INFO 6205

Program Structures & Algorithms

Fall 2020

Assignment No 02

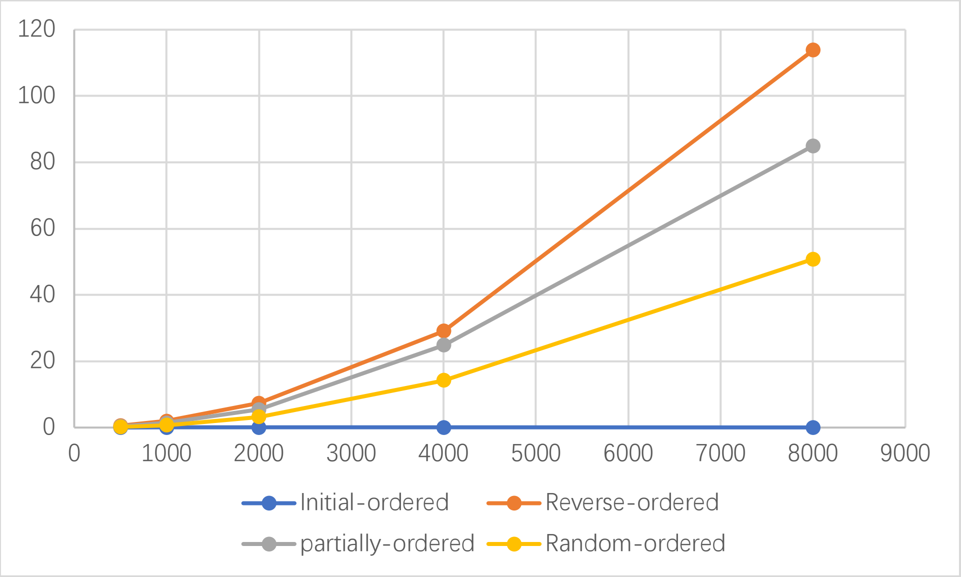
- Task：Benchmark-Timer

Relationship conclusion：t=O(N^2)，t=Ω(N)

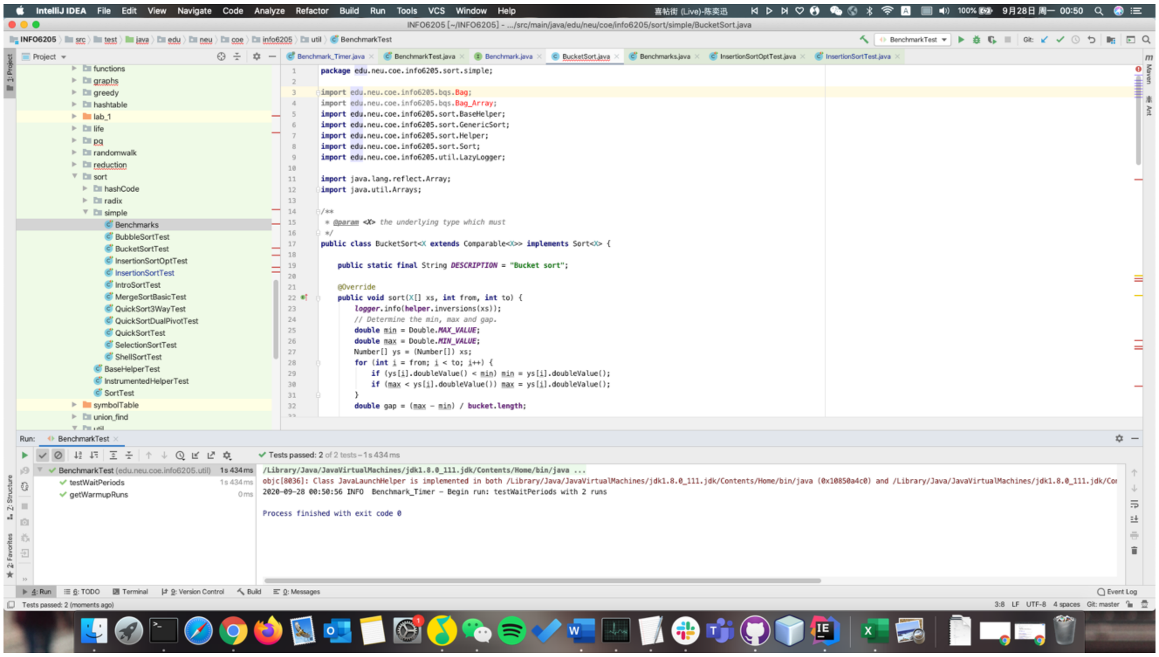
According to data analysis, as the array size doubles, the time required for sorting increases by a multiple of four in the worst case and increases by a multiple of two in the best case.

- Evidence to support relationship

N	Initial-ordered	Reverse-ordered	partially-ordered	Random-ordered
500	0.005	0.57	0.365	0.204
1000	0.009	1.923	1.419	0.755
2000	0.014	7.371	5.395	3.171
4000	0.017	29.115	24.846	14.229
8000	0.038	113.781	84.951	50.8



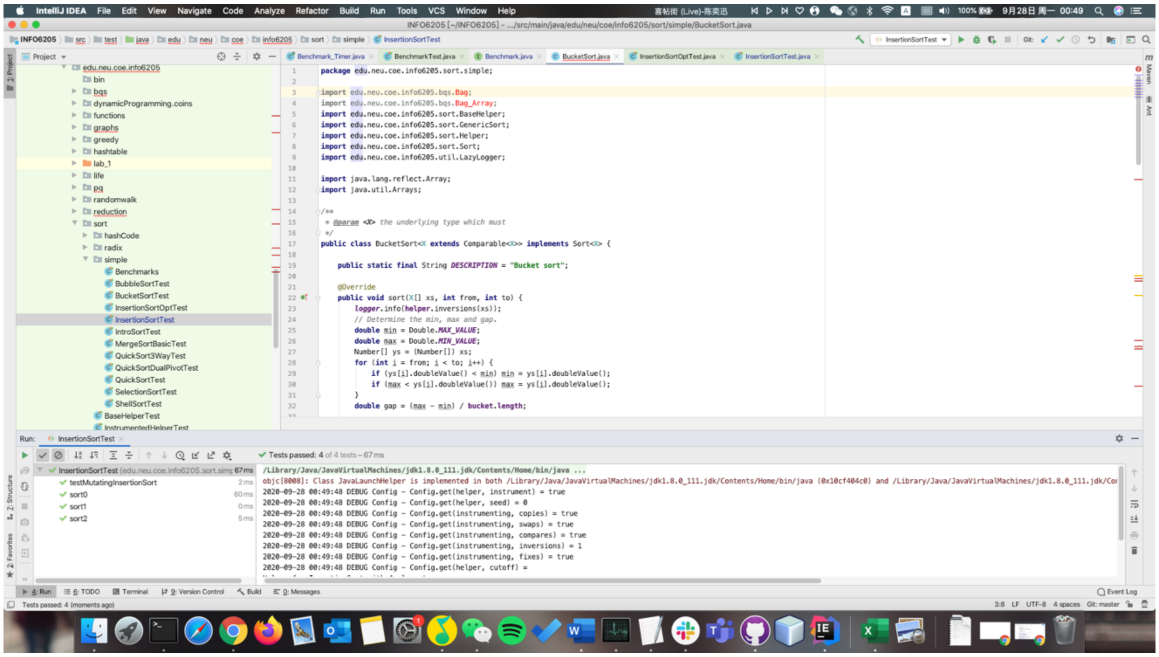
- **Screenshot of Unit test passing**



```java
package edu.neu.coe.info6205.sort.simple;

import edu.neu.coe.info6205.bqs.Bag;
import edu.neu.coe.info6205.bqs.Bag_Array;
import edu.neu.coe.info6205.sort.BaseHelper;
import edu.neu.coe.info6205.sort.GenericSort;
import edu.neu.coe.info6205.sort.Helper;
import edu.neu.coe.info6205.sort.Sort;
import edu.neu.coe.info6205.util.LazyLogger;

import java.lang.reflect.Array;
import java.util.Arrays;

/**
 * @param <X> the underlying type which must
 */
public class BucketSort<X extends Comparable<X>> implements Sort<X> {

    public static final String DESCRIPTION = "Bucket sort";

    @Override
    public void sort(X[] xs, int from, int to) {
        logger.info(helper.inversions(xs));
        // Determine the min, max and gap.
        double min = Double.MAX_VALUE;
        double max = Double.MIN_VALUE;
        Number[] ys = (Number[]) xs;
        for (int i = from; i < to; i++) {
            if (ys[i].doubleValue() < min) min = ys[i].doubleValue();
            if (max < ys[i].doubleValue()) max = ys[i].doubleValue();
        }
        double gap = (max - min) / bucket.length;
```

✓ Tests passed: 2 of 2 tests – 1 s 434 ms

```
/Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/bin/java ...
objc[8036]: Class JavaLaunchHelper is implemented in both /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/bin/java (0x10850a4c0) and /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Co
2020-09-28 00:50:56 INFO  Benchmark_Timer - Begin run: testWaitPeriods with 2 runs

Process finished with exit code 0
```



INFO6205 [~/INFO6205] - .../src/main/java/edu/neu/coe/info6205/sort/simple/BucketSort.java

```java
package edu.neu.coe.info6205.sort.simple;

import edu.neu.coe.info6205.bqs.Bag;
import edu.neu.coe.info6205.bqs.Bag_Array;
import edu.neu.coe.info6205.sort.BaseHelper;
import edu.neu.coe.info6205.sort.GenericSort;
import edu.neu.coe.info6205.sort.Helper;
import edu.neu.coe.info6205.sort.Sort;
import edu.neu.coe.info6205.util.LazyLogger;

import java.lang.reflect.Array;
import java.util.Arrays;

/**
 * @param <X> the underlying type which must
 */
public class BucketSort<X extends Comparable<X>> implements Sort<X> {

    public static final String DESCRIPTION = "Bucket sort";

    @Override
    public void sort(X[] xs, int from, int to) {
        logger.info(helper.inversions(xs));
        // Determine the min, max and gap.
        double min = Double.MAX_VALUE;
        double max = Double.MIN_VALUE;
        Number[] ys = (Number[]) xs;
        for (int i = from; i < to; i++) {
            if (ys[i].doubleValue() < min) min = ys[i].doubleValue();
            if (max < ys[i].doubleValue()) max = ys[i].doubleValue();
        }
        double gap = (max - min) / bucket.length;
```

Tests passed: 4 of 4 tests – 67 ms

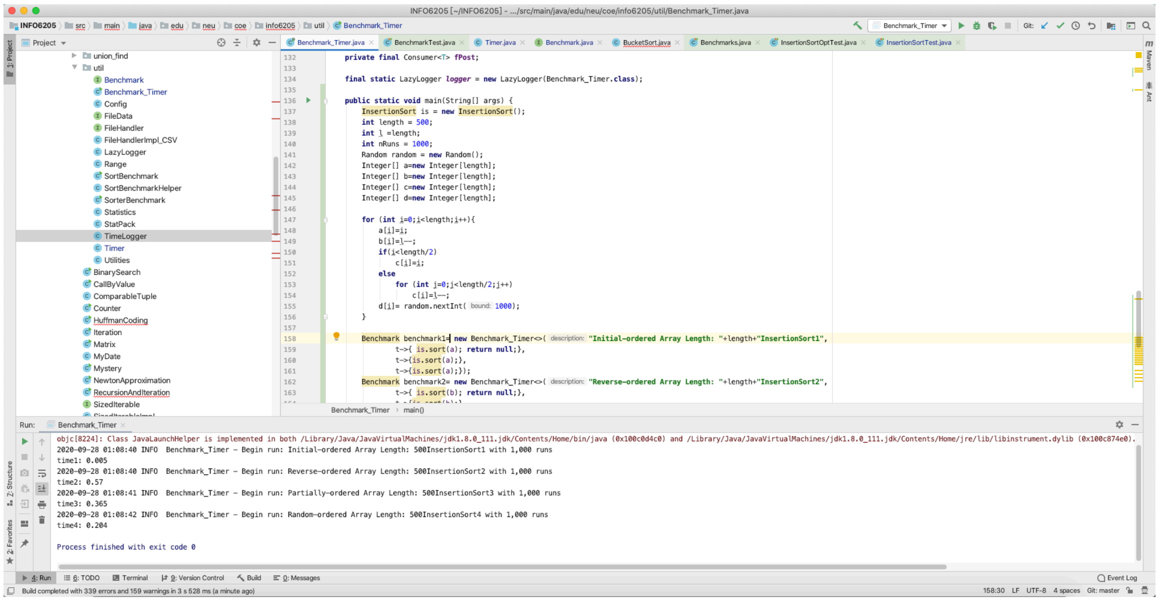
```
InsertionSortTest (edu.neu.coe.info6205.sort.simp 67 ms
  testMutatingInsertionSort   2 ms
  sort0                      60 ms
  sort1                       0 ms
  sort2                       5 ms
```

```
/Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/bin/java ...
objc[8008]: Class JavaLaunchHelper is implemented in both /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/bin/java (0x10cf404c0) and /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Co
2020-09-28 00:49:48 DEBUG Config - Config.get(helper, instrument) = true
2020-09-28 00:49:48 DEBUG Config - Config.get(helper, seed) = 0
2020-09-28 00:49:48 DEBUG Config - Config.get(instrumenting, copies) = true
2020-09-28 00:49:48 DEBUG Config - Config.get(instrumenting, swaps) = true
2020-09-28 00:49:48 DEBUG Config - Config.get(instrumenting, compares) = true
2020-09-28 00:49:48 DEBUG Config - Config.get(instrumenting, inversions) = 1
2020-09-28 00:49:48 DEBUG Config - Config.get(instrumenting, fixes) = true
2020-09-28 00:49:48 DEBUG Config - Config.get(helper, cutoff) =
```

Tests passed: 4 (moments ago)

Original Data

N=500



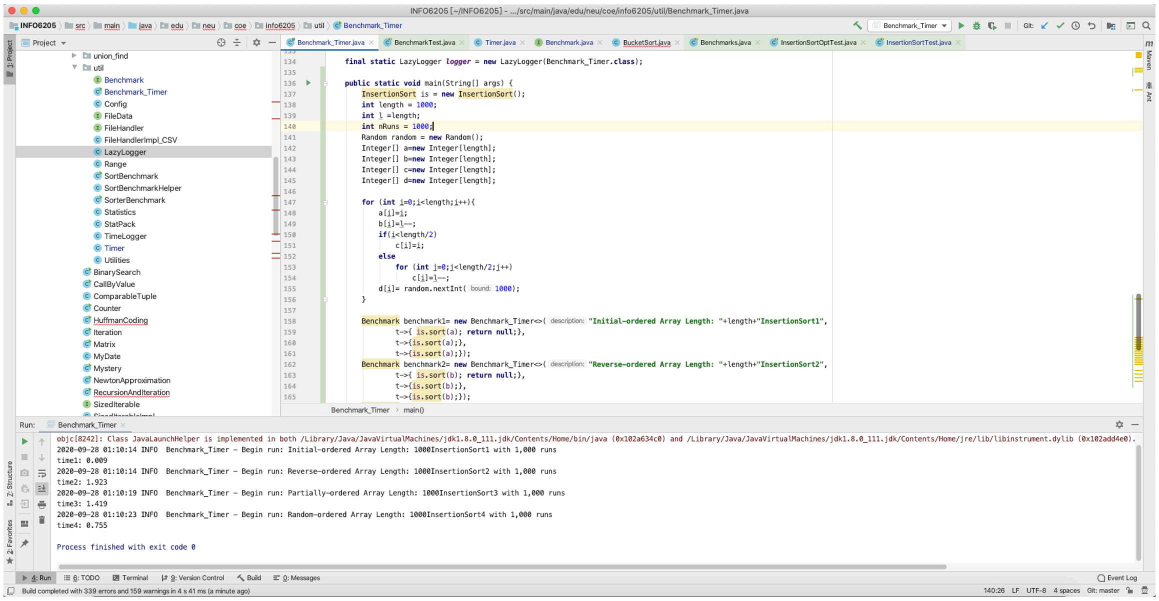
INFO6205 [~/INFO6205] - .../src/main/java/edu/neu/coe/info6205/util/Benchmark_Timer.java

```java
    private final Consumer<T> fPost;

    final static LazyLogger logger = new LazyLogger(Benchmark_Timer.class);

    public static void main(String[] args) {
        InsertionSort is = new InsertionSort();
        int length = 500;
        int l =length;
        int nRuns = 1000;
        Random random = new Random();
        Integer[] a=new Integer[length];
        Integer[] b=new Integer[length];
        Integer[] c=new Integer[length];
        Integer[] d=new Integer[length];

        for (int i=0;i<length;i++){
            a[i]=i;
            b[i]=l--;
            if(i<length/2)
                c[i]=i;
            else
                for (int j=0;j<length/2;j++)
                    c[i]=l--;
            d[i]= random.nextInt( bound: 1000);
        }

        Benchmark benchmark1= new Benchmark_Timer<>( description: "Initial-ordered Array Length: "+length+"InsertionSort1",
                t->{ is.sort(a); return null;},
                t->{is.sort(a);},
                t->{is.sort(a);});
        Benchmark benchmark2= new Benchmark_Timer<>( description: "Reverse-ordered Array Length: "+length+"InsertionSort2",
                t->{ is.sort(b); return null;},
```

```
objc[8224]: Class JavaLaunchHelper is implemented in both /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/bin/java (0x100c0d4c0) and /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/jre/lib/libinstrument.dylib (0x100c874e0).
2020-09-28 01:08:40 INFO  Benchmark_Timer - Begin run: Initial-ordered Array Length: 500InsertionSort1 with 1,000 runs
time1: 0.005
2020-09-28 01:08:40 INFO  Benchmark_Timer - Begin run: Reverse-ordered Array Length: 500InsertionSort2 with 1,000 runs
time2: 0.57
2020-09-28 01:08:41 INFO  Benchmark_Timer - Begin run: Partially-ordered Array Length: 500InsertionSort3 with 1,000 runs
time3: 0.365
2020-09-28 01:08:42 INFO  Benchmark_Timer - Begin run: Random-ordered Array Length: 500InsertionSort4 with 1,000 runs
time4: 0.204

Process finished with exit code 0
```

Build completed with 339 errors and 159 warnings in 3 s 528 ms (a minute ago)

N=1000



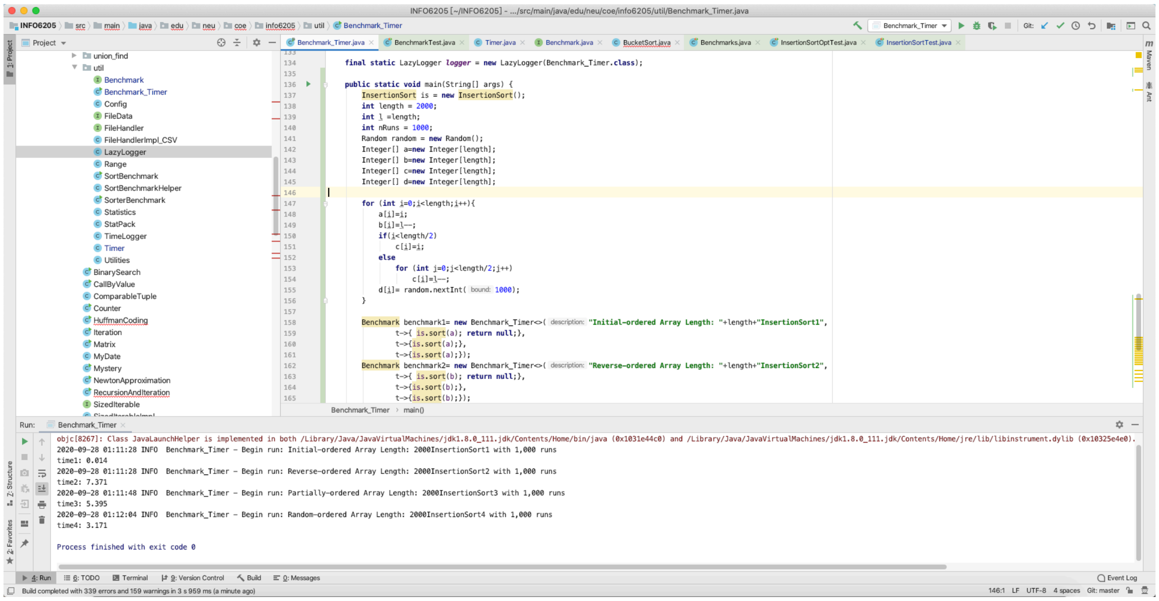
INFO6205 [~/INFO6205] - .../src/main/java/edu/neu/coe/info6205/util/Benchmark_Timer.java

```
    final static LazyLogger logger = new LazyLogger(Benchmark_Timer.class);

    public static void main(String[] args) {
        InsertionSort is = new InsertionSort();
        int length = 1000;
        int l =length;
        int nRuns = 1000;
        Random random = new Random();
        Integer[] a=new Integer[length];
        Integer[] b=new Integer[length];
        Integer[] c=new Integer[length];
        Integer[] d=new Integer[length];

        for (int i=0;i<length;i++){
            a[i]=i;
            b[i]=l--;
            if(i<length/2)
                c[i]=i;
            else
                for (int j=0;j<length/2;j++)
                    c[i]=l--;
            d[i]= random.nextInt( bound: 1000);
        }

        Benchmark benchmark1= new Benchmark_Timer<>( description: "Initial-ordered Array Length: "+length+"InsertionSort1",
                t->{ is.sort(a); return null;},
                t->{is.sort(a);},
                t->{is.sort(a);});
        Benchmark benchmark2= new Benchmark_Timer<>( description: "Reverse-ordered Array Length: "+length+"InsertionSort2",
                t->{ is.sort(b); return null;},
                t->{is.sort(b);},
                t->{is.sort(b);});
```

```
objc[8242]: Class JavaLaunchHelper is implemented in both /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/bin/java (0x102a634c0) and /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/jre/lib/libinstrument.dylib (0x102add4e0).
2020-09-28 01:10:14 INFO  Benchmark_Timer - Begin run: Initial-ordered Array Length: 1000InsertionSort1 with 1,000 runs
time1: 0.009
2020-09-28 01:10:14 INFO  Benchmark_Timer - Begin run: Reverse-ordered Array Length: 1000InsertionSort2 with 1,000 runs
time2: 1.923
2020-09-28 01:10:19 INFO  Benchmark_Timer - Begin run: Partially-ordered Array Length: 1000InsertionSort3 with 1,000 runs
time3: 1.419
2020-09-28 01:10:23 INFO  Benchmark_Timer - Begin run: Random-ordered Array Length: 1000InsertionSort4 with 1,000 runs
time4: 0.755

Process finished with exit code 0
```

Build completed with 339 errors and 159 warnings in 4 s 41 ms (a minute ago)

N=2000



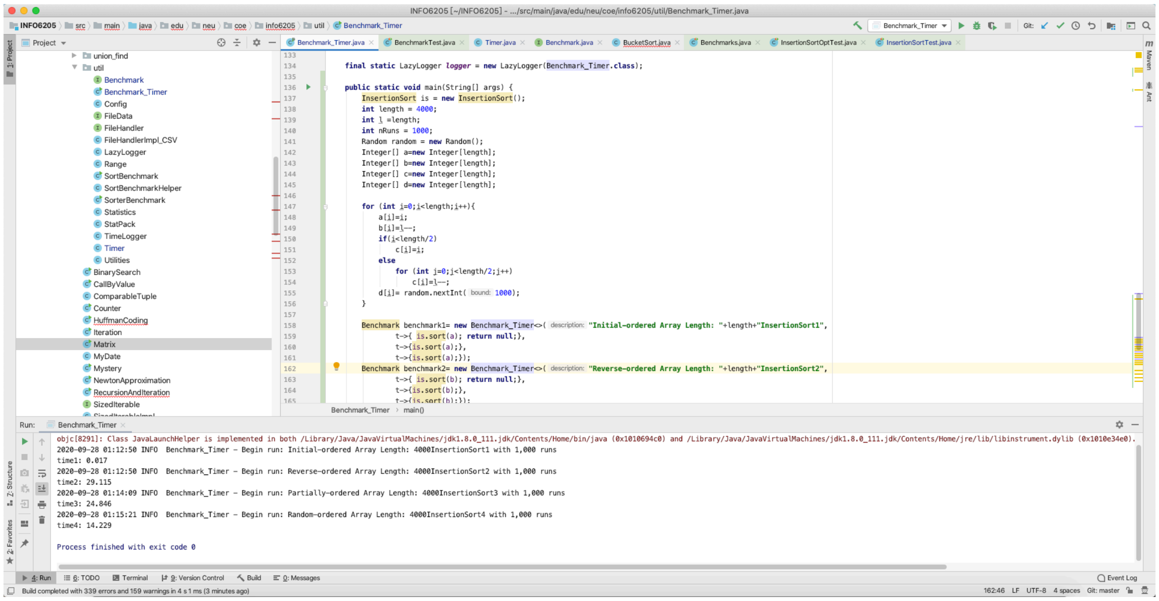
INFO6205 [~/INFO6205] - .../src/main/java/edu/neu/coe/info6205/util/Benchmark_Timer.java

```
    final static LazyLogger logger = new LazyLogger(Benchmark_Timer.class);

    public static void main(String[] args) {
        InsertionSort is = new InsertionSort();
        int length = 2000;
        int l =length;
        int nRuns = 1000;
        Random random = new Random();
        Integer[] a=new Integer[length];
        Integer[] b=new Integer[length];
        Integer[] c=new Integer[length];
        Integer[] d=new Integer[length];

        for (int i=0;i<length;i++){
            a[i]=i;
            b[i]=l--;
            if(i<length/2)
                c[i]=i;
            else
                for (int j=0;j<length/2;j++)
                    c[i]=l--;
            d[i]= random.nextInt( bound: 1000);
        }

        Benchmark benchmark1= new Benchmark_Timer<>( description: "Initial-ordered Array Length: "+length+"InsertionSort1",
                t->{ is.sort(a); return null;},
                t->{is.sort(a);},
                t->{is.sort(a);});
        Benchmark benchmark2= new Benchmark_Timer<>( description: "Reverse-ordered Array Length: "+length+"InsertionSort2",
                t->{ is.sort(b); return null;},
                t->{is.sort(b);},
                t->{is.sort(b);});
```

```
objc[8267]: Class JavaLaunchHelper is implemented in both /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/bin/java (0x1031e44c0) and /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/jre/lib/libinstrument.dylib (0x10325e4e0).
2020-09-28 01:11:28 INFO  Benchmark_Timer - Begin run: Initial-ordered Array Length: 2000InsertionSort1 with 1,000 runs
time1: 0.014
2020-09-28 01:11:28 INFO  Benchmark_Timer - Begin run: Reverse-ordered Array Length: 2000InsertionSort2 with 1,000 runs
time2: 7.371
2020-09-28 01:11:48 INFO  Benchmark_Timer - Begin run: Partially-ordered Array Length: 2000InsertionSort3 with 1,000 runs
time3: 5.395
2020-09-28 01:12:04 INFO  Benchmark_Timer - Begin run: Random-ordered Array Length: 2000InsertionSort4 with 1,000 runs
time4: 3.171

Process finished with exit code 0
```

Build completed with 339 errors and 159 warnings in 3 s 959 ms (a minute ago)

N=4000



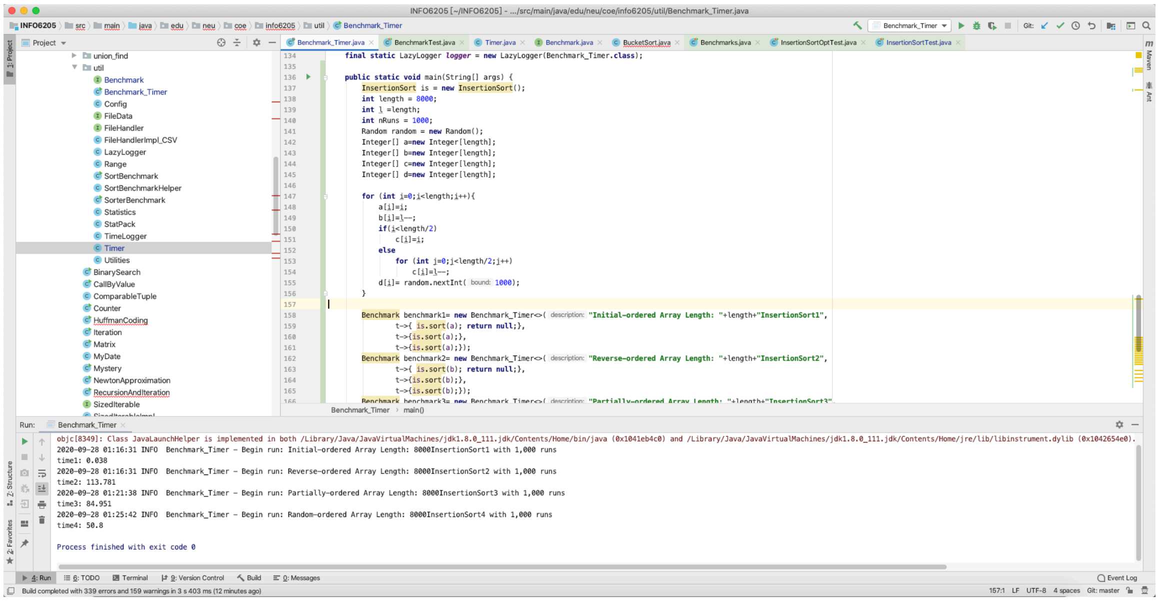
INFO6205 [~/INFO6205] - .../src/main/java/edu/neu/coe/info6205/util/Benchmark_Timer.java

```java

    final static LazyLogger logger = new LazyLogger(Benchmark_Timer.class);

    public static void main(String[] args) {
        InsertionSort is = new InsertionSort();
        int length = 4000;
        int l =length;
        int nRuns = 1000;
        Random random = new Random();
        Integer[] a=new Integer[length];
        Integer[] b=new Integer[length];
        Integer[] c=new Integer[length];
        Integer[] d=new Integer[length];

        for (int i=0;i<length;i++){
            a[i]=i;
            b[i]=l--;
            if(i<length/2)
                c[i]=i;
            else
                for (int j=0;j<length/2;j++)
                    c[i]=l--;
            d[i]= random.nextInt( bound: 1000);
        }

        Benchmark benchmark1= new Benchmark_Timer<>( description: "Initial-ordered Array Length: "+length+"InsertionSort1",
                t->{ is.sort(a); return null;},
                t->{is.sort(a);},
                t->{is.sort(a);});
        Benchmark benchmark2= new Benchmark_Timer<>( description: "Reverse-ordered Array Length: "+length+"InsertionSort2",
                t->{ is.sort(b); return null;},
                t->{is.sort(b);},
                t->{is.sort(b);});
```

```
objc[8291]: Class JavaLaunchHelper is implemented in both /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/bin/java (0x1010694c0) and /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/jre/lib/libinstrument.dylib (0x1010e34e0).
2020-09-28 01:12:50 INFO  Benchmark_Timer - Begin run: Initial-ordered Array Length: 4000InsertionSort1 with 1,000 runs
time1: 0.017
2020-09-28 01:12:50 INFO  Benchmark_Timer - Begin run: Reverse-ordered Array Length: 4000InsertionSort2 with 1,000 runs
time2: 29.115
2020-09-28 01:14:09 INFO  Benchmark_Timer - Begin run: Partially-ordered Array Length: 4000InsertionSort3 with 1,000 runs
time3: 24.846
2020-09-28 01:15:21 INFO  Benchmark_Timer - Begin run: Random-ordered Array Length: 4000InsertionSort4 with 1,000 runs
time4: 14.229

Process finished with exit code 0
```

Build completed with 339 errors and 159 warnings in 4 s 1 ms (3 minutes ago)

N=8000



INFO6205 [~/INFO6205] - .../src/main/java/edu/neu/coe/info6205/util/Benchmark_Timer.java

```java
    final static LazyLogger logger = new LazyLogger(Benchmark_Timer.class);

    public static void main(String[] args) {
        InsertionSort is = new InsertionSort();
        int length = 8000;
        int l =length;
        int nRuns = 1000;
        Random random = new Random();
        Integer[] a=new Integer[length];
        Integer[] b=new Integer[length];
        Integer[] c=new Integer[length];
        Integer[] d=new Integer[length];

        for (int i=0;i<length;i++){
            a[i]=i;
            b[i]=l--;
            if(i<length/2)
                c[i]=i;
            else
                for (int j=0;j<length/2;j++)
                    c[i]=l--;
            d[i]= random.nextInt( bound: 1000);
        }

        Benchmark benchmark1= new Benchmark_Timer<>( description: "Initial-ordered Array Length: "+length+"InsertionSort1",
                t->{ is.sort(a); return null;},
                t->{is.sort(a);},
                t->{is.sort(a);});
        Benchmark benchmark2= new Benchmark_Timer<>( description: "Reverse-ordered Array Length: "+length+"InsertionSort2",
                t->{ is.sort(b); return null;},
                t->{is.sort(b);},
                t->{is.sort(b);});
        Benchmark benchmark3= new Benchmark_Timer<>( description: "Partially-ordered Array Length: "+length+"InsertionSort3",
```

```
objc[8349]: Class JavaLaunchHelper is implemented in both /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/bin/java (0x1041eb4c0) and /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Home/jre/lib/libinstrument.dylib (0x1042654e0).
2020-09-28 01:16:31 INFO  Benchmark_Timer - Begin run: Initial-ordered Array Length: 8000InsertionSort1 with 1,000 runs
time1: 0.038
2020-09-28 01:16:31 INFO  Benchmark_Timer - Begin run: Reverse-ordered Array Length: 8000InsertionSort2 with 1,000 runs
time2: 113.781
2020-09-28 01:21:38 INFO  Benchmark_Timer - Begin run: Partially-ordered Array Length: 8000InsertionSort3 with 1,000 runs
time3: 84.951
2020-09-28 01:25:42 INFO  Benchmark_Timer - Begin run: Random-ordered Array Length: 8000InsertionSort4 with 1,000 runs
time4: 50.8

Process finished with exit code 0
```

Build completed with 339 errors and 159 warnings in 3 s 403 ms (12 minutes ago)