Homework 1

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Link to the Github repository

❗ Due: Fri, Jan 26, 2024 @ 11:59pm

Please read the instructions carefully before submitting your assignment.

1. This assignment requires you to:
   - Upload your Quarto markdown files to a `git` repository
   - Upload a `PDF` file on Canvas
2. Don't collapse any code cells before submitting.
3. Remember to make sure all your code output is rendered properly before uploading your submission.

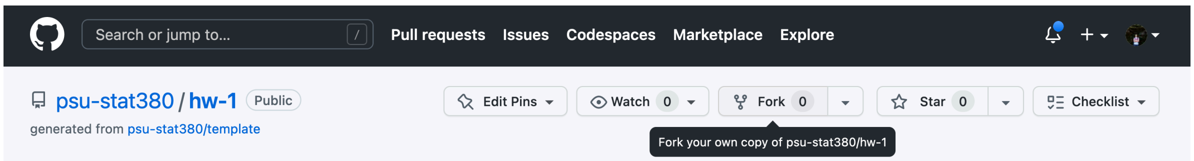
Please add your name to the the author information in the frontmatter before submitting your assignment.

Question 1

> 20 points

In this question, we will walk through the process of *forking* a `git` repository and submitting a *pull request*.

1. Navigate to the Github repository here and fork it by clicking on the icon in the top right



   Provide a sensible name for your forked repository when prompted.

2. Clone your Github repository on your local machine

```
$ git clone <<insert your repository url here>>
$ cd hw-1
```

3. In order to activate the `R` environment for the homework, make sure you have `renv` installed beforehand. To activate the `renv` environment for this assignment, open an instance of the `R` console from within the directory and type

```r
#install.packages("tidyverse")
#install.packages("yaml")
#install.packages("renv")
renv::activate()
```

```
Follow the instrutions in order to make sure that `renv` is configured correctly.
```

4. Work on the *reminaing part* of this assignment as a `.qmd` file.

   - Create a `PDF` and `HTML` file for your output by modifying the YAML frontmatter for the Quarto `.qmd` document

5. When you're done working on your assignment, push the changes to your github repository.

6. Navigate to the original Github repository here and submit a pull request linking to your repository.

   Remember to **include your name** in the pull request information!

If you're stuck at any step along the way, you can refer to the official Github docs here

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Question 2

30 points

Consider the following vector

```
my_vec <- c(
    "+0.07",
    "-0.07",
    "+0.25",
    "-0.84",
    "+0.32",
    "-0.24",
    "-0.97",
    "-0.36",
    "+1.76",
    "-0.36"
)
```

For the following questions, provide your answers in a code cell.

1. What data type does the vector contain? ::: {.cell}

```
typeof(my_vec)
```

```
[1] "character"
```

:::

1. Create two new vectors called `my_vec_double` and `my_vec_int` which converts `my_vec` to Double & Integer types, respectively,

```r
# Create a new vector of type double
my_vec_double <- as.numeric(my_vec)
my_vec_double
```

```
 [1]  0.07 -0.07  0.25 -0.84  0.32 -0.24 -0.97 -0.36  1.76 -0.36
```

```r
# Create a new vector of type integer
my_vec_int <- as.integer(my_vec)
my_vec_int
```

```
 [1] 0 0 0 0 0 0 0 0 1 0
```

1. Create a new vector `my_vec_bool` which comprises of:

   - `TRUE`if an element in `my_vec_double` is ≤ 0
   - `FALSE` if an element in `my_vec_double` is ≥ 0

   How many elements of `my_vec_double` are greater than zero? ::: {.cell}

```r
# Convert to double type first
my_vec_double <- as.numeric(my_vec)

# Create a logical vector
my_vec_bool <- my_vec_double <= 0

# Count elements greater than zero
sum(my_vec_double > 0)
```

```
[1] 4
```

::: 1. Sort the values of `my_vec_double` in ascending order.

```r
# Sort the vector
sorted_vec <- sort(my_vec_double)
sorted_vec
```

```
 [1] -0.97 -0.84 -0.36 -0.36 -0.24 -0.07  0.07  0.25  0.32  1.76
```

—

Question 3

50 points

In this question we will get a better understanding of how `R` handles large data structures in memory.

1. Provide `R` code to construct the following matrices:

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & \ldots & 100 \\ 1 & 4 & 9 & 16 & 25 & \ldots & 10000 \end{bmatrix}$$

   ::: {.callout-warning} ## Tip

Recall the discussion in class on how `R` fills in matrices :::

In the next part, we will discover how knowledge of the way in which a matrix is stored in memory can inform better code choices. To this end, the following function takes an input n and creates an $n \times n$ matrix with random entries.

```r
generate_matrix <- function(n){
    return(
        matrix(
            rnorm(n^2),
            nrow=n
        )
    )
}
```

For example:

```r
generate_matrix(4)
```

```
           [,1]       [,2]        [,3]        [,4]
[1,] -0.5856412 -0.5588938 -0.49455369  0.07863609
[2,] -1.1399401 -0.9997287 -1.52764179  0.54556752
[3,] -0.5612194 -0.1763169 -0.09906992 -0.79476193
[4,]  0.8720956  0.3131394 -1.12536155  0.58942771
```

Let `M` be a fixed 50×50 matrix

```r
M <- generate_matrix(50)
mean(M)
```

```
[1] -0.01579699
```

```r
# Matrix 1: 3x3 Matrix
matrix_1 <- matrix(1:9, nrow = 3, byrow = TRUE)

# Generate Matrix 2 with the specified pattern
matrix_2 <- matrix(c(1:100, (1:100)^2), nrow = 2, byrow= TRUE)


# Display matrices
print(matrix_1)
```

```
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
[3,]    7    8    9
```

```r
print(matrix_2)
```

```
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13] [,14]
[1,]    1    2    3    4    5    6    7    8    9    10    11    12    13    14
[2,]    1    4    9   16   25   36   49   64   81   100   121   144   169   196
     [,15] [,16] [,17] [,18] [,19] [,20] [,21] [,22] [,23] [,24] [,25] [,26]
[1,]    15    16    17    18    19    20    21    22    23    24    25    26
[2,]   225   256   289   324   361   400   441   484   529   576   625   676
     [,27] [,28] [,29] [,30] [,31] [,32] [,33] [,34] [,35] [,36] [,37] [,38]
[1,]    27    28    29    30    31    32    33    34    35    36    37    38
[2,]   729   784   841   900   961  1024  1089  1156  1225  1296  1369  1444
     [,39] [,40] [,41] [,42] [,43] [,44] [,45] [,46] [,47] [,48] [,49] [,50]
[1,]    39    40    41    42    43    44    45    46    47    48    49    50
[2,]  1521  1600  1681  1764  1849  1936  2025  2116  2209  2304  2401  2500
     [,51] [,52] [,53] [,54] [,55] [,56] [,57] [,58] [,59] [,60] [,61] [,62]
[1,]    51    52    53    54    55    56    57    58    59    60    61    62
[2,]  2601  2704  2809  2916  3025  3136  3249  3364  3481  3600  3721  3844
     [,63] [,64] [,65] [,66] [,67] [,68] [,69] [,70] [,71] [,72] [,73] [,74]
[1,]    63    64    65    66    67    68    69    70    71    72    73    74
```

```
[2,]  3969  4096  4225  4356  4489  4624  4761  4900  5041  5184  5329  5476
     [,75] [,76] [,77] [,78] [,79] [,80] [,81] [,82] [,83] [,84] [,85] [,86]
[1,]    75    76    77    78    79    80    81    82    83    84    85    86
[2,]  5625  5776  5929  6084  6241  6400  6561  6724  6889  7056  7225  7396
     [,87] [,88] [,89] [,90] [,91] [,92] [,93] [,94] [,95] [,96] [,97] [,98]
[1,]    87    88    89    90    91    92    93    94    95    96    97    98
[2,]  7569  7744  7921  8100  8281  8464  8649  8836  9025  9216  9409  9604
     [,99] [,100]
[1,]    99    100
[2,]  9801  10000
```

2. Write a function `row_wise_scan` which scans the entries of `M` one row after another and outputs the number of elements whose value is ≥ 0. You can use the following **starter code**

```r
row_wise_scan <- function(x){
    n <- nrow(x)
    m <- ncol(x)

    # Insert your code here
    count <- 0
    for(i in 1:n){
        for(j in 1:m){
            if(x[i, j] >= 0){
                count <- count + 1
            }
        }
    }

    return(count)
}
```

3. Similarly, write a function `col_wise_scan` which does exactly the same thing but scans the entries of `M` one column after another

```r
col_wise_scan <- function(x){
    count <- 0
    # Insert your code here
    n <- nrow(x)
    m <- ncol(x)
    for(j in 1:m){
        for(i in 1:n){
```

```
            if(x[i, j] >= 0){
                count <- count + 1
            }
        }
    }

    return(count)
}
```

You can check if your code is doing what it's supposed to using the function here[1]

4. Between `col_wise_scan` and `row_wise_scan`, which function do you expect to take shorter to run? Why?

Expectation on Runtime:

The row_wise_scan function is expected to run faster than col_wise_scan. This is because R stores matrices in a column-major order, so accessing elements column-wise results in better memory locality.

5. Write a function `time_scan` which takes in a method `f` and a matrix `M` and outputs the amount of time taken to run `f(M)`

```
time_scan <- function(f, M){
    initial_time <- Sys.time() # Write your code here
    f(M)
    final_time <- Sys.time()  # Write your code here

    total_time_taken <- final_time - initial_time
    return(total_time_taken)
}
```

Provide your output to

```
list(
    row_wise_time = time_scan(row_wise_scan, M),
    col_wise_time = time_scan(row_wise_scan, M)
)
```

```
$row_wise_time
```

[1] If your code is right, the following code should evaluate to be `TRUE`
`{R sapply(1:100, function(i) {     x <- generate_matrix(100)     row_wise_scan(x) == col_wise_scan(x) }) %>% sum == 100`

```
Time difference of 0.002946138 secs

$col_wise_time
Time difference of 0.0001261234 secs
```

Which took longer to run? row_wise function took longer to run

6. Repeat this experiment now when:

   - `M` is a 100×100 matrix
   - `M` is a 1000×1000 matrix
   - `M` is a 5000×5000 matrix

What can you conclude?

```r
# Function to repeat experiment
repeat_experiment <- function(n) {
    M <- generate_matrix(n)
    time_results <- list(
        row_wise_time = time_scan(row_wise_scan, M),
        col_wise_time = time_scan(col_wise_scan, M)
    )
    return(time_results)
}

# Experiment for different matrix sizes
experiment_results <- list(
    matrix_100 = repeat_experiment(100),
    matrix_1000 = repeat_experiment(1000),
    matrix_5000 = repeat_experiment(5000)
)
experiment_results
```

```
$matrix_100
$matrix_100$row_wise_time
Time difference of 0.0004849434 secs

$matrix_100$col_wise_time
Time difference of 0.003509045 secs


$matrix_1000
$matrix_1000$row_wise_time
```

```
Time difference of 0.04827285 secs

$matrix_1000$col_wise_time
Time difference of 0.04623485 secs


$matrix_5000
$matrix_5000$row_wise_time
Time difference of 1.526564 secs

$matrix_5000$col_wise_time
Time difference of 1.15332 secs
```

We can conclude that row_wise function takes longer to run than col_wise

---

Appendix

Print your `R` session information using the following command

```r
sessionInfo()
```

```
R version 4.3.1 (2023-06-16)
Platform: aarch64-apple-darwin20 (64-bit)
Running under: macOS Monterey 12.0.1

Matrix products: default
BLAS:   /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/lib/libRblas.0.dylib
LAPACK: /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/lib/libRlapack.dylib;  I

locale:
[1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8

time zone: America/New_York
tzcode source: internal

attached base packages:
[1] stats     graphics  grDevices datasets  utils     methods   base
```

```
loaded via a namespace (and not attached):
 [1] compiler_4.3.1    fastmap_1.1.1     cli_3.6.2         htmltools_0.5.7
 [5] tools_4.3.1       rstudioapi_0.15.0 yaml_2.3.8        rmarkdown_2.25
 [9] knitr_1.45        jsonlite_1.8.8    xfun_0.41         digest_0.6.34
[13] rlang_1.1.3       renv_1.0.3        evaluate_0.23
```