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PROGRAM STRUCTURES AND ALGORITHM
ASSIGNMENT-2

TASK:

Solve 3-SUM using the Quadrithmic, *Quadratic*, and *quadraticWithCalipers* approaches, as shown in skeleton code in the repository.

Approach:

For Cubic:

Implementation of ThreeSum which follows the brute-force approach of testing every candidate in the solution-space.The array provided in the constructor may be randomly ordered.
* Construct a ThreeSumCubic on a.
  * @param a :an array.

For Quadratic:

Implementation of ThreeSum which follows the approach of dividing the solution-space into
* N sub-spaces where each sub-space corresponds to a fixed value for the middle index of the three values.
* Each sub-space is then solved by expanding the scope of the other two indices outwards from the starting point.
* Since each sub-space can be solved in O(N) time, the overall complexity is O(N^2).
 * Construct a ThreeSumQuadratic on a.
   * @param a :a sorted array.
   * Get a list of Triples such that the middle index is the given value j.
   * @param j :the index of the middle value.
   * @return a Triple

For Quadratic with Calipers:

Implementation of ThreeSum which follows the approach of dividing the solution-space into
 * N sub-spaces where each sub-space corresponds to a fixed value for the middle index of the three values.
 * Each sub-space is then solved by expanding the scope of the other two indices outwards from the starting point.

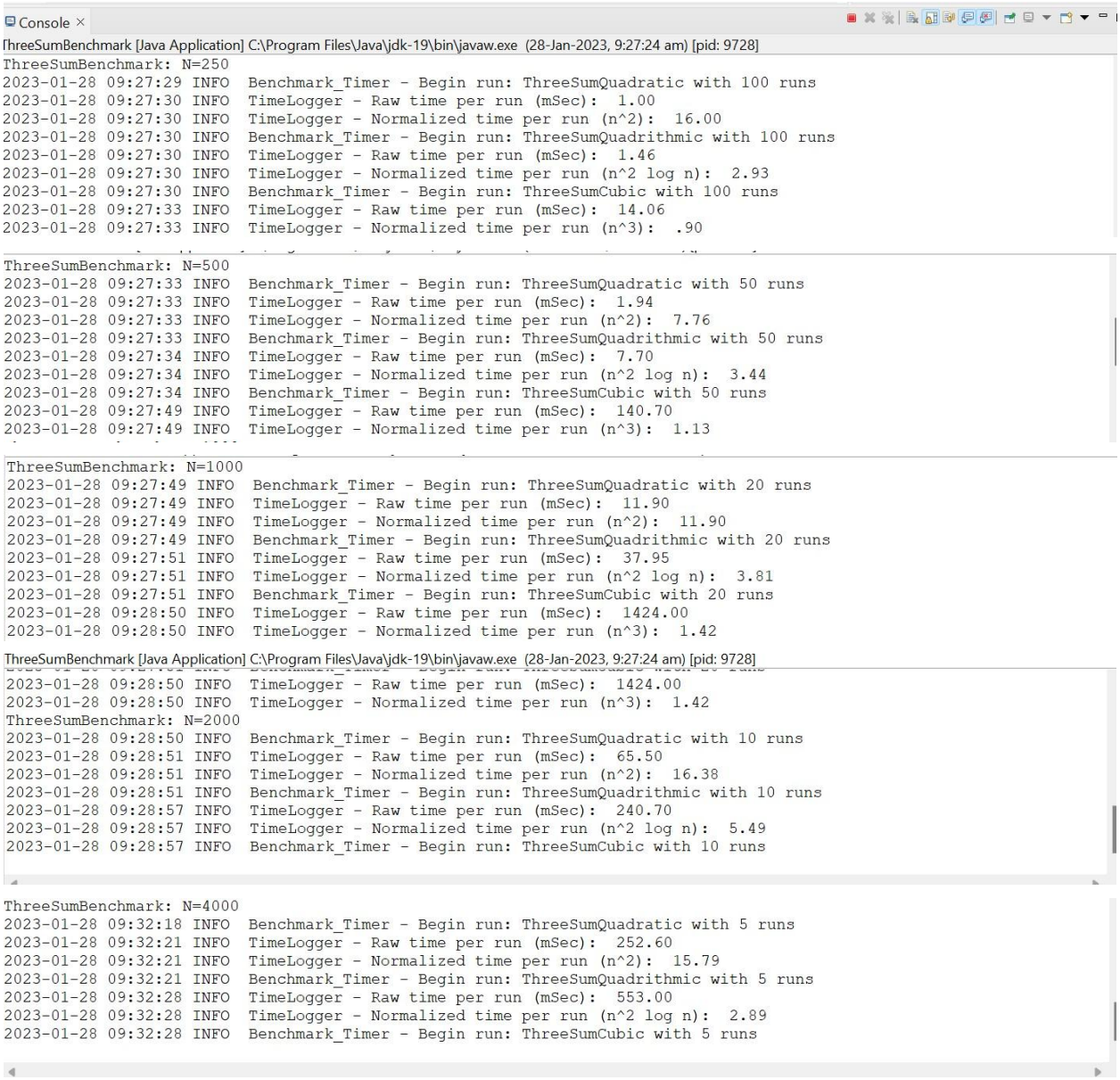
* Since each sub-space can be solved in O(N) time, the overall complexity is O(N^2).
The array provided in the constructor MUST be ordered.
    * Construct a ThreeSumQuadratic on a.
     * @param a: a sorted array.

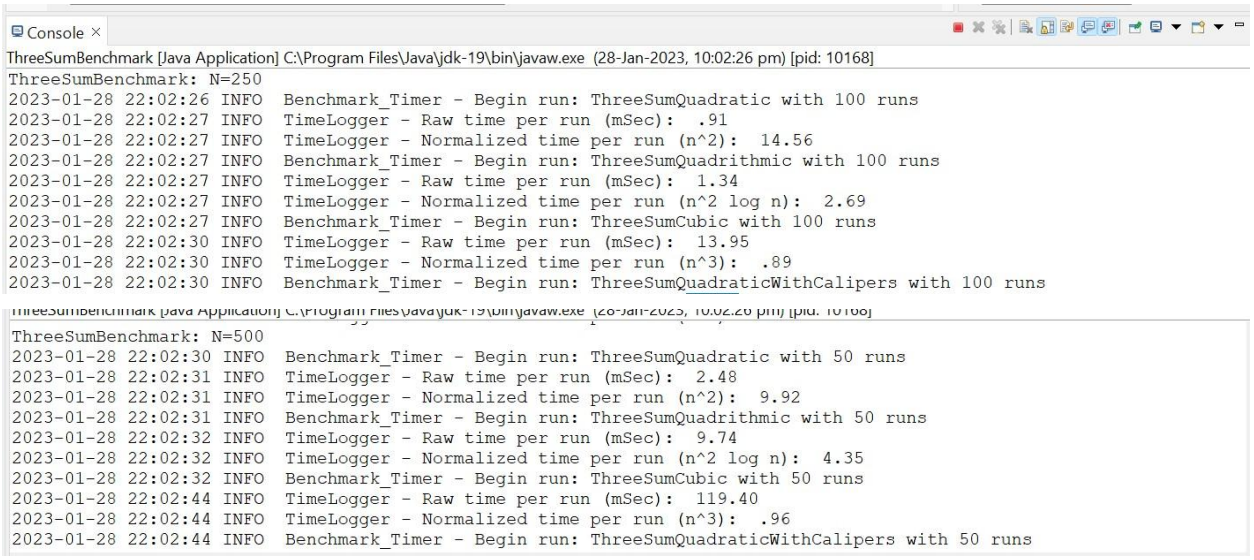
* Get a list of Triples such that the middle index is the given value i.
     * @param a : a sorted array of ints.
     * @param i : the index of the first element of resulting triples.
     * @param function : a function which takes a triple and returns the comparison of sum of the triple with zero.
     * @return a Triple

Relationship Conclusion: It can be observed from the results of the benchmark test: In the worst case scenario which happens when we generate all possible triplets and compare the sum of every triplet with the given value and therefore, runs in cubic time: O(n^3).

In the average and best case scenario which follows the approach of dividing the solution-space into N sub-spaces where each sub-space corresponds to a fixed value for the middle index of the three values. Each sub-space is then solved by expanding the scope of the other two indices outwards from the starting point. The array provided must be sorted.Since each sub-space can be solved in O(N) time, the overall complexity is O(N^2).

OUTPUT:


Console
ThreeSumBenchmark [Java Application] C:\Program Files\Java\jdk-19\bin\javaw.exe (28-Jan-2023, 9:27:24 am) [pid: 9728]
ThreeSumBenchmark: N=250
2023-01-28 09:27:29 INFO Benchmark_Timer - Begin run: ThreeSumQuadratic with 100 runs
2023-01-28 09:27:30 INFO TimeLogger - Raw time per run (mSec): 1.00
2023-01-28 09:27:30 INFO TimeLogger - Normalized time per run (n^2): 16.00
2023-01-28 09:27:30 INFO Benchmark_Timer - Begin run: ThreeSumQuadrithmic with 100 runs
2023-01-28 09:27:30 INFO TimeLogger - Raw time per run (mSec): 1.46
2023-01-28 09:27:30 INFO TimeLogger - Normalized time per run (n^2 log n): 2.93
2023-01-28 09:27:30 INFO Benchmark_Timer - Begin run: ThreeSumCubic with 100 runs
2023-01-28 09:27:33 INFO TimeLogger - Raw time per run (mSec): 14.06
2023-01-28 09:27:33 INFO TimeLogger - Normalized time per run (n^3): .90
ThreeSumBenchmark: N=500
2023-01-28 09:27:33 INFO Benchmark_Timer - Begin run: ThreeSumQuadratic with 50 runs
2023-01-28 09:27:33 INFO TimeLogger - Raw time per run (mSec): 1.94
2023-01-28 09:27:33 INFO TimeLogger - Normalized time per run (n^2): 7.76
2023-01-28 09:27:33 INFO Benchmark_Timer - Begin run: ThreeSumQuadrithmic with 50 runs
2023-01-28 09:27:34 INFO TimeLogger - Raw time per run (mSec): 7.70
2023-01-28 09:27:34 INFO TimeLogger - Normalized time per run (n^2 log n): 3.44
2023-01-28 09:27:34 INFO Benchmark_Timer - Begin run: ThreeSumCubic with 50 runs
2023-01-28 09:27:49 INFO TimeLogger - Raw time per run (mSec): 140.70
2023-01-28 09:27:49 INFO TimeLogger - Normalized time per run (n^3): 1.13
ThreeSumBenchmark: N=1000
2023-01-28 09:27:49 INFO Benchmark_Timer - Begin run: ThreeSumQuadratic with 20 runs
2023-01-28 09:27:49 INFO TimeLogger - Raw time per run (mSec): 11.90
2023-01-28 09:27:49 INFO TimeLogger - Normalized time per run (n^2): 11.90
2023-01-28 09:27:49 INFO Benchmark_Timer - Begin run: ThreeSumQuadrithmic with 20 runs
2023-01-28 09:27:51 INFO TimeLogger - Raw time per run (mSec): 37.95
2023-01-28 09:27:51 INFO TimeLogger - Normalized time per run (n^2 log n): 3.81
2023-01-28 09:27:51 INFO Benchmark_Timer - Begin run: ThreeSumCubic with 20 runs
2023-01-28 09:28:50 INFO TimeLogger - Raw time per run (mSec): 1424.00
2023-01-28 09:28:50 INFO TimeLogger - Normalized time per run (n^3): 1.42
ThreeSumBenchmark [Java Application] C:\Program Files\Java\jdk-19\bin\javaw.exe (28-Jan-2023, 9:27:24 am) [pid: 9728]
2023-01-28 09:28:50 INFO TimeLogger - Raw time per run (mSec): 1424.00
2023-01-28 09:28:50 INFO TimeLogger - Normalized time per run (n^3): 1.42
ThreeSumBenchmark: N=2000
2023-01-28 09:28:50 INFO Benchmark_Timer - Begin run: ThreeSumQuadratic with 10 runs
2023-01-28 09:28:51 INFO TimeLogger - Raw time per run (mSec): 65.50
2023-01-28 09:28:51 INFO TimeLogger - Normalized time per run (n^2): 16.38
2023-01-28 09:28:51 INFO Benchmark_Timer - Begin run: ThreeSumQuadrithmic with 10 runs
2023-01-28 09:28:57 INFO TimeLogger - Raw time per run (mSec): 240.70
2023-01-28 09:28:57 INFO TimeLogger - Normalized time per run (n^2 log n): 5.49
2023-01-28 09:28:57 INFO Benchmark_Timer - Begin run: ThreeSumCubic with 10 runs
ThreeSumBenchmark: N=4000
2023-01-28 09:32:18 INFO Benchmark_Timer - Begin run: ThreeSumQuadratic with 5 runs
2023-01-28 09:32:21 INFO TimeLogger - Raw time per run (mSec): 252.60
2023-01-28 09:32:21 INFO TimeLogger - Normalized time per run (n^2): 15.79
2023-01-28 09:32:21 INFO Benchmark_Timer - Begin run: ThreeSumQuadrithmic with 5 runs
2023-01-28 09:32:28 INFO TimeLogger - Raw time per run (mSec): 553.00
2023-01-28 09:32:28 INFO TimeLogger - Normalized time per run (n^2 log n): 2.89
2023-01-28 09:32:28 INFO Benchmark_Timer - Begin run: ThreeSumCubic with 5 runs



EVIDENCE:

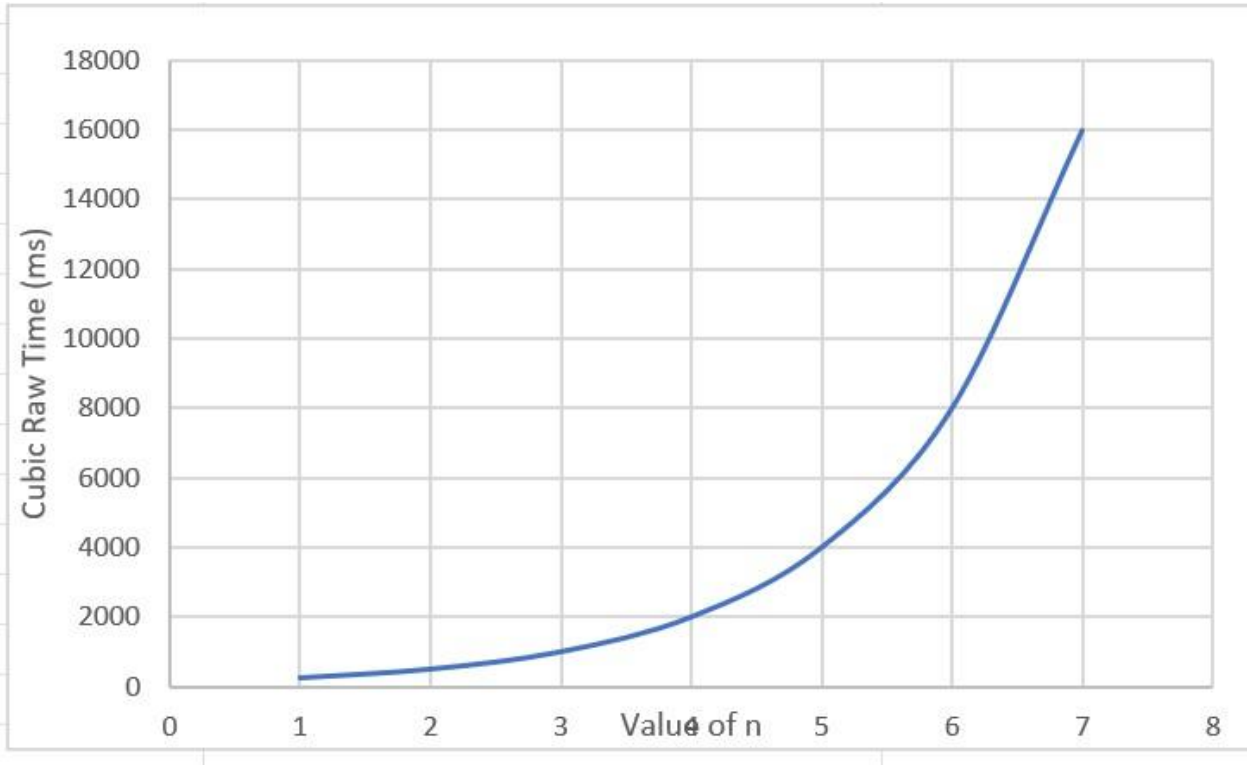
I have attached a table and chart to show the relationship between raw time and value of n.

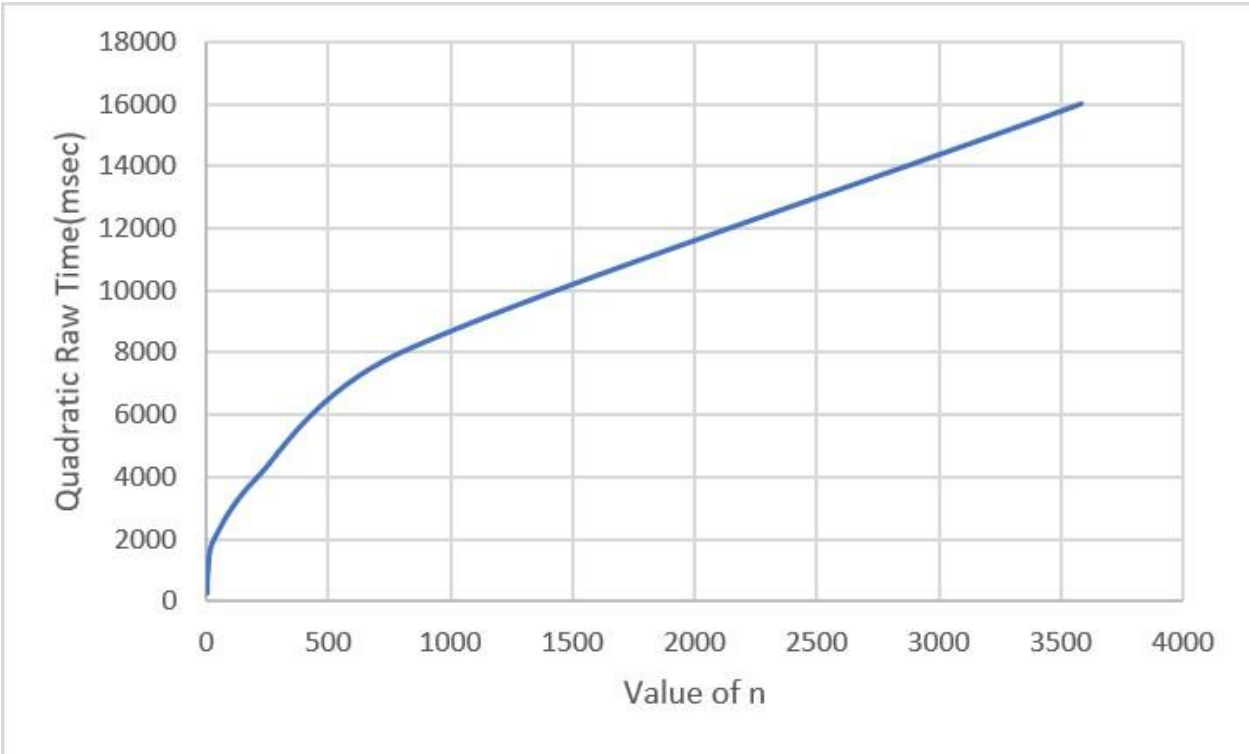
Value of n	No. of runs	Cubic Raw Time(ms)	Cubic Normalized Time(n^3)
250	100	14.06	0.9
500	50	140.7	1.13
1000	20	1424	1.42
2000	10	9401.5	1.18
4000	5	57412.6	0.9
8000	3	NA	NA
16000	2	NA	NA

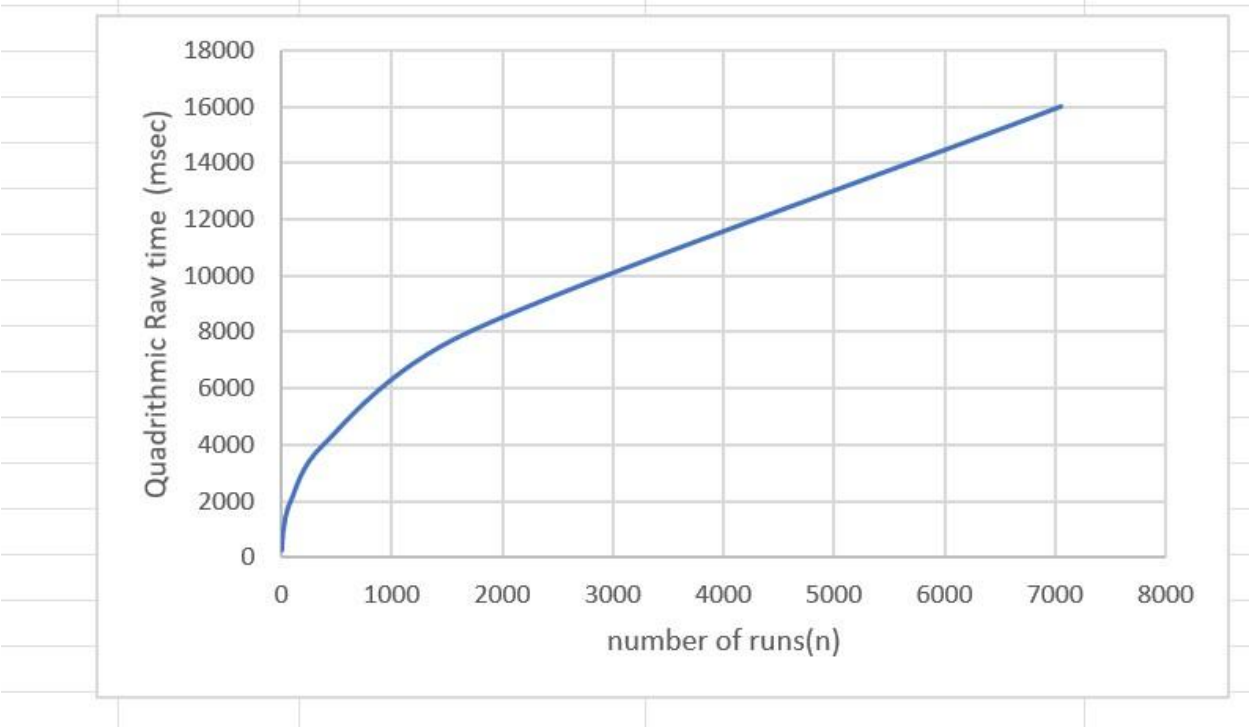
Value of n	No. of runs	Quadrithmic Raw Time(ms)	Quadrithmic Normalized Time(n^2logn)
250	100	1.46	4.45
500	50	6.82	3.04
1000	20	29.35	2.95
2000	10	131.8	1.11
4000	5	584.2	3.05
8000	3	3608.67	4.35
16000	2	16686	4.67

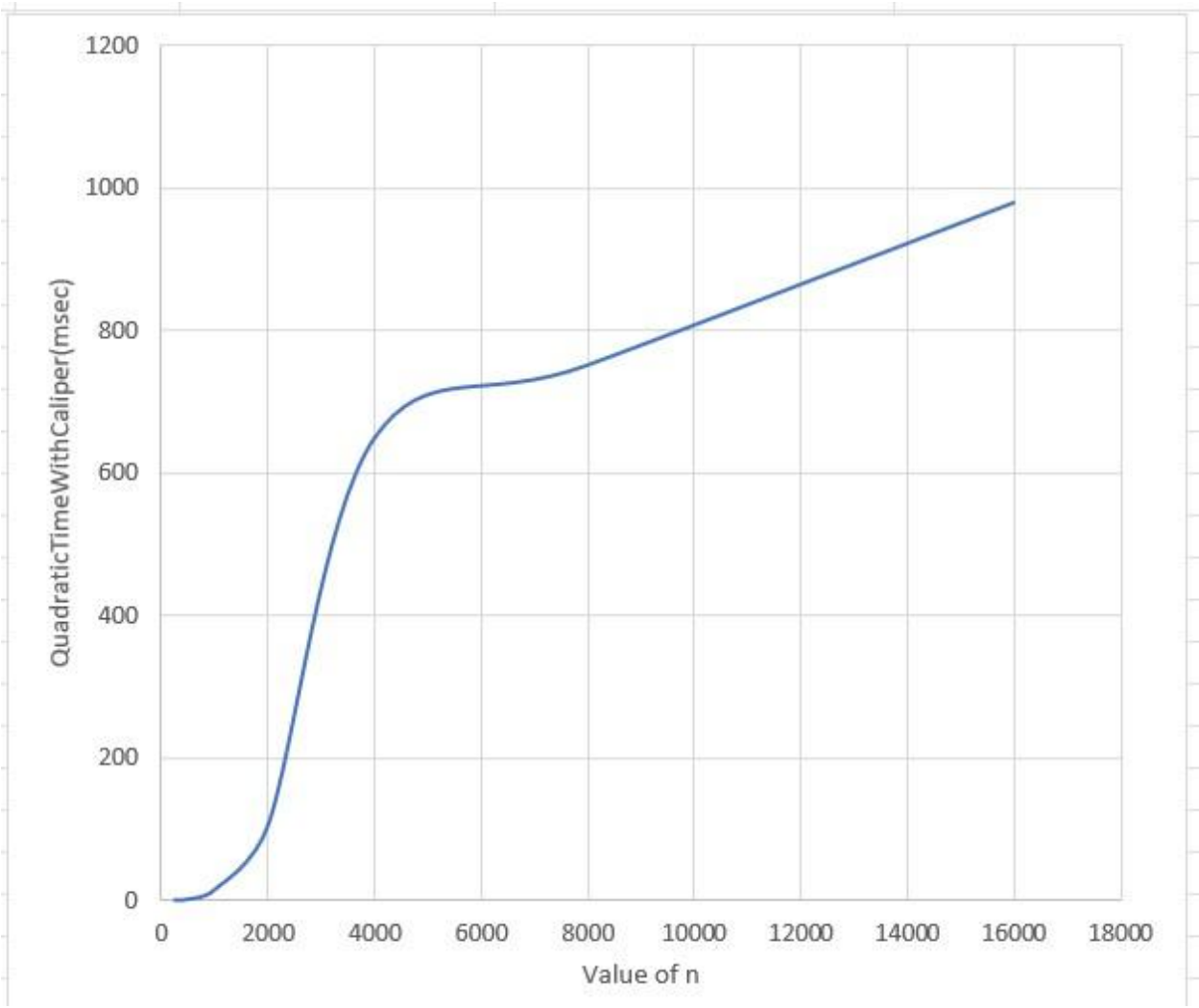
Value of n	No. of runs	Quadratic Raw Time(ms)	Quadratic Normalized Time(n^2)
250	100	1.17	18.72
500	50	1.68	6.72
1000	20	6.2	6.2
2000	10	44.2	11.05
4000	5	283	17.69
8000	3	1223	19.11
16000	2	6137.5	23.97

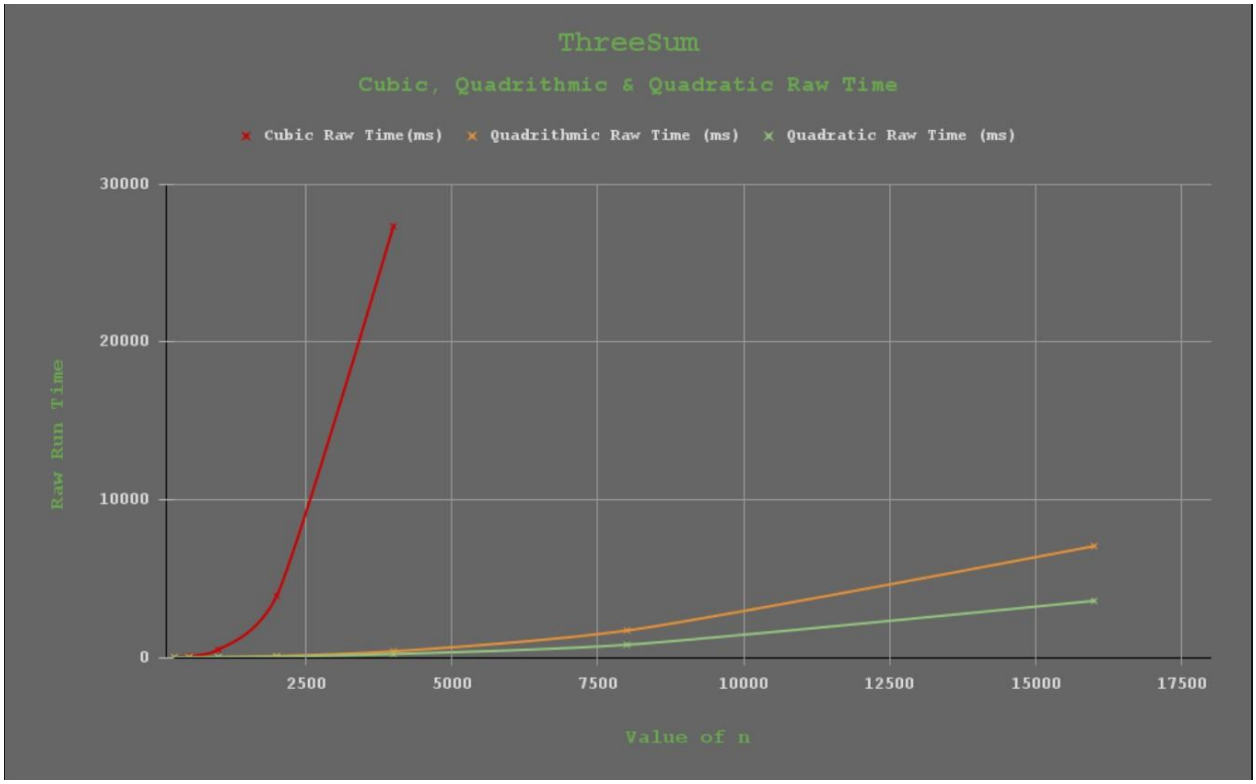
Value of n	No. of runs	QuadraticWithCalipers Raw Time(msec)	QuadraticWithCalipers Normalized Time(n^2)
250	100	1.22	19.52
500	50	2.48	9.92
1000	20	15.95	15.95
2000	10	105.6	26.4
4000	5	648.5	3.49
8000	3	750.65	4.45
16000	2	978.2	9.78




Quadratic Raw Time(msec)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
500
1000
1500
2000
2500
3000
3500
4000
Value of n


Quadrithmic Raw time (msec)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1000
2000
3000
4000
5000
6000
7000
8000
number of runs(n)


1200
1000
800
600
400
200
0
QuadraticTimeWithCaliper(msec)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Value of n


ThreeSum
Cubic, Quadrithmic & Quadratic Raw Time
Cubic Raw Time(ms)
Quadrithmic Raw Time (ms)
Quadratic Raw Time (ms)
30000
20000
10000
0
Raw Run Time
2500
5000
7500
10000
12500
15000
17500
Value of n

Passed Unit Test Cases: