

Program Structures and Algorithms
Spring 2023(SEC –1)

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Task

- 1.A cutoff (defaults to, say, 1000) which you will update according to the first argument in the command line when running. It's your job to experiment and come up with a good value for this cutoff. If there are fewer elements to sort than the cutoff, then you should use the system sort instead.
- 2.Recursion depth or the number of available threads. Using this determination, you might decide on an ideal number (t) of separate threads (stick to powers of 2) and arrange for that number of partitions to be parallelized (by preventing recursion after the depth of $\lg t$ is reached).
- 3.An appropriate combination of these.

Relationship Conclusion

During the experiment, it was observed that increasing the number of threads used did not result in significant performance improvements beyond a certain point, even when the cut-off values were kept the same. For instance, increasing the number of threads from 16 to 32 did not yield noticeable benefits. It was found that setting the cut-off value to half of the array size produced reasonably good results. It was found that from 16 threads the running time started give almost constant results. After cut-off value of more than half of the array size running time increased was gave almost constant results. The values obtained varies from computer to computer depending on the number of cores the processor has.

Evidence to support that conclusion

The conclusion is based on evidence gathered from an experiment, which is presented in the form of an Excel sheet. The data from the experiment supports the conclusion that has been drawn.

Data Obtained for array size of 2 million

| Cut off | 2 Threads | 4 Threads | 8 Threads | 16 Threads | 32 Threads |
|---------|-----------|-----------|-----------|------------|------------|
| 100000 | 137.8 | 79.2 | 89.6 | 70.4 | 72 |
| 200000 | 75.2 | 72.5 | 77.2 | 63.9 | 64.9 |
| 300000 | 74.6 | 68.2 | 83 | 63.7 | 64.8 |
| 400000 | 70.2 | 73 | 74.5 | 63.1 | 64.9 |
| 500000 | 70.8 | 69.8 | 71.5 | 65.6 | 64.8 |
| 600000 | 67.9 | 69.3 | 70.2 | 65.8 | 64.2 |
| 700000 | 66.8 | 69.3 | 70.8 | 65.6 | 65 |
| 800000 | 67.4 | 69.2 | 70.4 | 65.6 | 65.8 |
| 900000 | 67.8 | 68.6 | 69.5 | 65.4 | 63.8 |
| 1000000 | 67.9 | 69.2 | 69.9 | 63.2 | 67 |
| 1100000 | 87.1 | 87.2 | 93.3 | 85.6 | 85.5 |
| 1200000 | 87.3 | 88.4 | 90.7 | 84.2 | 85.5 |
| 1300000 | 92.6 | 87.2 | 88.7 | 82.3 | 84.5 |
| 1400000 | 87.8 | 85.4 | 84.3 | 84.8 | 83.2 |
| 1500000 | 86.1 | 86.9 | 86.3 | 84.3 | 83 |
| 1600000 | 88.3 | 88.1 | 86.7 | 84.9 | 85.6 |
| 1700000 | 86.7 | 88 | 86.2 | 86.2 | 85 |
| 1800000 | 85.9 | 88.3 | 85.1 | 83.4 | 84.7 |
| 1900000 | 86 | 88.8 | 84.5 | 86.1 | 83.3 |
| 2000000 | 86.1 | 86.7 | 85.9 | 84.2 | 84.5 |

Data obtained for array size of 3 million

| Cutoff | 2 Threads | 4 Threads | 8 Threads | 16 Threads | 32 Threads |
|---------|-----------|-----------|-----------|------------|------------|
| 100000 | 101.7 | 113.5 | 104.9 | 99.8 | 102 |
| 200000 | 97.9 | 99.4 | 100.7 | 98.5 | 98.4 |
| 300000 | 99.5 | 100.8 | 103 | 98.1 | 98.1 |
| 400000 | 100.6 | 102.7 | 112.5 | 99.8 | 103.7 |
| 500000 | 102.9 | 103.1 | 107.5 | 99.2 | 107.7 |
| 600000 | 102.1 | 104.5 | 102.9 | 104.6 | 108.6 |
| 700000 | 104.1 | 104 | 104.4 | 99.7 | 107.7 |
| 800000 | 101.7 | 102.4 | 101.5 | 101.3 | 108 |
| 900000 | 100.7 | 101.1 | 102.4 | 100.6 | 107.9 |
| 1000000 | 99.4 | 103.6 | 103.5 | 101.3 | 107.5 |
| 1100000 | 101.6 | 103.2 | 101 | 101.6 | 111.2 |
| 1200000 | 102.7 | 101.4 | 101.1 | 100.9 | 109.2 |
| 1300000 | 109.2 | 100.7 | 102.6 | 100.7 | 108.1 |
| 1400000 | 113.8 | 100.9 | 105.8 | 103.5 | 108.7 |
| 1500000 | 107.2 | 100.1 | 103.4 | 101.3 | 110.7 |
| 1600000 | 138.1 | 134.4 | 136.8 | 134 | 135.2 |
| 1700000 | 141.1 | 132.7 | 135.2 | 131.4 | 135.1 |
| 1800000 | 132.3 | 131.2 | 133.5 | 132.7 | 135.1 |
| 1900000 | 133.2 | 131.7 | 137.4 | 130 | 135 |
| 2000000 | 130.1 | 131.2 | 132.9 | 133.3 | 139.5 |
| 2100000 | 132 | 136.5 | 135 | 130.1 | 136.2 |
| 2200000 | 132.2 | 132.6 | 132.3 | 134 | 134.5 |
| 2300000 | 130.4 | 142.4 | 135.6 | 132.5 | 136.2 |
| 2400000 | 148.2 | 135 | 134 | 131.5 | 145.6 |
| 2500000 | 141 | 145.6 | 131.9 | 132 | 134.4 |
| 2600000 | 133.1 | 145.4 | 133.8 | 132.1 | 138.7 |
| 2700000 | 133.7 | 135.3 | 133.4 | 133.3 | 141.3 |
| 2800000 | 135.7 | 133.8 | 134.1 | 130 | 140.3 |
| 2900000 | 133.6 | 133.1 | 133.2 | 129.4 | 135.5 |
| 3000000 | 131.6 | 140.9 | 132.3 | 128.4 | 136.2 |

Data obtained for array size of 4 million

| Cutoff | 2 Threads | 4 threads | 8 threads | 16 Threads | 32 Threads |
|---------|-----------|-----------|-----------|------------|------------|
| 100000 | 161.3 | 154.7 | 172.3 | 172.5 | 186.6 |
| 200000 | 149.5 | 147 | 156.3 | 161.5 | 155.5 |
| 300000 | 146.3 | 149.9 | 151 | 155.9 | 150 |
| 400000 | 153.3 | 147.4 | 149.6 | 156.6 | 148.1 |
| 500000 | 161.1 | 149.4 | 145.3 | 149.5 | 149.5 |
| 600000 | 153.4 | 152.2 | 150 | 154.2 | 152 |
| 700000 | 150.8 | 149.7 | 150.6 | 158.7 | 151.2 |
| 800000 | 149.3 | 150.8 | 152.7 | 162.3 | 159.9 |
| 900000 | 153.6 | 147.2 | 152.6 | 166.8 | 155.1 |
| 1000000 | 153.1 | 156 | 146.6 | 159.7 | 153.4 |
| 1100000 | 150.1 | 148.9 | 149.1 | 154.8 | 151.6 |
| 1200000 | 156.4 | 150.9 | 146.2 | 154.6 | 154.2 |
| 1300000 | 151.7 | 150 | 149.6 | 150.7 | 153.4 |
| 1400000 | 149.4 | 148.6 | 154.8 | 155.9 | 155.6 |
| 1500000 | 151.2 | 149.9 | 149.3 | 155.7 | 162.1 |
| 1600000 | 154.5 | 147.9 | 156.4 | 151.8 | 176.8 |
| 1700000 | 154.2 | 147.9 | 150.4 | 151.4 | 169.2 |
| 1800000 | 152.3 | 145.7 | 146.9 | 151.3 | 167.2 |
| 1900000 | 149.1 | 147.7 | 148.1 | 153.8 | 170.5 |
| 2000000 | 150.3 | 147.3 | 162.3 | 152.1 | 169.2 |
| 2100000 | 184 | 182.7 | 204.5 | 185.5 | 202.7 |
| 2200000 | 182.9 | 182 | 194.6 | 186.7 | 199.3 |
| 2300000 | 183.7 | 183 | 185.3 | 189.3 | 199.4 |
| 2400000 | 186.9 | 183.9 | 185.2 | 190.5 | 189.8 |
| 2500000 | 191.1 | 196.6 | 187 | 191 | 188.7 |
| 2600000 | 181.9 | 180.3 | 187.7 | 189.2 | 188.9 |
| 2700000 | 183.5 | 182.7 | 187.7 | 196 | 185.1 |
| 2800000 | 182.9 | 179 | 186.5 | 189.5 | 183.2 |
| 2900000 | 182.5 | 180.2 | 190.9 | 197.2 | 187.4 |
| 3000000 | 181.5 | 181.5 | 184 | 189.8 | 187.9 |
| 3100000 | 185.1 | 183.8 | 191.9 | 195.8 | 186.3 |
| 3200000 | 181.8 | 180.1 | 189.9 | 191.9 | 189.5 |
| 3300000 | 181.7 | 181.1 | 183.6 | 192.9 | 191.6 |
| 3400000 | 186.5 | 179.3 | 183.5 | 192.6 | 190.7 |
| 3500000 | 182.6 | 179.1 | 182 | 193.6 | 188.5 |
| 3600000 | 185.3 | 180.1 | 184.7 | 195.1 | 190.5 |
| 3700000 | 183 | 179.5 | 184.1 | 206.9 | 190.1 |
| 3800000 | 181.4 | 181.2 | 188.2 | 195.1 | 201.2 |
| 3900000 | 183.2 | 180.1 | 188.6 | 193.6 | 202.7 |
| 4000000 | 181 | 188 | 182.4 | 193.4 | 191.4 |

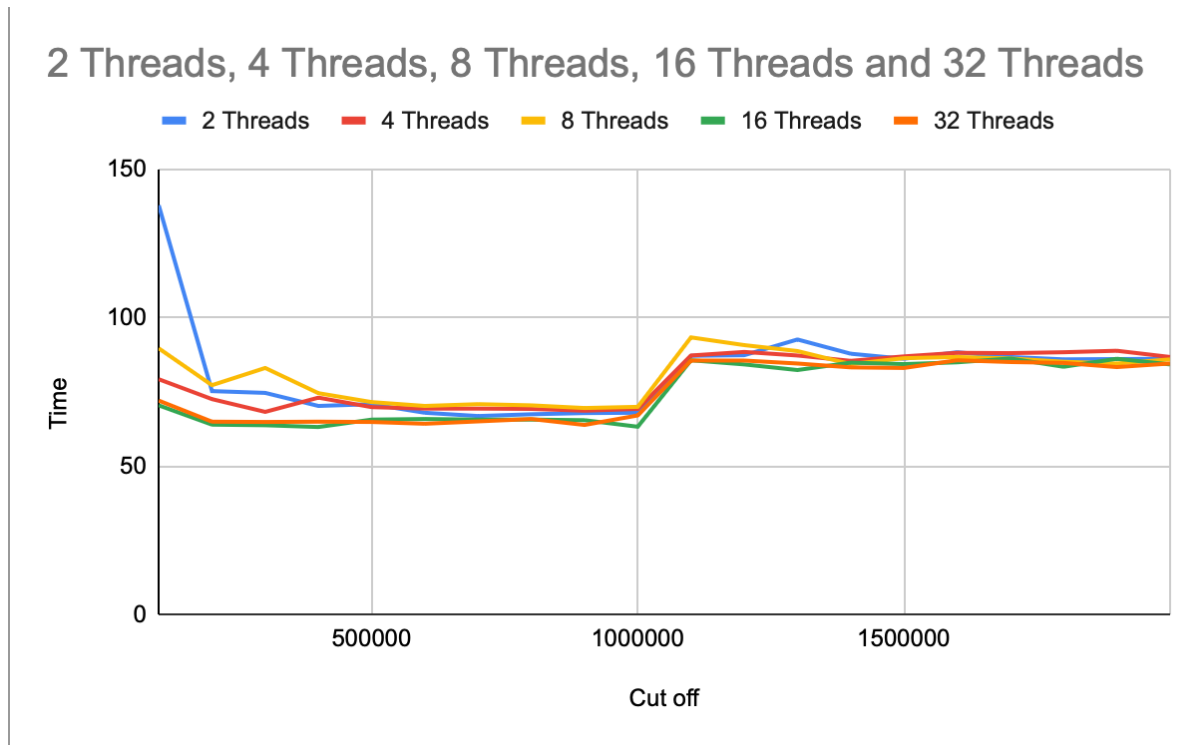
Data obtained for array size of 5 million

| Cutt off | 2 Threads | 4 Threads | 8 Threads | 16 Threads | 32 Threads |
|----------|-----------|-----------|-----------|------------|------------|
| 100000 | 228 | 249.7 | 242.4 | 217 | 218.4 |
| 200000 | 192 | 219.7 | 201.2 | 205 | 205.7 |
| 300000 | 201.8 | 220.8 | 195.6 | 234.1 | 199.5 |
| 400000 | 199.5 | 203.6 | 218.3 | 220 | 225.3 |
| 500000 | 204.2 | 203 | 200.6 | 226.6 | 199.9 |
| 600000 | 196.6 | 198.8 | 188.7 | 208.2 | 192.7 |
| 700000 | 193.5 | 209.3 | 192.6 | 193.9 | 193.3 |
| 800000 | 195.7 | 206.9 | 194.9 | 199.1 | 193.6 |
| 900000 | 199.2 | 200.3 | 194.2 | 201.6 | 190.2 |
| 1000000 | 202.2 | 201.6 | 214 | 191.6 | 252.8 |
| 1100000 | 203.7 | 207.2 | 211.5 | 194.3 | 212.1 |
| 1200000 | 207.4 | 201.7 | 215.4 | 194.5 | 218.3 |
| 1300000 | 201.8 | 199 | 207.5 | 199.3 | 194.3 |
| 1400000 | 193 | 200.2 | 204.4 | 193 | 194 |
| 1500000 | 196.3 | 202.3 | 198.4 | 200.4 | 202.7 |
| 1600000 | 195.1 | 198.8 | 189.6 | 200.2 | 186.6 |
| 1700000 | 202 | 195.3 | 195.3 | 206.5 | 191.2 |
| 1800000 | 210.2 | 196.5 | 190.3 | 228.6 | 191.4 |
| 1900000 | 218.1 | 199.4 | 207 | 205.3 | 187.8 |
| 2000000 | 258.2 | 196.6 | 216.2 | 234.2 | 195.5 |
| 2100000 | 214.3 | 201.1 | 204.2 | 269 | 202.4 |
| 2200000 | 200.4 | 200.3 | 211.7 | 290.9 | 198.3 |
| 2300000 | 191.6 | 199.2 | 214.3 | 270 | 197.8 |
| 2400000 | 193.1 | 199.8 | 210.7 | 217.4 | 215.1 |
| 2500000 | 190.4 | 205.7 | 205.3 | 209.9 | 240 |
| 2600000 | 238.1 | 249.7 | 237.3 | 244.2 | 253.4 |
| 2700000 | 259.1 | 245.3 | 235.9 | 246 | 243.9 |
| 2800000 | 250.7 | 261.5 | 244 | 241.4 | 242.9 |
| 2900000 | 240 | 245.2 | 238.6 | 239.4 | 239 |
| 3000000 | 244.8 | 241 | 243.6 | 244.2 | 241.4 |
| 3100000 | 242 | 245.8 | 239.5 | 245.2 | 233.4 |
| 3200000 | 245.4 | 248.6 | 242.4 | 246.2 | 234.4 |
| 3300000 | 252.8 | 255.4 | 238.4 | 253.9 | 249.6 |
| 3400000 | 256.7 | 243.8 | 242.4 | 243.4 | 237.9 |
| 3500000 | 251.6 | 250.6 | 241 | 247.5 | 232.4 |
| 3600000 | 244.1 | 241.3 | 249.1 | 249.4 | 230.1 |
| 3700000 | 241.1 | 243 | 243.8 | 243 | 232.3 |
| 3800000 | 243.9 | 250.2 | 240 | 249.9 | 232.8 |
| 3900000 | 248.3 | 245.6 | 239.4 | 243.7 | 231.4 |
| 4000000 | 251.2 | 243 | 243.3 | 246.2 | 230.3 |
| 4100000 | 246 | 248.4 | 244.4 | 239.9 | 233.6 |
| 4200000 | 244.9 | 247.3 | 245.6 | 251.5 | 237.1 |
| 4300000 | 244.7 | 242.3 | 240.7 | 244.6 | 234.7 |
| 4400000 | 247.1 | 245.5 | 241.6 | 243.2 | 238.9 |
| 4500000 | 249.8 | 245.5 | 248.2 | 242.7 | 229.3 |
| 4600000 | 244.8 | 247.1 | 321 | 243.6 | 238.5 |
| 4700000 | 250.5 | 241.9 | 249 | 234.8 | 236.3 |
| 4800000 | 248.6 | 238.6 | 246.7 | 237.2 | 235.2 |
| 4900000 | 250.5 | 246.1 | 244.1 | 235.1 | 232.8 |
| 5000000 | 248.6 | 249.5 | 237.3 | 239.1 | 233.2 |

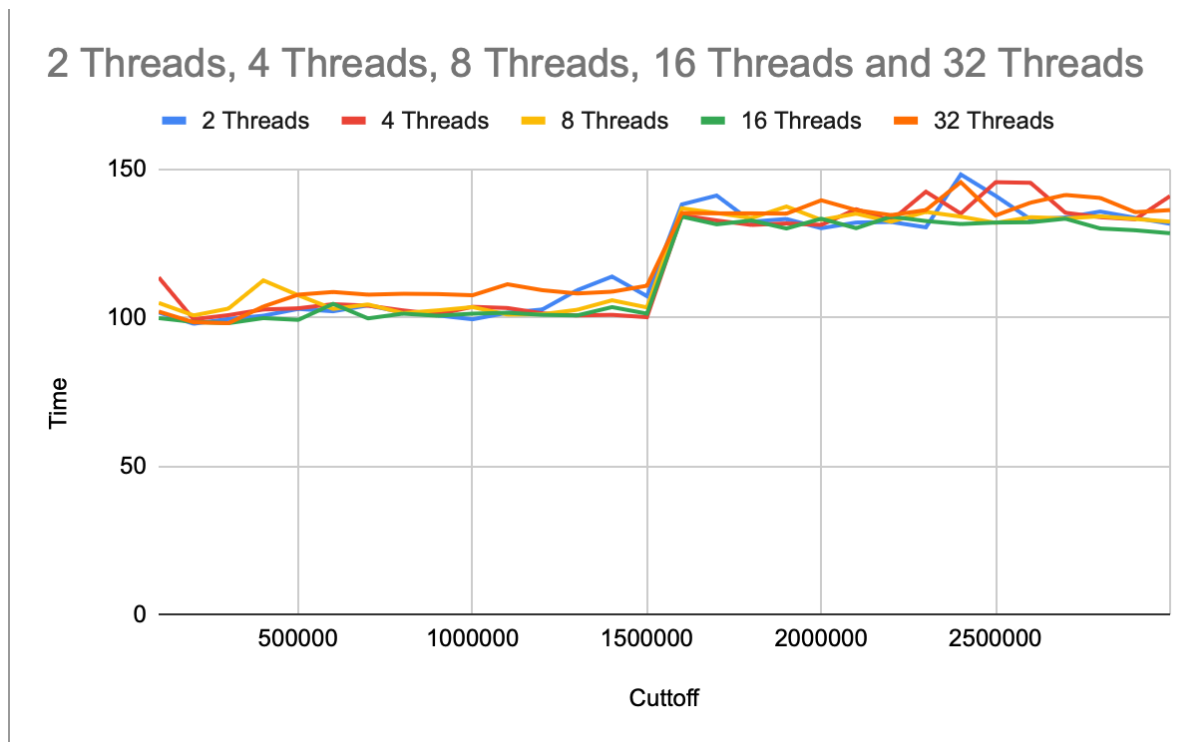
Graphical Representation

Below is the graphs obtained by plotting cutoff vs Execution time on x axis and y axis respectively.

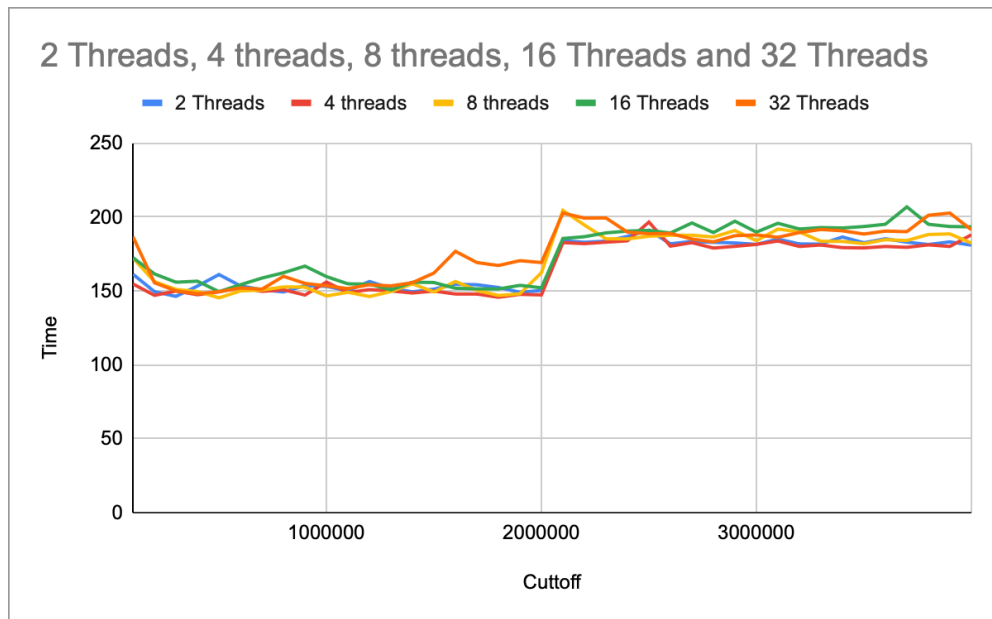
Graph obtained for array size of 2 million



Graph obtained for array size of 3 million



Graph obtained for array size of 4 million



Graph obtained for array size of 5 million

