

# High Performance Computing

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## 3. Load Libraries

```
library(doParallel)
```

```
## Loading required package: foreach
```

```
## Loading required package: iterators
```

```
## Loading required package: parallel
```

```
library(parallel)  
library(foreach)
```

## 4. Determine number of cores

```
detectCores()
```

```
## [1] 8
```

There are 8 cores on my device.

## 5/6. Loop with time check

```
Start_Time_multi=Sys.time()  
mean_random_numbers=c()  
loop=for (i in 1:4000) {  
  random_numbers=rnorm(100000, mean=10, sd=3)  
  mean_random_numbers[i]=mean(random_numbers)  
}  
Stop_Time_multi=Sys.time()  
  
Time_multi=Stop_Time_multi-Start_Time_multi  
Time_multi
```

```
## Time difference of 37.08117 secs
```

## 7. Prediction

I predict that a multi-threaded program will run eight times faster than the serial program with a time of 4.87963 seconds since we are running eight different iterations (one on each core) simultaneously rather than running the iterations one at a time.

## Parallel code

```
Cores <- parallel::makeCluster(detectCores())
doParallel::registerDoParallel(Cores)

Start_Time_parallel=Sys.time()

mean_random_numbers_parallel=c()

foreach(i=1:4000, .combine=rbind) %dopar%
{
  random_numbers_parallel=rnorm(100000, mean=10, sd=3)
  mean_random_numbers_parallel[i]=mean(random_numbers_parallel)
}
```

```
##          [,1]
## result.1    9.985051
## result.2    9.981398
## result.3    9.997933
## result.4   10.004359
## result.5    9.992554
## result.6   10.011349
## result.7    9.978386
## result.8    9.995113
## result.9   10.013793
## result.10   9.992971
## result.11  10.006517
## result.12   9.994266
## result.13   9.986680
## result.14  10.004257
## result.15  10.000732
## result.16  10.002872
## result.17   9.989037
## result.18   9.986706
## result.19   9.992738
## result.20   9.998318
## result.21   9.996123
## result.22  10.000668
## result.23  10.018022
## result.24  10.006970
## result.25   9.998088
## result.26  10.002324
## result.27   9.980947
## result.28   9.992688
## result.29  10.004043
## result.30   9.995421
## result.31   9.992073
## result.32  10.009080
## result.33   9.997076
## result.34  10.009042
## result.35  10.005599
## result.36   9.994575
## result.37  10.008497
## result.38   9.983102
## result.39  10.003114
## result.40   9.999506
## result.41   9.991232
## result.42   9.986606
## result.43  10.000786
## result.44  10.000237
## result.45   9.990520
## result.46  10.001458
## result.47  10.002460
## result.48  10.003727
## result.49  10.006608
## result.50   9.992556
## result.51   9.997280
```

## result.52	9.992198
## result.53	9.995884
## result.54	10.006862
## result.55	9.991049
## result.56	9.983741
## result.57	10.005213
## result.58	9.984166
## result.59	10.016642
## result.60	10.000578
## result.61	10.004342
## result.62	10.008165
## result.63	9.995595
## result.64	10.007696
## result.65	9.990847
## result.66	9.982614
## result.67	9.989667
## result.68	10.003854
## result.69	10.011010
## result.70	10.000030
## result.71	9.996610
## result.72	10.014366
## result.73	10.005722
## result.74	9.992420
## result.75	9.981021
## result.76	10.013446
## result.77	10.015786
## result.78	10.009774
## result.79	10.003656
## result.80	9.988607
## result.81	10.002674
## result.82	9.995214
## result.83	9.991816
## result.84	9.983325
## result.85	9.987209
## result.86	10.000620
## result.87	9.996636
## result.88	9.993960
## result.89	9.990382
## result.90	10.025772
## result.91	9.999195
## result.92	9.994975
## result.93	10.024386
## result.94	10.001207
## result.95	10.005089
## result.96	10.023419
## result.97	9.994420
## result.98	10.006842
## result.99	10.005073
## result.100	10.005108
## result.101	10.012122
## result.102	10.006447
## result.103	10.011005

```
## result.104    9.996394
## result.105   10.009888
## result.106   10.003272
## result.107   10.007580
## result.108   10.000055
## result.109    9.993703
## result.110    9.992517
## result.111    9.987191
## result.112    9.989442
## result.113    9.991114
## result.114    9.996520
## result.115    9.995791
## result.116    9.987456
## result.117    9.995059
## result.118   10.004734
## result.119   10.021843
## result.120   10.008658
## result.121   10.003391
## result.122   10.004846
## result.123    9.996265
## result.124    9.992248
## result.125   10.013705
## result.126   10.007313
## result.127    9.987426
## result.128   10.004142
## result.129   10.013028
## result.130    9.995437
## result.131   10.000832
## result.132   10.000582
## result.133    9.985365
## result.134    9.999157
## result.135   10.021672
## result.136   10.005144
## result.137    9.991186
## result.138    9.986646
## result.139    9.992352
## result.140    9.990829
## result.141    9.999286
## result.142   10.005460
## result.143   10.023157
## result.144   10.005691
## result.145   10.002491
## result.146   10.015905
## result.147    9.990537
## result.148   10.007837
## result.149    9.998595
## result.150    9.998128
## result.151    9.997393
## result.152   10.001901
## result.153    9.995644
## result.154    9.998532
## result.155   10.011070
```

```
## result.156 10.000519
## result.157 9.987519
## result.158 10.010539
## result.159 10.011498
## result.160 9.997367
## result.161 10.006761
## result.162 10.001376
## result.163 9.999981
## result.164 10.007840
## result.165 9.994104
## result.166 9.993854
## result.167 10.006304
## result.168 9.990507
## result.169 9.996513
## result.170 10.005184
## result.171 9.999067
## result.172 10.007195
## result.173 9.979269
## result.174 10.003626
## result.175 10.012032
## result.176 10.007483
## result.177 10.004953
## result.178 10.009025
## result.179 9.999654
## result.180 9.996185
## result.181 10.010384
## result.182 10.009215
## result.183 9.998297
## result.184 9.996506
## result.185 10.003497
## result.186 9.993830
## result.187 9.997296
## result.188 10.012210
## result.189 9.991946
## result.190 9.996810
## result.191 9.992490
## result.192 9.999341
## result.193 9.990267
## result.194 10.006336
## result.195 9.994274
## result.196 9.992244
## result.197 9.990908
## result.198 9.998524
## result.199 9.996854
## result.200 9.985298
## result.201 10.012271
## result.202 9.993769
## result.203 10.003356
## result.204 9.981658
## result.205 10.014969
## result.206 9.998798
## result.207 9.999949
```

```
## result.208 10.001758
## result.209 10.010144
## result.210 9.990172
## result.211 9.989927
## result.212 9.997909
## result.213 9.993904
## result.214 10.010212
## result.215 10.001458
## result.216 9.991936
## result.217 10.007826
## result.218 9.994122
## result.219 10.008794
## result.220 10.004596
## result.221 10.000829
## result.222 9.997379
## result.223 10.006764
## result.224 9.980441
## result.225 10.016451
## result.226 10.000538
## result.227 9.996508
## result.228 10.012768
## result.229 9.998936
## result.230 10.015787
## result.231 10.011136
## result.232 10.015742
## result.233 9.976609
## result.234 9.992304
## result.235 10.010459
## result.236 9.994141
## result.237 9.985493
## result.238 10.012009
## result.239 10.016269
## result.240 10.008673
## result.241 9.980001
## result.242 10.005643
## result.243 9.993383
## result.244 9.978523
## result.245 10.009330
## result.246 9.995775
## result.247 10.002759
## result.248 10.009813
## result.249 10.014732
## result.250 9.999049
## result.251 10.007840
## result.252 10.000371
## result.253 9.990004
## result.254 9.995837
## result.255 10.005922
## result.256 10.012131
## result.257 9.992859
## result.258 9.993922
## result.259 9.990827
```

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## result.260 10.011597
## result.261 9.998569
## result.262 10.004073
## result.263 10.008242
## result.264 9.996956
## result.265 10.014394
## result.266 10.013816
## result.267 10.016676
## result.268 10.001883
## result.269 9.978576
## result.270 10.005991
## result.271 9.983187
## result.272 10.004018
## result.273 9.986461
## result.274 10.004387
## result.275 9.991214
## result.276 9.987777
## result.277 10.003240
## result.278 9.984467
## result.279 10.012382
## result.280 9.988782
## result.281 9.992719
## result.282 10.005968
## result.283 10.016111
## result.284 10.008751
## result.285 9.993585
## result.286 9.986853
## result.287 10.012097
## result.288 9.995965
## result.289 10.003457
## result.290 9.993775
## result.291 9.992859
## result.292 9.978580
## result.293 9.995752
## result.294 10.001103
## result.295 10.006540
## result.296 9.985638
## result.297 9.984564
## result.298 10.005952
## result.299 10.002017
## result.300 9.997961
## result.301 9.995987
## result.302 9.989811
## result.303 10.009216
## result.304 9.987611
## result.305 9.996486
## result.306 9.988278
## result.307 9.986325
## result.308 9.996771
## result.309 10.018079
## result.310 10.009612
## result.311 10.004982
```



```
## result.312 10.003513
## result.313 9.993752
## result.314 9.995885
## result.315 9.999985
## result.316 10.007224
## result.317 10.016518
## result.318 9.995222
## result.319 9.990698
## result.320 9.997890
## result.321 10.006792
## result.322 10.014401
## result.323 9.993186
## result.324 10.004172
## result.325 10.003733
## result.326 9.988964
## result.327 10.000426
## result.328 10.006965
## result.329 10.005526
## result.330 10.006444
## result.331 9.999963
## result.332 9.998978
## result.333 9.987526
## result.334 10.020280
## result.335 9.987940
## result.336 9.991850
## result.337 10.004193
## result.338 9.992354
## result.339 9.994807
## result.340 9.996788
## result.341 9.994662
## result.342 9.999901
## result.343 10.000593
## result.344 9.970418
## result.345 9.989014
## result.346 9.999328
## result.347 10.006197
## result.348 9.998456
## result.349 10.011051
## result.350 10.005201
## result.351 10.028372
## result.352 10.007119
## result.353 10.000762
## result.354 9.993045
## result.355 10.019470
## result.356 9.992163
## result.357 9.997526
## result.358 9.993268
## result.359 9.996383
## result.360 9.985745
## result.361 10.008140
## result.362 9.995981
## result.363 9.997557
```

```
## result.364 10.000860
## result.365 10.000675
## result.366 9.994714
## result.367 10.001828
## result.368 9.987262
## result.369 10.006695
## result.370 10.012454
## result.371 9.991046
## result.372 10.016302
## result.373 9.990230
## result.374 10.003723
## result.375 9.990092
## result.376 9.987022
## result.377 9.984587
## result.378 10.000319
## result.379 9.986749
## result.380 9.996006
## result.381 9.995770
## result.382 9.992416
## result.383 9.992199
## result.384 9.990329
## result.385 10.001287
## result.386 9.991812
## result.387 10.004382
## result.388 9.998226
## result.389 9.995327
## result.390 9.979866
## result.391 9.998107
## result.392 9.997939
## result.393 10.000719
## result.394 10.002842
## result.395 9.995324
## result.396 9.994651
## result.397 9.997244
## result.398 10.018535
## result.399 9.991786
## result.400 10.000686
## result.401 10.020461
## result.402 10.008807
## result.403 9.989997
## result.404 9.996027
## result.405 10.012199
## result.406 9.987431
## result.407 9.992822
## result.408 9.991123
## result.409 10.003937
## result.410 9.995671
## result.411 9.992476
## result.412 10.003901
## result.413 10.000026
## result.414 9.990608
## result.415 9.989054
```

```
## result.416 9.988490
## result.417 10.006787
## result.418 10.008021
## result.419 9.999549
## result.420 9.986584
## result.421 10.014640
## result.422 9.993068
## result.423 10.003022
## result.424 10.002127
## result.425 9.986149
## result.426 9.990714
## result.427 9.990085
## result.428 10.005205
## result.429 10.005885
## result.430 10.001657
## result.431 10.001509
## result.432 9.986577
## result.433 9.988210
## result.434 10.006980
## result.435 9.996680
## result.436 9.995237
## result.437 10.008038
## result.438 9.991410
## result.439 9.993209
## result.440 10.005971
## result.441 10.011317
## result.442 10.010870
## result.443 9.987379
## result.444 10.002814
## result.445 10.002484
## result.446 9.992057
## result.447 10.005559
## result.448 10.014608
## result.449 9.988444
## result.450 10.010492
## result.451 9.995483
## result.452 10.010017
## result.453 9.999833
## result.454 9.993266
## result.455 9.981599
## result.456 10.012487
## result.457 9.995321
## result.458 10.010150
## result.459 9.988873
## result.460 10.006020
## result.461 9.989652
## result.462 10.007043
## result.463 9.999057
## result.464 10.010928
## result.465 10.010090
## result.466 9.991535
## result.467 10.004478
```

```
## result.468 10.005134
## result.469 9.999397
## result.470 9.998039
## result.471 9.997984
## result.472 9.996372
## result.473 10.017254
## result.474 10.000654
## result.475 9.989223
## result.476 9.997436
## result.477 10.005749
## result.478 10.010171
## result.479 9.992299
## result.480 10.001590
## result.481 9.997157
## result.482 10.017373
## result.483 10.010068
## result.484 10.001976
## result.485 9.989097
## result.486 10.003648
## result.487 9.995053
## result.488 10.008904
## result.489 10.001615
## result.490 9.995206
## result.491 9.995708
## result.492 10.002758
## result.493 10.009682
## result.494 9.997887
## result.495 10.011584
## result.496 9.975984
## result.497 9.985217
## result.498 10.005067
## result.499 9.990236
## result.500 9.986058
## result.501 10.013061
## result.502 9.995520
## result.503 10.000490
## result.504 10.001409
## result.505 10.001402
## result.506 9.999646
## result.507 9.998198
## result.508 9.999203
## result.509 9.988945
## result.510 10.003111
## result.511 9.976129
## result.512 9.999890
## result.513 9.987372
## result.514 10.001082
## result.515 10.000639
## result.516 10.002804
## result.517 10.000432
## result.518 10.002454
## result.519 10.000990
```

```
## result.520    9.991058
## result.521   10.004266
## result.522    9.983181
## result.523   10.009488
## result.524   10.001050
## result.525    9.992790
## result.526   10.010169
## result.527   10.000715
## result.528    9.983381
## result.529   10.007414
## result.530   10.010109
## result.531    9.992274
## result.532    9.995219
## result.533   10.006589
## result.534    9.988542
## result.535    9.992227
## result.536   10.015702
## result.537   10.023575
## result.538    9.987616
## result.539    9.994164
## result.540    9.990944
## result.541   10.006632
## result.542   10.003771
## result.543   10.004581
## result.544   10.011784
## result.545    9.992485
## result.546    9.991030
## result.547   10.019032
## result.548   10.006350
## result.549    9.995714
## result.550    9.998637
## result.551    9.988297
## result.552   10.003263
## result.553    9.994650
## result.554    9.986545
## result.555   10.007719
## result.556   10.005226
## result.557   10.005193
## result.558    9.987710
## result.559   10.017749
## result.560   10.001535
## result.561    9.997591
## result.562   10.003599
## result.563    9.994113
## result.564    9.998911
## result.565   10.009075
## result.566   10.003321
## result.567   10.001394
## result.568    9.990413
## result.569   10.008129
## result.570    9.999080
## result.571   10.005137
```

```
## result.572 10.001431
## result.573 9.988863
## result.574 9.991806
## result.575 9.997196
## result.576 9.981117
## result.577 9.999198
## result.578 9.997003
## result.579 9.996590
## result.580 9.998898
## result.581 9.996251
## result.582 10.002821
## result.583 10.015662
## result.584 9.998853
## result.585 9.999528
## result.586 10.007167
## result.587 10.015136
## result.588 9.990243
## result.589 10.012555
## result.590 9.997556
## result.591 10.000601
## result.592 10.000539
## result.593 9.999485
## result.594 9.988613
## result.595 9.986267
## result.596 9.993021
## result.597 10.011275
## result.598 9.997739
## result.599 10.004003
## result.600 10.000198
## result.601 9.979367
## result.602 10.013012
## result.603 9.993689
## result.604 9.995772
## result.605 9.993106
## result.606 9.986256
## result.607 10.008582
## result.608 9.999193
## result.609 9.982135
## result.610 10.001611
## result.611 10.008862
## result.612 9.991192
## result.613 10.004347
## result.614 10.004263
## result.615 9.990450
## result.616 10.001109
## result.617 9.997096
## result.618 9.989012
## result.619 9.992327
## result.620 9.991306
## result.621 9.990537
## result.622 10.003185
## result.623 10.001980
```

```
## result.624    9.992528
## result.625   10.008685
## result.626   10.005721
## result.627    9.998179
## result.628   10.018133
## result.629   10.003397
## result.630   10.007900
## result.631    9.999933
## result.632    9.996353
## result.633    9.997714
## result.634    9.989014
## result.635   10.006931
## result.636   10.008722
## result.637   10.000786
## result.638    9.998819
## result.639   10.003700
## result.640    9.999649
## result.641    9.995619
## result.642   10.004502
## result.643   10.002720
## result.644    9.991995
## result.645    9.993542
## result.646    9.998138
## result.647    9.993252
## result.648    9.982108
## result.649    9.990994
## result.650    9.986635
## result.651    9.998583
## result.652   10.005453
## result.653    9.997130
## result.654   10.006727
## result.655    9.994297
## result.656   10.001041
## result.657    9.988631
## result.658    9.988063
## result.659   10.011327
## result.660    9.994664
## result.661    9.981393
## result.662    9.986609
## result.663   10.005269
## result.664    9.994216
## result.665   10.002452
## result.666    9.988693
## result.667    9.994610
## result.668    9.985870
## result.669    9.990987
## result.670    9.989111
## result.671    9.977260
## result.672    9.997360
## result.673    9.991869
## result.674    9.997544
## result.675    9.985944
```

```
## result.676 9.994238
## result.677 9.991581
## result.678 9.987297
## result.679 9.983623
## result.680 9.999334
## result.681 10.009383
## result.682 9.990762
## result.683 9.990524
## result.684 9.995790
## result.685 9.988186
## result.686 10.020875
## result.687 9.999229
## result.688 10.012409
## result.689 9.996225
## result.690 9.989834
## result.691 10.008038
## result.692 9.990631
## result.693 10.007088
## result.694 9.979315
## result.695 10.001759
## result.696 9.999263
## result.697 10.009767
## result.698 9.989283
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## result.3523 9.998438
## result.3524 9.990667
## result.3525 10.009564
## result.3526 10.012966
## result.3527 10.006348
## result.3528 9.982517
## result.3529 10.003468
## result.3530 9.989840
## result.3531 10.007739
## result.3532 10.001400
## result.3533 10.013685
## result.3534 9.994177
## result.3535 9.994993
```

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## result.3536 10.002537
## result.3537 10.005501
## result.3538 10.016918
## result.3539 9.998623
## result.3540 9.996343
## result.3541 9.985495
## result.3542 10.009000
## result.3543 10.001070
## result.3544 10.003138
## result.3545 9.994046
## result.3546 9.995202
## result.3547 10.008147
## result.3548 10.007659
## result.3549 10.007760
## result.3550 10.005446
## result.3551 9.996250
## result.3552 10.027007
## result.3553 10.008645
## result.3554 10.003432
## result.3555 9.996229
## result.3556 9.997479
## result.3557 9.994499
## result.3558 9.997130
## result.3559 10.000793
## result.3560 9.991921
## result.3561 9.990394
## result.3562 9.994833
## result.3563 9.998284
## result.3564 10.003941
## result.3565 9.997916
## result.3566 10.007534
## result.3567 9.993953
## result.3568 10.000155
## result.3569 9.998156
## result.3570 9.989286
## result.3571 9.994687
## result.3572 10.001809
## result.3573 10.003145
## result.3574 10.019112
## result.3575 9.993384
## result.3576 10.006516
## result.3577 9.989672
## result.3578 10.010289
## result.3579 10.002438
## result.3580 10.001388
## result.3581 10.007603
## result.3582 10.007434
## result.3583 9.997227
## result.3584 10.009545
## result.3585 9.985538
## result.3586 9.984967
## result.3587 9.993227
```

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## result.3588 9.996305
## result.3589 9.993766
## result.3590 10.003916
## result.3591 10.010112
## result.3592 10.004062
## result.3593 10.009438
## result.3594 10.001808
## result.3595 9.984830
## result.3596 9.999653
## result.3597 9.998325
## result.3598 10.001406
## result.3599 9.998366
## result.3600 9.989404
## result.3601 10.017459
## result.3602 9.997188
## result.3603 10.000161
## result.3604 9.997904
## result.3605 10.017100
## result.3606 10.000932
## result.3607 10.009947
## result.3608 9.991333
## result.3609 9.991685
## result.3610 10.004463
## result.3611 10.011276
## result.3612 9.997198
## result.3613 10.003973
## result.3614 10.004061
## result.3615 9.996208
## result.3616 10.017488
## result.3617 9.983053
## result.3618 10.000319
## result.3619 9.997776
## result.3620 9.998852
## result.3621 10.003810
## result.3622 9.999234
## result.3623 10.014459
## result.3624 9.992497
## result.3625 10.006650
## result.3626 9.995174
## result.3627 10.003473
## result.3628 9.985051
## result.3629 9.996771
## result.3630 10.007500
## result.3631 9.988904
## result.3632 10.000737
## result.3633 10.002124
## result.3634 10.014211
## result.3635 10.008118
## result.3636 10.020053
## result.3637 10.004395
## result.3638 10.004121
## result.3639 10.000088
```



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## result.3640 9.991134
## result.3641 10.017909
## result.3642 9.994299
## result.3643 10.000164
## result.3644 10.000239
## result.3645 10.001220
## result.3646 9.993910
## result.3647 10.003092
## result.3648 10.020866
## result.3649 9.977421
## result.3650 9.996740
## result.3651 9.997470
## result.3652 9.997523
## result.3653 10.009610
## result.3654 10.005232
## result.3655 9.994585
## result.3656 9.997070
## result.3657 10.003555
## result.3658 9.993477
## result.3659 10.002343
## result.3660 9.996413
## result.3661 10.000873
## result.3662 9.995763
## result.3663 10.006837
## result.3664 9.995280
## result.3665 10.024054
## result.3666 9.991612
## result.3667 9.991932
## result.3668 9.998170
## result.3669 9.995058
## result.3670 10.010020
## result.3671 10.001597
## result.3672 9.991486
## result.3673 10.008649
## result.3674 9.995940
## result.3675 9.991630
## result.3676 10.006938
## result.3677 10.015297
## result.3678 10.012991
## result.3679 9.995168
## result.3680 10.009030
## result.3681 9.994225
## result.3682 10.000195
## result.3683 9.986916
## result.3684 10.019557
## result.3685 9.999560
## result.3686 10.014378
## result.3687 9.979217
## result.3688 10.004473
## result.3689 10.003307
## result.3690 9.995420
## result.3691 10.015683
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## result.3692 9.997736
## result.3693 9.993660
## result.3694 9.991462
## result.3695 10.013224
## result.3696 10.001644
## result.3697 9.988946
## result.3698 10.001989
## result.3699 10.017532
## result.3700 9.995938
## result.3701 10.002711
## result.3702 10.008095
## result.3703 9.991460
## result.3704 9.985806
## result.3705 9.991258
## result.3706 10.014176
## result.3707 9.984004
## result.3708 9.992386
## result.3709 10.012451
## result.3710 10.004798
## result.3711 9.998707
## result.3712 9.987895
## result.3713 9.983926
## result.3714 9.992317
## result.3715 10.014436
## result.3716 9.984938
## result.3717 9.998899
## result.3718 9.995019
## result.3719 10.006859
## result.3720 9.998652
## result.3721 10.012115
## result.3722 9.992805
## result.3723 10.006993
## result.3724 9.996826
## result.3725 10.002234
## result.3726 9.984733
## result.3727 9.996064
## result.3728 10.003543
## result.3729 10.004169
## result.3730 10.008303
## result.3731 9.992443
## result.3732 9.993982
## result.3733 10.000448
## result.3734 9.990080
## result.3735 9.987495
## result.3736 9.995540
## result.3737 9.982995
## result.3738 10.012729
## result.3739 9.991280
## result.3740 9.986847
## result.3741 10.004929
## result.3742 10.001669
## result.3743 10.018121
```

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## result.3744 9.988417
## result.3745 10.004895
## result.3746 9.982052
## result.3747 10.002642
## result.3748 10.004240
## result.3749 10.001162
## result.3750 10.001012
## result.3751 10.007655
## result.3752 9.990465
## result.3753 10.000742
## result.3754 10.002591
## result.3755 10.000231
## result.3756 9.985176
## result.3757 10.018007
## result.3758 10.004494
## result.3759 9.991198
## result.3760 9.994744
## result.3761 10.000070
## result.3762 10.007540
## result.3763 9.995293
## result.3764 10.004662
## result.3765 10.003028
## result.3766 10.014828
## result.3767 10.010498
## result.3768 10.005812
## result.3769 9.994343
## result.3770 10.000446
## result.3771 9.990683
## result.3772 9.983661
## result.3773 10.001405
## result.3774 9.999351
## result.3775 10.015737
## result.3776 9.982380
## result.3777 10.008026
## result.3778 9.994402
## result.3779 10.006893
## result.3780 9.996338
## result.3781 10.004569
## result.3782 9.999825
## result.3783 9.998590
## result.3784 10.009867
## result.3785 9.989207
## result.3786 10.019166
## result.3787 10.004588
## result.3788 9.998673
## result.3789 9.993441
## result.3790 9.997032
## result.3791 9.988687
## result.3792 10.014135
## result.3793 10.009936
## result.3794 10.003147
## result.3795 10.005751
```

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## result.3796 10.000564
## result.3797 9.982897
## result.3798 10.012234
## result.3799 9.998297
## result.3800 9.992678
## result.3801 9.999981
## result.3802 9.991741
## result.3803 10.006552
## result.3804 10.008705
## result.3805 9.981419
## result.3806 9.997835
## result.3807 9.998918
## result.3808 10.011349
## result.3809 9.980367
## result.3810 9.990330
## result.3811 9.995549
## result.3812 9.995206
## result.3813 9.991212
## result.3814 9.987765
## result.3815 10.002307
## result.3816 9.992625
## result.3817 9.989269
## result.3818 10.003266
## result.3819 10.004345
## result.3820 9.998862
## result.3821 10.017137
## result.3822 10.000048
## result.3823 10.022449
## result.3824 10.001215
## result.3825 10.022613
## result.3826 10.002061
## result.3827 9.997967
## result.3828 10.001374
## result.3829 9.983944
## result.3830 9.998487
## result.3831 9.999201
## result.3832 9.996740
## result.3833 10.003950
## result.3834 10.000806
## result.3835 10.005859
## result.3836 9.994903
## result.3837 10.001449
## result.3838 10.001245
## result.3839 9.997188
## result.3840 9.991630
## result.3841 10.010653
## result.3842 9.998629
## result.3843 10.005524
## result.3844 9.980711
## result.3845 10.003766
## result.3846 10.014768
## result.3847 10.016683
```

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## result.3848 9.996286
## result.3849 9.989688
## result.3850 10.010903
## result.3851 9.997397
## result.3852 9.975656
## result.3853 9.990110
## result.3854 10.012369
## result.3855 9.996883
## result.3856 9.996812
## result.3857 10.007448
## result.3858 10.018134
## result.3859 10.002697
## result.3860 10.006628
## result.3861 9.990187
## result.3862 9.987014
## result.3863 10.005043
## result.3864 10.013303
## result.3865 9.990044
## result.3866 9.998048
## result.3867 9.998362
## result.3868 10.017168
## result.3869 10.018382
## result.3870 9.999869
## result.3871 10.001639
## result.3872 9.996777
## result.3873 9.984078
## result.3874 9.999563
## result.3875 10.011462
## result.3876 9.986168
## result.3877 9.999572
## result.3878 9.996869
## result.3879 10.017115
## result.3880 9.989329
## result.3881 9.998600
## result.3882 10.003946
## result.3883 10.003671
## result.3884 9.993970
## result.3885 10.010766
## result.3886 10.010435
## result.3887 10.007636
## result.3888 10.012525
## result.3889 9.992498
## result.3890 9.993578
## result.3891 10.014091
## result.3892 9.998499
## result.3893 9.996969
## result.3894 9.992739
## result.3895 9.998380
## result.3896 10.006648
## result.3897 9.991513
## result.3898 10.009635
## result.3899 10.015842
```

```
## result.3900 10.001251
## result.3901 10.000912
## result.3902 10.013729
## result.3903 10.008614
## result.3904 10.002976
## result.3905 10.016622
## result.3906 10.001981
## result.3907 10.005696
## result.3908 10.005428
## result.3909 9.993495
## result.3910 9.999161
## result.3911 10.002479
## result.3912 10.005524
## result.3913 10.007539
## result.3914 10.000637
## result.3915 9.994657
## result.3916 10.010463
## result.3917 9.998344
## result.3918 9.996510
## result.3919 9.990279
## result.3920 9.974115
## result.3921 9.996213
## result.3922 9.998708
## result.3923 9.995941
## result.3924 10.001709
## result.3925 9.995224
## result.3926 10.019759
## result.3927 9.987046
## result.3928 10.009717
## result.3929 10.005181
## result.3930 10.000822
## result.3931 9.995817
## result.3932 10.004415
## result.3933 9.991576
## result.3934 10.009680
## result.3935 9.982308
## result.3936 9.981263
## result.3937 9.998755
## result.3938 9.988336
## result.3939 9.994777
## result.3940 9.978031
## result.3941 9.999437
## result.3942 10.006895
## result.3943 10.006661
## result.3944 9.966130
## result.3945 9.991820
## result.3946 9.996712
## result.3947 10.004848
## result.3948 10.012962
## result.3949 10.009607
## result.3950 9.994020
## result.3951 10.008704
```

```
## result.3952 10.003792
## result.3953 10.002702
## result.3954 10.007186
## result.3955 9.991023
## result.3956 10.009696
## result.3957 10.005988
## result.3958 10.008769
## result.3959 10.000032
## result.3960 10.009059
## result.3961 9.989094
## result.3962 9.997210
## result.3963 10.025530
## result.3964 10.008165
## result.3965 10.019054
## result.3966 10.014770
## result.3967 10.005803
## result.3968 9.999089
## result.3969 9.990831
## result.3970 9.997228
## result.3971 9.998746
## result.3972 9.995623
## result.3973 10.010542
## result.3974 10.014080
## result.3975 10.006890
## result.3976 9.995206
## result.3977 10.017954
## result.3978 9.999067
## result.3979 9.998948
## result.3980 10.011526
## result.3981 10.005561
## result.3982 9.998450
## result.3983 10.002926
## result.3984 10.024750
## result.3985 9.991819
## result.3986 9.989278
## result.3987 10.002561
## result.3988 9.993003
## result.3989 9.985270
## result.3990 9.997356
## result.3991 9.998287
## result.3992 9.995417
## result.3993 10.007045
## result.3994 9.997259
## result.3995 10.011884
## result.3996 10.000231
## result.3997 10.012311
## result.3998 9.997296
## result.3999 9.992480
## result.4000 10.002561
```

```
Stop_Time_parallel=Sys.time()

parallel::stopCluster(Cores)

Time_parallel=Stop_Time_parallel-Start_Time_parallel
Time_parallel
```

```
## Time difference of 8.171963 secs
```

## Results

The run times for my parallel and serial loops were 10.47711 seconds and 39.03701 seconds, respectively, and the theoretical run time I calculated for the parallel loop was 4.87963 seconds. The theoretical run time is much shorter than the actual run time of my program because it takes more time for the parallel loop to combine all the data points running in different threads.