General trend of: time vs. size of list to search for Processes as well as time vs. size of list to search for threads

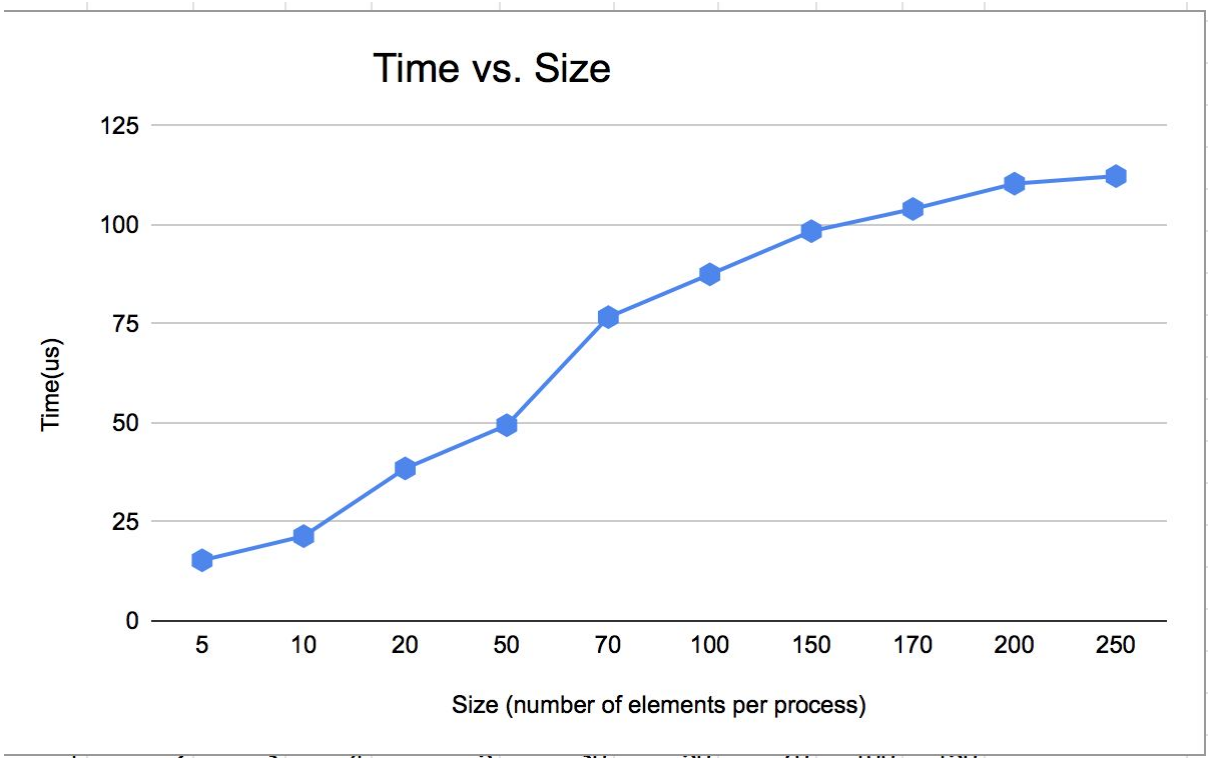
1. Time vs. number of elements per process/thread

Measure the effect of changing the number of elements searched per process/thread on time [number of elements per process/thread vs time]

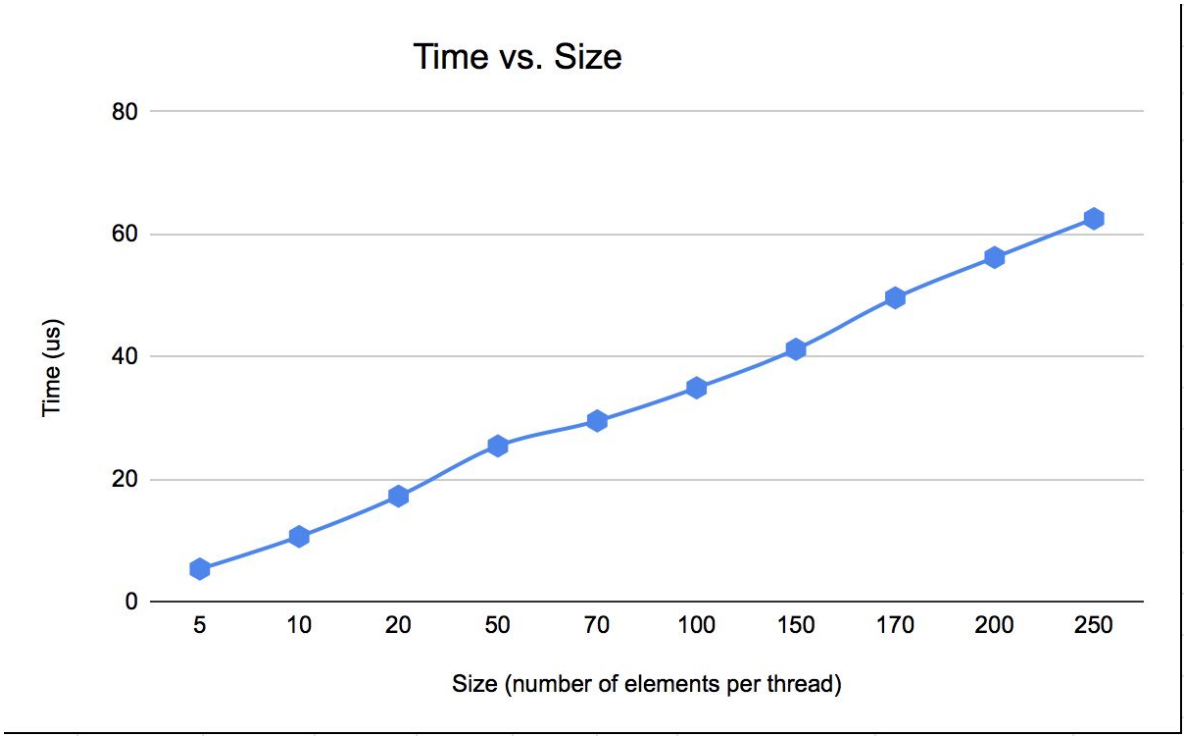
We ran ten different 1a- 1j tests for different number of elements per process/thread.
For the ten tests, we only had one process/thread and we recorded the time as we change the number of elements per process/thread (array size). We ran each test for 30 iterations and recorded the average time for each iteration. We came up with those ten tests to be able to find a relation between the number of elements per process/thread and the time. After we ran the test, we found that the time increases (almost linearly) with increasing the number of elements per process/thread excluding any switching between processes and threads.

Test number	Array size	Number of elements per process/thread	Avg time(us) for process	Avg time(us) for thread
1a	5	5	15.3	5.3
1b	10	10	21.4	10.6
1c	20	20	38.5	17.2
1d	50	50	49.4	25.4
1e	70	70	76.7	29.5
1f	100	100	87.5	34.9
1g	150	150	98.4	41.2
1h	170	170	104	49.6
1i	200	200	110.4	56.2
1j	250	250	112.03	62.53

Table(1): The data collected from running tests 1a - 1j using both the process and thread versions



fig(1): The relation between increasing the number of elements per process and time



fig(1): The relation between increasing the number of elements per thread and time

Below are screenshots of some of the tests to show how output should be printed

```
Test(1) j
-process mode
parameters of the test:
   -number of elements per process : 250
   -number of process created: 1
   -Array size: 250

(iteration: 0) Found element 210 at index 210 in process 0 , time=119 microseconds
(iteration: 1) Found element 210 at index 117 in process 0 , time=129 microseconds
(iteration: 2) Found element 210 at index 158 in process 0 , time=114 microseconds
(iteration: 3) Found element 210 at index 136 in process 0 , time=111 microseconds
(iteration: 4) Found element 210 at index 90 in process 0 , time=107 microseconds
(iteration: 5) Found element 210 at index 60 in process 0 , time=117 microseconds
(iteration: 6) Found element 210 at index 126 in process 0 , time=104 microseconds
(iteration: 7) Found element 210 at index 114 in process 0 , time=112 microseconds
(iteration: 8) Found element 210 at index 223 in process 0 , time=108 microseconds
(iteration: 9) Found element 210 at index 187 in process 0 , time=110 microseconds
(iteration: 10) Found element 210 at index 115 in process 0 , time=105 microseconds
(iteration: 11) Found element 210 at index 248 in process 0 , time=105 microseconds
(iteration: 12) Found element 210 at index 171 in process 0 , time=105 microseconds
(iteration: 13) Found element 210 at index 120 in process 0 , time=104 microseconds
(iteration: 14) Found element 210 at index 159 in process 0 , time=108 microseconds
(iteration: 15) Found element 210 at index 113 in process 0 , time=109 microseconds
(iteration: 16) Found element 210 at index 150 in process 0 , time=109 microseconds
(iteration: 17) Found element 210 at index 82 in process 0 , time=106 microseconds
(iteration: 18) Found element 210 at index 36 in process 0 , time=141 microseconds
(iteration: 19) Found element 210 at index 4 in process 0 , time=142 microseconds
(iteration: 20) Found element 210 at index 83 in process 0 , time=135 microseconds
(iteration: 21) Found element 210 at index 208 in process 0 , time=105 microseconds
(iteration: 22) Found element 210 at index 106 in process 0 , time=106 microseconds
(iteration: 23) Found element 210 at index 127 in process 0 , time=105 microseconds
(iteration: 24) Found element 210 at index 160 in process 0 , time=109 microseconds
(iteration: 25) Found element 210 at index 118 in process 0 , time=106 microseconds
(iteration: 26) Found element 210 at index 131 in process 0 , time=108 microseconds
(iteration: 27) Found element 210 at index 69 in process 0 , time=106 microseconds
(iteration: 28) Found element 210 at index 128 in process 0 , time=108 microseconds
(iteration: 29) Found element 210 at index 91 in process 0 , time=108 microseconds

Min = 104µs, Max = 142µs, Avg = 112.033333µs, Std Dev = 10.440307µs
```

```
Test(1) j
-thread mode
parameters of the test:
   -number of elements per thread : 250
   -number of thread created: 1
   -Array size: 250

(iteration: 0) Found 210 at index 210 in thread 0 , time=65 microseconds
(iteration: 1) Found 210 at index 117 in thread 0 , time=60 microseconds
(iteration: 2) Found 210 at index 158 in thread 0 , time=61 microseconds
(iteration: 3) Found 210 at index 136 in thread 0 , time=59 microseconds
(iteration: 4) Found 210 at index 90 in thread 0 , time=59 microseconds
(iteration: 5) Found 210 at index 60 in thread 0 , time=58 microseconds
(iteration: 6) Found 210 at index 126 in thread 0 , time=60 microseconds
(iteration: 7) Found 210 at index 114 in thread 0 , time=139 microseconds
(iteration: 8) Found 210 at index 223 in thread 0 , time=62 microseconds
(iteration: 9) Found 210 at index 187 in thread 0 , time=61 microseconds
(iteration: 10) Found 210 at index 115 in thread 0 , time=59 microseconds
(iteration: 11) Found 210 at index 248 in thread 0 , time=59 microseconds
(iteration: 12) Found 210 at index 171 in thread 0 , time=60 microseconds
(iteration: 13) Found 210 at index 120 in thread 0 , time=58 microseconds
(iteration: 14) Found 210 at index 159 in thread 0 , time=58 microseconds
(iteration: 15) Found 210 at index 113 in thread 0 , time=69 microseconds
(iteration: 16) Found 210 at index 150 in thread 0 , time=59 microseconds
(iteration: 17) Found 210 at index 82 in thread 0 , time=59 microseconds
(iteration: 18) Found 210 at index 36 in thread 0 , time=58 microseconds
(iteration: 19) Found 210 at index 4 in thread 0 , time=60 microseconds
(iteration: 20) Found 210 at index 83 in thread 0 , time=60 microseconds
(iteration: 21) Found 210 at index 208 in thread 0 , time=59 microseconds
(iteration: 22) Found 210 at index 106 in thread 0 , time=59 microseconds
(iteration: 23) Found 210 at index 127 in thread 0 , time=58 microseconds
(iteration: 24) Found 210 at index 160 in thread 0 , time=62 microseconds
(iteration: 25) Found 210 at index 118 in thread 0 , time=60 microseconds
(iteration: 26) Found 210 at index 131 in thread 0 , time=59 microseconds
(iteration: 27) Found 210 at index 69 in thread 0 , time=59 microseconds
(iteration: 28) Found 210 at index 128 in thread 0 , time=58 microseconds
(iteration: 29) Found 210 at index 91 in thread 0 , time=59 microseconds

Min = 58µs, Max = 139µs, Avg = 62.533333µs, Std Dev = 14.352700µs
```

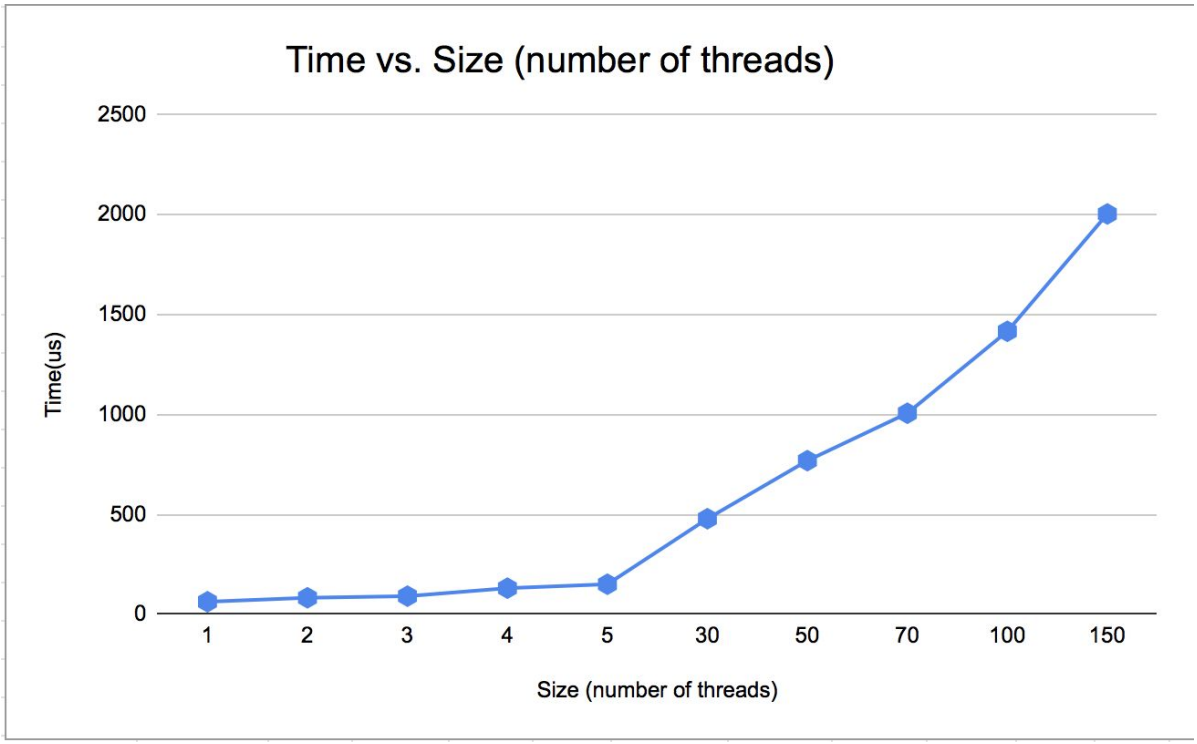
2. Time vs. number of processes/threads

Measure the effect of changing the number of processes/threads on time [number of processes/threads vs time]

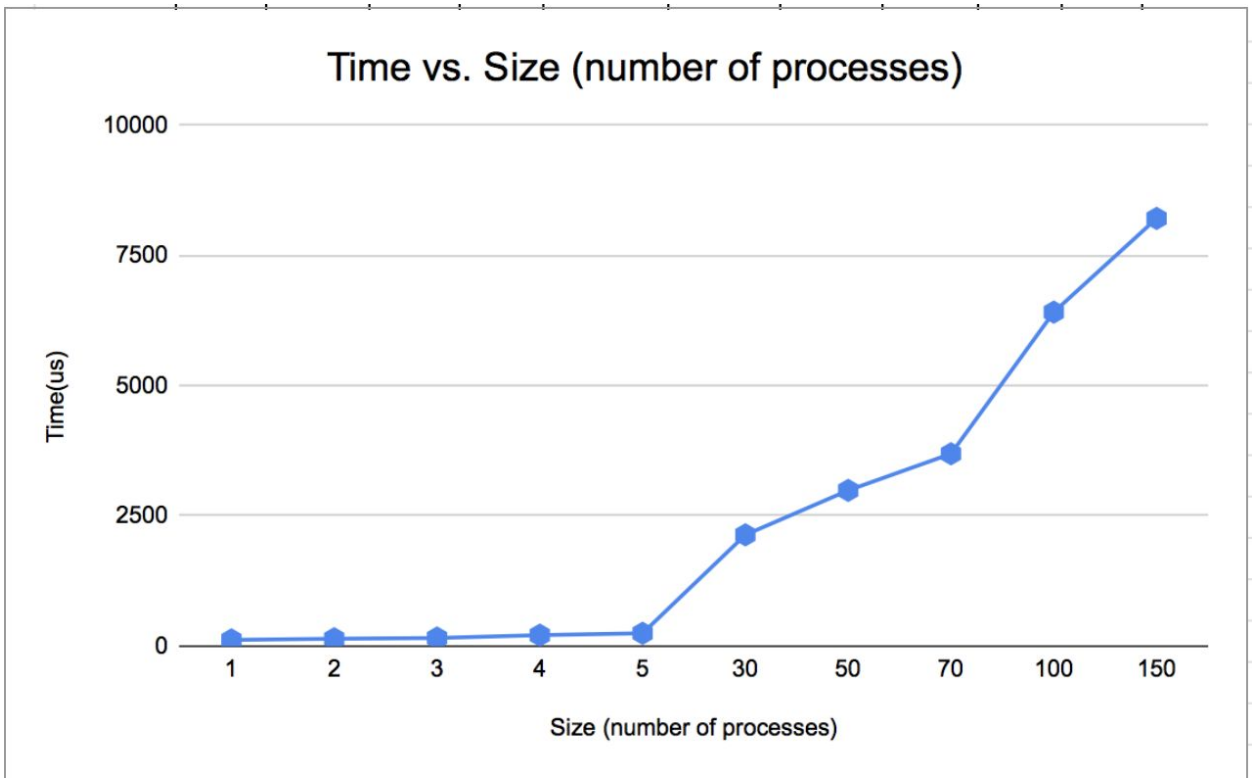
We ran ten different tests 2a- 2j for different number of process/thread.
For the ten tests, we have fixed the number of elements per process/thread to be 250 and we recorded the time as we changed the number of processes/threads (array size). We ran each test for 30 iterations and recorded the average time for each iteration. We came up with those ten tests to be able to find a relation between the number of processes/threads and the time. After running the tests, we found that increasing the number of processes/threads increases the time geometrically and not linearly alike the number of elements per process. Our reasoning behind that is the more processes we use to search an array, the more switching could occur, and therefore a large number of processes dramatically impacts the time as there are way more switching.

Test number	Array size	Number of process/thread	Avg time(us) for process	Avg time(us) for thread
2a	250	1	118.3	62.53
2b	500	2	135.5	82.4
2c	750	3	154.7	114.03
2d	1000	4	210.1	130.4
2e	1250	5	245.6	150.13
2f	7500	30	2134.53	477.63
2g	12500	50	2987.23	788.0
2h	17500	70	3689.87	1005.1
2i	25000	100	6407.98	1414.73
2j	37500	150	8206.067	2001.5

Table(2): The data collected from running tests 2a - 2j using both the process and thread versions



fig(3): The relation between increasing the number of threads and time with each thread searching 250 elements



fig(4): The relation between increasing the number of processes and time with each process searching 250 elements

Below are screenshots of some of the tests to show how output should be printed

```
Test(2) j
-process mode
parameters of the test:
   -number of elements per process : 250
   -number of process created: 150
   -Array size: 37500

(iteration: 0) Found element 2310 at index 35518 in process 142 , time=8376 microseconds
(iteration: 1) Found element 2310 at index 4188 in process 16 , time=7440 microseconds
(iteration: 2) Found element 2310 at index 33671 in process 134 , time=7675 microseconds
(iteration: 3) Found element 2310 at index 9129 in process 36 , time=12539 microseconds
(iteration: 4) Found element 2310 at index 26836 in process 107 , time=7879 microseconds
(iteration: 5) Found element 2310 at index 3777 in process 15 , time=9615 microseconds
(iteration: 6) Found element 2310 at index 24253 in process 97 , time=7664 microseconds
(iteration: 7) Found element 2310 at index 844 in process 3 , time=7311 microseconds
(iteration: 8) Found element 2310 at index 10855 in process 43 , time=8184 microseconds
(iteration: 9) Found element 2310 at index 31117 in process 124 , time=9287 microseconds
(iteration: 10) Found element 2310 at index 21765 in process 87 , time=7740 microseconds
(iteration: 11) Found element 2310 at index 31659 in process 126 , time=7510 microseconds
(iteration: 12) Found element 2310 at index 7295 in process 29 , time=7681 microseconds
(iteration: 13) Found element 2310 at index 12281 in process 49 , time=8641 microseconds
(iteration: 14) Found element 2310 at index 11160 in process 44 , time=8052 microseconds
(iteration: 15) Found element 2310 at index 20222 in process 80 , time=7364 microseconds
(iteration: 16) Found element 2310 at index 26869 in process 107 , time=7457 microseconds
(iteration: 17) Found element 2310 at index 36985 in process 147 , time=8766 microseconds
(iteration: 18) Found element 2310 at index 3460 in process 13 , time=8240 microseconds
(iteration: 19) Found element 2310 at index 5103 in process 20 , time=7935 microseconds
(iteration: 20) Found element 2310 at index 23902 in process 95 , time=7297 microseconds
(iteration: 21) Found element 2310 at index 20960 in process 83 , time=8255 microseconds
(iteration: 22) Found element 2310 at index 13138 in process 52 , time=8635 microseconds
(iteration: 23) Found element 2310 at index 19506 in process 78 , time=7942 microseconds
(iteration: 24) Found element 2310 at index 345 in process 1 , time=7302 microseconds
(iteration: 25) Found element 2310 at index 34836 in process 139 , time=8848 microseconds
(iteration: 26) Found element 2310 at index 33401 in process 133 , time=8715 microseconds
(iteration: 27) Found element 2310 at index 16272 in process 65 , time=7830 microseconds
(iteration: 28) Found element 2310 at index 5983 in process 23 , time=7704 microseconds
(iteration: 29) Found element 2310 at index 6290 in process 25 , time=8298 microseconds

Min = 7297µs, Max = 12539µs, Avg = 8206.066667µs, Std Dev = 997.489348µs
```

```
Test(2) j
-thread mode
parameters of the test:
   -number of elements per thread : 250
   -number of thread created: 150
   -Array size: 37500

(iteration: 0) Found 2310 at index 35518 in thread 142 , time=2122 microseconds
(iteration: 1) Found 2310 at index 4188 in thread 16 , time=2008 microseconds
(iteration: 2) Found 2310 at index 33671 in thread 134 , time=2037 microseconds
(iteration: 3) Found 2310 at index 9129 in thread 36 , time=1932 microseconds
(iteration: 4) Found 2310 at index 26836 in thread 107 , time=2000 microseconds
(iteration: 5) Found 2310 at index 3777 in thread 15 , time=1998 microseconds
(iteration: 6) Found 2310 at index 24253 in thread 97 , time=1876 microseconds
(iteration: 7) Found 2310 at index 844 in thread 3 , time=2140 microseconds
(iteration: 8) Found 2310 at index 10855 in thread 43 , time=2044 microseconds
(iteration: 9) Found 2310 at index 31117 in thread 124 , time=2024 microseconds
(iteration: 10) Found 2310 at index 21765 in thread 87 , time=2128 microseconds
(iteration: 11) Found 2310 at index 31659 in thread 126 , time=1882 microseconds
(iteration: 12) Found 2310 at index 7295 in thread 29 , time=1932 microseconds
(iteration: 13) Found 2310 at index 12281 in thread 49 , time=2030 microseconds
(iteration: 14) Found 2310 at index 11160 in thread 44 , time=1914 microseconds
(iteration: 15) Found 2310 at index 20222 in thread 80 , time=1903 microseconds
(iteration: 16) Found 2310 at index 26869 in thread 107 , time=2007 microseconds
(iteration: 17) Found 2310 at index 36985 in thread 147 , time=2013 microseconds
(iteration: 18) Found 2310 at index 3460 in thread 13 , time=1908 microseconds
(iteration: 19) Found 2310 at index 5103 in thread 20 , time=1991 microseconds
(iteration: 20) Found 2310 at index 23902 in thread 95 , time=2019 microseconds
(iteration: 21) Found 2310 at index 20960 in thread 83 , time=2045 microseconds
(iteration: 22) Found 2310 at index 13138 in thread 52 , time=1914 microseconds
(iteration: 23) Found 2310 at index 19506 in thread 78 , time=2049 microseconds
(iteration: 24) Found 2310 at index 345 in thread 1 , time=2065 microseconds
(iteration: 25) Found 2310 at index 34836 in thread 139 , time=1978 microseconds
(iteration: 26) Found 2310 at index 33401 in thread 133 , time=2055 microseconds
(iteration: 27) Found 2310 at index 16272 in thread 65 , time=2048 microseconds
(iteration: 28) Found 2310 at index 5983 in thread 23 , time=2028 microseconds
(iteration: 29) Found 2310 at index 6290 in thread 25 , time=1955 microseconds

Min = 1876µs, Max = 2140µs, Avg = 2001.500000µs, Std Dev = 69.469418µs
```

A tradeoff point for Processes vs threads

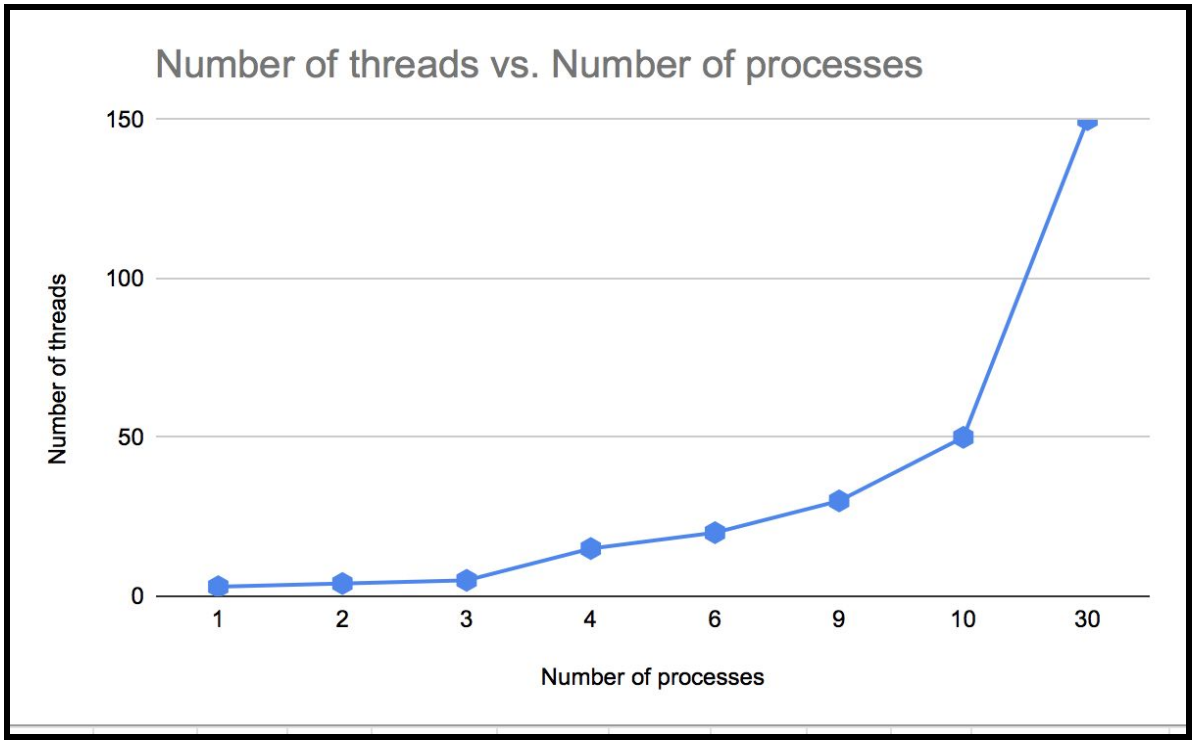
One process vs multiple threads with 250 elements per thread/process.

Running tests 3a to 3h, we got the following data in the table that helped us come up with the tradeoff point for processes and threads.

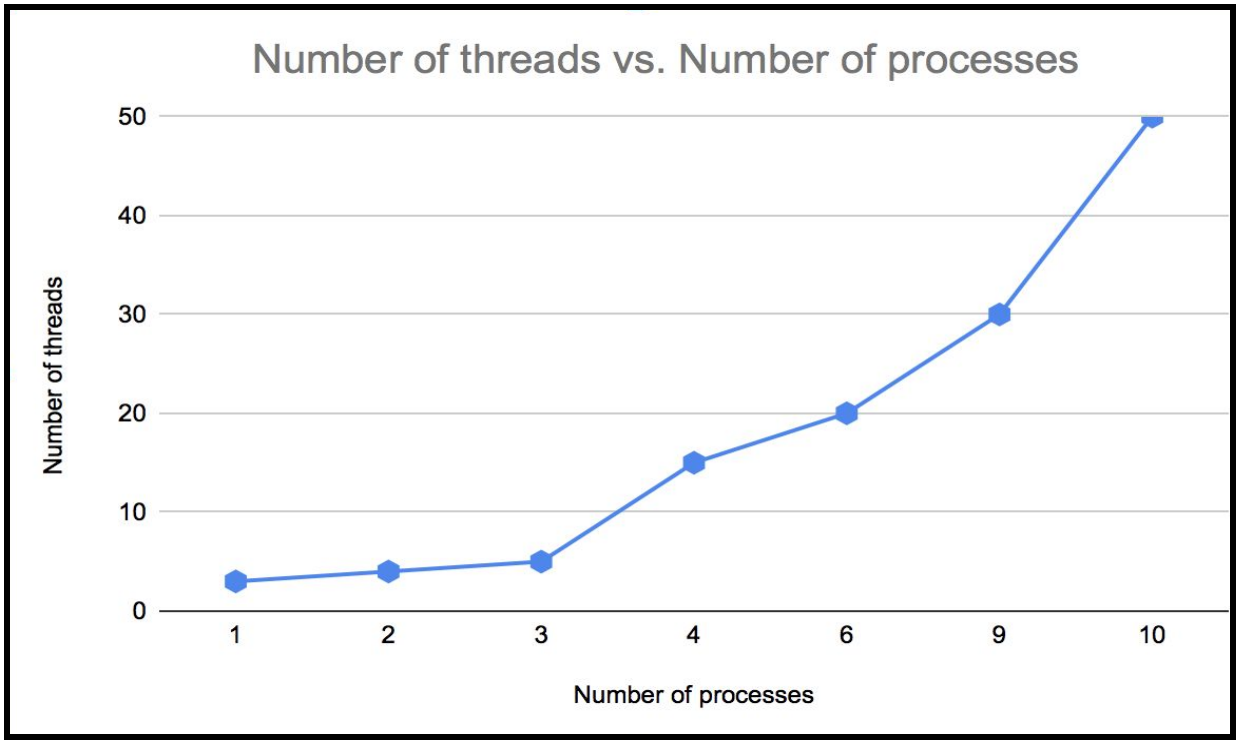
When running these tests, we found that as increasing the number of processes to search an array, the number of threads that give equivalent time increases geometrically(almost exponentially for large number of processes). We think this is because the more we increase the number of processes, the more switching between processes will occur which will dramatically increase the time for these processes to finish. As a result the number of threads becomes huge. In the first graph, for the small number of processes, the number of threads are definitely increasing but not at the same rate as for large number of processes in the second graph.

Process			Threads	
Test number	Number of processes	Array Size	Equivalent number of threads	Array Size
3a	1	250	3	750
3b	2	500	4	1000
3c	3	750	5	1250
3d	4	1000	15	3750
3e	6	1500	20	5000
3f	9	2250	30	7500
3g	10	2500	50	12500
3h	30	7500	150	37500

Table(3): The data collected from running tests 3a - 3j using both the process and thread versions



fig(5): The relation between the number of processes and the number of threads with a fixed number of elements per process/thread



fig(6): The relation between the number of processes and the number of threads with a fixed number of elements per process/thread not including large number of processes

Below are screenshots of a test that highlight the tradeoff for processes and threads

1 process → 3 threads

```
Test(1) j
-process mode
parameters of the test:
   -number of elements per process : 250
   -number of process created: 1
   -Array size: 250

(iteration: 0) Found element 210 at index 69 in process 0 , time=108 microseconds
(iteration: 1) Found element 210 at index 0 in process 0 , time=107 microseconds
(iteration: 2) Found element 210 at index 181 in process 0 , time=106 microseconds
(iteration: 3) Found element 210 at index 147 in process 0 , time=128 microseconds
(iteration: 4) Found element 210 at index 38 in process 0 , time=122 microseconds
(iteration: 5) Found element 210 at index 159 in process 0 , time=109 microseconds
(iteration: 6) Found element 210 at index 151 in process 0 , time=105 microseconds
(iteration: 7) Found element 210 at index 35 in process 0 , time=107 microseconds
(iteration: 8) Found element 210 at index 134 in process 0 , time=106 microseconds
(iteration: 9) Found element 210 at index 89 in process 0 , time=106 microseconds
(iteration: 10) Found element 210 at index 192 in process 0 , time=108 microseconds
(iteration: 11) Found element 210 at index 215 in process 0 , time=107 microseconds
(iteration: 12) Found element 210 at index 127 in process 0 , time=110 microseconds
(iteration: 13) Found element 210 at index 4 in process 0 , time=104 microseconds
(iteration: 14) Found element 210 at index 129 in process 0 , time=107 microseconds
(iteration: 15) Found element 210 at index 49 in process 0 , time=117 microseconds
(iteration: 16) Found element 210 at index 214 in process 0 , time=112 microseconds
(iteration: 17) Found element 210 at index 35 in process 0 , time=115 microseconds
(iteration: 18) Found element 210 at index 179 in process 0 , time=113 microseconds
(iteration: 19) Found element 210 at index 93 in process 0 , time=114 microseconds
(iteration: 20) Found element 210 at index 85 in process 0 , time=146 microseconds
(iteration: 21) Found element 210 at index 177 in process 0 , time=116 microseconds
(iteration: 22) Found element 210 at index 150 in process 0 , time=119 microseconds
(iteration: 23) Found element 210 at index 238 in process 0 , time=116 microseconds
(iteration: 24) Found element 210 at index 221 in process 0 , time=117 microseconds
(iteration: 25) Found element 210 at index 199 in process 0 , time=111 microseconds
(iteration: 26) Found element 210 at index 39 in process 0 , time=128 microseconds
(iteration: 27) Found element 210 at index 117 in process 0 , time=161 microseconds
(iteration: 28) Found element 210 at index 238 in process 0 , time=113 microseconds
(iteration: 29) Found element 210 at index 42 in process 0 , time=113 microseconds

Min = 104µs, Max = 161µs, Avg = 115.033333µs, Std Dev = 12.083046µs
```

```
Test(2) c
-thread mode
parameters of the test:
   -number of elements per thread : 250
   -number of thread created: 3
   -Array size: 750

(iteration: 0) Found 300 at index 377 in thread 1 , time=140 microseconds
(iteration: 1) Found 300 at index 480 in thread 1 , time=148 microseconds
(iteration: 2) Found 300 at index 171 in thread 0 , time=213 microseconds
(iteration: 3) Found 300 at index 697 in thread 2 , time=105 microseconds
(iteration: 4) Found 300 at index 457 in thread 1 , time=98 microseconds
(iteration: 5) Found 300 at index 158 in thread 0 , time=91 microseconds
(iteration: 6) Found 300 at index 200 in thread 0 , time=114 microseconds
(iteration: 7) Found 300 at index 378 in thread 1 , time=123 microseconds
(iteration: 8) Found 300 at index 229 in thread 0 , time=96 microseconds
(iteration: 9) Found 300 at index 107 in thread 0 , time=124 microseconds
(iteration: 10) Found 300 at index 8 in thread 0 , time=90 microseconds
(iteration: 11) Found 300 at index 553 in thread 2 , time=127 microseconds
(iteration: 12) Found 300 at index 679 in thread 2 , time=237 microseconds
(iteration: 13) Found 300 at index 257 in thread 1 , time=166 microseconds
(iteration: 14) Found 300 at index 522 in thread 2 , time=122 microseconds
(iteration: 15) Found 300 at index 425 in thread 1 , time=96 microseconds
(iteration: 16) Found 300 at index 710 in thread 2 , time=90 microseconds
(iteration: 17) Found 300 at index 302 in thread 1 , time=85 microseconds
(iteration: 18) Found 300 at index 654 in thread 2 , time=87 microseconds
(iteration: 19) Found 300 at index 558 in thread 2 , time=121 microseconds
(iteration: 20) Found 300 at index 690 in thread 2 , time=96 microseconds
(iteration: 21) Found 300 at index 626 in thread 2 , time=95 microseconds
(iteration: 22) Found 300 at index 652 in thread 2 , time=107 microseconds
(iteration: 23) Found 300 at index 336 in thread 1 , time=89 microseconds
(iteration: 24) Found 300 at index 235 in thread 0 , time=94 microseconds
(iteration: 25) Found 300 at index 106 in thread 0 , time=95 microseconds
(iteration: 26) Found 300 at index 696 in thread 2 , time=88 microseconds
(iteration: 27) Found 300 at index 373 in thread 1 , time=90 microseconds
(iteration: 28) Found 300 at index 54 in thread 0 , time=105 microseconds
(iteration: 29) Found 300 at index 501 in thread 2 , time=89 microseconds

Min = 85µs, Max = 237µs, Avg = 114.033333µs, Std Dev = 35.693137µs
```

A tradeoff point for parallelism for Processes and threads

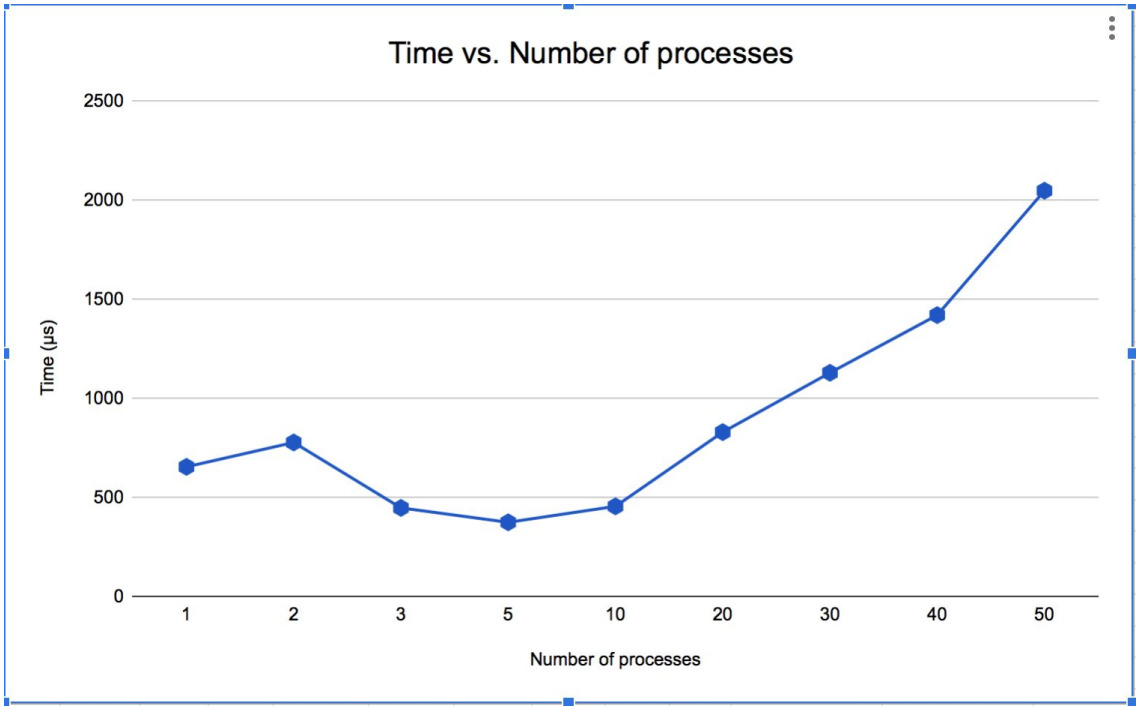
Running tests 4a to 4j, we got the following data that helped us come up with the tradeoff point for parallelism for both processes and threads

When running these tests, we found that at some point adding more threads/processes to search a fixed sized array increases the time it takes all the processes/threads to finish than running smaller number of processes/threads. This is mainly because increasing the number of processes/threads per a fixed size array decreases the number of elements per processes/thread decreases and increases the time the processes/threads switch between each other. The tradeoff point of parallelism happens when there is a good balance between the number of elements searched by each process/thread and the number of processes/threads on a fixed size array.

Array size is 250 elements for all tests in this table

Test number	Number of processes/threads	Number of elements per process/thread	Avg time (µs) (process)	Avg time (µs) (thread)
4a	1	250	654.86	78.37
4b	2	125	778.007	77.77
4c	3	84	447.6	99.67
4d	5	50	374.9	52.6
4e	10	25	455.46	112.27
4f	20	13	830.07	234.4
4g	30	9	1129.63	329.07
4h	40	7	1420.7	455.5
4i	50	5	2048.76	619.9
4j	250	1	9860.97	3534.13

Table(4): The data collected from running tests 4a - 4j using both the process and thread versions



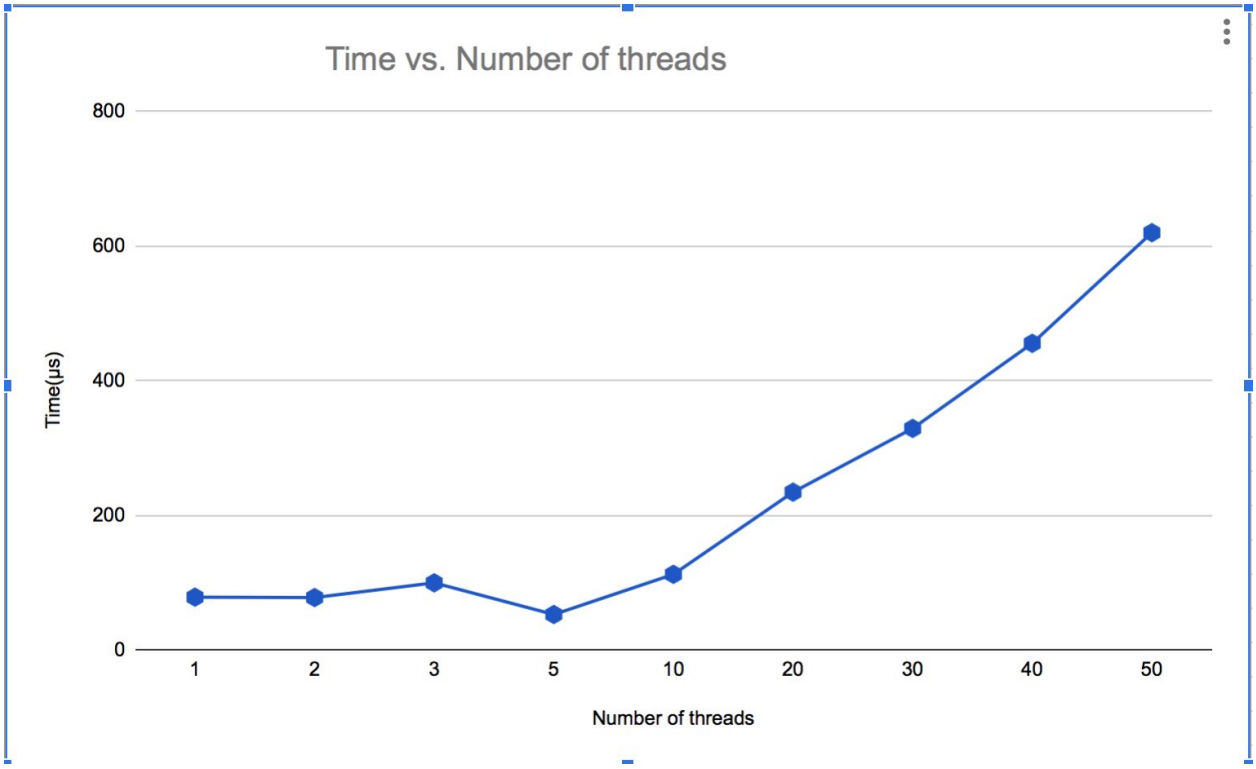
fig(7): The relation between increasing the number of processes vs time on a fixed array size

Below are screenshots of 3 tests that highlight where the tradeoff point happens for processes

```
Test(4) c
-process mode
parameters of the test:
   -number of elements per process : 84
   -number of process created: 3
   -Array size: 250

(iteration: 0) Found element 43 at index 85 in process 1 , time=682 microseconds
(iteration: 1) Found element 43 at index 225 in process 2 , time=573 microseconds
(iteration: 2) Found element 43 at index 188 in process 2 , time=605 microseconds
(iteration: 3) Found element 43 at index 157 in process 1 , time=688 microseconds
(iteration: 4) Found element 43 at index 229 in process 2 , time=673 microseconds
(iteration: 5) Found element 43 at index 186 in process 2 , time=501 microseconds
(iteration: 6) Found element 43 at index 210 in process 2 , time=454 microseconds
(iteration: 7) Found element 43 at index 164 in process 1 , time=450 microseconds
(iteration: 8) Found element 43 at index 171 in process 2 , time=432 microseconds
(iteration: 9) Found element 43 at index 210 in process 2 , time=472 microseconds
(iteration: 10) Found element 43 at index 54 in process 0 , time=450 microseconds
(iteration: 11) Found element 43 at index 28 in process 0 , time=433 microseconds
(iteration: 12) Found element 43 at index 27 in process 0 , time=439 microseconds
(iteration: 13) Found element 43 at index 50 in process 0 , time=449 microseconds
(iteration: 14) Found element 43 at index 248 in process 2 , time=437 microseconds
(iteration: 15) Found element 43 at index 56 in process 0 , time=432 microseconds
(iteration: 16) Found element 43 at index 152 in process 1 , time=337 microseconds
(iteration: 17) Found element 43 at index 44 in process 0 , time=337 microseconds
(iteration: 18) Found element 43 at index 197 in process 2 , time=343 microseconds
(iteration: 19) Found element 43 at index 199 in process 2 , time=375 microseconds
(iteration: 20) Found element 43 at index 43 in process 0 , time=363 microseconds
(iteration: 21) Found element 43 at index 39 in process 0 , time=367 microseconds
(iteration: 22) Found element 43 at index 2 in process 0 , time=346 microseconds
(iteration: 23) Found element 43 at index 178 in process 2 , time=430 microseconds
(iteration: 24) Found element 43 at index 153 in process 1 , time=412 microseconds
(iteration: 25) Found element 43 at index 0 in process 0 , time=410 microseconds
(iteration: 26) Found element 43 at index 181 in process 2 , time=399 microseconds
(iteration: 27) Found element 43 at index 147 in process 1 , time=394 microseconds
(iteration: 28) Found element 43 at index 38 in process 0 , time=406 microseconds
(iteration: 29) Found element 43 at index 159 in process 1 , time=339 microseconds

Min = 337µs, Max = 688µs, Avg = 447.600000µs, Std Dev = 99.131226µs
```

```
Test(4) d
-process mode
parameters of the test:
   -number of elements per process : 50
   -number of process created: 5
   -Array size: 250

(iteration: 0) Found element 4 at index 106 in process 2 , time=446 microseconds
(iteration: 1) Found element 4 at index 35 in process 0 , time=433 microseconds
(iteration: 2) Found element 4 at index 134 in process 2 , time=465 microseconds
(iteration: 3) Found element 4 at index 89 in process 1 , time=458 microseconds
(iteration: 4) Found element 4 at index 192 in process 3 , time=457 microseconds
(iteration: 5) Found element 4 at index 215 in process 4 , time=459 microseconds
(iteration: 6) Found element 4 at index 127 in process 2 , time=468 microseconds
(iteration: 7) Found element 4 at index 4 in process 0 , time=458 microseconds
(iteration: 8) Found element 4 at index 129 in process 2 , time=475 microseconds
(iteration: 9) Found element 4 at index 49 in process 0 , time=434 microseconds
(iteration: 10) Found element 4 at index 214 in process 4 , time=373 microseconds
(iteration: 11) Found element 4 at index 35 in process 0 , time=347 microseconds
(iteration: 12) Found element 4 at index 179 in process 3 , time=347 microseconds
(iteration: 13) Found element 4 at index 93 in process 1 , time=376 microseconds
(iteration: 14) Found element 4 at index 85 in process 1 , time=349 microseconds
(iteration: 15) Found element 4 at index 177 in process 3 , time=355 microseconds
(iteration: 16) Found element 4 at index 150 in process 3 , time=361 microseconds
(iteration: 17) Found element 4 at index 238 in process 4 , time=350 microseconds
(iteration: 18) Found element 4 at index 221 in process 4 , time=356 microseconds
(iteration: 19) Found element 4 at index 199 in process 3 , time=393 microseconds
(iteration: 20) Found element 4 at index 39 in process 0 , time=339 microseconds
(iteration: 21) Found element 4 at index 117 in process 2 , time=386 microseconds
(iteration: 22) Found element 4 at index 238 in process 4 , time=332 microseconds
(iteration: 23) Found element 4 at index 42 in process 0 , time=301 microseconds
(iteration: 24) Found element 4 at index 45 in process 0 , time=309 microseconds
(iteration: 25) Found element 4 at index 243 in process 4 , time=300 microseconds
(iteration: 26) Found element 4 at index 144 in process 2 , time=282 microseconds
(iteration: 27) Found element 4 at index 79 in process 1 , time=271 microseconds
(iteration: 28) Found element 4 at index 140 in process 2 , time=284 microseconds
(iteration: 29) Found element 4 at index 182 in process 3 , time=284 microseconds

Min = 271µs, Max = 475µs, Avg = 374.933333µs, Std Dev = 64.567794µs
```

```
Test(4) e
-process mode
parameters of the test:
   -number of elements per process : 25
   -number of process created: 10
   -Array size: 250

(iteration: 0) Found element 7 at index 44 in process 1 , time=504 microseconds
(iteration: 1) Found element 7 at index 41 in process 1 , time=470 microseconds
(iteration: 2) Found element 7 at index 69 in process 2 , time=513 microseconds
(iteration: 3) Found element 7 at index 76 in process 3 , time=479 microseconds
(iteration: 4) Found element 7 at index 232 in process 9 , time=478 microseconds
(iteration: 5) Found element 7 at index 11 in process 0 , time=447 microseconds
(iteration: 6) Found element 7 at index 42 in process 1 , time=489 microseconds
(iteration: 7) Found element 7 at index 110 in process 4 , time=435 microseconds
(iteration: 8) Found element 7 at index 117 in process 4 , time=452 microseconds
(iteration: 9) Found element 7 at index 23 in process 0 , time=475 microseconds
(iteration: 10) Found element 7 at index 11 in process 0 , time=430 microseconds
(iteration: 11) Found element 7 at index 81 in process 3 , time=450 microseconds
(iteration: 12) Found element 7 at index 59 in process 2 , time=430 microseconds
(iteration: 13) Found element 7 at index 190 in process 7 , time=441 microseconds
(iteration: 14) Found element 7 at index 175 in process 7 , time=432 microseconds
(iteration: 15) Found element 7 at index 246 in process 9 , time=501 microseconds
(iteration: 16) Found element 7 at index 117 in process 4 , time=444 microseconds
(iteration: 17) Found element 7 at index 177 in process 7 , time=434 microseconds
(iteration: 18) Found element 7 at index 234 in process 9 , time=429 microseconds
(iteration: 19) Found element 7 at index 190 in process 7 , time=446 microseconds
(iteration: 20) Found element 7 at index 126 in process 5 , time=429 microseconds
(iteration: 21) Found element 7 at index 24 in process 0 , time=424 microseconds
(iteration: 22) Found element 7 at index 57 in process 2 , time=441 microseconds
(iteration: 23) Found element 7 at index 114 in process 4 , time=488 microseconds
(iteration: 24) Found element 7 at index 168 in process 6 , time=436 microseconds
(iteration: 25) Found element 7 at index 205 in process 8 , time=430 microseconds
(iteration: 26) Found element 7 at index 108 in process 4 , time=492 microseconds
(iteration: 27) Found element 7 at index 62 in process 2 , time=444 microseconds
(iteration: 28) Found element 7 at index 136 in process 5 , time=446 microseconds
(iteration: 29) Found element 7 at index 100 in process 4 , time=455 microseconds

Min = 424µs, Max = 513µs, Avg = 455.466667µs, Std Dev = 25.826343µs
```



fig(8): The relation between increasing the number of threads vs time on a fixed array size

Below are screenshots of 3 tests that highlight where the tradeoff point happens for threads

```
Test(4) c
-thread mode
parameters of the test:
   -number of elements per thread : 84
   -number of thread created: 3
   -Array size: 250

(iteration: 0) Found 43 at index 85 in thread 1 , time=130 microseconds
(iteration: 1) Found 43 at index 225 in thread 2 , time=143 microseconds
(iteration: 2) Found 43 at index 188 in thread 2 , time=128 microseconds
(iteration: 3) Found 43 at index 157 in thread 1 , time=119 microseconds
(iteration: 4) Found 43 at index 229 in thread 2 , time=123 microseconds
(iteration: 5) Found 43 at index 186 in thread 2 , time=112 microseconds
(iteration: 6) Found 43 at index 210 in thread 2 , time=100 microseconds
(iteration: 7) Found 43 at index 164 in thread 1 , time=195 microseconds
(iteration: 8) Found 43 at index 171 in thread 2 , time=103 microseconds
(iteration: 9) Found 43 at index 210 in thread 2 , time=94 microseconds
(iteration: 10) Found 43 at index 54 in thread 0 , time=94 microseconds
(iteration: 11) Found 43 at index 28 in thread 0 , time=119 microseconds
(iteration: 12) Found 43 at index 27 in thread 0 , time=96 microseconds
(iteration: 13) Found 43 at index 50 in thread 0 , time=98 microseconds
(iteration: 14) Found 43 at index 248 in thread 2 , time=90 microseconds
(iteration: 15) Found 43 at index 56 in thread 0 , time=100 microseconds
(iteration: 16) Found 43 at index 152 in thread 1 , time=94 microseconds
(iteration: 17) Found 43 at index 44 in thread 0 , time=91 microseconds
(iteration: 18) Found 43 at index 197 in thread 2 , time=91 microseconds
(iteration: 19) Found 43 at index 199 in thread 2 , time=94 microseconds
(iteration: 20) Found 43 at index 43 in thread 0 , time=94 microseconds
(iteration: 21) Found 43 at index 39 in thread 0 , time=98 microseconds
(iteration: 22) Found 43 at index 2 in thread 0 , time=97 microseconds
(iteration: 23) Found 43 at index 178 in thread 2 , time=96 microseconds
(iteration: 24) Found 43 at index 153 in thread 1 , time=109 microseconds
(iteration: 25) Found 43 at index 0 in thread 0 , time=123 microseconds
(iteration: 26) Found 43 at index 181 in thread 2 , time=25 microseconds
(iteration: 27) Found 43 at index 147 in thread 1 , time=23 microseconds
(iteration: 28) Found 43 at index 38 in thread 0 , time=57 microseconds
(iteration: 29) Found 43 at index 159 in thread 1 , time=54 microseconds

Min = 23µs, Max = 195µs, Avg = 99.666667µs, Std Dev = 31.921779µs
```

```
Test(4) d
-thread mode
parameters of the test:
   -number of elements per thread : 50
   -number of thread created: 5
   -Array size: 250

(iteration: 0) Found 4 at index 106 in thread 2 , time=112 microseconds
(iteration: 1) Found 4 at index 35 in thread 0 , time=44 microseconds
(iteration: 2) Found 4 at index 134 in thread 2 , time=45 microseconds
(iteration: 3) Found 4 at index 89 in thread 1 , time=55 microseconds
(iteration: 4) Found 4 at index 192 in thread 3 , time=58 microseconds
(iteration: 5) Found 4 at index 215 in thread 4 , time=55 microseconds
(iteration: 6) Found 4 at index 127 in thread 2 , time=53 microseconds
(iteration: 7) Found 4 at index 4 in thread 0 , time=60 microseconds
(iteration: 8) Found 4 at index 129 in thread 2 , time=46 microseconds
(iteration: 9) Found 4 at index 49 in thread 0 , time=47 microseconds
(iteration: 10) Found 4 at index 214 in thread 4 , time=53 microseconds
(iteration: 11) Found 4 at index 35 in thread 0 , time=50 microseconds
(iteration: 12) Found 4 at index 179 in thread 3 , time=60 microseconds
(iteration: 13) Found 4 at index 93 in thread 1 , time=49 microseconds
(iteration: 14) Found 4 at index 85 in thread 1 , time=58 microseconds
(iteration: 15) Found 4 at index 177 in thread 3 , time=59 microseconds
(iteration: 16) Found 4 at index 150 in thread 3 , time=59 microseconds
(iteration: 17) Found 4 at index 238 in thread 4 , time=53 microseconds
(iteration: 18) Found 4 at index 221 in thread 4 , time=60 microseconds
(iteration: 19) Found 4 at index 199 in thread 3 , time=55 microseconds
(iteration: 20) Found 4 at index 39 in thread 0 , time=63 microseconds
(iteration: 21) Found 4 at index 117 in thread 2 , time=50 microseconds
(iteration: 22) Found 4 at index 238 in thread 4 , time=37 microseconds
(iteration: 23) Found 4 at index 42 in thread 0 , time=39 microseconds
(iteration: 24) Found 4 at index 45 in thread 0 , time=42 microseconds
(iteration: 25) Found 4 at index 243 in thread 4 , time=51 microseconds
(iteration: 26) Found 4 at index 144 in thread 2 , time=36 microseconds
(iteration: 27) Found 4 at index 79 in thread 1 , time=51 microseconds
(iteration: 28) Found 4 at index 140 in thread 2 , time=39 microseconds
(iteration: 29) Found 4 at index 182 in thread 3 , time=39 microseconds

Min = 36µs, Max = 112µs, Avg = 52.600000µs, Std Dev = 13.379088µs
```

```
Test(4) e
-thread mode
parameters of the test:
   -number of elements per thread : 25
   -number of thread created: 10
   -Array size: 250

(iteration: 0) Found 7 at index 44 in thread 1 , time=123 microseconds
(iteration: 1) Found 7 at index 41 in thread 1 , time=118 microseconds
(iteration: 2) Found 7 at index 69 in thread 2 , time=108 microseconds
(iteration: 3) Found 7 at index 76 in thread 3 , time=120 microseconds
(iteration: 4) Found 7 at index 232 in thread 9 , time=99 microseconds
(iteration: 5) Found 7 at index 11 in thread 0 , time=112 microseconds
(iteration: 6) Found 7 at index 42 in thread 1 , time=128 microseconds
(iteration: 7) Found 7 at index 110 in thread 4 , time=112 microseconds
(iteration: 8) Found 7 at index 117 in thread 4 , time=110 microseconds
(iteration: 9) Found 7 at index 23 in thread 0 , time=114 microseconds
(iteration: 10) Found 7 at index 11 in thread 0 , time=112 microseconds
(iteration: 11) Found 7 at index 81 in thread 3 , time=104 microseconds
(iteration: 12) Found 7 at index 59 in thread 2 , time=116 microseconds
(iteration: 13) Found 7 at index 190 in thread 7 , time=111 microseconds
(iteration: 14) Found 7 at index 175 in thread 7 , time=113 microseconds
(iteration: 15) Found 7 at index 246 in thread 9 , time=116 microseconds
(iteration: 16) Found 7 at index 117 in thread 4 , time=111 microseconds
(iteration: 17) Found 7 at index 177 in thread 7 , time=111 microseconds
(iteration: 18) Found 7 at index 234 in thread 9 , time=100 microseconds
(iteration: 19) Found 7 at index 190 in thread 7 , time=118 microseconds
(iteration: 20) Found 7 at index 126 in thread 5 , time=119 microseconds
(iteration: 21) Found 7 at index 24 in thread 0 , time=109 microseconds
(iteration: 22) Found 7 at index 57 in thread 2 , time=160 microseconds
(iteration: 23) Found 7 at index 114 in thread 4 , time=103 microseconds
(iteration: 24) Found 7 at index 168 in thread 6 , time=104 microseconds
(iteration: 25) Found 7 at index 205 in thread 8 , time=98 microseconds
(iteration: 26) Found 7 at index 108 in thread 4 , time=111 microseconds
(iteration: 27) Found 7 at index 62 in thread 2 , time=98 microseconds
(iteration: 28) Found 7 at index 136 in thread 5 , time=96 microseconds
(iteration: 29) Found 7 at index 100 in thread 4 , time=114 microseconds

Min = 96µs, Max = 160µs, Avg = 112.266667µs, Std Dev = 11.661904µs
```