Program Structures and Algorithms
Spring 2023(SEC –03)

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Task: Implement and compare 3 SUM with 4 different algorithms. The algorithms contains different time complexities, which are

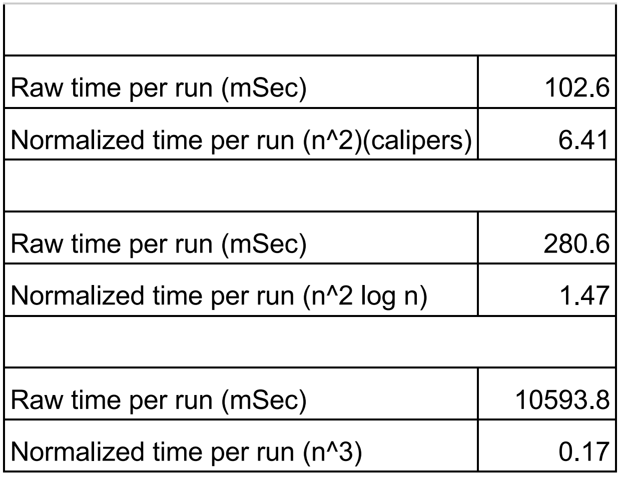
- Quadratic (O(n^2))
- Qaudratic with calipers method (O(n^2))
- Quadrithmic (O(n^2 lg(n)))
- Cubic (O(n^3))

Relationship Conclusion: After comparing time taken by each method using stopwatch shows that Cubic takes the most time out of all whereas Quadratic take the least time of all. Time taken by all the methods is as follows:
Cubic > Quadrithmic > Qaudratic with calipers method > Quadratic

Evidence to support that conclusion:

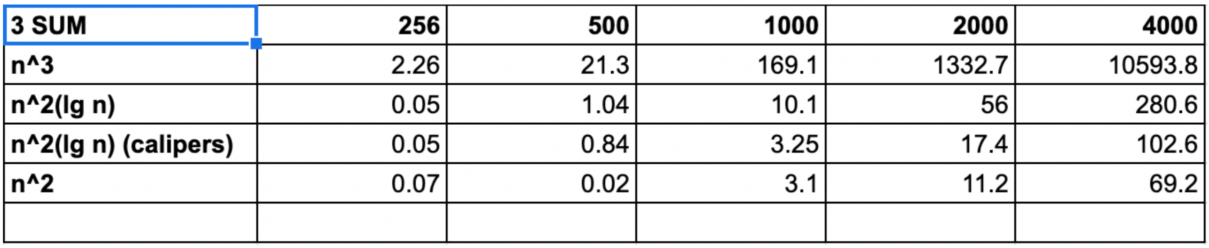
ThreeSumBenchmark: N=250	**Time (ms)**
Raw time per run (mSec)	0.07
Normalized time per run (n^2)	1.12
Raw time per run (mSec)	0.05
Normalized time per run (n^2)(calipers)	0.8
Raw time per run (mSec)	0.05
Normalized time per run (n^2 log n)	0.1
Raw time per run (mSec)	2.26
Normalized time per run (n^3)	0.14
ThreeSumBenchmark: N=500	
Raw time per run (mSec)	0.02
Normalized time per run (n^2)	0.08
Raw time per run (mSec)	0.84
Normalized time per run (n^2)(calipers)	3.36

Raw time per run (mSec)	1.04
Normalized time per run (n^2 log n)	0.46
Raw time per run (mSec)	21.3
Normalized time per run (n^3)	0.17
ThreeSumBenchmark: N=1000	
Raw time per run (mSec)	3.1
Normalized time per run (n^2)	3.1
Raw time per run (mSec)	3.25
Normalized time per run (n^2)(calipers)	3.25
Raw time per run (mSec)	10.1
Normalized time per run (n^2 log n)	1.01
Raw time per run (mSec)	169.1
Normalized time per run (n^3)	0.17
ThreeSumBenchmark: N=2000	
Raw time per run (mSec)	11.2
Normalized time per run (n^2)	2.8
Raw time per run (mSec)	17.4
Normalized time per run (n^2)(calipers)	4.35
Raw time per run (mSec)	56
Normalized time per run (n^2 log n)	1.28
Raw time per run (mSec)	1332.7
Normalized time per run (n^3)	0.17
ThreeSumBenchmark: N=4000	
Raw time per run (mSec)	69.2
Normalized time per run (n^2)	4.33

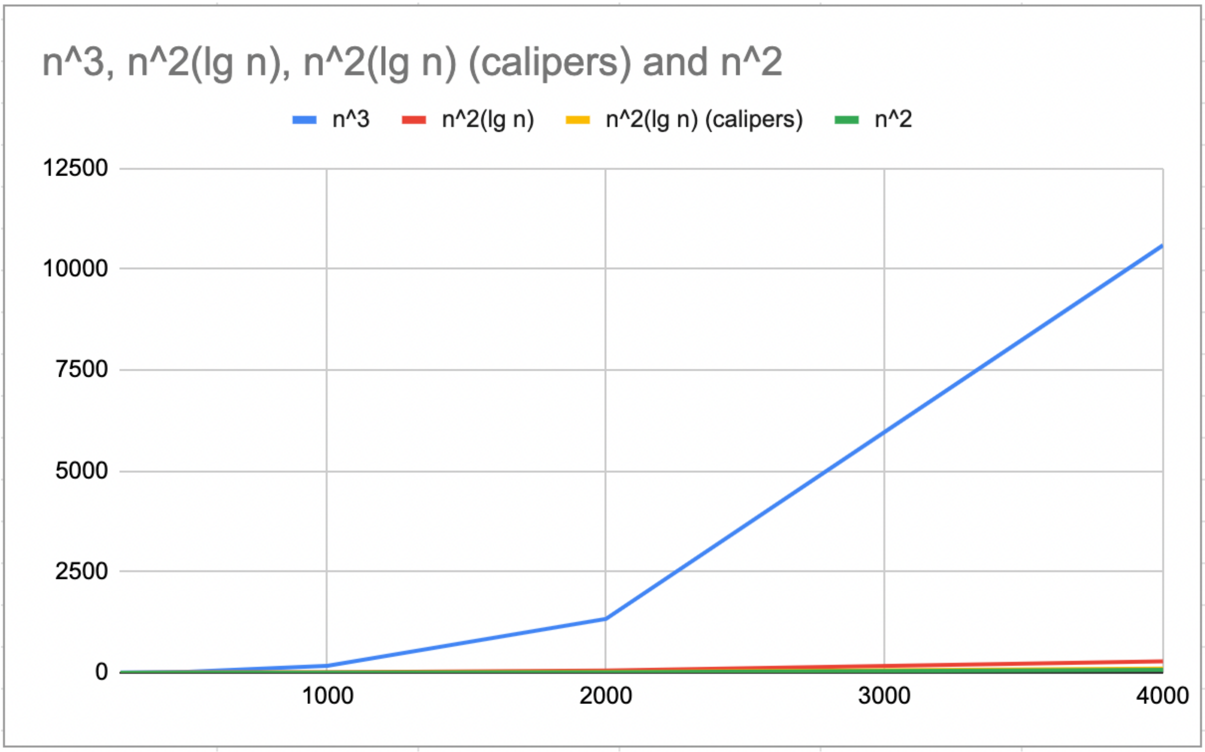


Raw time per run (mSec)	102.6
Normalized time per run (n^2)(calipers)	6.41
Raw time per run (mSec)	280.6
Normalized time per run (n^2 log n)	1.47
Raw time per run (mSec)	10593.8
Normalized time per run (n^3)	0.17

Graphical Representation:

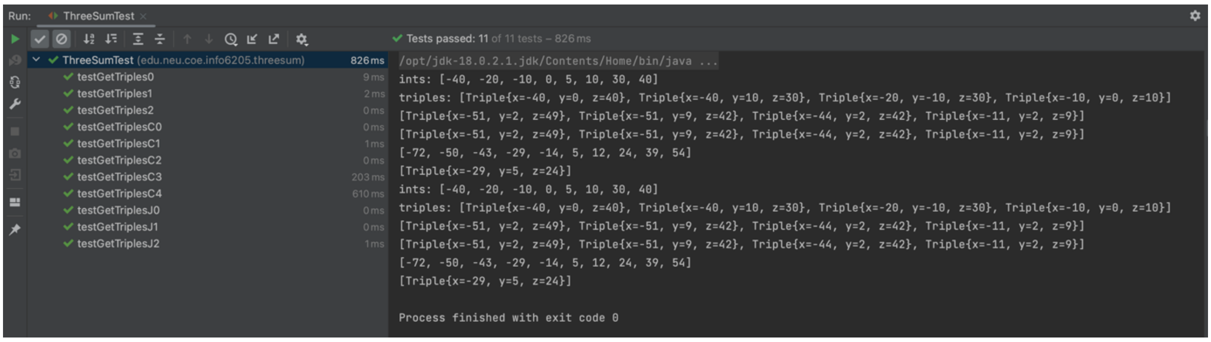


3 SUM	**256**	**500**	**1000**	**2000**	**4000**
n^3	2.26	21.3	169.1	1332.7	10593.8
n^2(lg n)	0.05	1.04	10.1	56	280.6
n^2(lg n) (calipers)	0.05	0.84	3.25	17.4	102.6
n^2	0.07	0.02	3.1	11.2	69.2



Here, X Axis represents number of elements in the array. And the Y Axis represents time taken by each algorithm.

Unit Test Screenshots:



✓ Tests passed: 11 of 11 tests – 826 ms

```
✓ ThreeSumTest (edu.neu.coe.info6205.threesum)  826 ms
    ✓ testGetTriples0     9 ms
    ✓ testGetTriples1     2 ms
    ✓ testGetTriples2     0 ms
    ✓ testGetTriplesC0    0 ms
    ✓ testGetTriplesC1    1 ms
    ✓ testGetTriplesC2    0 ms
    ✓ testGetTriplesC3  203 ms
    ✓ testGetTriplesC4  610 ms
    ✓ testGetTriplesJ0    0 ms
    ✓ testGetTriplesJ1    0 ms
    ✓ testGetTriplesJ2    1 ms
```

```
/opt/jdk-18.0.2.1.jdk/Contents/Home/bin/java ...
ints: [-40, -20, -10, 0, 5, 10, 30, 40]
triples: [Triple{x=-40, y=0, z=40}, Triple{x=-40, y=10, z=30}, Triple{x=-20, y=-10, z=30}, Triple{x=-10, y=0, z=10}]
[Triple{x=-51, y=2, z=49}, Triple{x=-51, y=9, z=42}, Triple{x=-44, y=2, z=42}, Triple{x=-11, y=2, z=9}]
[Triple{x=-51, y=2, z=49}, Triple{x=-51, y=9, z=42}, Triple{x=-44, y=2, z=42}, Triple{x=-11, y=2, z=9}]
[-72, -50, -43, -29, -14, 5, 12, 24, 39, 54]
[Triple{x=-29, y=5, z=24}]
ints: [-40, -20, -10, 0, 5, 10, 30, 40]
triples: [Triple{x=-40, y=0, z=40}, Triple{x=-40, y=10, z=30}, Triple{x=-20, y=-10, z=30}, Triple{x=-10, y=0, z=10}]
[Triple{x=-51, y=2, z=49}, Triple{x=-51, y=9, z=42}, Triple{x=-44, y=2, z=42}, Triple{x=-11, y=2, z=9}]
[Triple{x=-51, y=2, z=49}, Triple{x=-51, y=9, z=42}, Triple{x=-44, y=2, z=42}, Triple{x=-11, y=2, z=9}]
[-72, -50, -43, -29, -14, 5, 12, 24, 39, 54]
[Triple{x=-29, y=5, z=24}]

Process finished with exit code 0
```

A screen recorded video has been attached to prove that no test cases were changed while executing these results.