## **Problem Statement**

- 1. Create an m x n matrix with replicate(m, rnorm(n)) with m=10 column vectors of n=10 elements each, constructed with rnorm(n), which creates random normal numbers.
  - Then we transform it into a dataframe (thus 10 observations of 10 variables) and perform an algebraic operation on each element using a nested for loop: at each iteration, every element referred by the two indexes is incremented by a sinusoidal function, compare the vectorized and non-vectorized form of creating the solution and report the system time differences.

rbenchmark is intended to facilitate benchmarking of arbitrary R code.

The library consists of just one function, benchmark, which is a simple wrapper around system.time.

Given a specification of the benchmarking process (counts of replications, evaluation environment) and an arbitrary number of expressions, benchmark evaluates each of the expressions in the specified environment, replicating the evaluation as many times as specified, and returning the results conveniently wrapped into a data frame

> m x n matrix is created with replicate(m, rnorm(n)) with m=10 column vectors and n=10 elements each, constructed with rnorm(n), which creates random normal numbers.

m <- replicate(10, rnorm(10), simplify = "matrix")

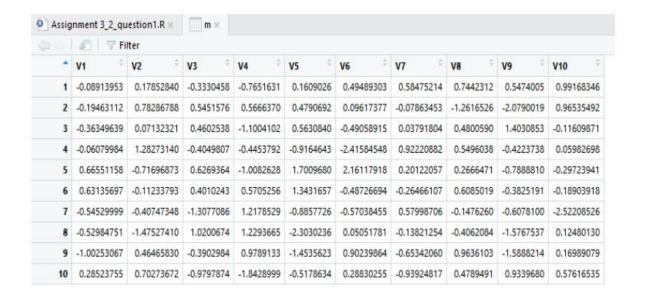
Then we transform it into a dataframe (thus 10 observations of 10 variables) using : m <- as.data.frame(m) View(m)

Then an algebraic operation is performed on each element using a nested for loop. At each iteration, every element referred by the two indexes is incremented by a sinusoidal function, the vectorized and non-vectorized form of creating the solution are compared and the system time differences are reported using following script:

```
library(rbenchmark)
benchmark(

vect = as.vector(m), # vecotrized form
conc = (n <- as.vector(for (i in seq(nrow(m))))
{
    for (j in seq(ncol(m)))
    { # nested for
    print(2*sin(m[i, j])) # performing algebraic function on each element
    }
}))
)</pre>
```

```
Terminal ×
> m <- replicate(10, rnorm(10), simplify = "matrix")</pre>
                      [,2]
                               [,3]
                                         [,4]
                                                   [,5]
                                                              [,6]
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                                                                                            [,9]
[1,] -0.08913953 0.17852840 -0.3330458 -0.7651631 0.1609026 0.49489303 0.58475214 0.7442312 0.5474005
                                                                                                 0.99168346
 [2,] -0.19463112  0.78286788  0.5451576  0.5666370  0.4790692  0.09617377 -0.07863453 -1.2616526 -2.0790019
[3,] -0.36349639 0.07132321 0.4602538 -1.1004102 0.5630840 -0.49058915 0.03791804 0.4800590 1.4030853 -0.11609871
[4,] -0.06079984 1.28273140 -0.4049807 -0.4453792 -0.9164643 -2.41584548 0.92220882 0.5496038 -0.4223738 0.05982698
 [5,] 0.66551158 -0.71696873 0.6269364 -1.0082628 1.7009680 2.16117918 0.20122057
                                                                             0.2666471 -0.7888810 -0.29723941
 [6,] 0.63135697 -0.11233793 0.4010243 0.5705256 1.3431657 -0.48726694 -0.26466107 0.6085019 -0.3825191 -0.18903918
[7,] -0.54529999 -0.40747348 -1.3077086 1.2178529 -0.8857726 -0.57038455 0.57998706 -0.1476260 -0.6078100 -2.52208526
[8,] -0.52984751 -1.47527410 1.0200674 1.2293665 -2.3030236 0.05051781 -0.13821254 -0.4062084 -1.5767537
                                                                                                 0.12480130
[10,] 0.28523755 0.70273672 -0.9797874 -1.8428999 -0.5178634 0.28830255 -0.93924817 0.4789491 0.9339680 0.57616535
  > m <- as.data.frame(m)</pre>
  > View(m)
```



```
library(rbenchmark)
benchmark(
                vect = as.vector(m),
                                             # vecotrized form
                conc = (n <- as.vector(for (i in seq(nrow(m))) {
                 for (j in seq(ncol(m))) { # nested for
                 print(2*sin(m[i, j])) # performing algebraic function on each element
                   }
                 }))
[1]
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    -0.7465174
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    -0.3758306
    -1.037349
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    -0.7925819
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[1] 1.876719
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    -1.548808
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    -1.079912
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    1.096026
    -0.2941808
[1] -1.142142
[1]
    -1.161268
[1] -1.010804
[1]
    -1.990882
[1] 1.704287
[1] 1.884554
[1] -1.48737
    -1.487375
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\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    -0.2755458
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    -1.685671
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[1] 1.659783
[1] -1.98627
    -1.986272
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[1] 1.642514
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    0.3381494
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[1] 0.5627708
[1]
    1.292617
    -1.660758
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    -1.926415
[1]
    -0.9900497
[1]
    0.5686505
[1]
    -1.614229
0.9216935
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1.607972

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[1] 1.089625
[1] -0.178043
[1] 0.3551631
     -0.1780431
     -0.653846
[1]
[1]
     -1.385309
[1] 0.3204185
[1] 0.949875
[1] 1.103985
[1]
     1.354813
[1]
     1.040939
[1] 1.673897
[1] -0.38680
     -0.3868093
[1]
     1.410631
     1.037106
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
      1.073595
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     0.9219067
     0.1920512
[1]
     -0.157107
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     -1.747238
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     1.644502
     -0.7110887
[1] 0.1425255
[1] 0.8883511
[1] -1.782787
[1] 1.067593
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     -0.9422913
[1] 0.07581791
[1] 0.9236631
[1] 1.971939
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     -0.2316761
     -0.1215248
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     1.917591
     -0.7880021
egin{bmatrix} 1\ 1\ \end{bmatrix}
     -0.8616003
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[1] 1.234923
egin{bmatrix} 1 \ 1 \end{bmatrix}
     -1.314205
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     0.526997
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     -1.41913
     -0.5857636
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
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     -0.2242036
[1]
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egin{bmatrix} 1 \ 1 \end{bmatrix}
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\begin{bmatrix} 1 \\ 1 \end{bmatrix}
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     -0.7925819
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[1]
     1.876719
[1]
     -1.548808
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
      -1.079912
     1.096026
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
      -0.2941808
```

-1.142142

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[1] -1.161268
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    -1.010804
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    -1.990882
    1.704287
[1] 1.884554
[1] -1.487375
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   1.292617
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
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[1] 1.607972
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    -1.385309
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    1.103985
[1]
   1.354813
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[1] 1.040939
[1] 1.673897
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    -0.9422913
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    1.971939
   -0.2316761
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   -0.7880021
[1]
    -0.8616003
[1]
   -1.586909
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    -1.327389
    1.593876
[1]
    1.044699
```

-0.8198536

```
[1] 0.1195826
[1] 1.234923
ĪΊ
    -1.314205
[1] 1.173333
[1] -1.69181
    -1.691813
[1] 1.983079
[1] 1.661455
[1] 0.3997308
[1] 0.526997
[1] -1.41913
[1] -0.5857636
[1] 1.180481
[1] -0.2242036
[1] 0.7807231
[1] 1.080149
    1.080149
1.948408
[1]
    -0.9364253
    -0.5231643
[1]
[1] 1.143278
[1]
    -0.7465174
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    -0.3758306
    -1.037349
[1] -0.7925819
[1] -1.931183
    -0.7925819
[1] 1.876719
[1] -1.548808
[1]
    -1.079912
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[1] -0.294180
    -0.2941808
[1]
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\begin{bmatrix} 1 \\ 1 \end{bmatrix}
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    -1.010804
    -1.990882
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[1] 1.704287
[1] 1.884554
[1] -1.48737
    -1.487375
[1] 0.1009927
[1] -0.2755458
[1] -0.7902583
[1] -1.999965
[1] 0.2489552
[1] -1.685671
[1] 0.8962347
[1] -0.7609283
[1] 1.659783
[1] -1.986272
    -0.7609287
[1] 1.569631
[1]
    -1.215812
[1] 1.642514
[1] -1.999675
[1] 0.3381494
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\begin{bmatrix} 1 \\ 1 \end{bmatrix}
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    -0.9900497
[1] 0.5686505
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[1] 1.607972
[1] 1.089625
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[1] 0.3551631
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[1]
     -1.385309
[1]
    0.3204185
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     0.949875
     1.103985
[1]
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     1.354813
```

1.040939

```
[1] 1.673897
[1] -0.38680
[1] 1.410631
   -0.3868093
[1] 1.037106
[1] 1.073595
[1] 0.9219067
[1] 0.1920512
[1] -0.157107
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
   -1.905189
    -1.747238
[1] 1.644502
[1]
    -0.7110887
[1] 0.1425255
[1] 0.8883511
[1]
    -1.782787
[1] 1.067593
   -0.9422913
[1]
[1] 0.07581791
[1] 0.9236631
[1] 1.971939
[1] -0.2316761
[1] -0.1215248
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    1.917591
   -0.7880021
[1] -0.8616003
[1]
   -1.586909
[1]
   -1.327389
[1] 1.593876
[1] 1.044699
[1] -0.8198536
[1] 0.1195826
[1] 1.234923
[1] -1.314205
[1] 1.173333
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    -1.691813
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[1] 1.661455
[1] 0.3997308
[1] 0.526997
   -1.41913
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[1] 1.180481
[1] -0.2242036
   0.7807231
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[1] 1.143278
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[1] -1.037349
[1] -0.7925819
[1] -1.931183
[1] 1.876719
[1] -1.548808
   -1.079912
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[1] 1.096026
[1] -0.2941808
[1]
    -1.142142
ar{1}
    -1.161268
    -1.010804
[1]
    -1.990882
[1] 1.704287
[1] 1.884554
[1] -1.487375
[1] 0.1009927
[1]
    -0.2755458
```

[1]

-0.7902583 -1.999965

```
[1] 0.2489552
[1]
     -1.685671
[1] 0.8962347
[1]
     -0.7609287
[1] 1.659783
[1] -1.986272
[1] 1.569631
[1] -1.215812
     -1.215812
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     1.642514
     -1.999675
[1] 0.3381494
[1] 0.5627708
[1] 1.292617
     -1.660758
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[1]
     -1.926415
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     -0.9900497
     0.5686505
[1]
     -1.614229
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     0.9216935
     1.607972
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     1.089625
     -0.1780431
[1] 0.3551631
[1] -0.653846
[1] -1.385309
[1] 0.3204185
[1] 0.949875
[1] 1.103985
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\begin{bmatrix} 1 \\ 1 \end{bmatrix}
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[1] 0.9219067
[1] 0.1920512
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     -0.157107
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     -0.7110887
    0.1425255
    0.8883511
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
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[1] -0.9422913
[1] 0.07581791
[1] 0.9236631
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[1]
     -0.2316761
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     -0.1215248
     1.917591
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     -0.7880021
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     -1.586909
     -1.327389
[1]
     1.593876
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[1] 1.044699
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     -0.8198536
[1]
    0.1195826
    1.234923
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     -1.314205
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     1.173333
     -1.691813
[1]
     1.983079
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
     1.661455
     0.3997308
```

 $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$ 

0.526997 -1.41913

```
[1] -0.5857636
[1] 1.180481
[1]
    -0.2242036
[1] 0.7807231
     1.080149
[1] 1.948408
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    -0.9364253
    -0.5231643
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    1.143278
    -0.7465174
[1] -0.3758306
[1]
    -1.037349
    -0.7925819
[1]
[1] -1.931183
[1] 1.876719
     -1.931183
    -1.548808
[1]
    -1.079912
[1]
[1] 1.096026
[1]
    -0.2941808
[1]
    -1.142142
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    -1.161268
    -1.010804
[1] -1.990882
[1] 1.704287
[1] 1.884554
[1] -1.487375
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    -0.2755458
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[1]
     -1.685671
    0.8962347
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[1]
    -0.7609287
[1] 1.659783
[1] -1.986272
    -1.986272
[1] 1.569631
     -1.215812
[1]
[1] 1.642514
    -1.999675
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    0.3381494
[1] 0.5627708
[1] 1.292617
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    -1.660758
\begin{bmatrix} 1 \\ 1 \end{bmatrix}
    -1.926415
    -0.9900497
[1] 0.5686505
[1]
    -1.614229
[1] 0.9216935
[1] 1.607972
[1] 1.089625
```

```
test replications elapsed relative user.self sys.self user.child sys.child
                100
                       4.01
2 conc
                                   NA
                                           3.75
                                                      0.1
                                                                  NA
                                                                             NA
1 vect
                100
                       0.00
                                   NA
                                           0.00
                                                      0.0
                                                                  NA
                                                                             NA
```

```
#Vectorized form
set.seed(100)
#create matrix
mat_1<- replicate(10,rnorm(10))
#transform into data frame
df 1= data.frame(mat 1)
df_1 < -df_1 + 2*sin(0.75*pi)
#non-vectorized form
set.seed(100)
#create matrix
mat_1<- replicate(10,rnorm(10))
#transform into data frame
df_1= data.frame(mat_1)
for(i in 1:10){
for(j in 1:10){
  df_1[i,j] <- df_1[i,j] + 2*sin(0.75*pi)
  print(df_1)
}
#time difference
system.time(
df_1[i,j] <- df_1[i,j] + 2*sin(0.75*pi)
)
system.time(
for(i in 1:10){
 for(j in 1:10){
  df_1[i,j] < -df_1[i,j] + 2*sin(0.75*pi)
 }
}
)
```

## Explanation:

- Here, Vectorized form and non- Vectorized form is created and converted into dataframes respectively.
- · Hence, the time difference is calculated using system.time()

```
0.9120212 1.5040997 0.9761236 1.3231000 1.3125843 0.96715138 1.1522178
   1.5457447 1.5104880 2.1782742 3.1715892 2.8174171 -0.32438438 1.3453695 1.3352965 1.2125796 1.6761749 1.2762840 -0.3625621 1.59307841 1.0353300
4 2.3009984 2.1540541 2.1876182 1.3030201 2.0370810 3.31167926 3.9961725
   0.8324229 1.0253593 0.6939920 1.5971212 1.0507732 0.01538795 2.0522078
   2.1287463 1.9250698 1.6451581 1.8315368 2.7332793 3.23908599 1.6159052 0.5889541 0.5003994 0.2564841 2.4796159 1.4579926 2.79551229 1.3442966
8
9
10 1.0543514 3.7245104 1.6612896 2.3844156 -0.4644423 0.57536169 1.3217237
            X8
                          X9
                                     X10
    1.8631168 2.31103583 0.8570913
1
    0.3498579 1.36421780 2.8425150
    0.2517942 0.06886425 0.5212562
3.0627353 -0.51699797 0.2566423
3
4
   -0.6478825 2.12379515 0.8839171
    1.4269633 1.25630853 3.8598963
0.3266852 1.63058144 0.5817178
6
    1.6847531 2.23157564 1.8277334
9 2.4226654 3.14138932 0.2355304
10 -0.6601912 1.31044327 0.2401788
> #time difference
> system.time(
    df_1[i,j] \leftarrow df_1[i,j] + 2*sin(0.75*pi)
+
   user system elapsed
      0
> system.time(
    for(i in 1:10){
+
       for(j in 1:10){
         df_1[i,j] \leftarrow df_1[i,j] + 2*sin(0.75*pi)
+
+
+ )
   user system elapsed
   0.02
            0.00
                     0.02
```