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### Assignment 3

#### Task:

**Part 1** - To implement three methods (*repeat*, *getClock*, and *toMillisecs*) of a class called *Timer* and checking the implementation by running the unit tests in *BenchmarkTest* and *TimerTest*.

**Part 2**-Implementation of InsertionSort *and testing using InsertionSortTest*.

**Part 3**- Implementation of main program to run the benchmarks using four different initial array ordering situations: random, ordered, partially ordered and reverse-ordered. To also draw conclusions from your observations regarding the order of growth.

#### Relationship Conclusion:

The time complexity of Insertion sort for random arrays is  $O(n^2)$  where  $n$  is the number of elements in the array. When the input array is already ordered the time complexity will be  $O(n)$  as no swapping of elements will be required which is the best-case scenario but when the input array is reverse ordered the time complexity is  $O(n^2)$  which is the worst-case scenario.

In the partially ordered case, the time complexity will be somewhere between  $O(n)$  and  $O(n^2)$ , depending on the order of the elements of the array

The time required to sort a random array of  $n$  elements is  $O(n^2)$ , in the worst case.

Hence, the performance of insertion sort varies based on the initial ordering of the elements in the array. This means that the time required to sort the array grows quadratically with the size of the input.

#### Evidence to support that conclusion:

Below are the run values for values of  $N$  in each case using Insertion sort ,

N	Random	Ordered	Reverse Ordered	Partially Ordered
250	380765	24372	756997	119567
500	532544	13092	414641	186926
1000	901381	13050	1795917	946829
2000	3436569	37604	6595801	738746
4000	13224606	194317	26255279	2772493
8000	53436437	57441	109268153	45383446

```
private static long getClock() {
    // FIXME by replacing the following code
    return System.nanoTime();
    //return 0;
    // END
}
```

```
public double millisecs() {
    if (running) throw new TimerException();
    return toMillisecs(ticks);
}
```

```
public <T, U> double repeat(int n, Supplier<T> supplier, Function<T, U> function, UnaryOperator<U> preFunction, Consumer<U> postFunction) {
    logger.trace("repeat: with " + n + " runs");
    pause();
    // FIXME: note that the timer is running when this method is called and should still be running when it returns. by replacing the following code
    double tTime = 0;
    for (int i = 1; i <= n; i++) {
        T inputValue = supplier.get();
        if (preFunction != null) {
            inputValue = preFunction.apply(inputValue);
        }
        resume();
        long startTime = System.nanoTime();
        U result = function.apply(inputValue);
        long endTime = System.nanoTime();
        tTime += (endTime - startTime) / 1_000_000.0;
        pauseAndLap();
        if (postFunction != null) {
            postFunction.accept(result);
        }
    }
    resume();
    return tTime / n;
    //return 0;
    // END
}
```

## InsertionSort

```
1 override * xiaohuanlin *
public void sort(X[] xs, int from, int to) {
    final Helper<X> helper = getHelper();

    for (int i = from + 1; i < to; i++) {
        X x = xs[i];
        int j = i;
        while (j > from && helper.compare(xs[j - 1], x) > 0) {
            //xs[j] = xs[j - 1];
            helper.swap(xs, j - 1, j);
            j--;
        }
        xs[j] = x;
    }
}
```

```
Run: InsertionSortTest.Random x
[Icons] Tests passed: 1 of 1 test - 7 sec 500 ms
InsertionSortTest (edu.neu.coe.info6205) 7 sec 500 ms /Library/Java/JavaVirtualMachines/jdk-12.0.2.jdk/Contents/Home/bin/java ...
  Random
    Time taken on average to sort Random array of size 250 is 281152
    Time taken on average to sort Random array of size 500 is 475690
    Time taken on average to sort Random array of size 1000 is 895323
    Time taken on average to sort Random array of size 2000 is 3221929
    Time taken on average to sort Random array of size 4000 is 13114901
    Time taken on average to sort Random array of size 8000 is 54682227

    Process finished with exit code 0
```

```
Run: InsertionSortTest.Ordered x
[Icons] Tests passed: 1 of 1 test - 290 ms
InsertionSortTest (edu.neu.coe.info6205) 290 ms /Library/Java/JavaVirtualMachines/jdk-12.0.2.jdk/Contents/Home/bin/java ...
  Ordered
    Time taken on average to sort Ordered array 250 is 25163 on runs 100
    Time taken on average to sort Ordered array 500 is 12797 on runs 100
    Time taken on average to sort Ordered array 1000 is 13161 on runs 100
    Time taken on average to sort Ordered array 2000 is 33063 on runs 100
    Time taken on average to sort Ordered array 4000 is 178631 on runs 100
    Time taken on average to sort Ordered array 8000 is 51193 on runs 100

    Process finished with exit code 0
```

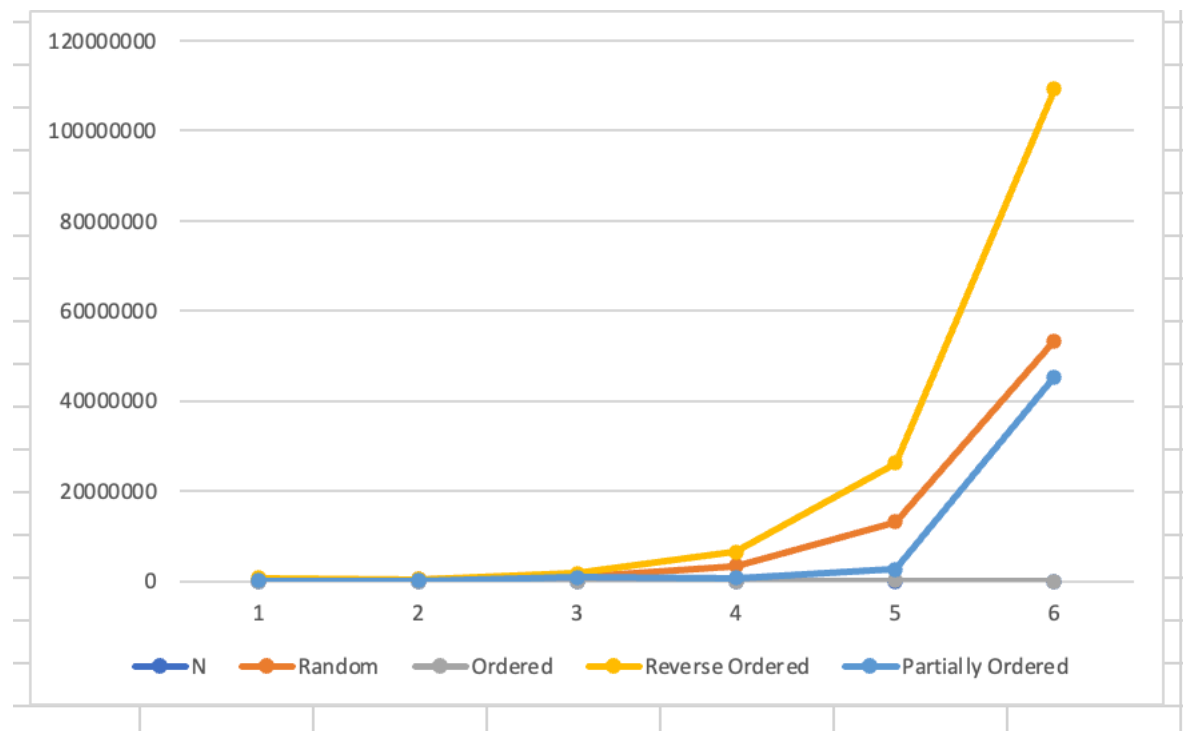
```
Run: InsertionSortTest.ReverseOrdered x
[Icons] Tests passed: 1 of 1 test - 14 sec 886 ms
InsertionSortTest (edu.neu.coe.info6214) 14 sec 886 ms /Library/Java/JavaVirtualMachines/jdk-12.0.2.jdk/Contents/Home/bin/java ...
  Reverse Ordered
    Time taken on average to sort Reverse Ordered array 250 is 592794 on runs 100
    Time taken on average to sort Reverse Ordered array 500 is 425916 on runs 100
    Time taken on average to sort Reverse Ordered array 1000 is 1827688 on runs 100
    Time taken on average to sort Reverse Ordered array 2000 is 6716775 on runs 100
    Time taken on average to sort Reverse Ordered array 4000 is 26504771 on runs 100
    Time taken on average to sort Reverse Ordered array 8000 is 110242364 on runs 100

    Process finished with exit code 0
```

```
Run: InsertionSortTest.PartialOrdered x
[Icons] Tests passed: 1 of 1 test - 1 min 5 sec
InsertionSortTest (edu.neu.coe.info6205) 1 min 5 sec /Library/Java/JavaVirtualMachines/jdk-12.0.2.jdk/Contents/Home/bin/java ...
  Partial Ordered
    Time taken on average to sort Partial Ordered array 250 is 159090 on runs 1000
    Time taken on average to sort Partial Ordered array 500 is 224544 on runs 1000
    Time taken on average to sort Partial Ordered array 1000 is 789976 on runs 1000
    Time taken on average to sort Partial Ordered array 2000 is 3031052 on runs 1000
    Time taken on average to sort Partial Ordered array 4000 is 12088563 on runs 1000
    Time taken on average to sort Partial Ordered array 8000 is 48324801 on runs 1000

    Process finished with exit code 0
```

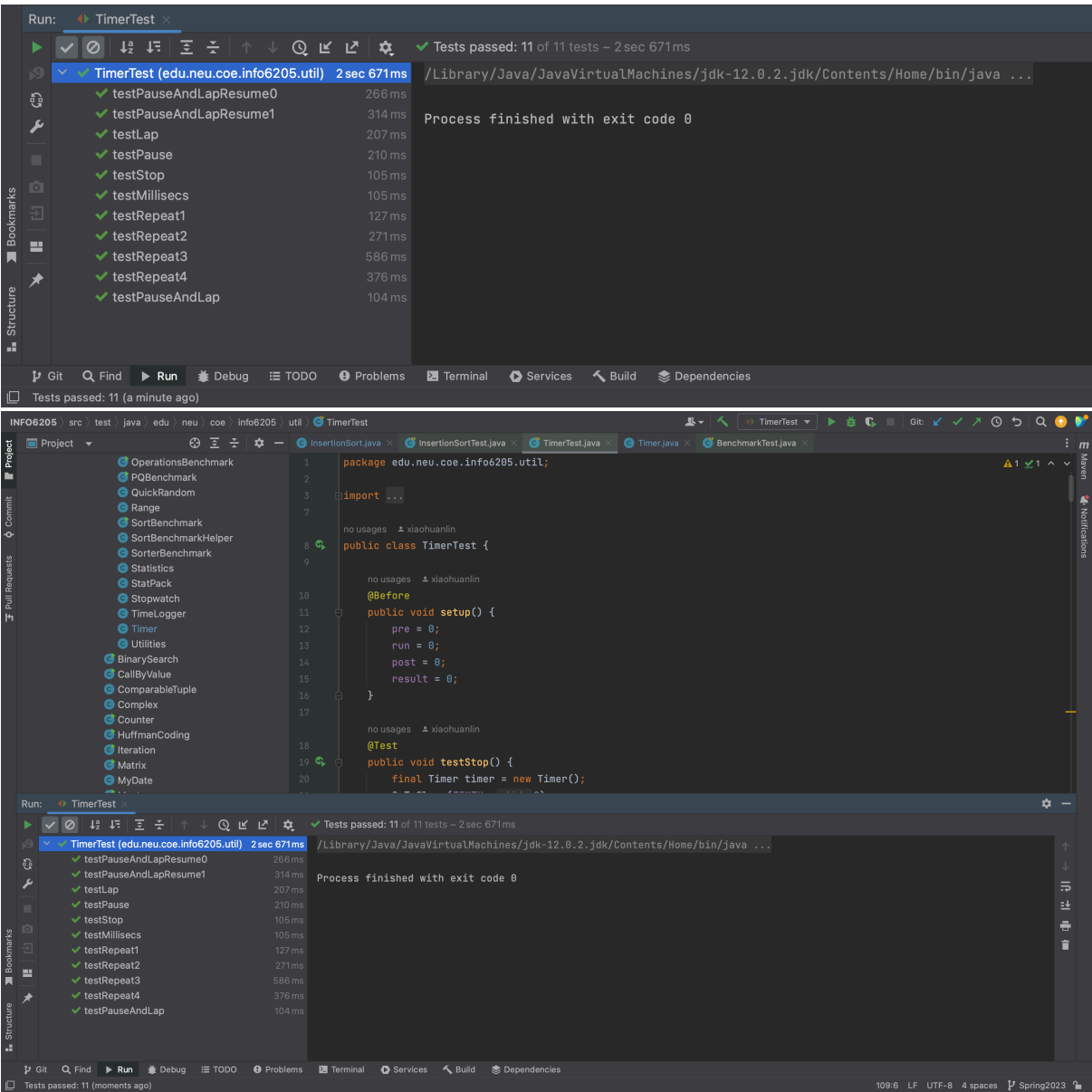
### Graphical Representation:



N	Random	Ordered	Reverse Ordered	Partially Ordered
250	380765	24372	756997	119567
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Unit Test Screenshots:

1.TimerTest



## 2. BenchmarkTest

The screenshot displays an IDE interface with two panels. The top panel shows the results of a JUnit test run for `BenchmarkTest`. The bottom panel shows the source code of `BenchmarkTest.java`.

**Test Results (Top Panel):**

- Run: BenchmarkTest
- Tests passed: 2 of 2 tests - 1 sec 565 ms
- Test cases:
  - ✓ BenchmarkTest (edu.neu.coe.info6205) 1 sec 565 ms
  - ✓ testWaitPeriods 1 sec 564 ms
  - ✓ getWarmupRuns 1 ms
- Log output:
  - 2023-02-04 19:15:22 INFO Benchmark\_Timer - Begin run: testWaitPeriods with 2 runs
  - Process finished with exit code 0

**Source Code (Bottom Panel):**

```
1 //...
2
3 package edu.neu.coe.info6205.util;
4
5 import org.junit.Test;
6
7 import static org.junit.Assert.assertEquals;
8
9 //...
10
11 //...
12
13 public class BenchmarkTest {
14
15     2 usages
16     int pre = 0;
17
18     2 usages
19     int run = 0;
20
21     2 usages
22     int post = 0;
23
24     no usages 1 xiaohuanlin
25     @Test // Slow
26     public void testWaitPeriods() throws Exception {
27         int nRuns = 2;
28         int warmups = 2;
29     }
30 }
```

### 3.InsertionSortTest

The screenshot displays an IDE interface with the `InsertionSortTest` class open. The class is located in the package `edu.neu.coe.info6205.sort.elementary`. It contains a `@Test` method `sort0()` that tests the insertion sort algorithm. The test results show that all 6 tests passed, with a total execution time of 268 ms. The test results are as follows:

Test Name	Duration (ms)
testMutatingInsertionSort	192
sort0	31
sort1	26
sort2	14
sort3	3
testStaticInsertionSort	2

The test results also include performance metrics for the `StatPack` class, such as hits, normalized values, copies, inversions, and swaps. The test results are displayed in the Run tab of the IDE.

```
package edu.neu.coe.info6205.sort.elementary;

import ...

/ALL/
public class InsertionSortTest {

    no usages  xiaohuanlin +1
    @Test
    public void sort0() throws Exception {
        final List<Integer> list = new ArrayList<>();
        list.add(1);
        list.add(2);
        list.add(3);
        list.add(4);
        Integer[] xs = list.toArray(new Integer[0]);
        final Config config = Config.setupConfig( instrumenting: "true", seed: "0", inversions: "1", cutoff: "", interminInversions: ...
        Helper<Integer> helper = HelperFactory.create( description: "InsertionSort", list.size(), config);
        helper.init(list.size());
        final PrivateMethodTester privateMethodTester = new PrivateMethodTester(helper);
        final StatPack statPack = (StatPack) privateMethodTester.invokePrivate( name: "getStatPack");
    }
}
```