Program Structures and Algorithms

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**Task:** Solve 3-SUM using the Quadrithmic, Quadratic, and (bonus point) quadraticWithCalipers approaches, as shown in skeleton code in the repository. There are hints at the end of Lesson 2.5 Entropy.

There are also hints in the comments of the existing code.  There are a number of unit tests which you should be able to run successfully.

Submit (in your own repository--see instructions elsewhere--include the source code and the unit tests of course):

(a) evidence (screenshot) of your unit tests running (try to show the actual unit test code as well as the green strip);

(b) a spreadsheet showing your timing observations--using the doubling method for at least five values of N--for each of the algorithms (include cubic); Timing should be performed either with an actual stopwatch (e.g. your iPhone) or using the Stopwatch class in the repository.

(c) your brief explanation of why the quadratic method(s) work.

**Relationship Conclusion:**

The raw time per run for a cubic solution increases dramatically as N increase. In contrast to the cubic solution, the time required for execution does not significantly alter for a quadratic solution as the value of N doubles.

For N = 8000, the cubic solution takes 80110.33milliseconds, while the quadratic solution takes 420.33milliseconds.

Cubic solution for N = 16000 is 658956.50 milliseconds, and quadratic solution is 2702.00 milliseconds.

Quadratic solutions require substantially less computing time for bigger values of N. Therefore, the optimum solution for any value of N is the quadratic one.

**Evidence to support that conclusion:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **N** | **Runs** | **Time per Run** | **Quadratic**  **(millisecs)** | **Quadrithmic**  **(millisecs)** | **Cubic**  **(millisecs)** | **Quadratic with callipers**  **(millisecs)** |
| **250** | **100** | **Raw time** | **.26** | **.20** | **2.94** | **.01** |
|  |  | **Normalized time** | **4.16** | **0.40** | **.19** | **.16** |
|  |  |  |  |  |  |  |
| **500** | **50** | **Raw time** | **1.04** | **2.04** | **20.46** | **.20** |
|  |  | **Normalized time** | **4.16** | **.91** | **.16** | **.80** |
|  |  |  |  |  |  |  |
| **1000** | **20** | **Raw time** | **3.80** | **11.00** | **165.70** | **2.85** |
|  |  | **Normalized time** | **3.80** | **1.20** | **.17** | **2.85** |
|  |  |  |  |  |  |  |
| **2000** | **10** | **Raw time** | **18.30** | **60.30** | **1354.90** | **15.10** |
|  |  | **Normalized time** | **4.58** | **1.37** | **.17** | **3.75** |
|  |  |  |  |  |  |  |
| **4000** | **5** | **Raw time** | **105.00** | **310.00** | **11682.80** | **76.60** |
|  |  | **Normalized time** | **6.56** | **1.62** | **.** **18** | **4.79** |
|  |  |  |  |  |  |  |
| **8000** | **3** | **Raw time** | **492.67** | **1636.00** | **80110.33** | **420.33** |
|  |  | **Normalized time** | **7.70** | **1.97** | **0.15** | **6.57** |
|  |  |  |  |  |  |  |
| **16000** | **2** | **Raw time** | **2702.00** | **7930.00** | **658956.50** | **2386.00** |
|  |  | **Normalized time** | **10.55** | **2.28** | **0.16** | **9.32** |
|  |  |  |  |  |  |  |

**Graphical Representation:**

**Graph for Quadratic:**

**Graph for Cubic:**

**Unit Test Screenshots:**

Graphical user interface, text

Description automatically generated

Solution for Quadratic

Text

Description automatically generated

Solution for Quadratic with callipers

Text

Description automatically generated