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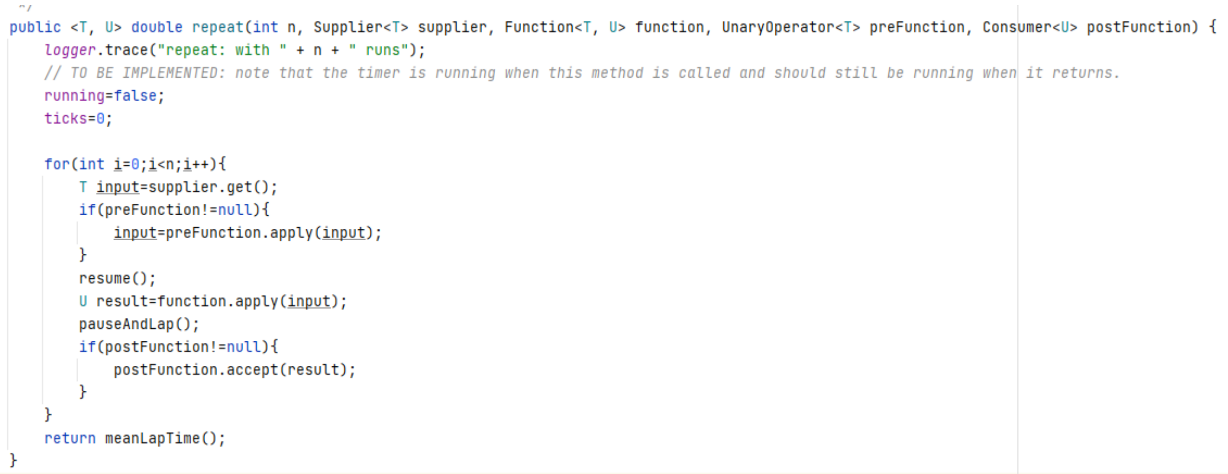
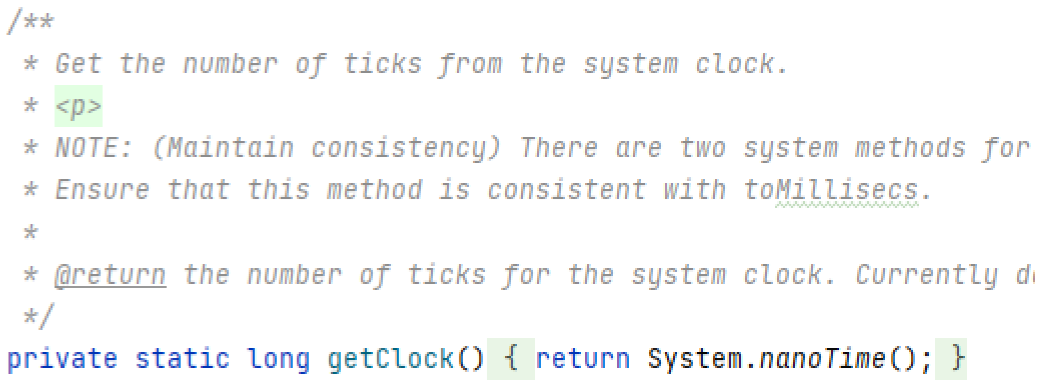
INFO 6205
Program Structures & Algorithms
Spring 2021

Assignment No.2

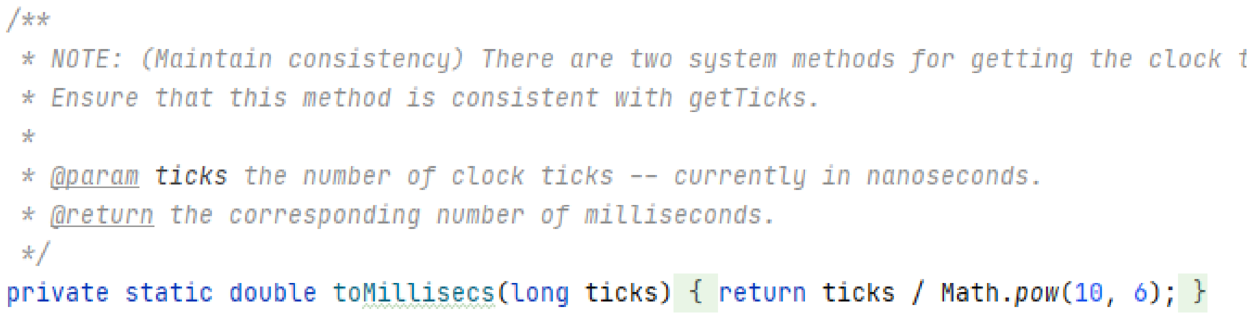
- **The implement of three methods of Timer class and test result**



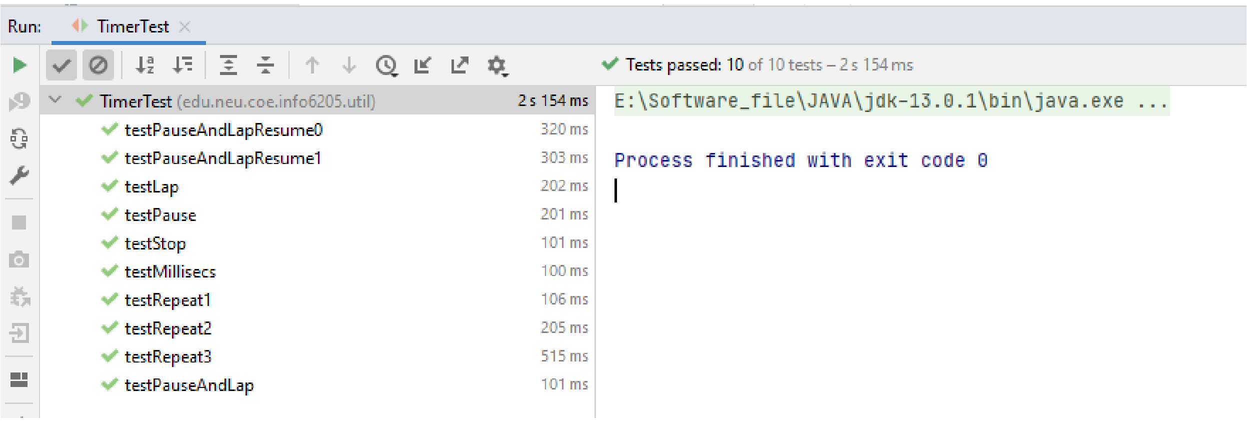
```
 */
public <T, U> double repeat(int n, Supplier<T> supplier, Function<T, U> function, UnaryOperator<T> preFunction, Consumer<U> postFunction) {
    logger.trace("repeat: with " + n + " runs");
    // TO BE IMPLEMENTED: note that the timer is running when this method is called and should still be running when it returns.
    running=false;
    ticks=0;

    for(int i=0;i<n;i++){
        T input=supplier.get();
        if(preFunction!=null){
            input=preFunction.apply(input);
        }
        resume();
        U result=function.apply(input);
        pauseAndLap();
        if(postFunction!=null){
            postFunction.accept(result);
        }
    }
    return meanLapTime();
}
```



```
/**
 * Get the number of ticks from the system clock.
 * <p>
 * NOTE: (Maintain consistency) There are two system methods for
 * Ensure that this method is consistent with toMillisecs.
 *
 * @return the number of ticks for the system clock. Currently d
 */
private static long getClock() { return System.nanoTime(); }
```



```
/**
 * NOTE: (Maintain consistency) There are two system methods for getting the clock t
 * 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) { return ticks / Math.pow(10, 6); }
```

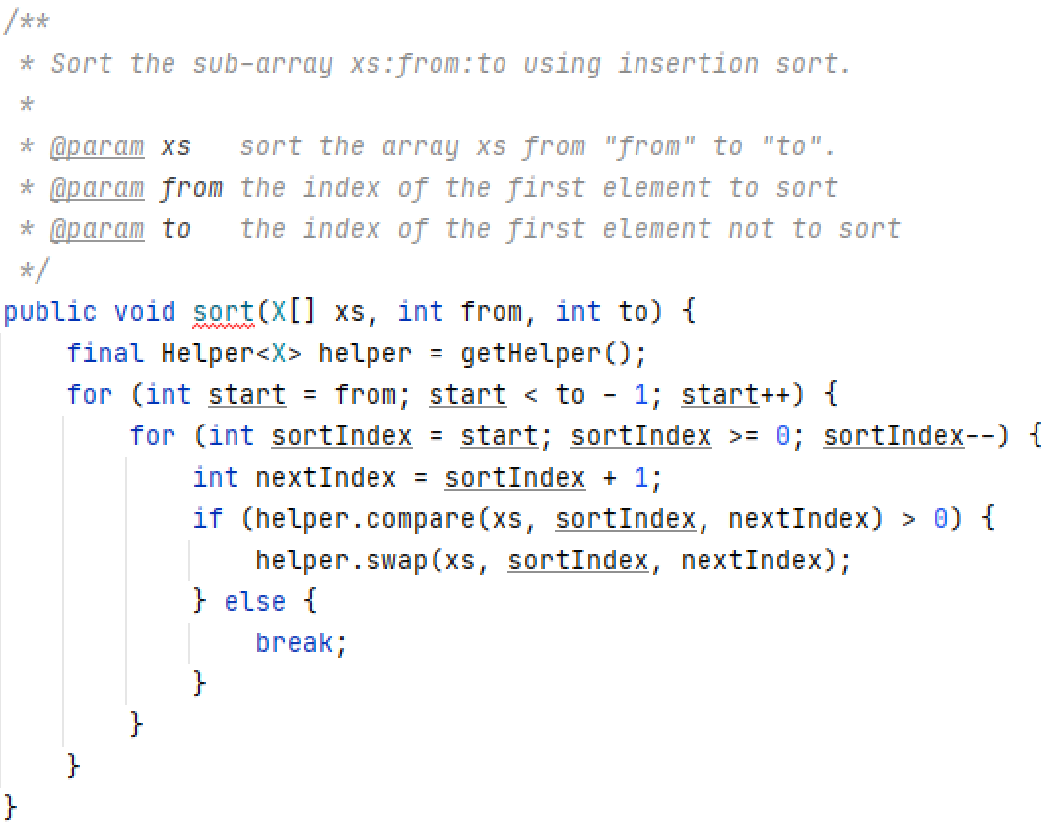


```
✓ Tests passed: 10 of 10 tests – 2 s 154 ms

✓ TimerTest (edu.neu.coe.info6205.util)   2 s 154 ms
    ✓ testPauseAndLapResume0              320 ms
    ✓ testPauseAndLapResume1              303 ms
    ✓ testLap                             202 ms
    ✓ testPause                           201 ms
    ✓ testStop                            101 ms
    ✓ testMillisecs                       100 ms
    ✓ testRepeat1                         106 ms
    ✓ testRepeat2                         205 ms
    ✓ testRepeat3                         515 ms
    ✓ testPauseAndLap                     101 ms
```

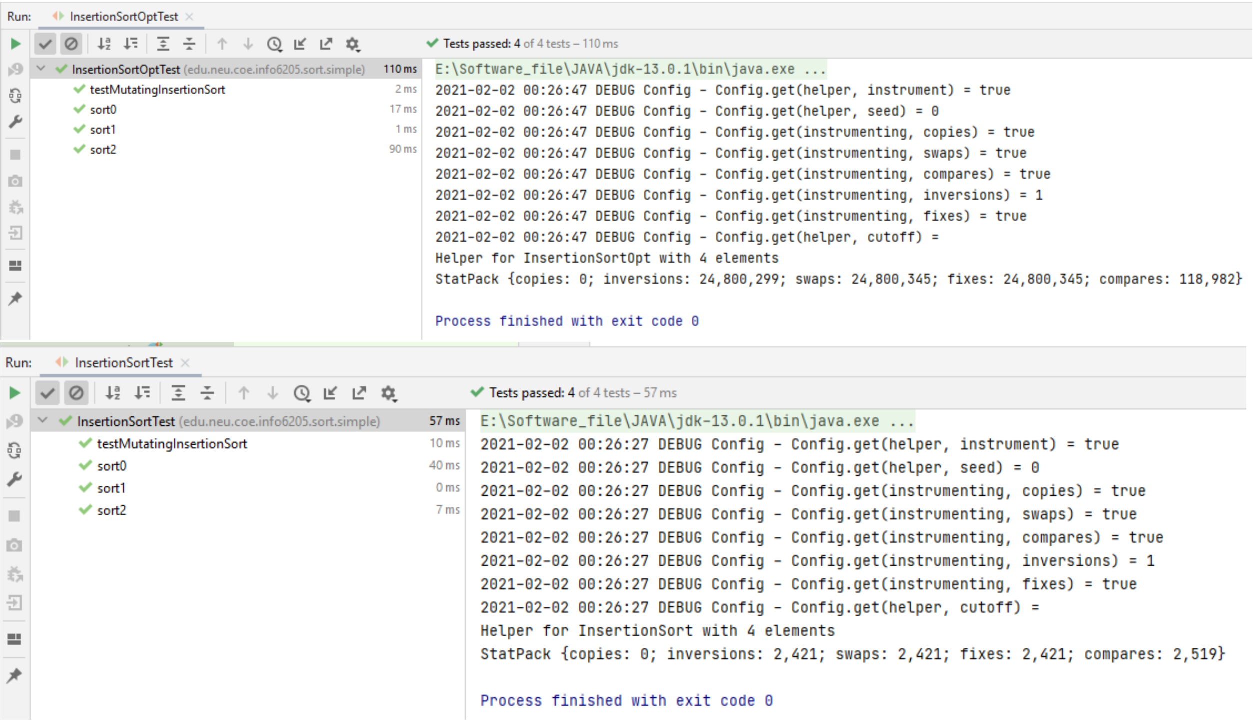
```
E:\Software_file\JAVA\jdk-13.0.1\bin\java.exe ...

Process finished with exit code 0
```

Figure 1. The test result of Timer class

- **The implement of insertionSort class and test result**



```java
/**
 * Sort the sub-array xs:from:to using insertion sort.
 *
 * @param xs   sort the array xs from "from" to "to".
 * @param from the index of the first element to sort
 * @param to   the index of the first element not to sort
 */
public void sort(X[] xs, int from, int to) {
    final Helper<X> helper = getHelper();
    for (int start = from; start < to - 1; start++) {
        for (int sortIndex = start; sortIndex >= 0; sortIndex--) {
            int nextIndex = sortIndex + 1;
            if (helper.compare(xs, sortIndex, nextIndex) > 0) {
                helper.swap(xs, sortIndex, nextIndex);
            } else {
                break;
            }
        }
    }
}
```



```
✓ InsertionSortOptTest (edu.neu.coe.info6205.sort.simple)   110 ms
    ✓ testMutatingInsertionSort                               2 ms
    ✓ sort0                                                  17 ms
    ✓ sort1                                                   1 ms
    ✓ sort2                                                  90 ms
```

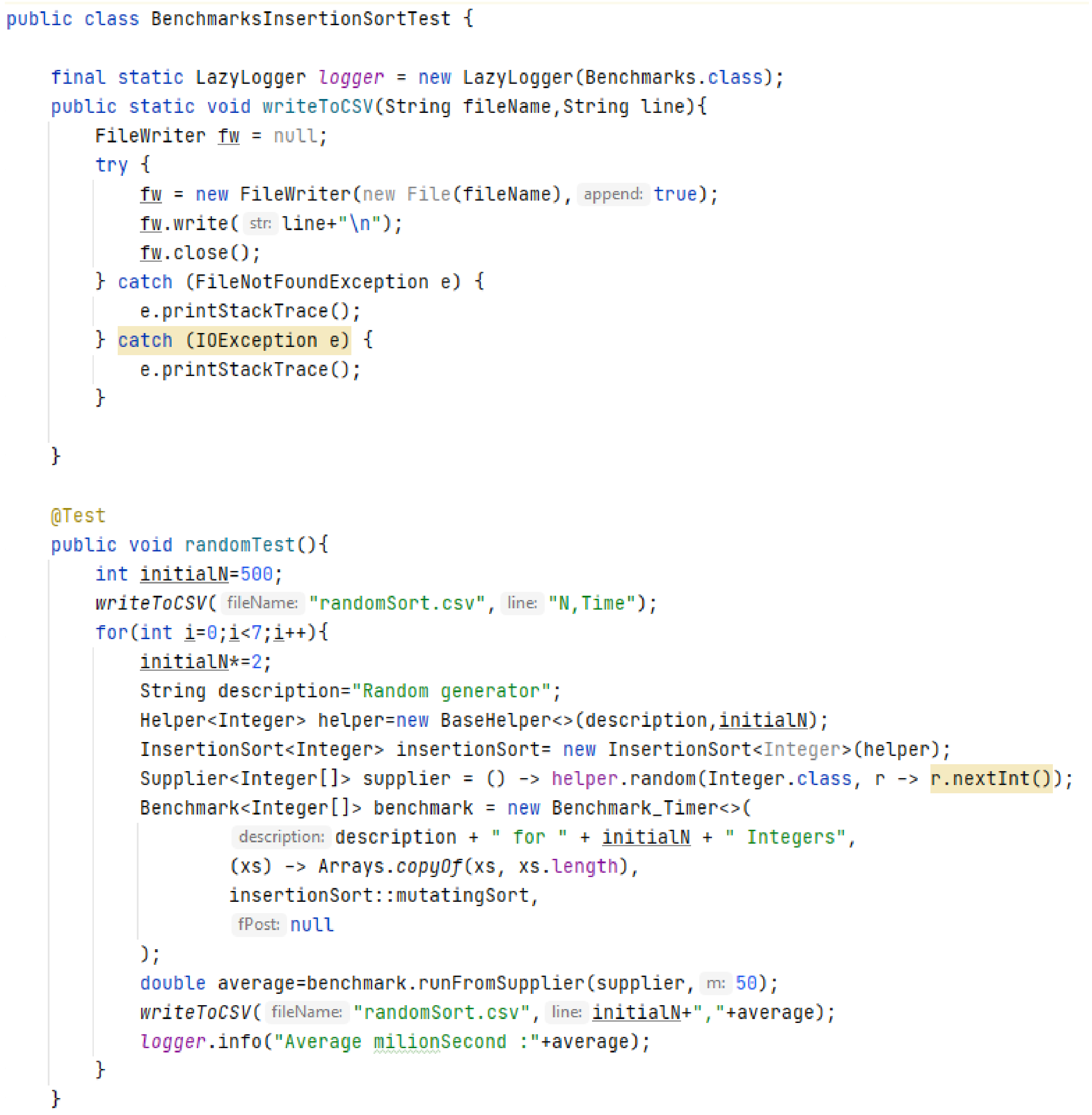
```
E:\Software_file\JAVA\jdk-13.0.1\bin\java.exe ...
2021-02-02 00:26:47 DEBUG Config - Config.get(helper, instrument) = true
2021-02-02 00:26:47 DEBUG Config - Config.get(helper, seed) = 0
2021-02-02 00:26:47 DEBUG Config - Config.get(instrumenting, copies) = true
2021-02-02 00:26:47 DEBUG Config - Config.get(instrumenting, swaps) = true
2021-02-02 00:26:47 DEBUG Config - Config.get(instrumenting, compares) = true
2021-02-02 00:26:47 DEBUG Config - Config.get(instrumenting, inversions) = 1
2021-02-02 00:26:47 DEBUG Config - Config.get(instrumenting, fixes) = true
2021-02-02 00:26:47 DEBUG Config - Config.get(helper, cutoff) = 
Helper for InsertionSortOpt with 4 elements
StatPack {copies: 0; inversions: 24,800,299; swaps: 24,800,345; fixes: 24,800,345; compares: 118,982}

Process finished with exit code 0
```

```
✓ InsertionSortTest (edu.neu.coe.info6205.sort.simple)   57 ms
    ✓ testMutatingInsertionSort                            10 ms
    ✓ sort0                                                40 ms
    ✓ sort1                                                 0 ms
    ✓ sort2                                                 7 ms
```

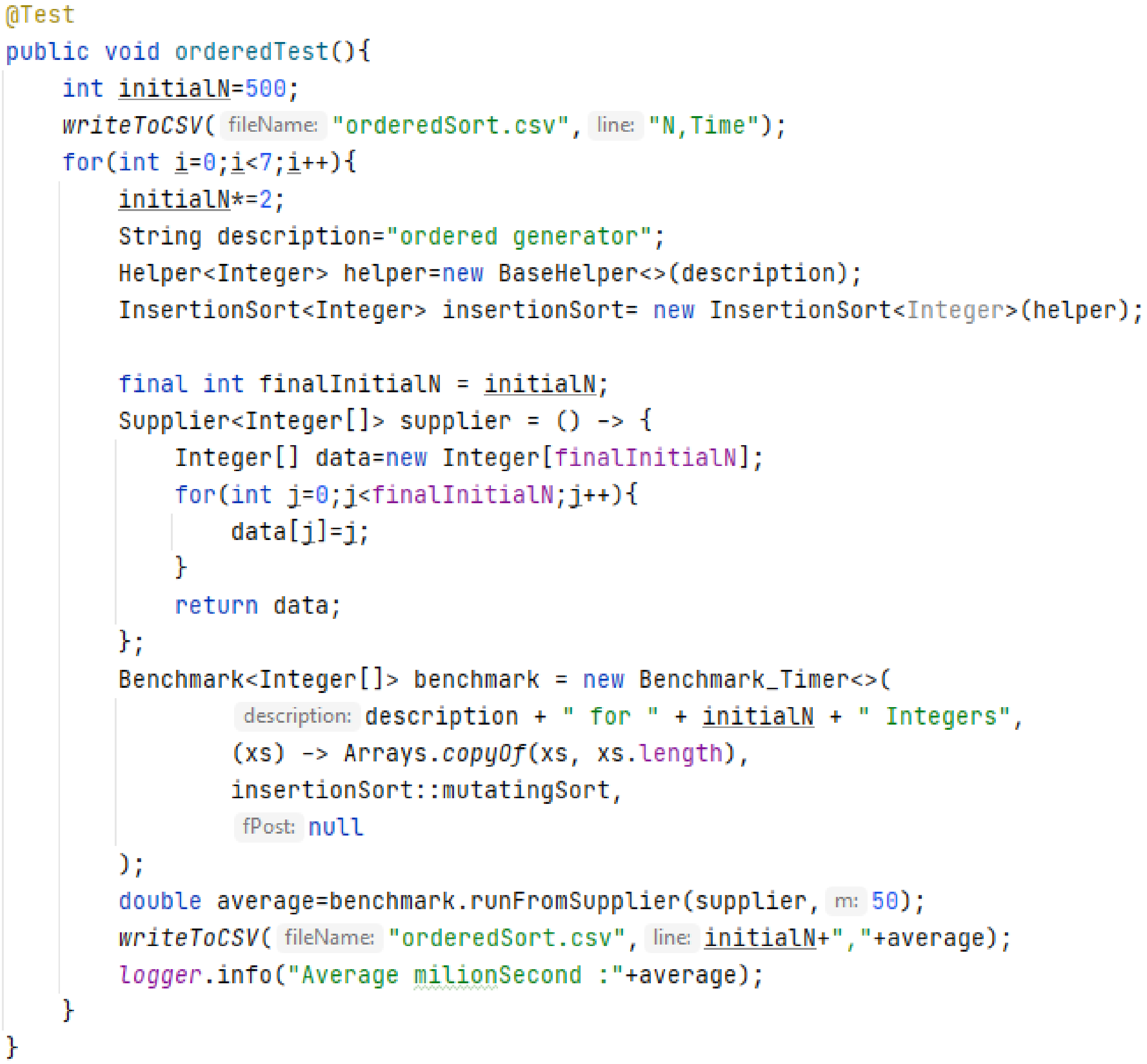
```
E:\Software_file\JAVA\jdk-13.0.1\bin\java.exe ...
2021-02-02 00:26:27 DEBUG Config - Config.get(helper, instrument) = true
2021-02-02 00:26:27 DEBUG Config - Config.get(helper, seed) = 0
2021-02-02 00:26:27 DEBUG Config - Config.get(instrumenting, copies) = true
2021-02-02 00:26:27 DEBUG Config - Config.get(instrumenting, swaps) = true
2021-02-02 00:26:27 DEBUG Config - Config.get(instrumenting, compares) = true
2021-02-02 00:26:27 DEBUG Config - Config.get(instrumenting, inversions) = 1
2021-02-02 00:26:27 DEBUG Config - Config.get(instrumenting, fixes) = true
2021-02-02 00:26:27 DEBUG Config - Config.get(helper, cutoff) = 
Helper for InsertionSort with 4 elements
StatPack {copies: 0; inversions: 2,421; swaps: 2,421; fixes: 2,421; compares: 2,519}

Process finished with exit code 0
```

Figure 2. The Test result of insertion sort class

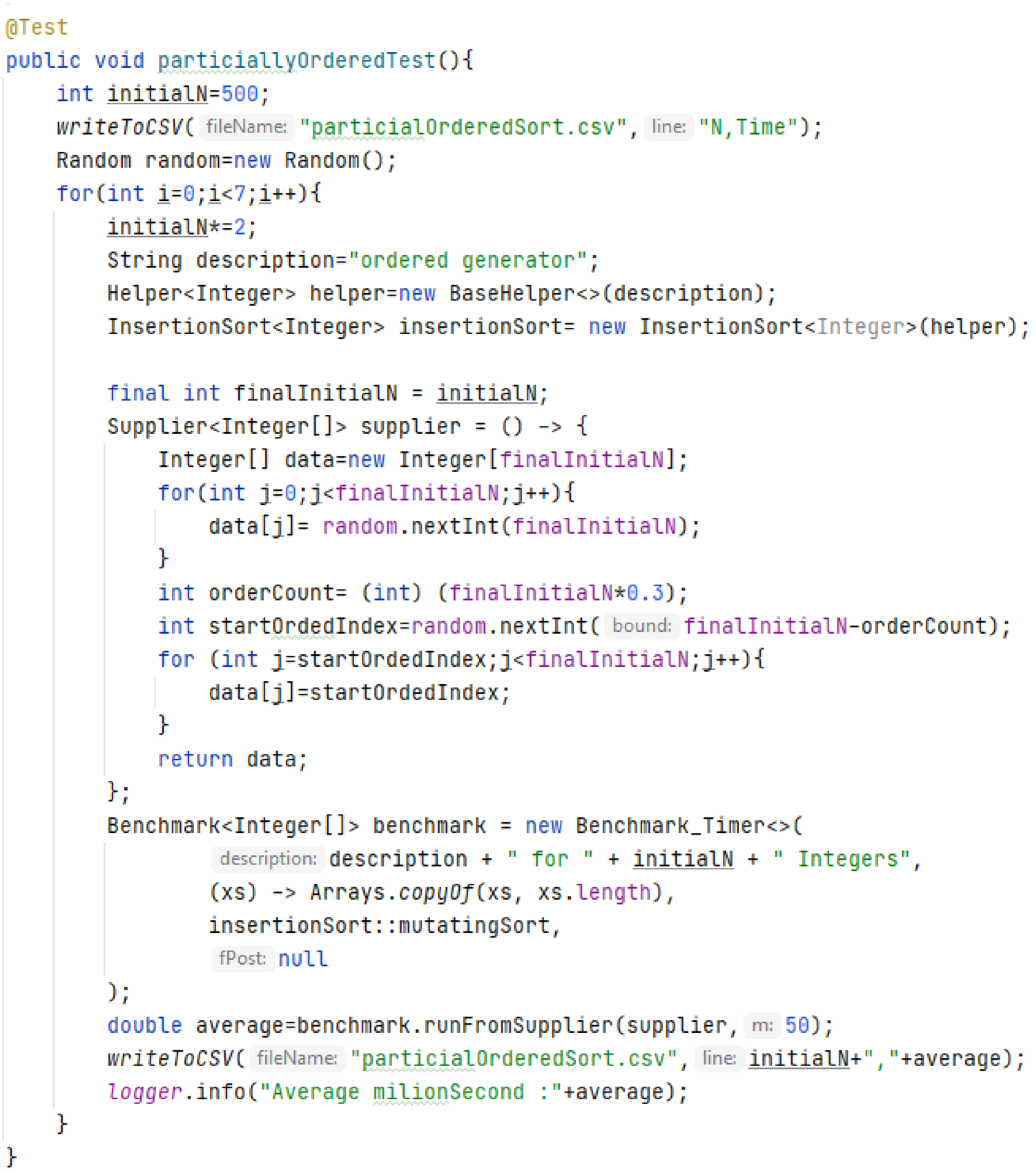
- **The implement of unit test for insertion sort benchmarks on different input data**



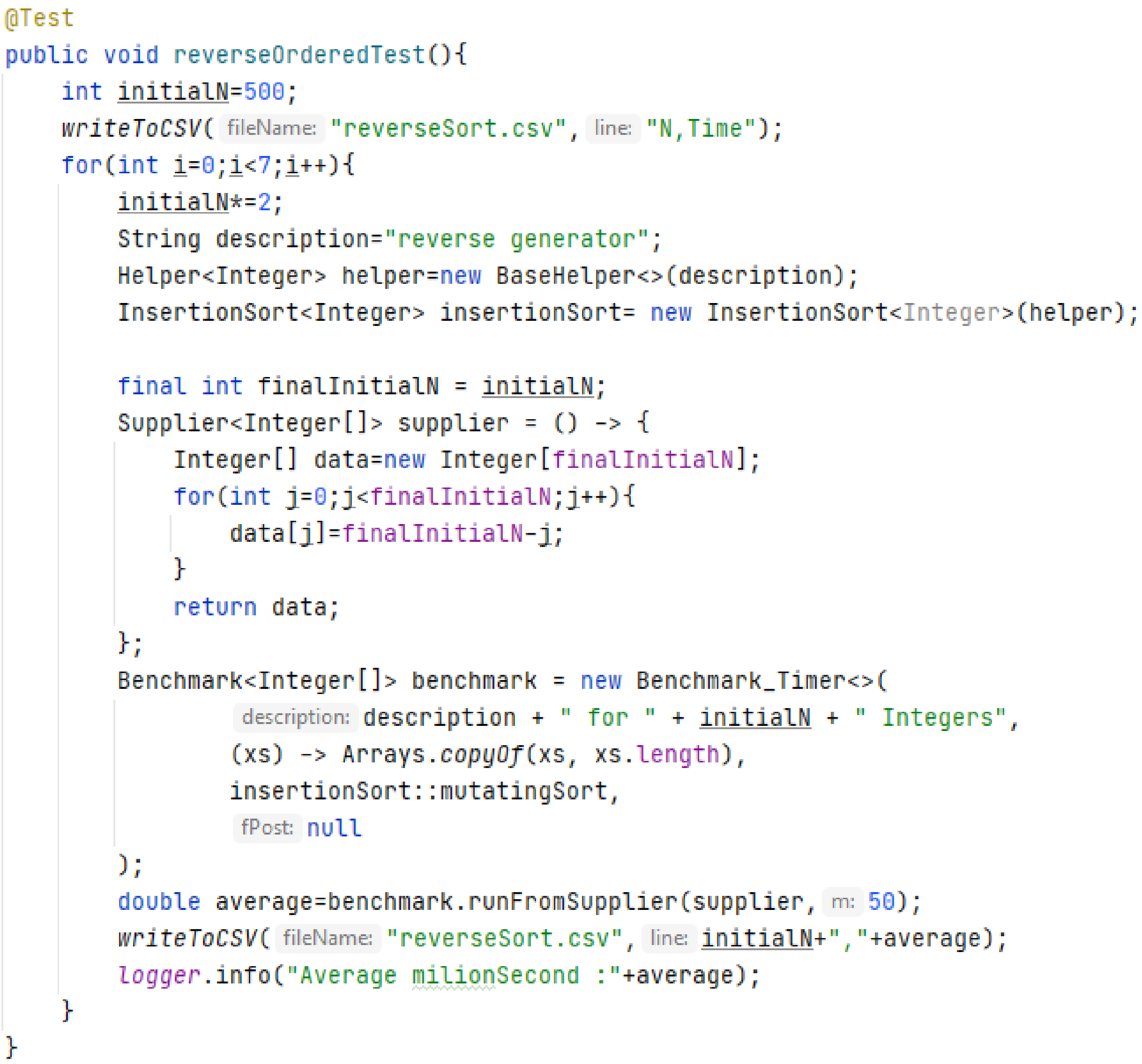
```
public class BenchmarksInsertionSortTest {

    final static LazyLogger logger = new LazyLogger(Benchmarks.class);
    public static void writeToCSV(String fileName,String line){
        FileWriter fw = null;
        try {
            fw = new FileWriter(new File(fileName), append: true);
            fw.write( str: line+"\n");
            fw.close();
        } catch (FileNotFoundException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }

    }

    @Test
    public void randomTest(){
        int initialN=500;
        writeToCSV( fileName: "randomSort.csv", line: "N,Time");
        for(int i=0;i<7;i++){
            initialN*=2;
            String description="Random generator";
            Helper<Integer> helper=new BaseHelper<>(description,initialN);
            InsertionSort<Integer> insertionSort= new InsertionSort<Integer>(helper);
            Supplier<Integer[]> supplier = () -> helper.random(Integer.class, r -> r.nextInt());
            Benchmark<Integer[]> benchmark = new Benchmark_Timer<>(
                    description: description + " for " + initialN + " Integers",
                    (xs) -> Arrays.copyOf(xs, xs.length),
                    insertionSort::mutatingSort,
                    fPost: null
            );
            double average=benchmark.runFromSupplier(supplier, m: 50);
            writeToCSV( fileName: "randomSort.csv", line: initialN+","+average);
            logger.info("Average milionSecond :"+average);
        }
    }
```



```
@Test
public void orderedTest(){
    int initialN=500;
    writeToCSV( fileName: "orderedSort.csv", line: "N,Time");
    for(int i=0;i<7;i++){
        initialN*=2;
        String description="ordered generator";
        Helper<Integer> helper=new BaseHelper<>(description);
        InsertionSort<Integer> insertionSort= new InsertionSort<Integer>(helper);

        final int finalInitialN = initialN;
        Supplier<Integer[]> supplier = () -> {
            Integer[] data=new Integer[finalInitialN];
            for(int j=0;j<finalInitialN;j++){
                data[j]=j;
            }
            return data;
        };
        Benchmark<Integer[]> benchmark = new Benchmark_Timer<>(
                description: description + " for " + initialN + " Integers",
                (xs) -> Arrays.copyOf(xs, xs.length),
                insertionSort::mutatingSort,
                fPost: null
        );
        double average=benchmark.runFromSupplier(supplier, m: 50);
        writeToCSV( fileName: "orderedSort.csv", line: initialN+","+average);
        logger.info("Average milionSecond :"+average);
    }
}
```

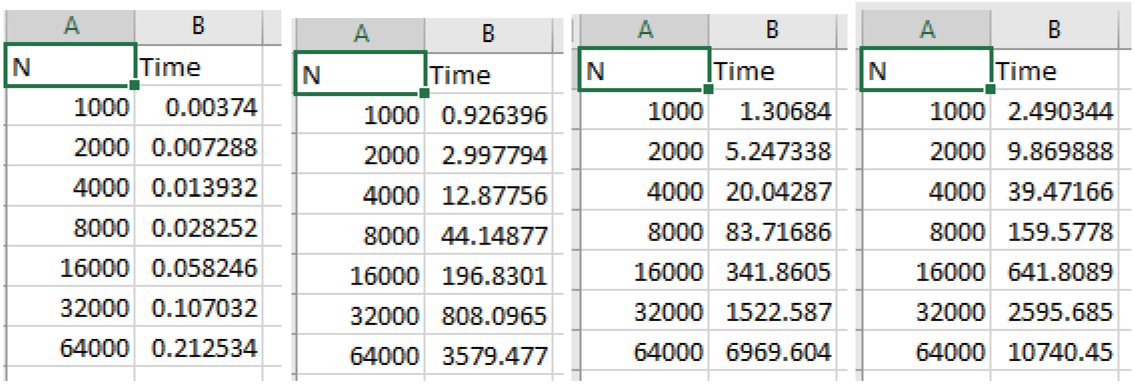


```
@Test
public void particiallyOrderedTest(){
    int initialN=500;
    writeToCSV( fileName: "particialOrderedSort.csv", line: "N,Time");
    Random random=new Random();
    for(int i=0;i<7;i++){
        initialN*=2;
        String description="ordered generator";
        Helper<Integer> helper=new BaseHelper<>(description);
        InsertionSort<Integer> insertionSort= new InsertionSort<Integer>(helper);

        final int finalInitialN = initialN;
        Supplier<Integer[]> supplier = () -> {
            Integer[] data=new Integer[finalInitialN];
            for(int j=0;j<finalInitialN;j++){
                data[j]= random.nextInt(finalInitialN);
            }
            int orderCount= (int) (finalInitialN*0.3);
            int startOrdedIndex=random.nextInt( bound: finalInitialN-orderCount);
            for (int j=startOrdedIndex;j<finalInitialN;j++){
                data[j]=startOrdedIndex;
            }
            return data;
        };
        Benchmark<Integer[]> benchmark = new Benchmark_Timer<>(
                description: description + " for " + initialN + " Integers",
                (xs) -> Arrays.copyOf(xs, xs.length),
                insertionSort::mutatingSort,
                fPost: null
        );
        double average=benchmark.runFromSupplier(supplier, m: 50);
        writeToCSV( fileName: "particialOrderedSort.csv", line: initialN+","+average);
        logger.info("Average milionSecond :"+average);
    }
}
```



```
@Test
public void reverseOrderedTest(){
    int initialN=500;
    writeToCSV( fileName: "reverseSort.csv", line: "N,Time");
    for(int i=0;i<7;i++){
        initialN*=2;
        String description="reverse generator";
        Helper<Integer> helper=new BaseHelper<>(description);
        InsertionSort<Integer> insertionSort= new InsertionSort<Integer>(helper);

        final int finalInitialN = initialN;
        Supplier<Integer[]> supplier = () -> {
            Integer[] data=new Integer[finalInitialN];
            for(int j=0;j<finalInitialN;j++){
                data[j]=finalInitialN-j;
            }
            return data;
        };
        Benchmark<Integer[]> benchmark = new Benchmark_Timer<>(
                description: description + " for " + initialN + " Integers",
                (xs) -> Arrays.copyOf(xs, xs.length),
                insertionSort::mutatingSort,
                fPost: null
        );
        double average=benchmark.runFromSupplier(supplier, m: 50);
        writeToCSV( fileName: "reverseSort.csv", line: initialN+","+average);
        logger.info("Average milionSecond :"+average);
    }
}
```

- **Conclusion**



A	B
N	Time
1000	0.00374
2000	0.007288
4000	0.013932
8000	0.028252
16000	0.058246
32000	0.107032
64000	0.212534

A	B
N	Time
1000	0.926396
2000	2.997794
4000	12.87756
8000	44.14877
16000	196.8301
32000	808.0965
64000	3579.477

A	B
N	Time
1000	1.30684
2000	5.247338
4000	20.04287
8000	83.71686
16000	341.8605
32000	1522.587
64000	6969.604

A	B
N	Time
1000	2.490344
2000	9.869888
4000	39.47166
8000	159.5778
16000	641.8089
32000	2595.685
64000	10740.45

Figure 3. The T/N grow result on ordered, partial ordered, random and reversed input

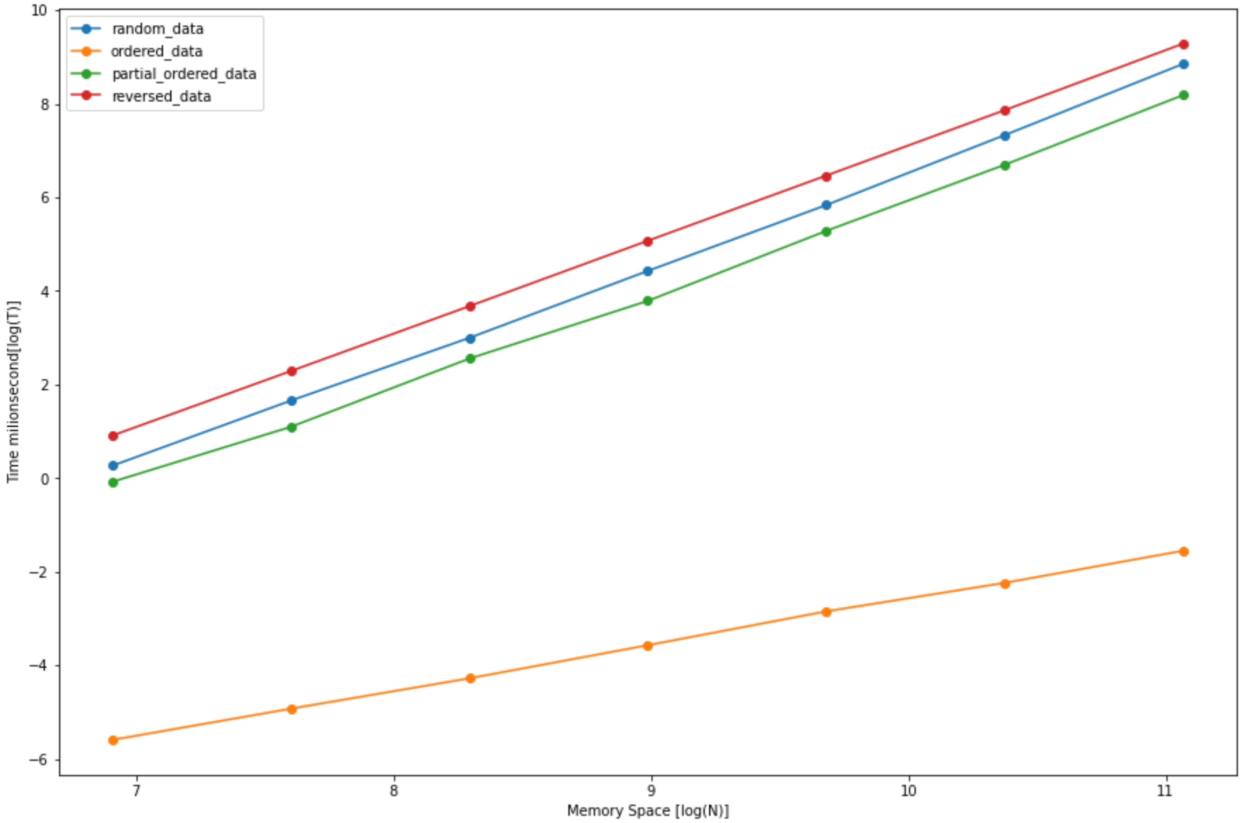


Figure 4. The insertion sort T/N grow logarithm graph

According the insertion sort logarithm graph, when the input data is reversed, the cost of time is biggest which is more than the cost of time on random data. Besides, time cost of sorting random data is a bit more than sorting partial ordered data. When the input data is ordered, this sorting algorithm has the minimal time cost which is far less three previous situations. In addition, this sorting algorithm has liner increasement on this logarithm graph, which means that the subtraction of log(T2) and log(T1) is constant that is log(T2)-log(T1) ~ log(2N*(2N+1)/2)-log(N*(N+1)/2) ~ log 4.