Homework 1

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Link to the Github repository

❗ Due: Sun, Jan 29, 2023 @ 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.

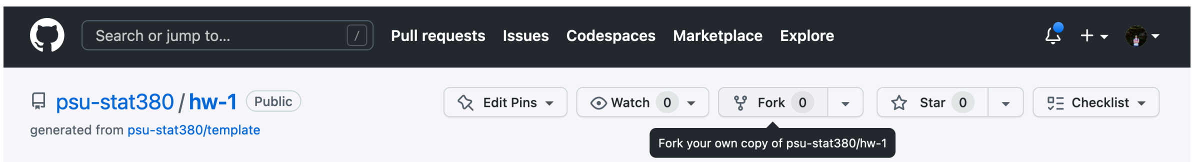
Please add your name to the the author information in the frontmatter before submitting your assignment.

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
   ```

   Alternatively, you can use Github codespaces to get started from your repository directly.

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

   ```
   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?

```
"The vector contains strings of numbers."
```

```
[1] "The vector contains strings of numbers."
```

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

```
my_vec_double <- as.double(my_vec)
my_vec_int <- as.integer(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
```

```
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?

```
my_vec_bool <- c()
for(i in my_vec_double){
  if (i<=0){
    append(my_vec_bool, TRUE)
  } else {
    append(my_vec_bool, "FALSE")
  }

}

my_vec_bool
```

```
NULL
```

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

```
sort(my_vec_double, decreasing = FALSE)
```

```
[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:

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

⚠ Tip

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

```r
matrix(1:9, nrow=3, byrow=TRUE)
```

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

```r
data <- seq(1,100, 1)

data2 <- data^2

datafull <- c(data, data2)

matrix(datafull, nrow=2, ncol=100, byrow=TRUE)
```

```
     [,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
```

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.

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

For example:

```
generate_matrix(4)
```

```
           [,1]        [,2]       [,3]      [,4]
[1,]  1.6728761 -0.05038914 -0.6384420 -1.245019
[2,] -0.2996037 -0.61468184 -0.9783364 -1.384736
[3,] -1.0674522  1.23126115 -1.1114686 -1.180828
[4,] -0.6122153 -0.66503622 -1.5509850  2.125437
```

Let `M` be a fixed 50×50 matrix

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

```
[1] 0.01030167
```

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**

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

    # Insert your code here
    count <- 0
    for(...){
        for(...){
            if(...){
                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

```
col_wise_scan <- function(x){
    count <- 0

    ... # Insert your code here

    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?

[1] If your code is right, the following code should evaluate to be `TRUE`

```
sapply(1:100, function(i) {
    x <- generate_matrix(100)
    row_wise_scan(x) == col_wise_scan(x)
}) %>% sum == 100
```

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 <- ... # Write your code here
    f(M)
    final_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)
)
```

Which 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?

Appendix

Print your `R` session information using the following command

```
sessionInfo()
```

```
R version 4.2.2 (2022-10-31 ucrt)
Platform: x86_64-w64-mingw32/x64 (64-bit)
Running under: Windows 10 x64 (build 22621)
```

```
Matrix products: default

locale:
[1] LC_COLLATE=English_United States.utf8
[2] LC_CTYPE=English_United States.utf8
[3] LC_MONETARY=English_United States.utf8
[4] LC_NUMERIC=C
[5] LC_TIME=English_United States.utf8

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

loaded via a namespace (and not attached):
 [1] compiler_4.2.2  fastmap_1.1.0   cli_3.6.0       htmltools_0.5.4
 [5] tools_4.2.2     yaml_2.3.7      rmarkdown_2.20  knitr_1.42
 [9] xfun_0.36       digest_0.6.31   jsonlite_1.8.4  rlang_1.0.6
[13] renv_0.16.0-53  evaluate_0.20
```