Zixuan.Zhu (002196924)

Program Structures & Algorithms

Fall 2021

Assignment No. 2

Task

Your task for this assignment is in three parts.

(Part 1) You are to implement three methods of a class called Timer. Please see the skeleton class that I created in the repository. Timer is invoked from a class called Benchmark_Timer which implements the Benchmark interface. The APIs of these class are as follows:

```
public interface Benchmark<T> {
   default double run(T t, int m) {
      return runFromSupplier(() -> t, m);
   }

   double runFromSupplier(Supplier<T> supplier, int m);
}

public class Benchmark_Timer<T> implements Benchmark<T> {

public Benchmark_Timer(String description, UnaryOperator<T> fPre, Consumer<T> fRun, Consumer<T> fPost)

public Benchmark_Timer(String description, UnaryOperator<T> fPre, Consumer<T> fRun)

public Benchmark_Timer(String description, Consumer<T> fRun, Consumer<T> fPost)

public Benchmark_Timer(String description, Consumer<T> f)

public class Timer {
... // see below for methods to be implemented...
}
```

```
public <T, U> double repeat(int n, Supplier<T> supplier, Function<T, U> func
tion, UnaryOperator<T> preFunction, Consumer<U> postFunction) {
// TO BE IMPLEMENTED
}

private static long getClock() {
   // TO BE IMPLEMENTED
}

private static double toMillisecs(long ticks) {
   // TO BE IMPLEMENTED
}
```

The function to be timed, hereinafter the "target" function, is the Consumer function fRun (or just f) passed in to one or other of the constructors. For example, you might create a function which sorts an array with n elements.

The generic type T is that of the input to the target function.

The first parameter to the first run method signature is the parameter that will, in turn, be passed to target function. In the second signature, supplier will be invoked each time to get a t which is passed to the other run method.

The second parameter to the run function (m) is the number of times the target function will be called.

The return value from run is the average number of milliseconds taken for each run of the target function.

Don't forget to check your implementation by running the unit tests in BenchmarkTest and TimerTest. If you have trouble with the exact timings in the unit tests, it's quite OK (in this assignment only) to change parameters until the tests run. Different machine architectures will result in different behavior.

- (Part 2) Implement InsertionSort (in the InsertionSort class) by simply looking up the insertion code used by Arrays.sort. If you have the instrument = true setting in test/resources/config.ini, then you will need to use the helper methods for comparing and swapping (so that they properly

count the number of swaps/compares). The easiest is to use the helper.swapStableConditional method, continuing if it returns true, otherwise breaking the loop. Alternatively, if you are not using instrumenting, then you can write (or copy) your own compare/swap code. Either way, you must run the unit tests in InsertionSortTest.

- (Part 3) Implement a main program (or you could do it via your own unit tests) to actually run the following benchmarks: measure the running times of this sort, using four different initial array ordering situations: random, ordered, partially-ordered and reverse-ordered. I suggest that your arrays to be sorted are of type Integer. Use the doubling method for choosing n and test for at least five values of n. Draw any conclusions from your observations regarding the order of growth.

  As usual, the submission will be your entire project (clean, i.e. without the target and project folders). There are stubs and unit tests in the repository.

  Report on your observations and show screenshots of the runs and also the unit tests. Please note that you may have to adjust the required execution time for the insertion sort unit test(s) because your computer may not run at the same speed as mine.

  Further notes: you should use the System.nanoTime method to get the clock time. This isn't guaranteed to be accurate which is one of the reasons you should run the experiment several times for each value of n. Also, for each invocation of run, run the given target function ten times to get the system "warmed up" before you start the timing properly.

  The Sort interface takes care of copying the array when the sort(array) signature is called. It returns a new array as a result. The original array is unchanged. Therefore, you do not need to worry about the insertion-based sorts getting quicker because of the arrays getting more sorted (they don't).

- **Relationship Conclusion:**

  Comparison of the running time of four differently sorted but same length(n) arrays (random, ordered, partially-ordered and reverse-ordered)when using insertion sort:

  reverse-ordered>random>partially-ordered>ordered

  ("partially-ordered" in this assignment means that array is ordered from "array.length/2" to "array.length")

- **Evidence to support the conclusion:**

  Github address:
  Timer:
  https://github.com/ZixuanZhu-faye/INFO-6205/blob/e60c0539e66af2048d8e425d4d26703827c0c691/INFO6205-Fall2021/src/main/java/edu/neu/coe/info6205/util/Timer.java
  InsertionSort:
  https://github.com/ZixuanZhu-faye/INFO-6205/blob/e60c0539e66af2048d8e425d4d26703827c0c691/INFO6205-Fall2021/src/main/java/edu/neu/coe/info6205/sort/elementary/InsertionSort.java
  Benchmark_Timer:
  https://github.com/ZixuanZhu-faye/INFO-6205/blob/e60c0539e66af2048d8e425d4d26703827c0c691/INFO6205-Fall2021/src/main/java/edu/neu/coe/info6205/util/Benchmark_Timer.java

1. **Output**

B-E-G-I-N
Round 1
Random: n = 40
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:1.3333333333333333
meantime:1.0333333333333334
Meantime: 1.0333333333333334
Partially-ordered: n = 40
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.6666666666666666
meantime:0.8333333333333334
Meantime: 0.8333333333333334
Ordered: n = 40
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs

meantime:0.6666666666666666
meantime:0.7333333333333333
Meantime: 0.7333333333333333
Reverse-ordered n = 40
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.6666666666666666
meantime:0.7333333333333333
Mean lap time: 0.7333333333333333
Round 2
Random: n = 80
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.5666666666666667
Meantime: 0.5666666666666667
Partially-ordered: n = 80
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.7333333333333333
Meantime: 0.7333333333333333
Ordered: n = 80
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.3333333333333333
Meantime: 0.3333333333333333
Reverse-ordered n = 80
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.5
Mean lap time: 0.5
Round 3
Random: n = 160
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.5
Meantime: 0.5
Partially-ordered: n = 160
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.36666666666666664
Meantime: 0.36666666666666664
Ordered: n = 160
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.8

Meantime: 0.8
Reverse-ordered n = 160
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.4666666666666667
Mean lap time: 0.4666666666666667
Round 4
Random: n = 320
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.5333333333333333
Meantime: 0.5333333333333333
Partially-ordered: n = 320
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.36666666666666664
Meantime: 0.36666666666666664
Ordered: n = 320
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.0
meantime:0.3333333333333333
Meantime: 0.3333333333333333
Reverse-ordered n = 320
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.6666666666666666
meantime:0.9666666666666667
Mean lap time: 0.9666666666666667
Round 5
Random: n = 640
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:1.3333333333333333
meantime:0.9666666666666667
Meantime: 0.9666666666666667
Partially-ordered: n = 640
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.6666666666666666
meantime:0.6
Meantime: 0.6
Ordered: n = 640
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.6
Meantime: 0.6
Reverse-ordered n = 640

2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:1.0
meantime:1.2666666666666666
Mean lap time: 1.2666666666666666
Round 6
Random: n = 1280
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:1.6666666666666667
meantime:1.9666666666666666
Meantime: 1.9666666666666666
Partially-ordered: n = 1280
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:1.3333333333333333
meantime:2.2666666666666666
Meantime: 2.2666666666666666
Ordered: n = 1280
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.6666666666666666
meantime:0.23333333333333334
Meantime: 0.23333333333333334
Reverse-ordered n = 1280
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:3.6666666666666665
meantime:5.033333333333333
Mean lap time: 5.033333333333333
Round 7
Random: n = 2560
2021-09-26 16:59:17 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:6.666666666666667
meantime:7.633333333333334
Meantime: 7.633333333333334
Partially-ordered: n = 2560
2021-09-26 16:59:18 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:4.666666666666667
meantime:5.166666666666667
Meantime: 5.166666666666667
Ordered: n = 2560
2021-09-26 16:59:18 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.0
meantime:0.13333333333333333
Meantime: 0.13333333333333333
Reverse-ordered n = 2560
2021-09-26 16:59:18 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:13.0

meantime:12.7
Mean lap time: 12.7
Round 8
Random: n = 5120
2021-09-26 16:59:18 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:26.333333333333332
meantime:29.833333333333332
Meantime: 29.833333333333332
Partially-ordered: n = 5120
2021-09-26 16:59:19 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:20.666666666666668
meantime:22.766666666666666
Meantime: 22.766666666666666
Ordered: n = 5120
2021-09-26 16:59:20 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.0
meantime:0.13333333333333333
Meantime: 0.13333333333333333
Reverse-ordered n = 5120
2021-09-26 16:59:20 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:63.0
meantime:62.266666666666666
Mean lap time: 62.266666666666666
Round 9
Random: n = 10240
2021-09-26 16:59:22 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:154.0
meantime:123.2
Meantime: 123.2
Partially-ordered: n = 10240
2021-09-26 16:59:26 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:108.0
meantime:78.86666666666666
Meantime: 78.86666666666666
Ordered: n = 10240
2021-09-26 16:59:29 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.0
meantime:0.2
Meantime: 0.2
Reverse-ordered n = 10240
2021-09-26 16:59:29 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:216.0
meantime:206.66666666666666
Mean lap time: 206.66666666666666

Round 10
Random: n = 20480
2021-09-26 16:59:36 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:442.3333333333333
meantime:449.6666666666667
Meantime: 449.6666666666667
Partially-ordered: n = 20480
2021-09-26 16:59:51 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:336.0
meantime:324.73333333333335
Meantime: 324.73333333333335
Ordered: n = 20480
2021-09-26 17:00:02 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:0.3333333333333333
meantime:0.23333333333333334
Meantime: 0.23333333333333334
Reverse-ordered n = 20480
2021-09-26 17:00:02 INFO Benchmark_Timer - Begin run: InsertionSort Time with 30 runs
meantime:967.3333333333334
meantime:956.1
Mean lap time: 956.1
E-N-D

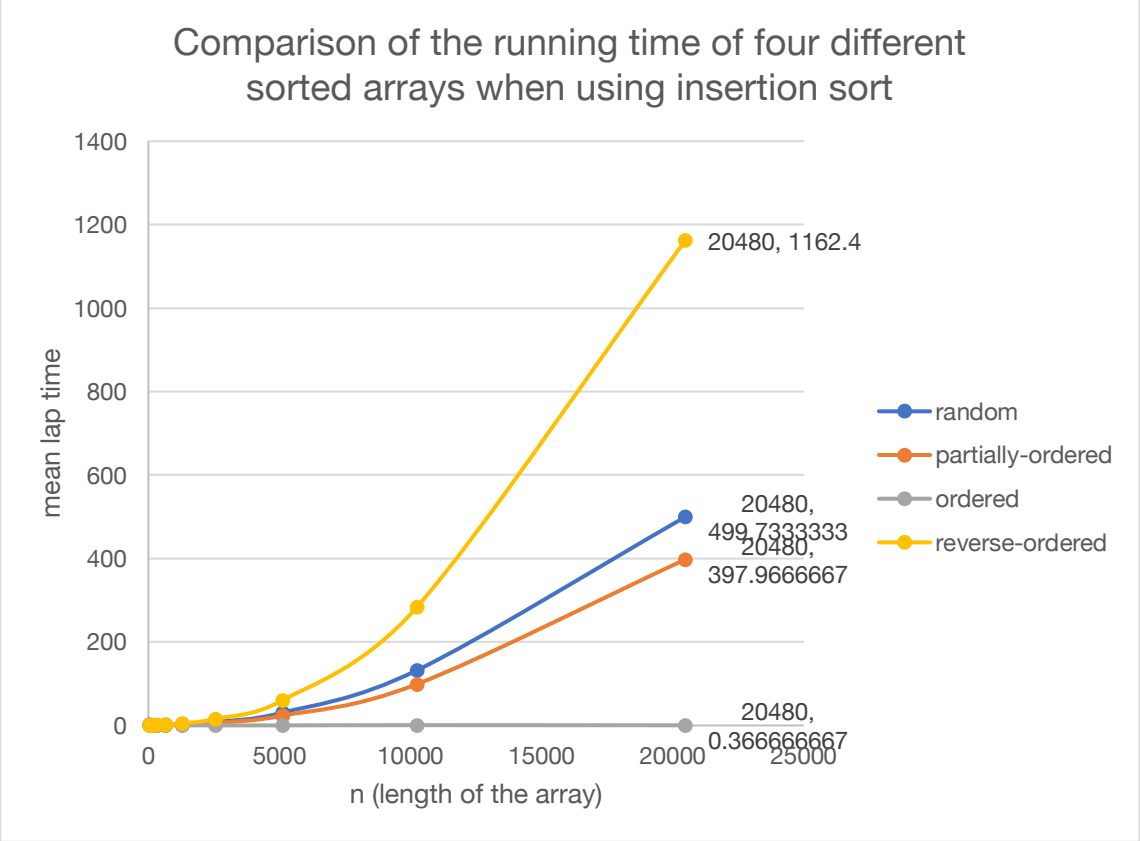
2. Graphical Representation

Data:

n	random	partially-ordered	ordered	reverse-ordered
40	1.366666667	1.333333333	0.8	0.733333333
80	0.7	1	0.8	0.633333333
160	0.8	0.766666667	0.5	0.7
320	0.766666667	0.7	0.633333333	1.066666667
640	1.066666667	0.966666667	0.466666667	1.6
1280	3.633333333	2.133333333	0.266666667	4.8
2560	8.266666667	6.3	0.133333333	15.66666667
5120	30.8	23.36666667	0.166666667	60.46666667
10240	132.1	98.93333333	0.666666667	283.4666667
20480	499.7333333	397.9666667	0.366666667	1162.4

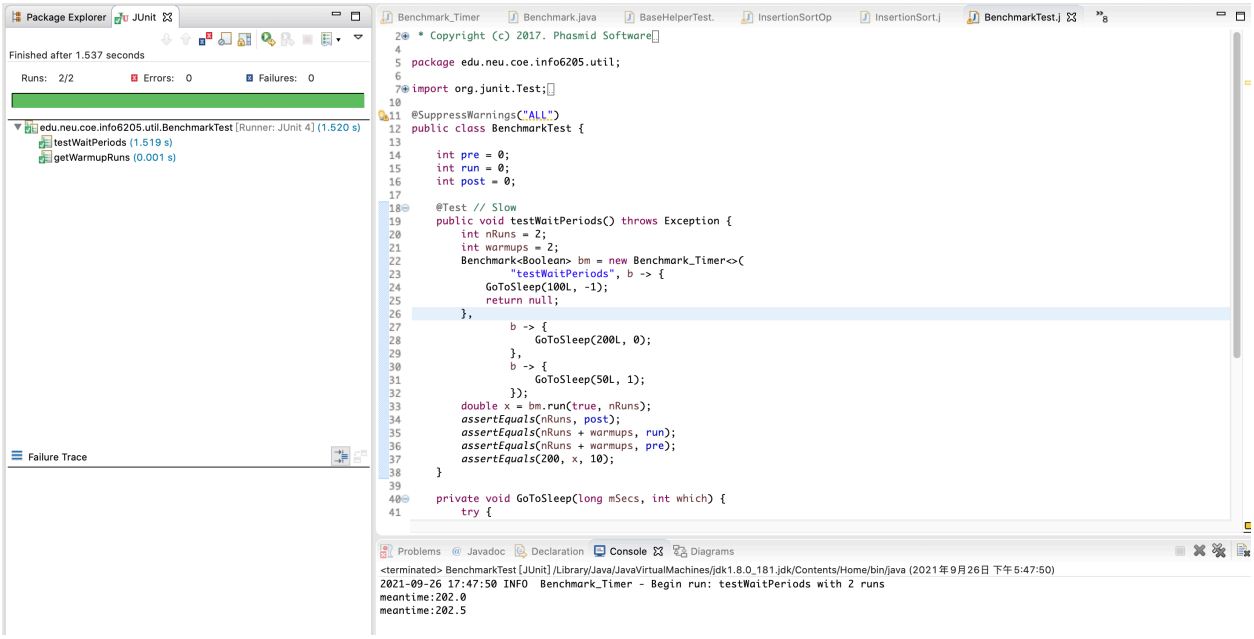
“n” is the number of elements of the array.

Graph:

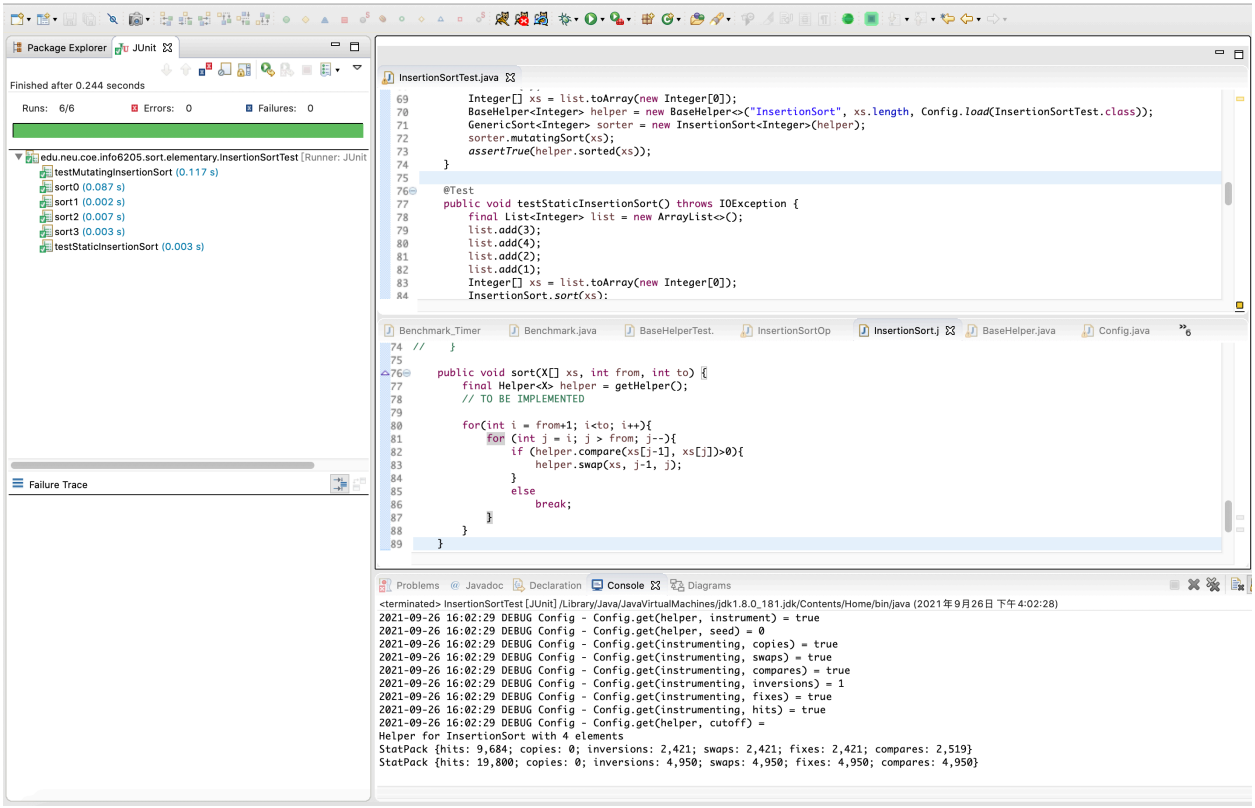


- **Unit tests result:**

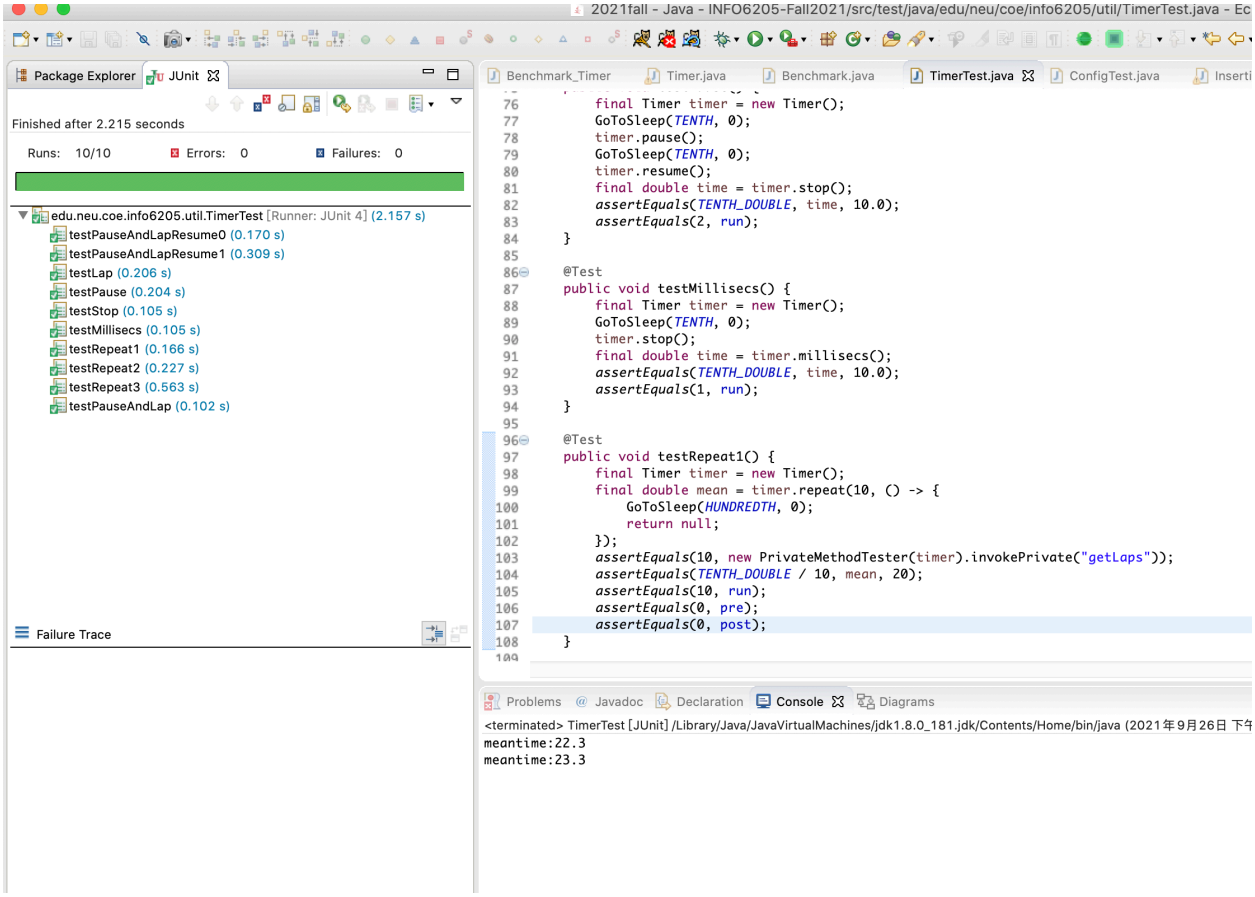
BenchmarkTest:



InsertionSortTest:



TimerTest:




```
76          final Timer timer = new Timer();
77          GoToSleep(TENTH, 0);
78          timer.pause();
79          GoToSleep(TENTH, 0);
80          timer.resume();
81          final double time = timer.stop();
82          assertEquals(TENTH_DOUBLE, time, 10.0);
83          assertEquals(2, run);
84      }
85
86      @Test
87      public void testMillisecs() {
88          final Timer timer = new Timer();
89          GoToSleep(TENTH, 0);
90          timer.stop();
91          final double time = timer.millisecs();
92          assertEquals(TENTH_DOUBLE, time, 10.0);
93          assertEquals(1, run);
94      }
95
96      @Test
97      public void testRepeat1() {
98          final Timer timer = new Timer();
99          final double mean = timer.repeat(10, () -> {
100             GoToSleep(HUNDREDTH, 0);
101             return null;
102         });
103         assertEquals(10, new PrivateMethodTester(timer).invokePrivate("getLaps"));
104         assertEquals(TENTH_DOUBLE / 10, mean, 20);
105         assertEquals(10, run);
106         assertEquals(0, pre);
107         assertEquals(0, post);
108     }
```