

Program Structures & Algorithms

Spring 2022

Assignment No. 3

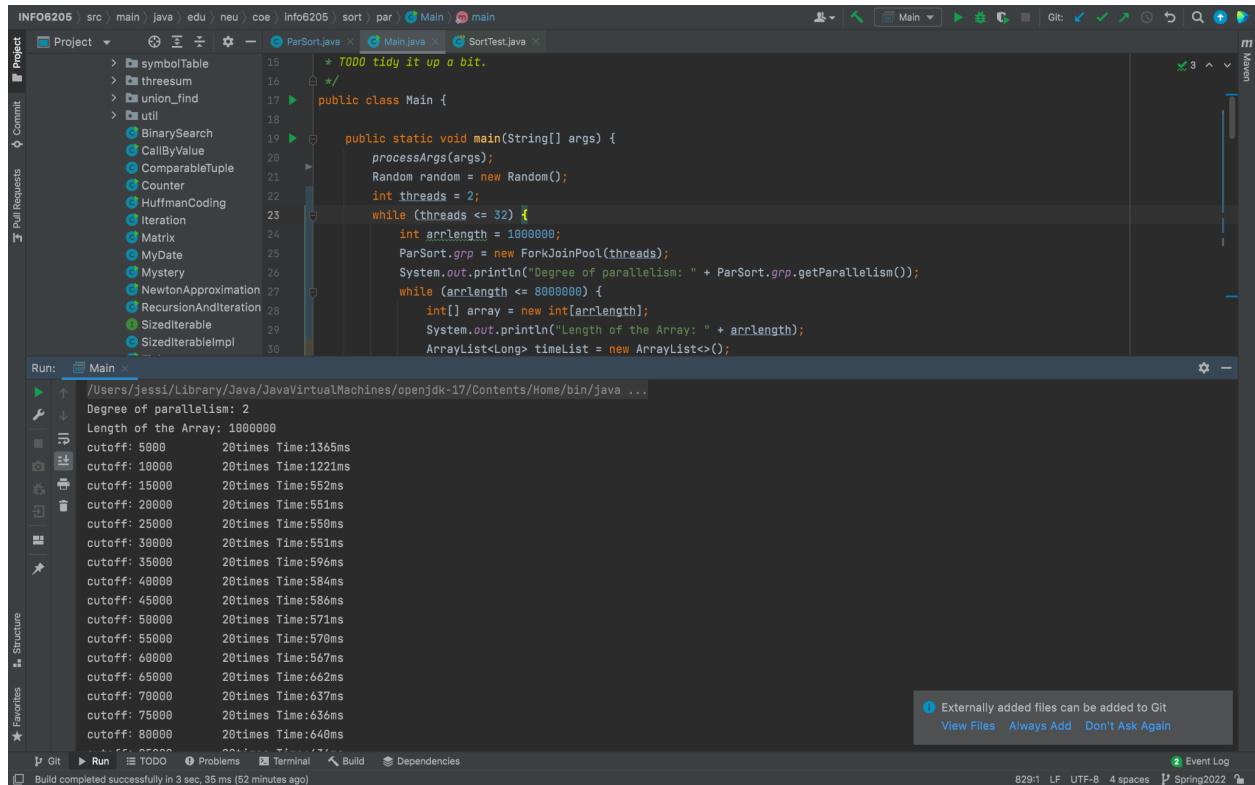
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Task:

1. Determine an ideal cutoff to sort an array with a large number of elements to sort.
2. Determine an ideal number of threads which restricts the depth of the recursion for sorting a huge array.
3. An appropriate combination of these which can be used for sorting a huge array.

Output screenshot:



The screenshot shows an IDE with a project named 'INFO6205'. The code editor displays a Java file 'Main.java' with the following code:

```
15 // TODO tidy it up a bit.
16
17 public class Main {
18
19     public static void main(String[] args) {
20         processArgs(args);
21         Random random = new Random();
22         int threads = 2;
23         while (threads <= 32) {
24             int arrLength = 1000000;
25             ParSort.grp = new ForkJoinPool(threads);
26             System.out.println("Degree of parallelism: " + ParSort.grp.getParallelism());
27             while (arrLength <= 8000000) {
28                 int[] array = new int[arrLength];
29                 System.out.println("Length of the Array: " + arrLength);
30                 ArrayList<Long> timeList = new ArrayList<>();
```

The Run console shows the following output:

```

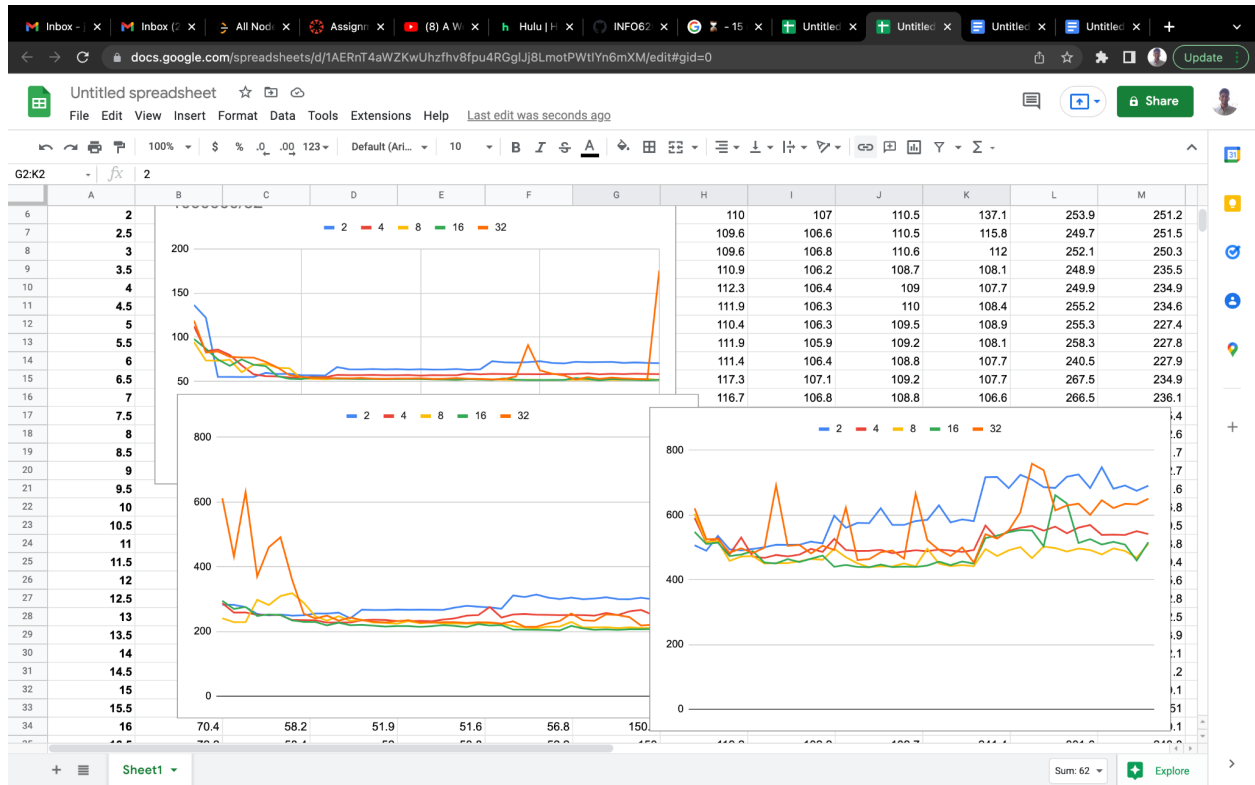
/Users/jessi/Library/Java/JavaVirtualMachines/openjdk-17/Contents/Home/bin/java ...
Degree of parallelism: 2
Length of the Array: 1000000
cutoff: 5000      20times Time:1365ms
cutoff: 10000    20times Time:1221ms
cutoff: 15000    20times Time:552ms
cutoff: 20000    20times Time:551ms
cutoff: 25000    20times Time:550ms
cutoff: 30000    20times Time:551ms
cutoff: 35000    20times Time:596ms
cutoff: 40000    20times Time:584ms
cutoff: 45000    20times Time:586ms
cutoff: 50000    20times Time:571ms
cutoff: 55000    20times Time:570ms
cutoff: 60000    20times Time:567ms
cutoff: 65000    20times Time:662ms
cutoff: 70000    20times Time:637ms
cutoff: 75000    20times Time:636ms
cutoff: 80000    20times Time:640ms
```

The status bar at the bottom indicates 'Build completed successfully in 3 sec, 35 ms (52 minutes ago)'.

Conclusion:

For the arrays of relatively smaller size the thread count and cut off limit are not affecting the time. The times are relative to the size of the array. As the array size increases, time is getting proportional to the number of threads. The cutoff values are not affecting the times as long as they are above 0.5% of the array size.

Evidence / Graph:



| Arr Le ngt h | 100 000 0 | | | | | 200 000 0 | | | | | | 400 000 0 | | | | | 800 000 0 | | | | |
|-----------------------------|-----------------|-------|------|------|-------|-----------------|-------|-------|-------|-------|-------|-----------------|---------|-------|-------|-------|-----------------|-------|-------|-------|--|
| Cut -off /Th reads | 2 | 4 | 8 | 16 | 32 | 2 | 4 | 8 | 16 | 32 | 2 | 4 | 8 | 16 | 32 | 2 | 4 | 8 | 16 | 32 | |
| 0.5 | 136.5 | 112.4 | 94.4 | 98 | 118.9 | 115.2 | 117.9 | 114.6 | 119.7 | 126.2 | 282.5 | 287.3 | 240.8 | 294.6 | 611.6 | 506.6 | 591.1 | 604.2 | 547.9 | 620.9 | |
| 1 | 122.1 | 84.3 | 73.6 | 87 | 82.7 | 113 | 113.9 | 109.7 | 113 | 117.6 | 282.1 | 258.2 | 228.6 | 269.7 | 431.3 | 489.9 | 514.6 | 517.3 | 510.7 | 525.6 | |
| 1.5 | 55.2 | 86.1 | 73.3 | 74.9 | 83.8 | 112.7 | 111.8 | 109.4 | 113.2 | 169.5 | 275.3 | 258.8 | 229 | 275.8 | 630.9 | 535.9 | 528.8 | 519.3 | 514.9 | 526.3 | |
| 2 | 55.1 | 80 | 74.6 | 67.6 | 77.8 | 112.7 | 110 | 107 | 110.5 | 137.1 | 253.9 | 251.2 | 297.8 | 248.1 | 370 | 494.2 | 478.5 | 458.4 | 473.5 | 483.2 | |
| 2.5 | 55 | 68.2 | 60.4 | 74.9 | 77.1 | 112.4 | 109.6 | 106.6 | 110.5 | 115.8 | 249.7 | 251.5 | 281.7 | 252.7 | 460.5 | 490.5 | 530.6 | 471.9 | 477.8 | 497.5 | |
| 3 | 55.1 | 58 | 68.8 | 68.8 | 76.9 | 112.2 | 109.6 | 106.8 | 110.6 | 112 | 252.1 | 250.3 | 430.9.5 | 251.1 | 491.1 | 495.3 | 471.7 | 473.5 | 488.4 | 482.7 | |

| | | | | | | | | | | | | | | | | | | | | |
|------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 3.5 | 59. 6 | 55. 9 | 69. 8 | 67. 4 | 72. 2 | 118 | 110 .9 | 106 .2 | 108 .7 | 108 .1 | 248 .9 | 235 .5 | 318 .1 | 233 .9 | 360 .1 | 500 .5 | 467 .6 | 450 .3 | 453 .3 | 499 |
| 4 | 58. 4 | 55. 7 | 65. 4 | 55. 9 | 65. 7 | 118 .2 | 112 .3 | 106 .4 | 109 | 107 .7 | 249 .9 | 234 .9 | 288 .7 | 229 .6 | 254 .9 | 508 .4 | 476 .6 | 451 .9 | 450 .6 | 691 .3 |
| 4.5 | 58. 6 | 54. 5 | 64. 8 | 53 | 57. 1 | 118 .2 | 111 .9 | 106 .3 | 110 | 108 .4 | 255 .2 | 234 .6 | 246 .7 | 229 .4 | 240 | 508 | 472 .5 | 451 .7 | 464 | 505 |
| 5 | 57. 1 | 54. 4 | 53. 2 | 52. 6 | 55. 2 | 118 .1 | 110 .4 | 106 .3 | 109 .5 | 108 .9 | 255 .3 | 227 .4 | 233 .6 | 218 .9 | 249 | 508 .3 | 477 .6 | 457 .1 | 455 .1 | 508 |
| 5.5 | 57 | 55. 1 | 52. 9 | 54. 4 | 53. 8 | 118 .2 | 111 .9 | 105 .9 | 109 .2 | 108 .1 | 258 .3 | 227 .8 | 247 .1 | 227 .1 | 233 .2 | 518 .1 | 495 .4 | 464 .5 | 465 | 481 .4 |
| 6 | 56. 7 | 54. 7 | 52. 5 | 53. 7 | 53. 8 | 117 .5 | 111 .4 | 106 .4 | 108 .8 | 107 .7 | 240 .5 | 227 .9 | 232 .5 | 219 .5 | 243 .1 | 512 .3 | 486 .3 | 461 .8 | 474 .9 | 505 .1 |
| 6.5 | 66. 2 | 57. 4 | 53. 2 | 53 | 53. 7 | 132 .2 | 117 .3 | 107 .1 | 109 .2 | 107 .7 | 267 .5 | 234 .9 | 236 .1 | 220 .7 | 234 .8 | 598 .2 | 526 .3 | 495 .9 | 440 .2 | 492 .5 |
| 7 | 63. 7 | 57. 2 | 53. 6 | 52. 9 | 53. 3 | 132 .5 | 116 .7 | 106 .8 | 108 .8 | 106 .6 | 266 .5 | 236 .1 | 227 .4 | 217 .6 | 230 .1 | 560 .7 | 491 .8 | 469 .7 | 445 .8 | 622 .9 |
| 7.5 | 63. 6 | 57. 2 | 53. 1 | 52. 8 | 54 | 131 .8 | 117 .1 | 107 .1 | 107 .6 | 109 .5 | 266 .4 | 235 .4 | 226 .5 | 215 .3 | 228 | 575 .8 | 489 .3 | 450 .8 | 439 .8 | 461 .1 |
| 8 | 64 | 57. 4 | 53. 1 | 52. 7 | 53. 1 | 132 .8 | 117 .6 | 106 .2 | 108 | 110 .5 | 267 .6 | 232 .6 | 223 .9 | 216 .8 | 231 .8 | 574 .8 | 489 .7 | 438 .9 | 438 .8 | 463 .6 |
| 8.5 | 63. 6 | 57 | 52. 6 | 52. 8 | 52. 9 | 131 .6 | 116 .7 | 106 .5 | 108 .8 | 108 .9 | 267 .2 | 231 .7 | 231 .7 | 216 .6 | 234 .7 | 621 .3 | 492 .6 | 441 .8 | 447 .1 | 485 |
| 9 | 63. 9 | 57 57 | 53 53 | 52. 8 | 53. 2 | 132 .8 | 116 .8 | 109 .6 | 108 .5 | 107 | 267 .4 | 232 .7 | 225 .3 | 214 .2 | 228 .1 | 569 .4 | 482 .3 | 441 .1 | 439 | 490 .3 |
| 9.5 | 63. 3 | 57. 3 | 53. 2 | 52. 7 | 53. 2 | 131 .7 | 117 .7 | 107 .9 | 108 .8 | 109 .1 | 267 | 231 .6 | 228 .1 | 216 .3 | 227 .2 | 569 .5 | 487 .1 | 450 .4 | 440 .7 | 465 .5 |
| 10 | 63. 8 | 56. 6 | 52. 9 | 52. 7 | 53. 6 | 132 .6 | 117 .2 | 110 .7 | 108 .7 | 108 .6 | 266 .8 | 236 .8 | 224 .6 | 219 .7 | 228 .6 | 581 .7 | 491 .1 | 441 .6 | 439 .9 | 665 .6 |
| 10.5 | 63. 3 | 57. 2 | 52. 8 | 52. 4 | 52. 8 | 131 .6 | 116 .9 | 116 | 107 .1 | 107 .6 | 273 .9 | 240 .5 | 224 .8 | 216 .9 | 228 .9 | 585 .2 | 488 .3 | 496 .2 | 443 .9 | 522 .7 |
| 11 | 63. 5 | 57 | 52. 3 | 52. 3 | 53 53 | 133 .3 | 116 .5 | 113 .8 | 115 .2 | 107 .5 | 279 .1 | 248 .8 | 224 .2 | 213 .5 | 226 | 630 .1 | 493 .4 | 450 .3 | 456 .3 | 492 .5 |
| 11.5 | 64 | 57 | 51. 8 | 51. 9 | 53. 9 | 131 .3 | 117 .7 | 115 .6 | 108 .5 | 106 .8 | 276 .5 | 250 .4 | 224 .4 | 222 .6 | 228 .4 | 577 .3 | 490 .6 | 442 .2 | 445 .3 | 473 .5 |
| 12 | 63 | 58. 9 | 52. 8 | 52. 6 | 53 | 131 .8 | 116 .7 | 117 .2 | 108 .7 | 107 .3 | 274 .4 | 275 .6 | 225 .9 | 218 .5 | 227 .7 | 586 .7 | 486 .1 | 445 .1 | 456 .5 | 500 .1 |
| 12.5 | 63. 7 | 57. 9 | 52. 3 | 52. 2 | 52. 7 | 131 .9 | 116 .7 | 106 .3 | 108 | 106 .6 | 270 .3 | 242 .8 | 223 .9 | 219 .6 | 224 .3 | 581 .2 | 491 .9 | 442 .3 | 449 .8 | 453 .3 |
| 13 | 72. 9 | 58. 5 | 52. 2 | 51. 7 | 52. 3 | 151 .2 | 119 .7 | 101 .8 | 101 .7 | 102 .7 | 311 .2 | 252 .5 | 216 .3 | 205 .8 | 231 .3 | 717 | 567 .8 | 495 .1 | 529 | 541 |
| 13.5 | 71. 6 | 58. 3 | 51. 9 | 53. 4 | 52. 7 | 148 .6 | 119 .6 | 102 .9 | 102 .8 | 103 .2 | 306 .5 | 253 .9 | 212 .5 | 205 .8 | 214 .3 | 717 .7 | 527 .8 | 473 .4 | 536 .5 | 527 .6 |
| 14 | 71. 2 | 58. 2 | 51. 6 | 52 | 55. 7 | 149 .4 | 120 | 104 .5 | 102 .2 | 111 .8 | 313 .9 | 252 .1 | 210 | 205 .1 | 214 .5 | 683 .2 | 551 .4 | 491 .1 | 547 | 552 .6 |
| 14. | 71. | 58. | 51. | 51. | 91 | 149 | 119 | 102 | 102 | 113 | 304 | 251 | 214 | 204 | 224 | 724 | 560 | 501 | 554 | 608 |

| | | | | | | | | | | | | | | | | | | | | |
|------------------|----------|----------|-----------|-----------|-----------|-----------|-----------|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 5 | 8 | 1 | 9 | 5 | | .5 | .6 | .3 | .3 | .6 | .8 | .2 | .9 | .6 | .9 | .3 | .9 | .1 | .1 | .5 |
| 15 | 72. 9 | 58 | 51. 7 | 51. 5 | 62. 5 | 154 | 120 .4 | 102 .5 | 102 .8 | 127 .9 | 300 .1 | 250 .1 | 215 .4 | 203 .2 | 232 .2 | 709 .8 | 566 .3 | 466 .9 | 552 .3 | 758 .7 |
| 15. 5 | 71 | 58. 4 | 51. 4 | 51. 7 | 58. 8 | 150 .6 | 120 .9 | 103 103 | 103 .9 | 216 .1 | 304 .6 | 251 | 229 .4 | 217 .2 | 255 .5 | 686 .2 | 551 .8 | 502 .8 | 503 .6 | 738 .9 |
| 16 | 70. 4 | 58. 2 | 51. 9 | 51. 6 | 56. 8 | 150 .7 | 120 | 102 .6 | 102 .2 | 168 .1 | 299 .7 | 250 .1 | 212 .3 | 209 .3 | 234 .6 | 684 | 564 .4 | 498 .1 | 661 .5 | 614 .5 |
| 16. 5 | 72. 2 | 58. 4 | 53. 52 | 52. 8 | 52. 2 | 150 | 119 .2 | 102 .2 | 102 .7 | 241 .4 | 301 .6 | 248 .8 | 212 .3 | 205 .2 | 232 .7 | 718 .5 | 543 .7 | 487 .3 | 636 | 629 .7 |
| 17 | 71. 7 | 59. 1 | 51. 9 | 52. 9 | 54. 8 | 149 .5 | 120 .5 | 103 .7 | 100 .8 | 180 .7 | 305 .7 | 257 .3 | 212 .8 | 206 .4 | 253 .1 | 725 .6 | 561 .2 | 496 .5 | 513 .7 | 635 .2 |
| 17. 5 | 71. 8 | 57. 9 | 51. 9 | 51. 51 | 52. 9 | 149 .5 | 120 .3 | 104 .1 | 103 .9 | 103 .3 | 299 .9 | 250 .6 | 210 .7 | 205 | 250 .7 | 683 .4 | 569 .4 | 492 | 525 .8 | 600 .6 |
| 18 | 72 | 58. 6 | 51. 8 | 52. 7 | 54. 3 | 147 .6 | 120 | 103 .2 | 106 .9 | 126 .8 | 299 .5 | 262 .2 | 212 .5 | 206 .8 | 244 .3 | 747 .7 | 538 .8 | 478 .3 | 509 | 646 |
| 18. 5 | 71 | 58. 2 | 51. 8 | 52. 1 | 53. 4 | 149 .8 | 119 .4 | 105 108 | 109 .4 | 304 .7 | 266 .2 | 210 .5 | 206 .9 | 218 .8 | 218 .2 | 681 .4 | 539 .7 | 496 .9 | 517 .5 | 621 .7 |
| 19 | 71. 5 | 58. 8 | 52. 1 | 51. 7 | 52. 7 | 148 .3 | 120 .6 | 102 .3 | 103 .6 | 460 47 | 299 | 251 .3 | 210 .6 | 207 .6 | 220 .9 | 691 .4 | 538 .6 | 489 | 508 .7 | 634 .8 |
| 19. 5 | 71 | 58. 4 | 52. 7 | 51. 3 | 52. 4 | 154 .6 | 119 .9 | 102 .5 | 103 | 227 .7 | 298 .8 | 252 .6 | 209 .4 | 206 .3 | 221 .1 | 675 | 550 .2 | 468 .3 | 459 .7 | 633 .1 |
| 20 | 70. 7 | 58. 1 | 51. 7 | 51. 9 | 175 .4 | 149 .6 | 119 .4 | 101 .4 | 104 .9 | 255 .3 | 301 .2 | 251 | 212 .3 | 205 .4 | 211 .5 | 690 .7 | 541 .3 | 510 .9 | 516 | 650 .4 |