

High Performance Computing

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GitHub Repository (https://github.com/alyssagreen02/BIOL432_HighPerformanceComputing)

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 38.82113 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 10.003360
## result.2  9.998369
## result.3  9.979663
## result.4  9.993396
## result.5  9.997380
## result.6  9.998090
## result.7  9.997021
## result.8 10.002470
## result.9 10.009765
## result.10 9.988083
## result.11 10.010868
## result.12 10.013425
## result.13  9.997201
## result.14 10.019242
## result.15 10.012801
## result.16 10.003607
## result.17  9.997506
## result.18  9.988732
## result.19 10.006575
## result.20 10.008911
## result.21  9.968839
## result.22  9.997268
## result.23  9.996625
## result.24  9.995012
## result.25  9.993446
## result.26 10.002715
## result.27  9.993755
## result.28  9.988398
## result.29  9.992344
## result.30  9.979750
## result.31 10.012983
## result.32 10.002756
## result.33 10.019195
## result.34 10.012830
## result.35  9.991195
## result.36  9.995887
## result.37  9.988414
## result.38 10.003489
## result.39 10.001312
## result.40  9.996249
## result.41  9.991766
## result.42 10.008226
## result.43 10.004400
## result.44 10.012638
## result.45 10.000500
## result.46 10.008585
## result.47 10.006752
## result.48  9.973116
## result.49  9.999733
## result.50 10.006724
## result.51  9.994198
```

```
## result.52 10.004589
## result.53 9.987430
## result.54 9.983607
## result.55 10.006746
## result.56 10.013645
## result.57 10.004243
## result.58 9.994965
## result.59 10.008145
## result.60 9.991552
## result.61 10.004631
## result.62 9.993149
## result.63 9.994109
## result.64 10.007734
## result.65 10.002912
## result.66 9.993218
## result.67 9.986456
## result.68 9.996863
## result.69 9.983939
## result.70 10.005569
## result.71 9.986166
## result.72 10.001783
## result.73 9.987805
## result.74 10.001544
## result.75 9.987906
## result.76 9.996653
## result.77 9.986138
## result.78 9.990804
## result.79 10.000858
## result.80 10.002004
## result.81 9.993851
## result.82 9.990226
## result.83 9.987131
## result.84 10.004551
## result.85 10.010290
## result.86 9.986466
## result.87 9.995012
## result.88 10.009347
## result.89 10.002685
## result.90 10.000805
## result.91 9.973319
## result.92 10.003509
## result.93 9.983583
## result.94 10.010892
## result.95 9.991453
## result.96 10.005505
## result.97 9.996090
## result.98 9.992022
## result.99 9.998849
## result.100 10.007347
## result.101 9.986770
## result.102 9.999754
## result.103 9.992696
```

```
## result.104  9.999056
## result.105  9.996173
## result.106  10.006814
## result.107  9.999610
## result.108  9.985738
## result.109  9.989566
## result.110  10.005870
## result.111  9.993023
## result.112  10.000425
## result.113  10.014437
## result.114  9.992549
## result.115  10.001830
## result.116  10.001849
## result.117  9.999577
## result.118  10.002377
## result.119  10.001862
## result.120  9.998172
## result.121  9.998842
## result.122  10.010294
## result.123  10.000580
## result.124  10.007985
## result.125  9.994152
## result.126  10.017738
## result.127  10.009448
## result.128  10.009317
## result.129  10.020808
## result.130  9.992715
## result.131  9.996309
## result.132  9.996359
## result.133  10.022772
## result.134  10.004614
## result.135  10.012009
## result.136  10.008533
## result.137  9.987646
## result.138  10.000195
## result.139  10.001490
## result.140  9.984849
## result.141  9.994196
## result.142  10.000482
## result.143  10.012303
## result.144  9.994791
## result.145  9.995064
## result.146  9.992050
## result.147  10.002139
## result.148  10.003044
## result.149  9.998861
## result.150  9.991107
## result.151  10.003601
## result.152  9.992030
## result.153  9.988440
## result.154  10.002150
## result.155  9.984424
```

```
## result.156 10.011721
## result.157 10.002147
## result.158 9.986240
## result.159 10.003520
## result.160 9.990184
## result.161 9.992860
## result.162 9.996002
## result.163 9.995290
## result.164 10.010832
## result.165 9.999959
## result.166 10.010831
## result.167 9.999415
## result.168 10.008936
## result.169 9.996230
## result.170 9.995606
## result.171 10.006528
## result.172 10.006823
## result.173 10.026186
## result.174 10.005954
## result.175 9.992458
## result.176 10.012092
## result.177 10.015072
## result.178 9.994916
## result.179 10.007531
## result.180 10.009083
## result.181 10.023751
## result.182 9.990334
## result.183 9.986278
## result.184 9.991648
## result.185 9.989871
## result.186 10.004273
## result.187 9.992706
## result.188 9.985116
## result.189 10.012629
## result.190 9.988797
## result.191 9.996569
## result.192 9.992456
## result.193 10.013161
## result.194 9.992711
## result.195 9.977177
## result.196 9.996101
## result.197 9.997470
## result.198 10.007354
## result.199 9.994643
## result.200 10.001229
## result.201 10.004090
## result.202 9.999280
## result.203 10.008849
## result.204 9.995999
## result.205 9.997323
## result.206 10.012185
## result.207 10.005632
```

```
## result.208 9.998370
## result.209 9.999239
## result.210 10.002950
## result.211 10.011648
## result.212 10.001231
## result.213 9.996678
## result.214 9.994538
## result.215 10.007888
## result.216 10.004458
## result.217 10.006391
## result.218 10.006991
## result.219 10.002370
## result.220 9.997067
## result.221 10.007067
## result.222 10.007797
## result.223 9.989050
## result.224 9.999421
## result.225 9.990847
## result.226 10.012982
## result.227 10.010122
## result.228 9.998852
## result.229 9.997403
## result.230 9.993295
## result.231 9.993909
## result.232 9.996208
## result.233 10.007519
## result.234 9.998871
## result.235 9.993979
## result.236 10.014079
## result.237 10.013057
## result.238 9.988618
## result.239 9.995821
## result.240 9.988545
## result.241 9.998242
## result.242 10.014654
## result.243 10.000107
## result.244 10.015708
## result.245 9.998932
## result.246 10.000796
## result.247 10.021176
## result.248 9.990358
## result.249 10.020262
## result.250 9.996822
## result.251 9.995829
## result.252 9.987868
## result.253 9.999864
## result.254 10.002796
## result.255 9.977128
## result.256 10.017527
## result.257 9.999920
## result.258 9.987261
## result.259 9.998321
```

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## result.260 10.000225
## result.261 9.999681
## result.262 9.997661
## result.263 10.015825
## result.264 10.005036
## result.265 10.017809
## result.266 10.003700
## result.267 10.015076
## result.268 10.021780
## result.269 10.010206
## result.270 10.003680
## result.271 10.002903
## result.272 10.007132
## result.273 9.994929
## result.274 9.990769
## result.275 10.015642
## result.276 9.992194
## result.277 9.995728
## result.278 10.007196
## result.279 9.994432
## result.280 10.000858
## result.281 9.999941
## result.282 9.988519
## result.283 10.004427
## result.284 9.999302
## result.285 9.998066
## result.286 10.018546
## result.287 9.986755
## result.288 9.990232
## result.289 9.997876
## result.290 9.996153
## result.291 10.006568
## result.292 9.997922
## result.293 10.005188
## result.294 9.997764
## result.295 10.007454
## result.296 9.991639
## result.297 9.998291
## result.298 9.992451
## result.299 10.009535
## result.300 9.983451
## result.301 9.997414
## result.302 10.001308
## result.303 9.997804
## result.304 10.005706
## result.305 10.002644
## result.306 10.015756
## result.307 10.010656
## result.308 10.003429
## result.309 10.011199
## result.310 10.006565
## result.311 10.018857
```



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## result.312 10.011759
## result.313 9.992944
## result.314 9.990915
## result.315 10.017790
## result.316 9.997545
## result.317 10.009871
## result.318 10.004094
## result.319 10.008586
## result.320 9.986092
## result.321 9.995865
## result.322 9.995482
## result.323 10.004468
## result.324 9.987966
## result.325 9.995760
## result.326 10.011331
## result.327 9.999192
## result.328 9.992873
## result.329 10.003681
## result.330 9.996639
## result.331 10.000678
## result.332 9.998409
## result.333 9.987709
## result.334 9.983305
## result.335 10.010916
## result.336 9.986481
## result.337 9.987562
## result.338 9.996502
## result.339 10.007385
## result.340 10.001503
## result.341 10.011072
## result.342 10.016680
## result.343 9.986237
## result.344 10.003423
## result.345 9.987330
## result.346 10.002579
## result.347 9.981908
## result.348 10.003372
## result.349 9.993096
## result.350 9.989135
## result.351 10.005189
## result.352 9.992081
## result.353 9.994095
## result.354 10.007952
## result.355 10.001541
## result.356 9.987317
## result.357 9.994260
## result.358 9.992690
## result.359 10.000581
## result.360 10.004594
## result.361 9.997638
## result.362 10.010774
## result.363 10.003389
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## result.364 10.000090
## result.365 10.010899
## result.366 9.990565
## result.367 9.982236
## result.368 9.976834
## result.369 10.007419
## result.370 9.994202
## result.371 10.008132
## result.372 10.009825
## result.373 9.982260
## result.374 9.990698
## result.375 9.987508
## result.376 9.993612
## result.377 9.989785
## result.378 10.018239
## result.379 9.998009
## result.380 9.999210
## result.381 9.997176
## result.382 9.989990
## result.383 10.003250
## result.384 10.015162
## result.385 9.999627
## result.386 10.009548
## result.387 10.011468
## result.388 10.004315
## result.389 9.999101
## result.390 10.001933
## result.391 10.011227
## result.392 9.999805
## result.393 10.002684
## result.394 9.983238
## result.395 10.003313
## result.396 10.006815
## result.397 9.993573
## result.398 10.012112
## result.399 9.995911
## result.400 10.002083
## result.401 9.997820
## result.402 9.998079
## result.403 10.010471
## result.404 9.978316
## result.405 10.007541
## result.406 9.989089
## result.407 9.988872
## result.408 10.012253
## result.409 10.010655
## result.410 9.989551
## result.411 10.013994
## result.412 10.021157
## result.413 9.999260
## result.414 9.996933
## result.415 9.993453
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## result.416 10.005915
## result.417 10.006008
## result.418 10.017848
## result.419 9.994673
## result.420 10.010775
## result.421 10.005602
## result.422 9.988167
## result.423 9.999360
## result.424 9.996171
## result.425 10.007512
## result.426 10.005309
## result.427 9.999968
## result.428 9.998592
## result.429 9.998341
## result.430 10.018684
## result.431 10.015512
## result.432 9.989833
## result.433 9.995846
## result.434 9.995816
## result.435 10.004338
## result.436 9.999588
## result.437 9.990544
## result.438 10.004794
## result.439 10.005634
## result.440 10.013941
## result.441 10.013354
## result.442 9.999364
## result.443 9.999706
## result.444 9.992798
## result.445 10.002922
## result.446 9.985472
## result.447 9.998539
## result.448 10.014434
## result.449 9.998940
## result.450 9.997620
## result.451 10.005703
## result.452 10.004789
## result.453 9.984226
## result.454 10.001928
## result.455 10.016351
## result.456 10.001013
## result.457 9.999717
## result.458 10.012422
## result.459 9.994912
## result.460 10.008734
## result.461 10.006540
## result.462 9.994455
## result.463 10.018667
## result.464 9.993198
## result.465 9.989511
## result.466 9.988616
## result.467 10.001051
```

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## result.468 9.989142
## result.469 10.002116
## result.470 10.001826
## result.471 9.996700
## result.472 10.006973
## result.473 9.990290
## result.474 10.007541
## result.475 10.001792
## result.476 10.009881
## result.477 9.985788
## result.478 10.000021
## result.479 10.007967
## result.480 9.989848
## result.481 9.991646
## result.482 9.998718
## result.483 9.995788
## result.484 9.992766
## result.485 10.004111
## result.486 9.998324
## result.487 9.995772
## result.488 10.003600
## result.489 9.989782
## result.490 10.007535
## result.491 10.000485
## result.492 10.004944
## result.493 10.013006
## result.494 10.000291
## result.495 10.008779
## result.496 9.999175
## result.497 9.982178
## result.498 9.997626
## result.499 9.995211
## result.500 10.004691
## result.501 9.992464
## result.502 9.992992
## result.503 10.009990
## result.504 9.992044
## result.505 9.993443
## result.506 10.003971
## result.507 10.000332
## result.508 10.003908
## result.509 10.011133
## result.510 9.993688
## result.511 10.002382
## result.512 10.014244
## result.513 9.998110
## result.514 9.990891
## result.515 10.001386
## result.516 10.010081
## result.517 9.982347
## result.518 10.010689
## result.519 10.001543
```

```
## result.520    9.998725
## result.521   10.005393
## result.522    9.990036
## result.523    9.998359
## result.524    9.987133
## result.525    9.990388
## result.526    9.994464
## result.527   10.006238
## result.528   10.002890
## result.529    9.990816
## result.530   10.013276
## result.531   10.009382
## result.532    9.999588
## result.533   10.012271
## result.534    9.989573
## result.535    9.998167
## result.536    9.991272
## result.537    9.990980
## result.538    9.993254
## result.539    9.991275
## result.540    9.994149
## result.541    9.987950
## result.542    9.990310
## result.543   10.013172
## result.544   10.004338
## result.545   10.000172
## result.546   10.019979
## result.547   10.000839
## result.548    9.998786
## result.549   10.002007
## result.550    9.988637
## result.551    9.998136
## result.552   10.002667
## result.553    9.994563
## result.554   10.014620
## result.555    9.997051
## result.556   10.013789
## result.557    9.989989
## result.558    9.993401
## result.559    9.989763
## result.560    9.994349
## result.561   10.003967
## result.562    9.983599
## result.563    9.997171
## result.564   10.006818
## result.565    9.990020
## result.566   10.001483
## result.567   10.009921
## result.568    9.991582
## result.569    9.988892
## result.570   10.007600
## result.571   10.009152
```

```
## result.572    9.992269
## result.573    9.992380
## result.574   10.020171
## result.575   10.005106
## result.576   10.021390
## result.577   10.004744
## result.578    9.976988
## result.579   10.009312
## result.580   10.000170
## result.581    9.990040
## result.582    9.989311
## result.583    9.987965
## result.584    9.998632
## result.585    9.994512
## result.586    9.973919
## result.587   10.004198
## result.588   10.002762
## result.589    9.990134
## result.590   10.006368
## result.591   10.001366
## result.592    9.985045
## result.593    9.997228
## result.594    9.993906
## result.595   10.001430
## result.596    9.992867
## result.597   10.025510
## result.598    9.992332
## result.599    9.991049
## result.600    9.987357
## result.601   10.000856
## result.602   10.008700
## result.603    9.997796
## result.604    9.997484
## result.605   10.015041
## result.606    9.991214
## result.607    9.985217
## result.608   10.009710
## result.609    9.996069
## result.610   10.012165
## result.611    9.995582
## result.612   10.005046
## result.613   10.000579
## result.614    9.988141
## result.615   10.000187
## result.616   10.015446
## result.617   10.006316
## result.618   10.004234
## result.619   10.011638
## result.620   10.015808
## result.621    9.999324
## result.622    9.994460
## result.623   10.004044
```

```
## result.624 9.996074
## result.625 9.990580
## result.626 9.997252
## result.627 10.009410
## result.628 10.010526
## result.629 10.008703
## result.630 10.003158
## result.631 9.978706
## result.632 10.012570
## result.633 10.008132
## result.634 10.002178
## result.635 10.013553
## result.636 9.996321
## result.637 10.009642
## result.638 10.008617
## result.639 9.997148
## result.640 10.003073
## result.641 9.988132
## result.642 9.985302
## result.643 9.993292
## result.644 9.992357
## result.645 9.995763
## result.646 9.989749
## result.647 9.991833
## result.648 10.000234
## result.649 10.003264
## result.650 9.995941
## result.651 9.993161
## result.652 10.002386
## result.653 10.015992
## result.654 9.996106
## result.655 9.998082
## result.656 10.005950
## result.657 10.005489
## result.658 9.995762
## result.659 9.996203
## result.660 10.002434
## result.661 10.015002
## result.662 9.995749
## result.663 10.000883
## result.664 10.013508
## result.665 10.006340
## result.666 9.993152
## result.667 10.003609
## result.668 9.997594
## result.669 9.994271
## result.670 9.998264
## result.671 10.025121
## result.672 10.000492
## result.673 10.012011
## result.674 10.002141
## result.675 9.998398
```

```
## result.676 10.013423
## result.677 10.002366
## result.678 9.994654
## result.679 10.001744
## result.680 10.000665
## result.681 9.988929
## result.682 9.991965
## result.683 10.007399
## result.684 9.995036
## result.685 9.999466
## result.686 10.004464
## result.687 10.008445
## result.688 9.997043
## result.689 9.989377
## result.690 9.991901
## result.691 10.007921
## result.692 9.997248
## result.693 10.005249
## result.694 9.984110
## result.695 10.007947
## result.696 9.996192
## result.697 10.003515
## result.698 10.006848
## result.699 9.993960
## result.700 9.991083
## result.701 9.991466
## result.702 10.002127
## result.703 9.993548
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## result.3543 9.993788
## result.3544 10.007632
## result.3545 9.992107
## result.3546 10.009183
## result.3547 9.995234
## result.3548 9.995361
## result.3549 10.004836
## result.3550 9.990699
## result.3551 9.985477
## result.3552 9.999967
## result.3553 10.011595
## result.3554 9.994361
## result.3555 10.002515
## result.3556 9.990332
## result.3557 9.989525
## result.3558 9.983264
## result.3559 10.002483
## result.3560 9.992963
## result.3561 9.982109
## result.3562 9.998376
## result.3563 10.011237
## result.3564 9.993765
## result.3565 9.991176
## result.3566 9.990273
## result.3567 9.997462
## result.3568 10.000267
## result.3569 9.992944
## result.3570 9.994020
## result.3571 9.995919
## result.3572 9.996026
## result.3573 9.988521
## result.3574 10.005962
## result.3575 10.007169
## result.3576 9.998214
## result.3577 9.985537
## result.3578 9.999872
## result.3579 9.994449
## result.3580 10.007005
## result.3581 10.007083
## result.3582 9.993540
## result.3583 9.995493
## result.3584 9.998354
## result.3585 9.992573
## result.3586 10.008289
## result.3587 10.010259
```

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## result.3588 10.012242
## result.3589 10.003436
## result.3590 10.006228
## result.3591 9.989482
## result.3592 10.000465
## result.3593 10.015185
## result.3594 10.008116
## result.3595 9.982878
## result.3596 10.002661
## result.3597 9.993750
## result.3598 10.004066
## result.3599 9.990156
## result.3600 9.979112
## result.3601 9.993253
## result.3602 9.984134
## result.3603 10.004744
## result.3604 9.990516
## result.3605 9.997516
## result.3606 10.002449
## result.3607 10.000488
## result.3608 9.991967
## result.3609 9.994054
## result.3610 9.992489
## result.3611 9.999020
## result.3612 9.998265
## result.3613 9.992529
## result.3614 9.989453
## result.3615 10.006129
## result.3616 9.989606
## result.3617 10.005890
## result.3618 9.988468
## result.3619 9.994060
## result.3620 9.995092
## result.3621 9.989452
## result.3622 10.006318
## result.3623 10.003809
## result.3624 9.987762
## result.3625 10.002870
## result.3626 9.992762
## result.3627 10.003263
## result.3628 9.998735
## result.3629 9.982922
## result.3630 9.998178
## result.3631 10.000106
## result.3632 9.996864
## result.3633 9.985075
## result.3634 9.988491
## result.3635 9.995125
## result.3636 9.996588
## result.3637 10.007407
## result.3638 10.007899
## result.3639 9.986872
```



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## result.3640 10.004056
## result.3641 10.011787
## result.3642 10.003758
## result.3643 10.005272
## result.3644 9.989955
## result.3645 10.010110
## result.3646 9.991534
## result.3647 9.996992
## result.3648 9.995363
## result.3649 10.006878
## result.3650 10.010644
## result.3651 9.998520
## result.3652 10.011402
## result.3653 9.994024
## result.3654 9.993692
## result.3655 10.000573
## result.3656 10.008263
## result.3657 9.988997
## result.3658 9.999748
## result.3659 10.011312
## result.3660 10.011709
## result.3661 10.002898
## result.3662 9.998669
## result.3663 10.006386
## result.3664 9.995130
## result.3665 10.002735
## result.3666 9.996232
## result.3667 9.997955
## result.3668 10.001619
## result.3669 9.996436
## result.3670 9.995795
## result.3671 10.005938
## result.3672 9.967424
## result.3673 9.992688
## result.3674 10.005188
## result.3675 9.994330
## result.3676 10.015785
## result.3677 10.004403
## result.3678 10.011937
## result.3679 10.007074
## result.3680 10.011161
## result.3681 9.987962
## result.3682 9.996889
## result.3683 10.002351
## result.3684 9.994822
## result.3685 10.009667
## result.3686 10.005450
## result.3687 10.008633
## result.3688 10.017281
## result.3689 10.001047
## result.3690 10.005328
## result.3691 9.997220
```

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## result.3692 9.993367
## result.3693 10.006905
## result.3694 9.994251
## result.3695 10.009539
## result.3696 10.001466
## result.3697 10.003632
## result.3698 9.992021
## result.3699 10.018995
## result.3700 9.990408
## result.3701 9.996290
## result.3702 9.993497
## result.3703 9.995574
## result.3704 10.000822
## result.3705 9.998610
## result.3706 9.991156
## result.3707 10.002753
## result.3708 9.994328
## result.3709 9.999411
## result.3710 10.011217
## result.3711 10.005777
## result.3712 9.991004
## result.3713 9.987725
## result.3714 9.984044
## result.3715 10.013149
## result.3716 10.011751
## result.3717 10.005666
## result.3718 9.999544
## result.3719 9.998621
## result.3720 10.002733
## result.3721 10.010153
## result.3722 10.011368
## result.3723 9.995430
## result.3724 9.988761
## result.3725 9.998061
## result.3726 10.011750
## result.3727 10.014840
## result.3728 10.005725
## result.3729 10.002348
## result.3730 9.983406
## result.3731 10.007931
## result.3732 10.000688
## result.3733 10.009210
## result.3734 10.007948
## result.3735 10.003179
## result.3736 10.003533
## result.3737 9.976772
## result.3738 9.983477
## result.3739 9.999395
## result.3740 9.998988
## result.3741 10.003245
## result.3742 9.999153
## result.3743 10.017071
```

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## result.3744 10.012806
## result.3745 10.004094
## result.3746 10.002684
## result.3747 9.985703
## result.3748 9.993880
## result.3749 9.994700
## result.3750 9.974167
## result.3751 9.992531
## result.3752 10.007846
## result.3753 10.005035
## result.3754 9.999604
## result.3755 9.995985
## result.3756 10.006806
## result.3757 9.997112
## result.3758 10.010233
## result.3759 9.996627
## result.3760 10.005632
## result.3761 10.009307
## result.3762 9.993612
## result.3763 9.994206
## result.3764 9.999768
## result.3765 9.988871
## result.3766 9.991493
## result.3767 9.997632
## result.3768 9.986016
## result.3769 10.004810
## result.3770 9.996288
## result.3771 9.989084
## result.3772 10.000866
## result.3773 10.005661
## result.3774 10.000907
## result.3775 9.997681
## result.3776 10.022975
## result.3777 10.001047
## result.3778 10.011774
## result.3779 10.017107
## result.3780 9.994505
## result.3781 9.994784
## result.3782 9.979757
## result.3783 9.981830
## result.3784 9.998448
## result.3785 9.993391
## result.3786 9.996451
## result.3787 9.993008
## result.3788 9.984819
## result.3789 9.987121
## result.3790 10.012452
## result.3791 10.016773
## result.3792 10.000688
## result.3793 10.015759
## result.3794 9.995214
## result.3795 10.003905
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## result.3796 10.001891
## result.3797 9.993058
## result.3798 9.999310
## result.3799 10.018387
## result.3800 10.003368
## result.3801 10.009847
## result.3802 9.996003
## result.3803 9.998064
## result.3804 10.011820
## result.3805 10.009181
## result.3806 10.000898
## result.3807 9.993545
## result.3808 10.000798
## result.3809 9.978128
## result.3810 9.998907
## result.3811 10.001195
## result.3812 10.000870
## result.3813 10.001211
## result.3814 9.994171
## result.3815 10.022484
## result.3816 10.010812
## result.3817 9.990725
## result.3818 10.000930
## result.3819 9.994714
## result.3820 9.980951
## result.3821 10.002312
## result.3822 9.980987
## result.3823 10.001619
## result.3824 9.999746
## result.3825 10.012187
## result.3826 9.999599
## result.3827 9.998997
## result.3828 9.986375
## result.3829 10.005752
## result.3830 9.997444
## result.3831 9.991498
## result.3832 9.982436
## result.3833 10.001783
## result.3834 9.999353
## result.3835 10.012920
## result.3836 9.993136
## result.3837 10.009727
## result.3838 9.990785
## result.3839 10.011518
## result.3840 10.012043
## result.3841 10.003840
## result.3842 9.987126
## result.3843 9.996781
## result.3844 9.985790
## result.3845 9.992218
## result.3846 10.000534
## result.3847 9.994300
```

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## result.3848 10.014709
## result.3849 10.004568
## result.3850 10.000431
## result.3851 9.997616
## result.3852 10.004169
## result.3853 9.997003
## result.3854 10.007624
## result.3855 10.016852
## result.3856 10.007227
## result.3857 9.997763
## result.3858 10.005248
## result.3859 10.020611
## result.3860 9.987840
## result.3861 9.999572
## result.3862 10.007750
## result.3863 10.001565
## result.3864 10.001287
## result.3865 9.996579
## result.3866 9.995097
## result.3867 10.001385
## result.3868 9.995501
## result.3869 10.010256
## result.3870 9.992792
## result.3871 10.007134
## result.3872 10.011012
## result.3873 9.999989
## result.3874 9.981888
## result.3875 9.984353
## result.3876 10.002495
## result.3877 10.000278
## result.3878 9.997884
## result.3879 9.988983
## result.3880 9.996707
## result.3881 10.007061
## result.3882 10.008652
## result.3883 9.996914
## result.3884 10.012219
## result.3885 9.996638
## result.3886 10.002977
## result.3887 9.992652
## result.3888 10.002225
## result.3889 10.001116
## result.3890 10.001167
## result.3891 9.998483
## result.3892 9.982017
## result.3893 9.993852
## result.3894 10.006843
## result.3895 9.999025
## result.3896 10.002622
## result.3897 9.993235
## result.3898 10.014945
## result.3899 9.986775
```

```
## result.3900 10.000388
## result.3901 10.003961
## result.3902 9.994624
## result.3903 10.014608
## result.3904 9.983917
## result.3905 9.999689
## result.3906 10.008223
## result.3907 9.988161
## result.3908 9.999258
## result.3909 10.001093
## result.3910 10.017155
## result.3911 9.997530
## result.3912 9.985464
## result.3913 9.995524
## result.3914 10.013460
## result.3915 10.004873
## result.3916 10.007765
## result.3917 10.007316
## result.3918 9.992598
## result.3919 10.012182
## result.3920 10.006891
## result.3921 10.003554
## result.3922 9.987891
## result.3923 9.993067
## result.3924 9.998021
## result.3925 10.003901
## result.3926 10.006119
## result.3927 9.983099
## result.3928 9.997834
## result.3929 10.003763
## result.3930 9.993431
## result.3931 9.995553
## result.3932 10.012541
## result.3933 10.001033
## result.3934 9.999684
## result.3935 9.992474
## result.3936 10.012759
## result.3937 10.001163
## result.3938 9.991506
## result.3939 10.000015
## result.3940 10.012310
## result.3941 10.020736
## result.3942 9.997568
## result.3943 9.969918
## result.3944 9.988121
## result.3945 10.002704
## result.3946 9.994789
## result.3947 9.987304
## result.3948 10.018533
## result.3949 9.993489
## result.3950 9.991807
## result.3951 9.998259
```

```
## result.3952 10.003005
## result.3953 9.998066
## result.3954 10.003241
## result.3955 10.001261
## result.3956 10.001222
## result.3957 9.997530
## result.3958 10.004018
## result.3959 10.000617
## result.3960 9.993148
## result.3961 9.987476
## result.3962 10.000821
## result.3963 9.991629
## result.3964 9.991037
## result.3965 10.003837
## result.3966 10.012439
## result.3967 10.003089
## result.3968 9.998259
## result.3969 9.996767
## result.3970 9.993396
## result.3971 9.995483
## result.3972 9.996550
## result.3973 9.999200
## result.3974 10.007896
## result.3975 10.008300
## result.3976 10.012109
## result.3977 9.982961
## result.3978 10.018391
## result.3979 10.006916
## result.3980 10.014588
## result.3981 9.990348
## result.3982 10.006955
## result.3983 9.992002
## result.3984 10.012382
## result.3985 10.001643
## result.3986 10.003619
## result.3987 9.995060
## result.3988 10.004174
## result.3989 9.997894
## result.3990 10.013316
## result.3991 10.000777
## result.3992 10.009420
## result.3993 9.997137
## result.3994 10.001526
## result.3995 9.998814
## result.3996 10.003589
## result.3997 10.000199
## result.3998 10.000285
## result.3999 10.001480
## result.4000 9.982800
```

```
Stop_Time_parallel=Sys.time()

parallel::stopCluster(Cores)

Time_parallel=Stop_Time_parallel-Start_Time_parallel
Time_parallel
```

```
## Time difference of 7.568167 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.