
  - Watch out for suppressing conflict by avoiding discussing controversial ideas!

Performing (Working)

- Team members work fluidly together to finish the common goals.
- Main stage of the group process
- Teams may stumble back to prior stages or never reach this stage.

Adjourning / Mourning (Finale)

- Completion of the common task and the end of the group
  - Anxiousness, Sadness, or Relief
- Reflect on how the group worked and channel it into the next group
- Congratulate team members on a job well down and note the individual contributions
- Finish any other administrative tasks
  - e.g. Write a peer review of each group member.

Tips for Group Work - Part 1

- **Work Hard**
  - Do your share and more to set both an example and communicate willingness
- **Include All Team Members in Group Activities**
  - Being left out *stinks* and its hard to get over.
  - Try to provide reasonable deadlines for time sensitive decisions.
- **Take Turns**
  - Cycle leadership, following, organization, note taker, and discussant roles.
  - Promotes an atmosphere of shared equity.

Tips for Group Work - Part 2

- **Constructive Dialog**
  - Focus on the **idea** and **not** the person proposing it.
  - Try to **extend**, **shape**, or **add** to a proposed idea
- **Data Driven Decisions**
  - Avoid "I don't like it" in favor of evidence.
  - Personal preferences are not evidence and are hard to articulate.
- **Focus on the Task**
  - Utilize your time appropriately by being prepared and ontime.

Tips for Group Work - Part 3

- **A Happy Group Makes for Happy Group Members**
  - Make a positive statement in the beginning
  - Bring something to the meeting (e.g. food, drinks, et cetera)
- **Move On**
  - Don't sweat not being able to agree
  - Take breaks and revisit the idea later.
- **Avoid Assigning Blame**
  - Suggest ideas to fix problems
  - Try to understand the other persons viewpoint
- **Deliverables**
  - Figure out **who** is doing **what** task and **when** it will be done.

Tools for Collaboration

- **Create a shared space to store all your materials**
  - CITES Wiki
  - Dropbox (2.5 gigs), BoxSync (50 gigs), & Google Drive (Unlimited Storage!!!)
- **Group Document Editing**
  - Google Docs
  - ShareLaTeX (1 Collaborator + Supports Knitr)
  - Overleaf (1 gig + unlimited collaborators)
  - MS Word's Track Document Changes
- **Use a discussion board**
  - Google Groups
  - Illinois Mailing Lists
- **Use a Versioning Tool**
  - git
  - svn
- **Remote Communications Tools**
  - Skype
  - Google Hangouts

One Last Secret

Groups that do well tend to sit together in class.

Summary of Group Work

- In the industry and academia, working in groups is the standard.
  - **Avoid being a lone wolf**
- Provided tips and tricks to working in a group
- Emphasized **tool** usage.

Coming up next. . .

Next on the agenda is talking about **Control Structures** in *R*.

Control Structures and Flow of Control

- A **control structure** is a piece of code whose **analysis of a variable** results in a **choice being made as to the direction** the program should go.
- Meanwhile, the **Flow of Control** specifies the **direction** the program takes or **flows** when given conditions and parameters.

Types of Control Structures:

There are **three** different types of control structures.

- **Sequential:** Executes code statements one line after another
  - Exactly adhering to an algorithm like creating a cake from a recipe.
- **Selection:** Allows for decisions between 2 or more alternative paths.
  - Making a choice as to whether I want a Cold Brew or Iced Coffee from *Starbucks*.
- **Iteration:** Enables the looping or repeating of a section code multiple times.
  - Saying the same words over and over again.

Logical Operators

To control the structure, we sometimes must make **decisions** that have different cases based on a *boolean* (0 or 1) expression.
A few such structures are given as:

Operator	Explanation
`x == y`	`x` equal to `y`
`x != y`	`x` not equal to `y`
`x < y`	`x` less than `y`
`x > y`	`x` greater than `y`
`x <= y`	`x` less than or equal to `y`
`x >= y`	`x` greater than or equal to `y`

Combining Logical Operators

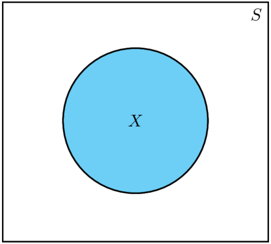
We can combine logical operators using:

Operator	Explanation
`!x`	not `x`
`x || y`	`x` or `y`
`x && y`	`x` and `y`

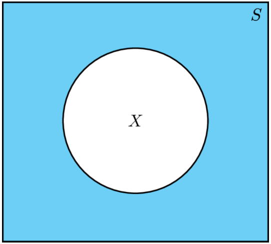
Examples of Logical Operators

Explanation	Example	Result
x equal to y	`1 == 10`	`FALSE`
x not equal to y	`1 != 10`	`TRUE`
x less than y	`1 < 10`	`TRUE`
x greater than y	`1 > 10`	`FALSE`
x less than or equal to y	`1 <= 10`	`TRUE`
x greater than or equal to y	`1 >= 10`	`FALSE`
not x	`!(1 < 10)`	`FALSE`
x or y	`FALSE || TRUE`	`TRUE`
x and y	`(1 < 10) && (15 > 10)`	`TRUE`

Venn Diagrams of Logic

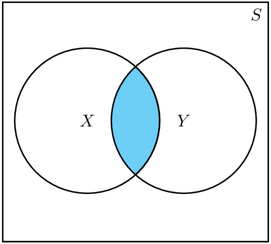


$P(X)$ is the same as X

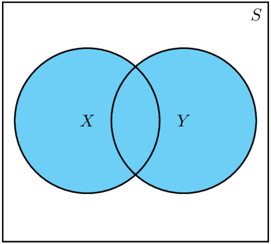


$P(X^c)$ is the same as $!X$

Venn Diagrams of Logic



$P(X \cap Y)$ is the same as $X \&\& Y$



$P(X \cup Y)$ is the same as $X || Y$

Short Circuit Evaluation

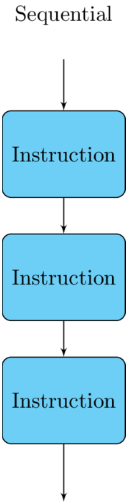
- The `&&` and `||` operators both have a feature called **short-circuit evaluation**.
- Consider the `&&` (`AND`) expression (`x && y`) ...
  - If `x` is `FALSE`, then there is no reason to evaluate `y` so the evaluation stops.
  - Take for example a division check for zero:

```
x = 0; y = 4           # Define Variables
(x != 0 &&  y/x > 0)   # Evaluates only x != 0
                       # so y/x never runs.
```

- Similarly, the `||` (`OR`) expression (`x || y`) ...
  - If `x` is `TRUE`, then whole expression is `TRUE` so there is no need to evaluate `y`.
  - Only in the case when `x` is `FALSE` does `y` get evaluated.

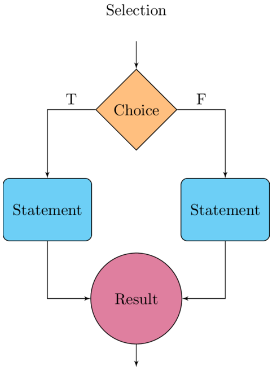
Sequential Control

Sequential control is the default operating behavior of a computer program. The program will read each line one after another and execute it.



Selection Control

- **Selection:** Allows for decisions between 2 or more alternative paths.
  - `if`
  - `if/else`
  - `if/elseif/else`
  - `switch`



Selection Control - `if` and `if/else`

The `if` statement provides the ability to execute code only when the `expression` is `TRUE` like so:

```
if (expression){ # True Case
  # statement
}
```

Traditionally, one would normally use `if/else` statement to address both `TRUE` and `FALSE` cases:

```
if (expression){ # True Case
  # statement
} else {         # False Case
  # statement
}
```

Selection Control - `if` and `if/else` Examples

Selection control in action:

```r
x = 2
if (x > 0){   # Detect if x is a positive number
  cat(x,"\n") # Print `x` to console
}
```

```
## 2
```

```r
if (x != 42){     # True Case
  cat("This is not the meaning of life\n")
  x = 42
} else {          # False Case
  cat("This is the meaning of life!\n")
}
```

```
## This is not the meaning of life
```

Selection Control - `if` and `if/else` Example

Consider the following `if/else` statement, how will the program operator?

```
if (x < 1)
  cat("True\n")
else
  cat("False\n")
  cat("Too bad!\n");
```

Selection Control - `if` and `if/else` Common Mistakes

A few other problematic areas when working with `expressions` for `if` statements in R:

Example 1:

```
user_input = readline(prompt="Enter y or n:")
if (user_input != "y" || user_input != "n")
  cat("Please enter either y or n (y for yes and n for no)\
```

Example 2:

```
x = 9; y = 20
if (x < 10) && (y < 35)
  cat("Bingo was his name!\n")
```

Example 3:

```
x = 43
if (x == 42 || 43 || 44)
  cat("That's close to my age!\n")
```

Selection Control - `if` and `if/else` Common Mistakes

Example 4:

```
x = seq(0,1,by = 0.1)
y = seq(.1,1.1,by = 0.1)
if (x < y)
  TRUE
```

Selection Control - Vectorized `if/else`

In the case of the last `if` statement, we have the ability to use *R*'s vectorized `ifelse()`

```
ifelse(expression, TRUE-CONDITION, FALSE-CONDITION)
```

Example:

```
x = seq(0,1,by = 0.1)
y = seq(0.1,1.1,by = 0.1)
ifelse(x < y, TRUE, FALSE)
```

```
##  [1] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE T
```

Note: Watch out for vector recycling!

Selection Control - `if/elseif/else`

Sometimes, we may wish to group together certain conditions

```
if(expression){
    # statements
} else if (expression2){
    # statements
} else {
    # statements
}
```

In this case, the first statement is checked, if it does not contain the correct value the next statement is check and so until either one of the `expressions` is true or it arrives at the `else` condition.

Selection Control - `if/elseif/else`

Example:

```
x = 3
if (x ==1) {
  cat('Equal\n')
} else if (x > 1){
  cat('Greater Than\n')
} else {
  cat('Less Than\n')
}
```

```
## Greater Than
```

Selection Control - `if/elseif/else`

An equivalent, though, less desirable statement could be written using only `if/else`

```
x = 3
if (x == 42) {
  cat('Equal\n')
} else {
  if (x > 42){
    cat('Greater Than\n')
  } else {
    cat('Less Than\n')
  }
}
```

```
## Less Than
```

Discussion: Why might structuring the `if` this way be not so ideal?

Selection Control - Vectorized `if/elseif/else`

Following in the previous examples footsteps, we can write a vectorized version to process multiple observations via:

```r
ifelse(x == 42, 'Equal',
       ifelse(x > 42, 'Greater Than', 'Less Than'))
```

```
## [1] "Less Than"
```

Selection - Ternary Operator

Previously, we saw a *vectorized* version of the ternary operator given by `ifelse()`.
What makes a selection statement a **ternary operator** is it is meant to be an **inline** `if/else` statement. e.g.

```
if(expression) TRUE  else  FALSE
```

Consider:

```
x = 42
a = if(x == 42) TRUE else FALSE # Verbose
a = (x == 42)                   # Concise
```

Selection Control - `switch`

Within a `switch`, the expression is evaluated as the first parameter and then compared against the values in the case labels.

```
switch(type,
       case_1 = statement_1,
       case_2 = statement_2,
       statement_3 # Default / Else
)
```

Switch are often represented as `if/elseif/else` like:

```
if (type == case_1){
  # statement 1
} else if (type == case_2){
  # statement 2
} else{
  # statement 3
}
```

Selection Control - `switch` Example

There are multiple ways to switch in R. Principally, switches either respond to **index** or **named expression**.

Index:

```
switch(1,
       "First",
       "Second")
```

```
## [1] "First"
```

Named Expression:

```
switch("toad",
       prince = "First",
       toad = "Second",
       "Third")
```

```
## [1] "Second"
```

Note: Faster to use a `switch` than an `if/elseif/else` in *R*!

Selection Control - `switch` Example

Consider the following switch:

```
switch(2,
       prince = "First",
       toad = "Second",
       "Third")
```

- What will be the output?

Selection Control - `switch` Example

Let's make a modification to the previous switch to use an index, e.g.

```
switch(4,                ## Switched to Numeric
       prince = "First",
       toad = "Second",
       "Third")
```

What will be the output?

Selection Control - `switch` Example

- What happens when we change to use a named expression?

```
switch("Fourth",            ## Switched to Named
       prince = "First",
       toad = "Second",
       "Third")
```

- How does this jive with the previous `switch` example?

Iteration Control

- **Iteration:** Enables the looping or repeating of a section code multiple times.
  - `for`
  - `while`
  - `do/while`

Iteration Control

> *"I choose a lazy person to do a hard job. Because a lazy person will find an easy way to do it."*
> *— Bill Gates*

Iteration is the advent of the ability to repeat statements like:

```
cat("Hello World!\n")
cat("Hello World!\n")
cat("Hello World!\n")
```

Without having to type it!

Iteration Control - `for`

The simplistic loop within *R* is that of the `for` loop.

```
summed = 0               # Output Variable
for (i in 1:5) {         # Iteration Sequence
  summed = summed + i    # Statement
}
```

Iteration Control - `for`

The `for` loop provides the ability to **automatically** increment the counting variable or iterate through a set of named expressions.

```
x = c("coffee","doppio espresso",
      "iced coffee", "cold brew")

for (i in x) {
  cat(x[i],"\n")
}

for (i in 1:4) {
  cat(x[i],"\n")
}
```

Iteration Control - Index Examples

Consider the loop of:

```
a = numeric(0)
for(i in 1:length(a)){
  cat("Hello!\n")
}
```

What should be the output?

Iteration Control - Index Protection

Instead of using `1:length(a)` to iterate a loop counter, try to use: `seq_len(length(a))` or `seq_along(a)`

```
a = numeric()
for(i in seq_len(length(a))){
  cat("Hello!\n")
}

for(i in seq_along(a)){
  cat("Hello!\n")
}
```

Iteration Control - `for` skipping

Sometimes, we might have a case that we want to *skip* in the loop. To do so, we use the `next` statement to move the loop forward.

```
for (i in 1:4) {
  if(i == 2){
    next      # skip case 2
  }
  cat(x[i],"\n")
}
```

Iteration Control - `while`

Meanwhile, a `while` loop requires three items:

1. expression,
2. statement,
3. change logic

```
while (expression) {
  # statement

  # change logic
}
```

Iteration Control - `while`

Take for example the following loop:

```r
i = 1
while (i < 3) {
  cat(i, "\n")
  i = i + 1    # Do not forget to increment!
}
```

This is a perfect candidate for looping as long as we remember to **increment** the looping variable.

Iteration Control - `break` out from a loop

We may obtain the desired result before the end of the loop and, thus, no longer need to continue the iteration.
To escape from a loop, we need to use `break`.

```
i = 1
while (i < 5) {
  if(i == 3){  # Stops the loop at the 3rd iteration.
    break
  }
  cat(i, "\n")
  i = i + 1    # Do not forget to increment!
}
```

Iteration Control - `repeat` or a `do-while`

Previously, for both `for` and `while` we had to have the initial condition met before the loop would run. However, sometimes we might want to let the code run up until we get a specific number of convergences within a simulation.

```
x = 1
y = 10
ntrials = 0
repeat{

  if(runif(1) > 0.5){
    x = x + 1
  }

  ntrials = ntrials + 1

  if(x < y){
    break
  }
```

Summary of Control Structures

- Discussed logical expressions
- Explored the different levels of selection controls `if`, `if/else`, `if/elseif/else`, `switch`
- Talked about the different types of R loops: `for`, `while`, and `repeat`
- Emphasized proper loop indexing techniques.

Onto the next one...

Up next, we're going to talk about the Big O!

Not **the** Big O…

Big O

- Big O notation or Landau's symbol, given as a capital $O()$ **[o, not zero]**, describes the amount of time an algorithm needs to run by analyzing asymptotic behavior of functions.
- This describes how fast an algorithm grows relative to the input (e.g. Sample Size n) as it goes to infinity (∞).

Big O Indepth

- Let:
  - $T(n)$ be called the *run time*
  - $O(n)$ be the ***approximate*** *run time*.
- **Formal Definition:**
  - $T(n) = O(F(n))$ as $n \to \infty$ if and only if for every constant $M > 0$ there exists a real number n_0 such that $|T(n)| \leqslant M|F(n)|$ for all $x \geq x_0$.
- **Unformal Definition:**
  - $T(n)$ is considered to be the ***exact*** complexity of an algorithm as a function of data size n.
  - $F(n)$ acts as an upper-bound in regards to that complexity.
  - Need to pick the smallest $F(n)$ to obtain the ***least*** upper bound.

Big O Idiosyncrasies

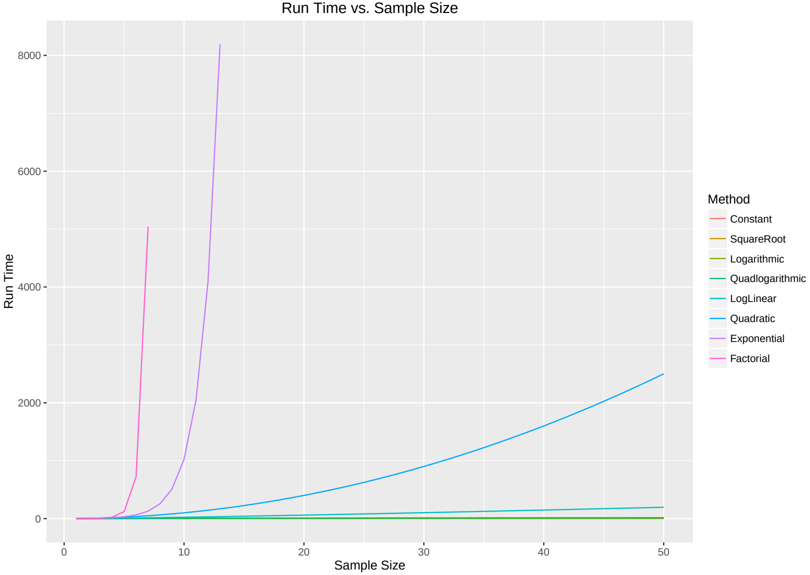
- We only care about the **largest exponent**.
  - If $T(n) = 1 + n^2 + log(n) + n$, then the $O(n^2)$
- $T(n) = O(n^2)$ describes **growth rate** of $T(n)$ to be n^2.
- Big O is given in the **worst** or **slowest** case normally.
- Sometimes, when we **disregard constants** they might matter!
  - If $T(n) = n/2 + 10$, then the $O(n)$
  - If $T(n) = n + 10$, then the $O(n)$

Notation

Common Big O's

Notation	**Name**
$O(1)$	Constant
$O(\log(n))$	Logarithmic
$O((\log(n))^c)$	Polylogarithmic
$O(n\log(n))$	Log Linear
$O(\sqrt{n})$	Square Root
$O(n)$	Linear
$O(n^2)$	Quadratic
$O(n^3)$	Cubic
$O(n^c)$	Polynomial
$O(c^n)$	Exponential
$O(n!)$	Factorial

Big O Run Times



Note: Even with a small sample size, certain methods take considerably long.

Few quick examples

- $O(5n) = O(n)$
- $O(n^2 - n + 5) = O(n^2)$
- $O(2n^3 - 8n^2 - 4n + 9) = O(n^3)$
- $O(n^2 \log(n) + n^2 + n + 1) = O(n^2 \log(n))$, where $n > 2$

Freebies

Within Big O, there are a few freebies that are **no cost** these are:

- Function definitions

```
myfun = function(x){}
```

- Return statements

```
return(x)
```

Constant - Sequence of Statements

Consider a sequence of statements:

```
statement 1
statement 2
...
statement n
```

The total time is found by adding the times for all statements:

$$T(n) = T(statement1) + T(statement2) + ... + T(statementn)$$

In this case, each statement is **constant** since it is **simple** and, thus, has a Big O of: $O(1)$.

Linear - `if/else`

Consider an `if/else` statement

```
if (expression){ # True Case
  # statement 1
} else {         # False Case
  # statement 2
}
```

Either the first statement or the second statement will run. Hence, the worst-case or the longest run time is given by the max of:

$$\max(T(statement1), T(statement2))$$

For this example, if statement 1 is $O(N)$ and statement 2 is $O(1)$ what would be the big O?

Linear - Iteration

Consider a `for` iteration statement:

```
for(i in 1:n){ # Loop incrementor
  # statement
}
```

For this example, we assume the statement is simple, $O(1)$. Therefore, we are repeating this statement N times. Thus, we have $O(N)$.

Big O Rules

If $T_1(n) = O(F(n))$ and $T_2(n) = O(G(n))$, then:

- $k * T_1(n) = O(F(n)))$
- $T_1(n) + T_2(n) = \max(O(F(n)), O(G(n)))$
- $T_1(n) * T_2(n) = O(F(n)) * O(G(n))$

Example: Accumulative Sum on a Vector

Often, we need to obtain summaries on vectors. Take for instance:

```
sum_vec = function(x){          # Cost: 0
  total_sum = 0                 # Cost: 1

  # Cost: 1 (Variable), N+1 (In Check), 2N (i = i + 1)
  for(i in seq_len(nrow(x))){
    # Cost: 2N (1 addition, 1 assignment)
    total_sum = total_sum + i
  }

  return(total_sum)             # Cost: 0
}
```

The total time in this case is:

$$T(N) = 0 + 1 + 1 + (N + 1) + 2N + 2N = 5N + 2$$

which has a Big O of $O(N)$.

Polynomial - Iteration

Returning to iteration statements, what happens if we have three loops inside themselves with $K < J < I$?

```
for(i in 1:I){      # Loop incrementor
  for(j in 1:J){    # Loop incrementor
    for(k in 1:K){ # Loop incrementor
      # statement
    }
  }
}
```

In what case could we obtain $O(n^4)$? How about $O(n^{100})$?

Summary of Big O

- We discussed the idea behind Big O
- Observed different worst case scenarios in code

References

Tuckman, Bruce W., and Mary Ann C. Jensen. 2010. "Stages of Small-Group Development Revisited." *Group Facilitation: A Research & Applications Journal* 10: 43–48. `http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=49049910&site=ehost-live`.