Program Structures and Algorithms
Spring 2023(SEC –03)

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Task:
Assignment 2 (3-SUM)

Relationship Conclusion:
For ThreeSumCubic:
y = 7.2*10^(-10)*x^3.61
For ThreeSumQuadrithmic:
y = 3.9*10^(-6)*x^2logx
For ThreeSumQuadratic:
y = 1.6*10^(-6)*x^2
For ThreeSumQuadraticWithCalipers:
Y = 5.9*10^(-6)*x^2

Explanation of ThreeSumQuadratic:
First, we determine the second value for triples. There are N possible places for second values.
For every second value, we find all possible places for first values and third values that sum to 0. Assume second value's indice is j. We use 2 pointers. P1 points to j-1, and P2 points to j+1. If the triple sum to 0, we add it to result. If it's smaller than 0, P2 = P2 + 1. If it's greater than 0, P1 = P1 - 1.
For available triple (i, j, k), if P1 reaches i first, P2 is smaller than k. So, the current triple (i, j, p2) is less than 0. We will move P2 forward until it equals k. So we can reach every possible triple.
In the worst case, we will check all values in the array using these 2 pointers. It will take O(N) time. So, the total time complexity is O(N^2).

Evidence to support that conclusion:
Timing observations – ThreeSumCubic

N	Time	logN	logTime
600	9	9.22881869	3.169925
1200	58	10.2288187	5.857981
2400	1754	11.2288187	10.776433
4800	17705	12.2288187	14.1118692
9600	141460	13.2288187	17.1100346

Timing observations – ThreeSumQuadrithmic

N	Time	logN	logTime
600	3	9.22881869	1.5849625
1200	11	10.2288187	3.45943162
2400	68	11.2288187	6.08746284
4800	335	12.2288187	8.38801729
9600	1446	13.2288187	10.4978518

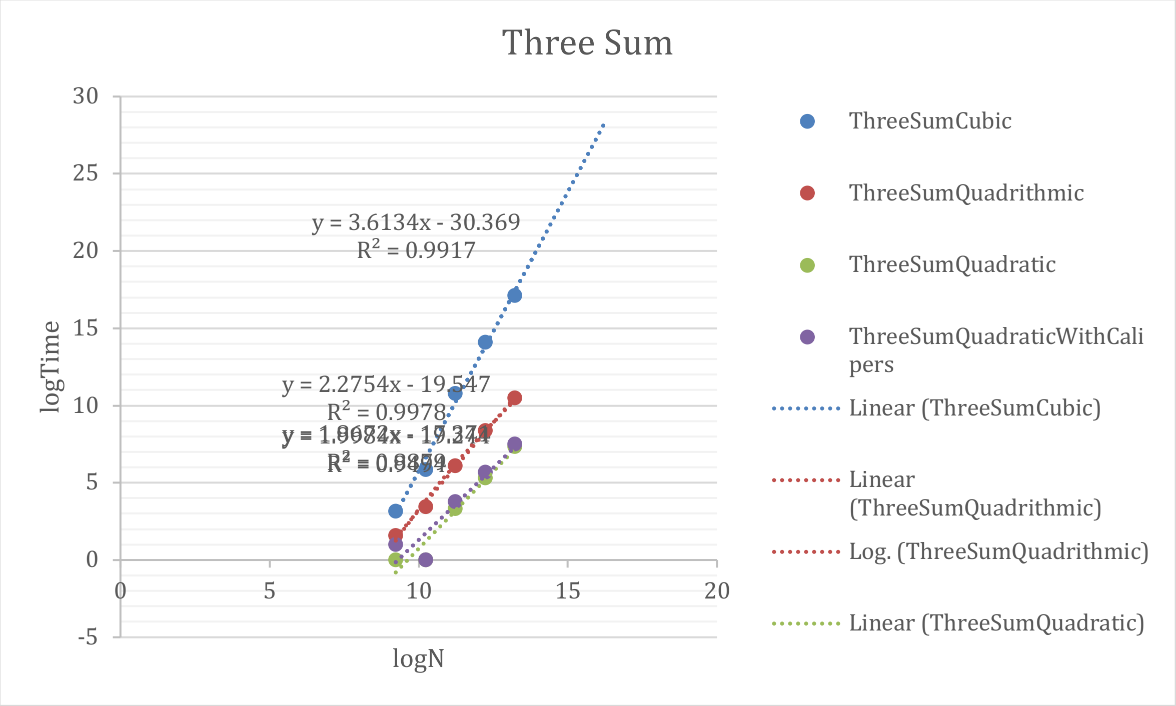
Timing observations – ThreeSumQuadratic

N	Time	logN	logTime
600	1	9.22881869	0
1200	1	10.2288187	0
2400	10	11.2288187	3.32192809
4800	40	12.2288187	5.32192809
9600	161	13.2288187	7.33091688

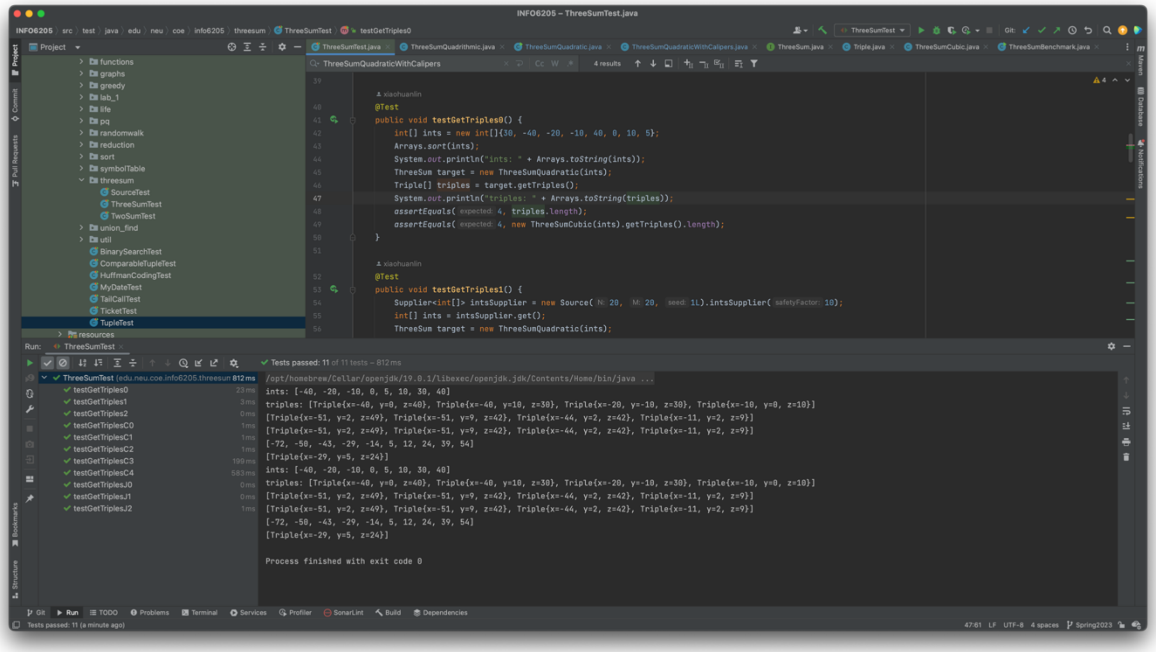
Timing observations – ThreeSumQuadraticWithCalipers

N	Time	logN	logTime
600	2	9.22881869	1
1200	1	10.2288187	0
2400	14	11.2288187	3.80735492
4800	51	12.2288187	5.67242534
9600	181	13.2288187	7.49984589

Graphical Representation:



Unit Test Screenshots:



```java
    @Test
    public void testGetTriples0() {
        int[] ints = new int[]{30, -40, -20, -10, 40, 0, 10, 5};
        Arrays.sort(ints);
        System.out.println("ints: " + Arrays.toString(ints));
        ThreeSum target = new ThreeSumQuadratic(ints);
        Triple[] triples = target.getTriples();
        System.out.println("triples: " + Arrays.toString(triples));
        assertEquals( expected: 4, triples.length);
        assertEquals( expected: 4, new ThreeSumCubic(ints).getTriples().length);
    }

    @Test
    public void testGetTriples1() {
        Supplier<int[]> intsSupplier = new Source( N: 20,  M: 20,  seed: 1L).intsSupplier( safetyFactor: 10);
        int[] ints = intsSupplier.get();
        ThreeSum target = new ThreeSumQuadratic(ints);
```

Tests passed: 11 of 11 tests – 812 ms

```
ThreeSumTest (edu.neu.coe.info6205.threesum 812 ms
    testGetTriples0     23 ms
    testGetTriples1      3 ms
    testGetTriples2      0 ms
    testGetTriplesC0     1 ms
    testGetTriplesC1     1 ms
    testGetTriplesC2     1 ms
    testGetTriplesC3   199 ms
    testGetTriplesC4   583 ms
    testGetTriplesJ0     0 ms
    testGetTriplesJ1     0 ms
    testGetTriplesJ2     1 ms
```

```
/opt/homebrew/Cellar/openjdk/19.0.1/libexec/openjdk.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
```

Tests passed: 11 (a minute ago)