Program Structures and Algorithms
Spring 2024

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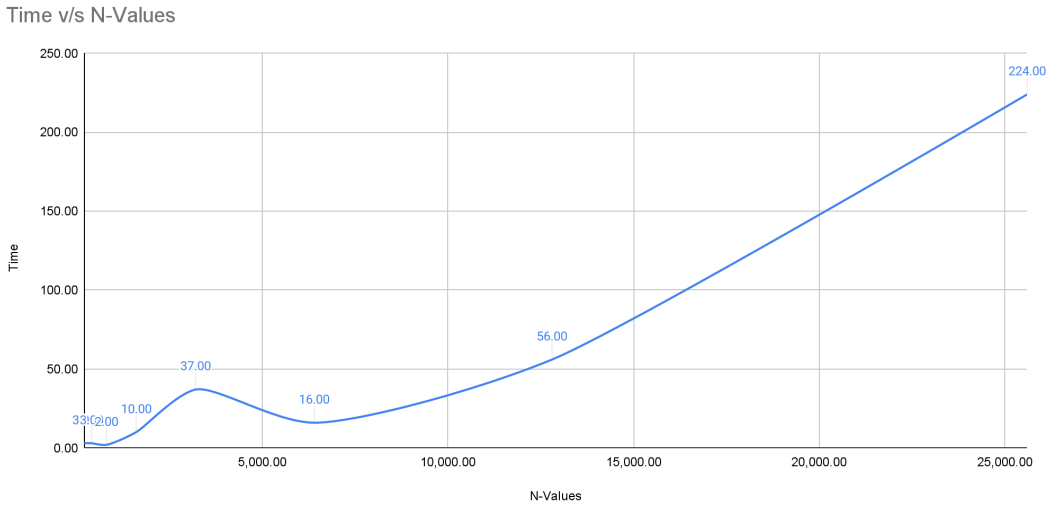
Github Link: https://github.com/tarunangrish-neu/INFO6205

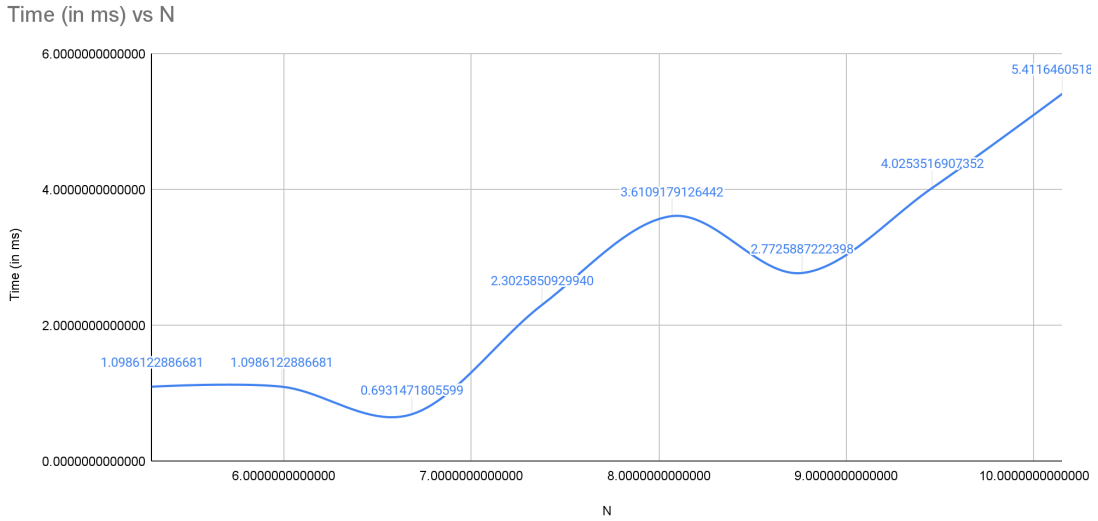
Task: For this assignment, we were supposed to implement the logic for the Three Sum Problem with Quadratic, Quadrathmic, and Quadratic with Callipers Approaches. Then, we were supposed to run a benchmark of the Time taken for execution of the approaches and analyze them.

Relationship Conclusion:

1) **Cubic**:

N	Time (in ms)
200.00	3.00
400.00	3.00
800.00	2.00
1,600.00	10.00
3,200.00	37.00
6,400.00	16.00
12,800.00	56.00
25,600.00	224.00
Values in Log-Log	
N	Time (in ms)
5.2983173665480	1.0986122886681
5.9914645471080	1.0986122886681
6.6846117276679	0.6931471805599
7.3777589082279	2.3025850929940
8.0709060887878	3.6109179126442
8.7640532693478	2.7725887222398
9.4572004499077	4.0253516907352
10.1503476304676	5.4116460518550





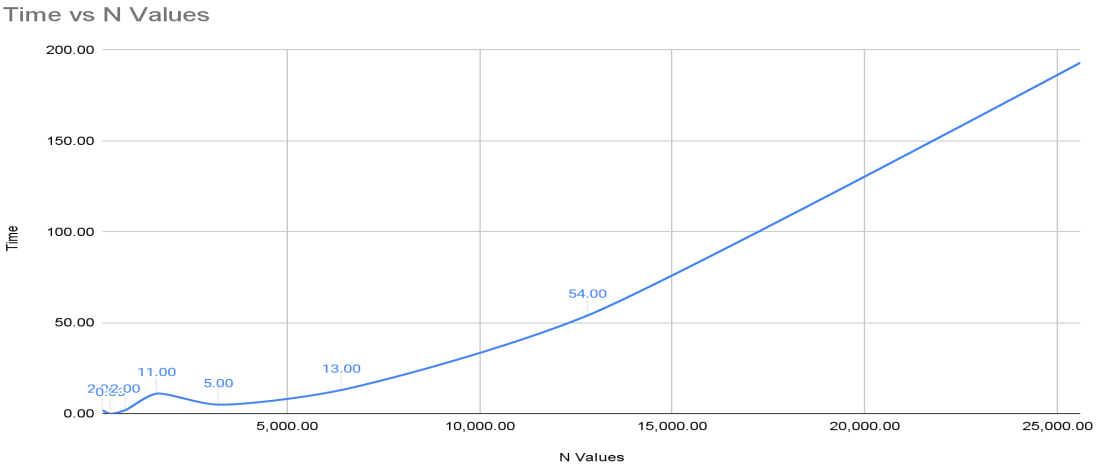
The growth function of the Cubic Approach can be given by:

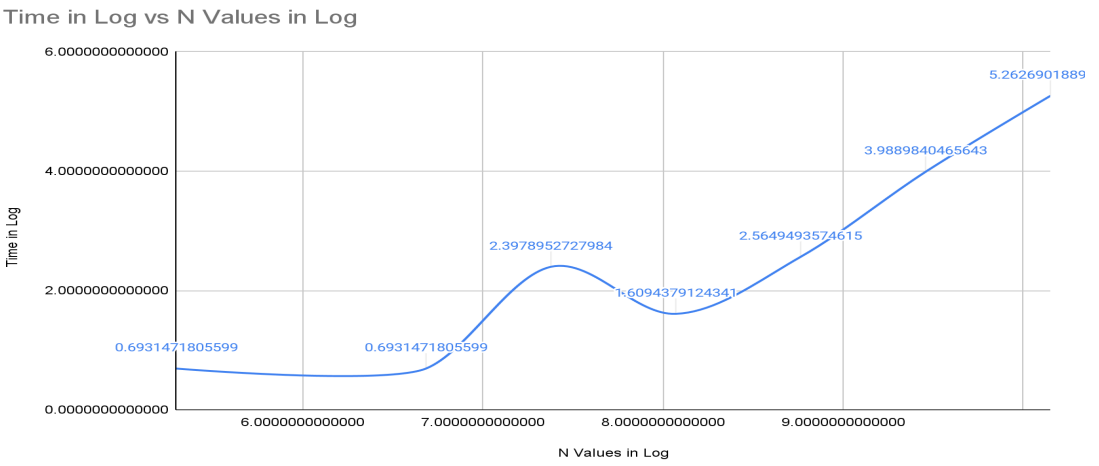
$$y = n^3$$

2) **Quadratic**:

N Values	Time
200.00	2.00
400.00	0.00
800.00	2.00
1,600.00	11.00
3,200.00	5.00
6,400.00	13.00
12,800.00	54.00
25,600.00	193.00

Quadratic With Log-Log	
N Values in Log	Time in Log
5.2983173665480	0.6931471805599
6.6846117276679	0.6931471805599
7.3777589082279	2.3978952727984
8.0709060887878	1.6094379124341
8.7640532693478	2.5649493574615
9.4572004499077	3.9889840465643
10.1503476304676	5.2626901889049



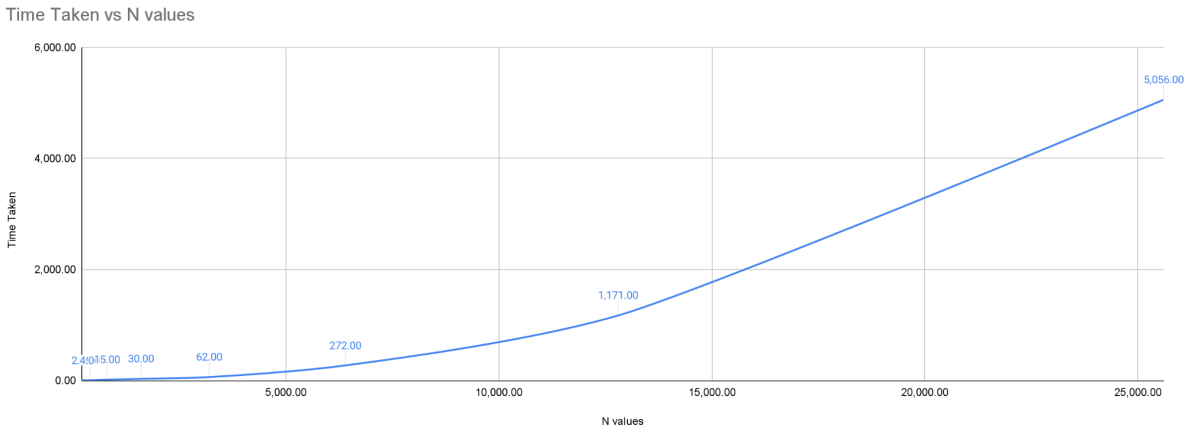


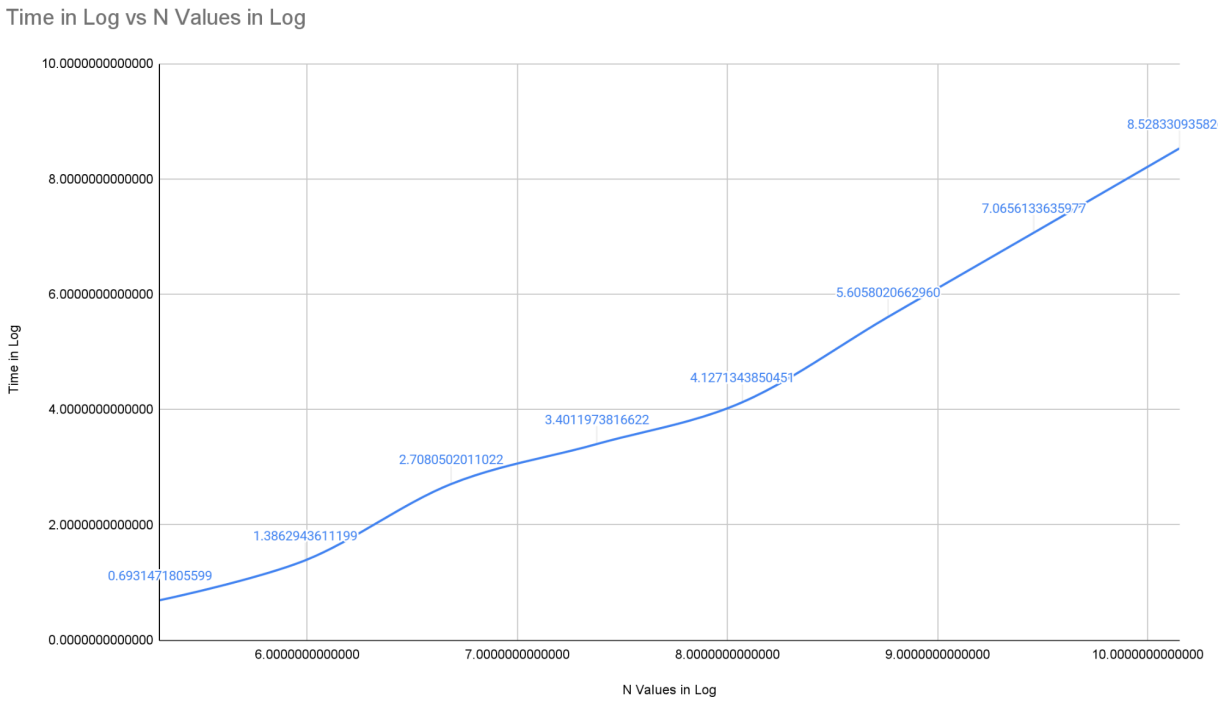
The growth function of the Quadratic Approach can be given by:

$$y = n^2$$

3) Quadrathmic Approach:

N values	Time Taken
200.00	2.00
400.00	4.00
800.00	15.00
1,600.00	30.00
3,200.00	62.00
6,400.00	272.00
12,800.00	1,171.00
25,600.00	5,056.00
Quadrathmic in Log	
N Values in Log	Time in Log
5.2983173665480	0.6931471805599
5.9914645471080	1.3862943611199
6.6846117276679	2.7080502011022
7.3777589082279	3.4011973816622
8.0709060887878	4.1271343850451
8.7640532693478	5.6058020662960
9.4572004499077	7.0656133635977
10.1503476304676	8.5283309358267





The growth function of the Quadrithmic Approach can be given by:

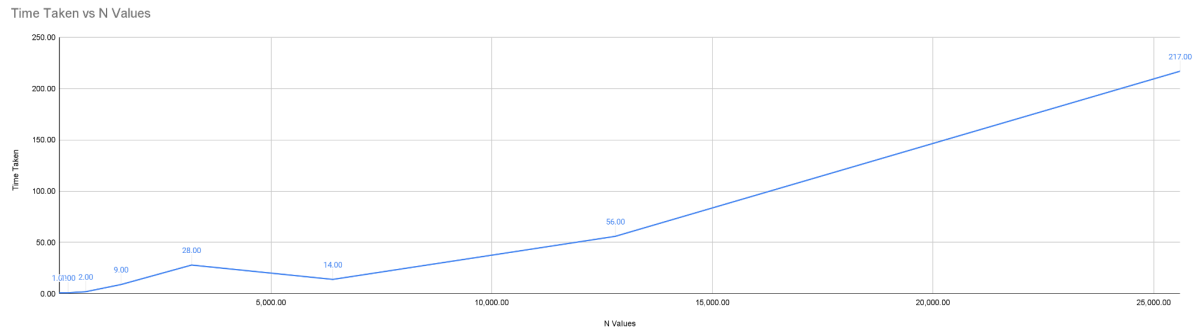
$$y = n^2 logn$$

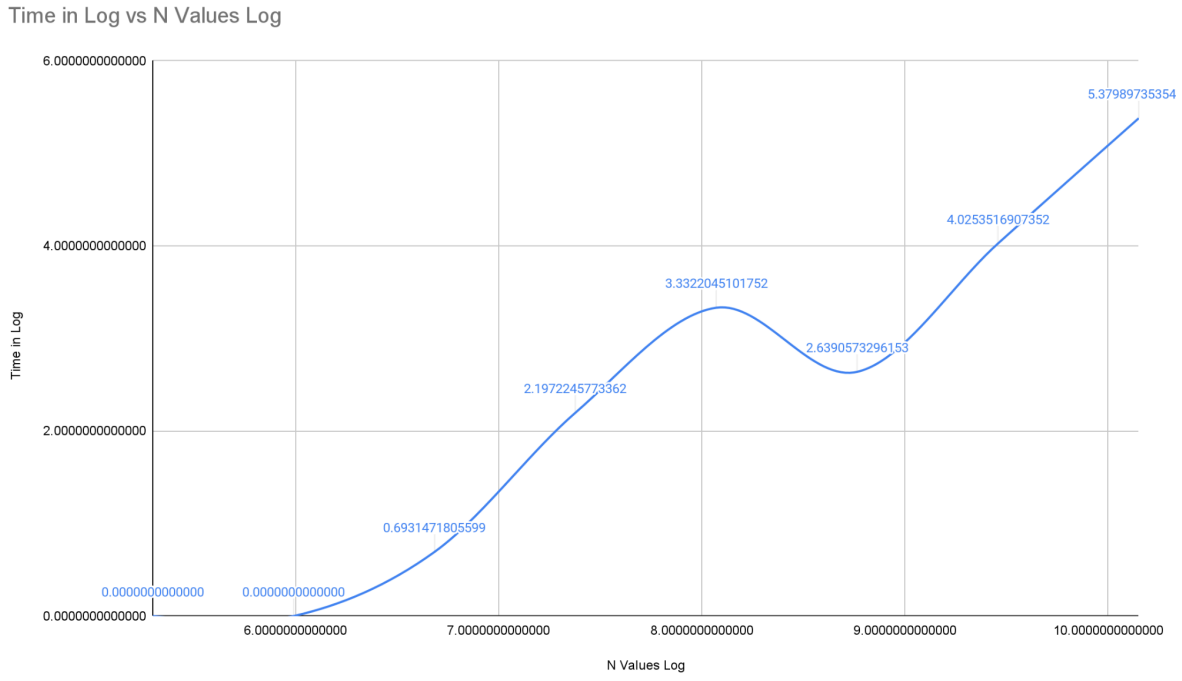
The Growth order for this can be proved by calculating the slope of the function and can be approximated to the value of the closest log value multiplied by the slope we get in the Quadratic Approach.

4) Quadratic With Callipers:

N Values	Time Taken
200.00	1.00
400.00	1.00
800.00	2.00
1,600.00	9.00
3,200.00	28.00
6,400.00	14.00
12,800.00	56.00
25,600.00	217.00
Quadratic with callipers in Log	
N Values Log	Time in Log
5.2983173665480	0.0000000000000

5.9914645471080	0.0000000000000
6.6846117276679	0.6931471805599
7.3777589082279	2.1972245773362
8.0709060887878	3.3322045101752
8.7640532693478	2.6390573296153
9.4572004499077	4.0253516907352
10.1503476304676	5.3798973535405

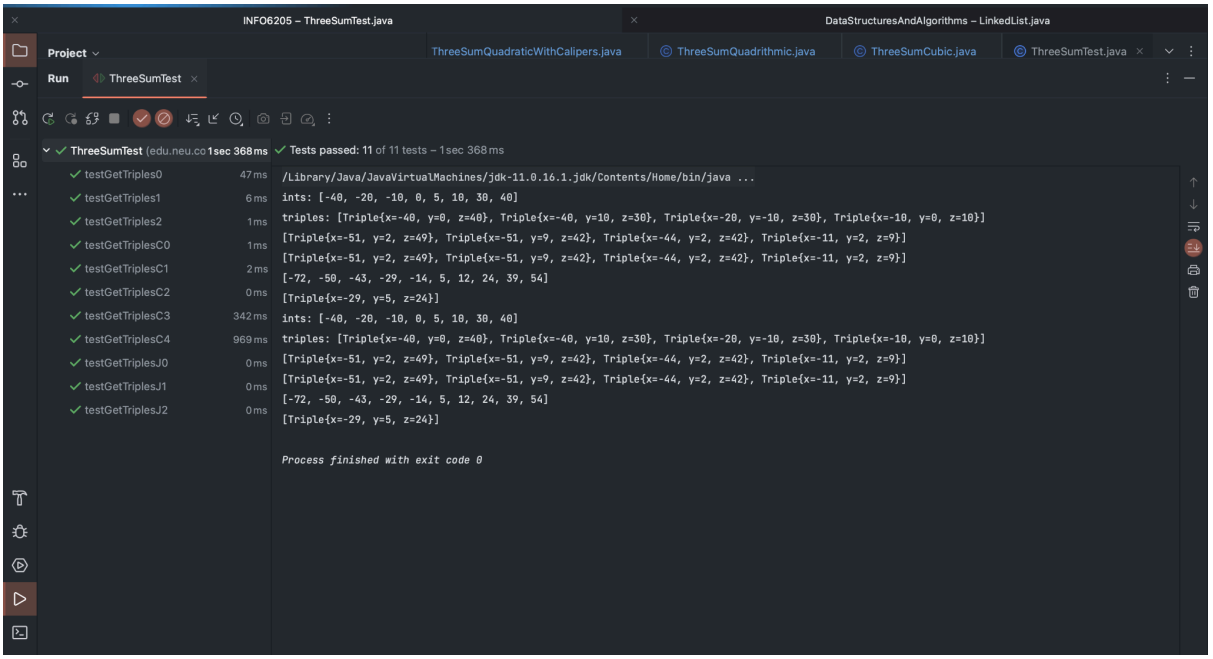




The Growth of the approach Quadratic with Callipers can be approximated by:

$$y = kn^2$$

Unit Test Evidence:



Why the quadratic methods work:

The quadratic method for the problem ‘three sum’ works because we are given the middle element of the triplet and use the two pointers approach, where one pointer points to the element before the middle and one points to the element after. We then compare the sum of these three elements to the target value. If the sum of the variables is greater than the target, we move the right pointer to the left and if the sum is less than the target value, we move the left pointer to the right. We repeat this process for each middle element therefore the overall complexity of this algorithm is O(N^2), as we have one Loop which iterates through the middle elements of the array and the other loop which moves the left and right pointers to calculate the sum of the triplets which should be equal to 0.