**Assignment 3 - Program Structures and Algorithms Spring 2023(SEC - 1)**

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## Task - 1:

You are to implement three (3) methods (*repeat*, *getClock*, and *toMillisecs*) 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.

```
public <T, U> double repeat(int n, Supplier<T> supplier, Function<T, U> fun
ction, 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.

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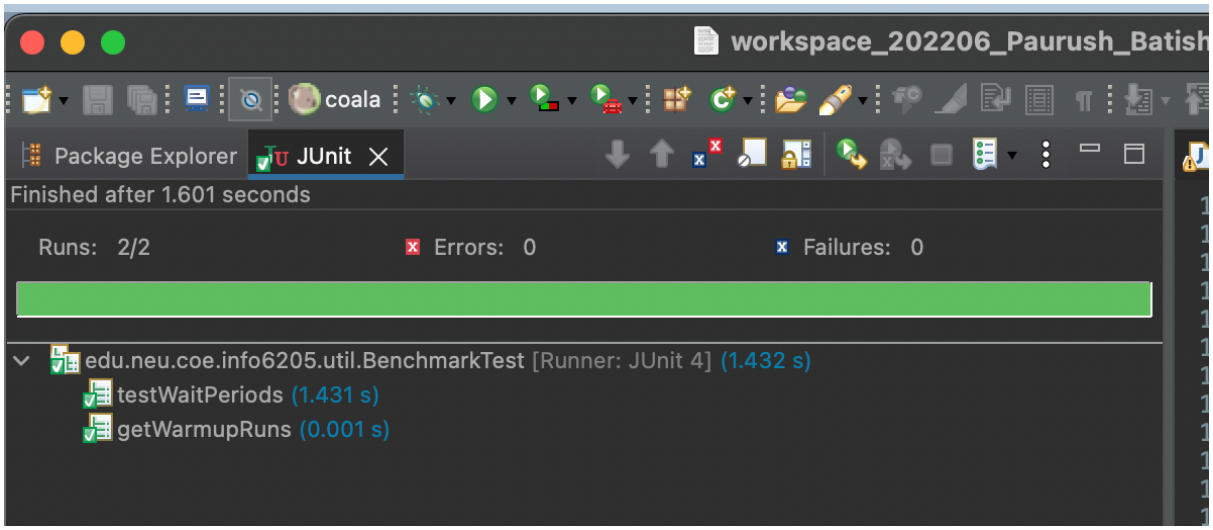
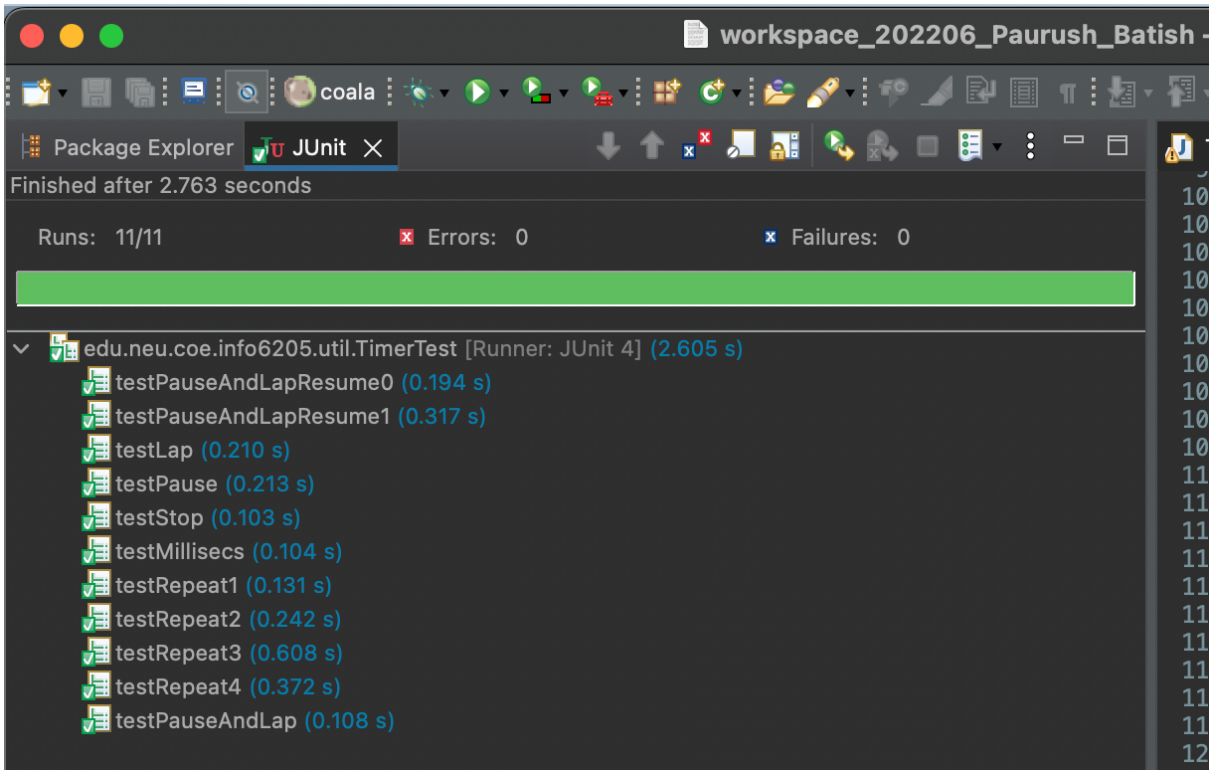
Solution –

```java
public <T, U> double repeat(int n, Supplier<T> supplier, Function<T, U> function, UnaryOperator<T> preFunction, Consumer<U> postFunction) {
    pause(); // pause the timer
    T preFunctioninputt = supplier.get();
    for (int i = 0; i < n; i++) {
        if (preFunction != null)
            preFunctioninputt = preFunction.apply(supplier.get()); // getting the supply not timed
        resume(); // start the timer again
        U u = function.apply(preFunctioninputt); // this will be timed !!!
        pauseAndLap(); //pause the timer postFunction !!
        if (postFunction != null)
            postFunction.accept(u);
    }
    final double result = meanLapTime();
    return result;

}
```

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

/**
 * NOTE: (Maintain consistency) There are two system methods for getting the clock time.
 * Ensure that this method is consistent with getTicks.
 *
 * @param ticks the number of clock ticks -- currently in nanoseconds.
 * @return the corresponding number of milliseconds.
 */
private static double toMillisecs(long ticks) {
    // FIXME by replacing the following code
     return ticks / 1_000_000.0;
    // END
}
```

## Unit Test –



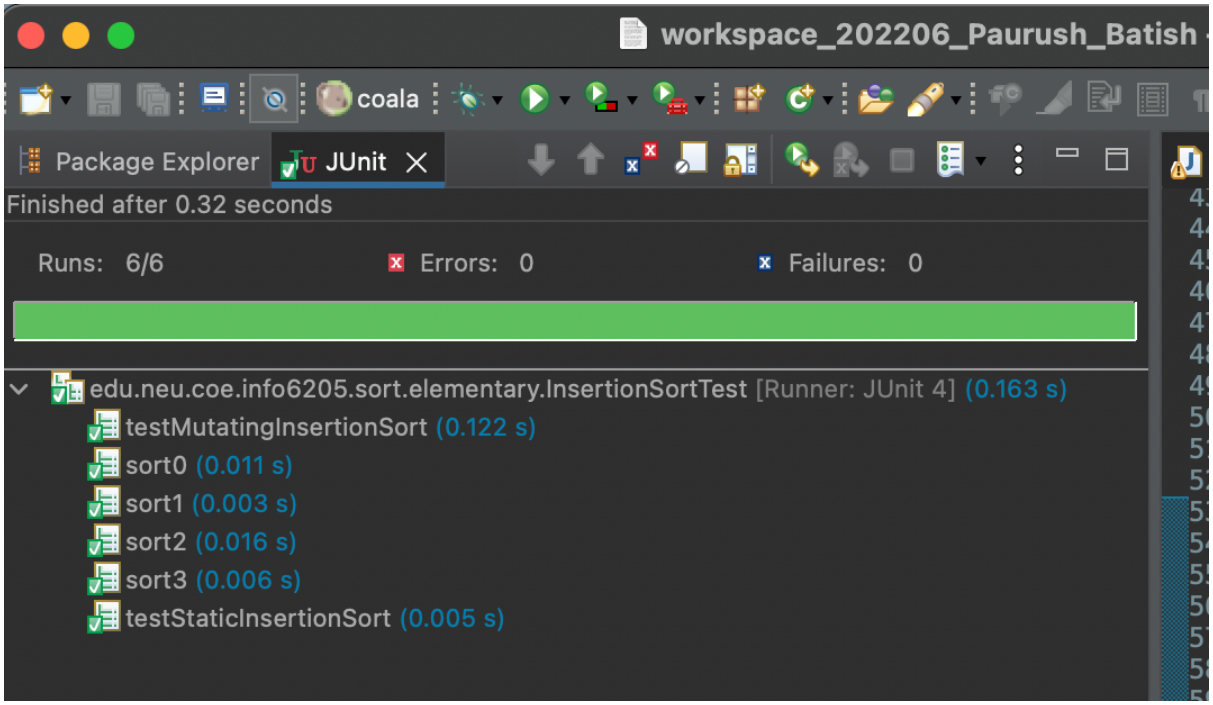



## Task - 2:

(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*.

```
public void sort(X[] xs, int from, int to) {
    final Helper<X> helper = getHelper();
    for (int i = from + 1; i < to; i++) {
        int j = i;
        while (j > from && helper.swapStableConditional(xs, j)) {
            j--;
        }
    }

}
```

**Unit Test –**




## Task - 3:

(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.

Solution –

Taking no of operations as 5

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```
Random array:
Time elapsed: 23ms
Ordered array:
Time elapsed: 1ms
Partially ordered array:
Time elapsed: 17ms
Reverse ordered array:
Time elapsed: 7ms

Random array:
Time elapsed: 5ms
```

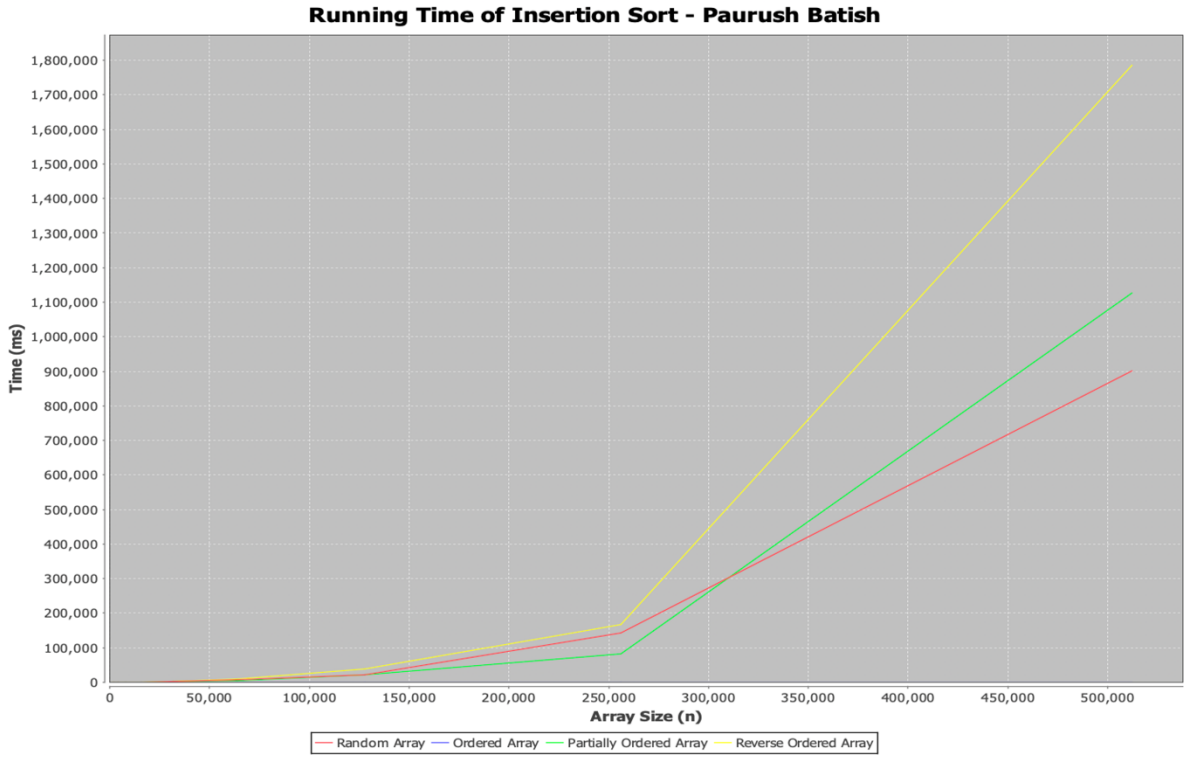
```
Ordered array:
Time elapsed: 1ms
Partially ordered array:
Time elapsed: 4ms
Reverse ordered array:
Time elapsed: 10ms

Random array:
Time elapsed: 19ms
Ordered array:
Time elapsed: 0ms
Partially ordered array:
Time elapsed: 19ms
Reverse ordered array:
Time elapsed: 38ms

Random array:
Time elapsed: 75ms
Ordered array:
Time elapsed: 0ms
Partially ordered array:
Time elapsed: 75ms
Reverse ordered array:
Time elapsed: 154ms

Random array:
Time elapsed: 369ms
Ordered array:
Time elapsed: 0ms
Partially ordered array:
Time elapsed: 304ms
Reverse ordered array:
Time elapsed: 607ms
```


## Taking no of operations as 10

```
Random array:
Time elapsed: 27ms
Ordered array:
Time elapsed: 0ms
Partially ordered array:
Time elapsed: 17ms
Reverse ordered array:
Time elapsed: 6ms

Random array:
Time elapsed: 6ms
Ordered array:
Time elapsed: 0ms
Partially ordered array:
Time elapsed: 5ms
Reverse ordered array:
Time elapsed: 9ms

Random array:
Time elapsed: 19ms
Ordered array:
Time elapsed: 0ms
```

```
Partially ordered array:
Time elapsed: 19ms
Reverse ordered array:
Time elapsed: 38ms

Random array:
Time elapsed: 75ms
Ordered array:
Time elapsed: 0ms
Partially ordered array:
Time elapsed: 77ms
Reverse ordered array:
Time elapsed: 153ms

Random array:
Time elapsed: 359ms
Ordered array:
Time elapsed: 1ms
Partially ordered array:
Time elapsed: 305ms
Reverse ordered array:
Time elapsed: 613ms

Random array:
Time elapsed: 1227ms
Ordered array:
Time elapsed: 0ms
Partially ordered array:
Time elapsed: 1220ms
Reverse ordered array:
Time elapsed: 2439ms

Random array:
Time elapsed: 7941ms
Ordered array:
Time elapsed: 0ms
Partially ordered array:
Time elapsed: 4877ms
Reverse ordered array:
Time elapsed: 9869ms

Random array:
Time elapsed: 22153ms
Ordered array:
Time elapsed: 0ms
Partially ordered array:
Time elapsed: 20949ms
Reverse ordered array:
Time elapsed: 39393ms
```

```
Random array:
Time elapsed: 141614ms
Ordered array:
Time elapsed: 1ms
Partially ordered array:
Time elapsed: 83242ms
Reverse ordered array:
Time elapsed: 167183ms

Random array:
Time elapsed: 902150ms
Ordered array:
Time elapsed: 2ms
Partially ordered array:
Time elapsed: 1126381ms
Reverse ordered array:
Time elapsed: 1784869ms
```




Based on the operations we can see that sorted array takes minimum time to perform insertion sort whereas reverse ordered array takes maximum time.

For a sorted list →

Since the list is already in sorted order the complexity will be in O(n).

For reverse sorted list →

We have to traverse n-1 times the inner loop and same with outer loop. Then the O(n*(n-1)) = O($n^2$)