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# Program Structures & Algorithms

# Spring 2021

# Assignment No. 3

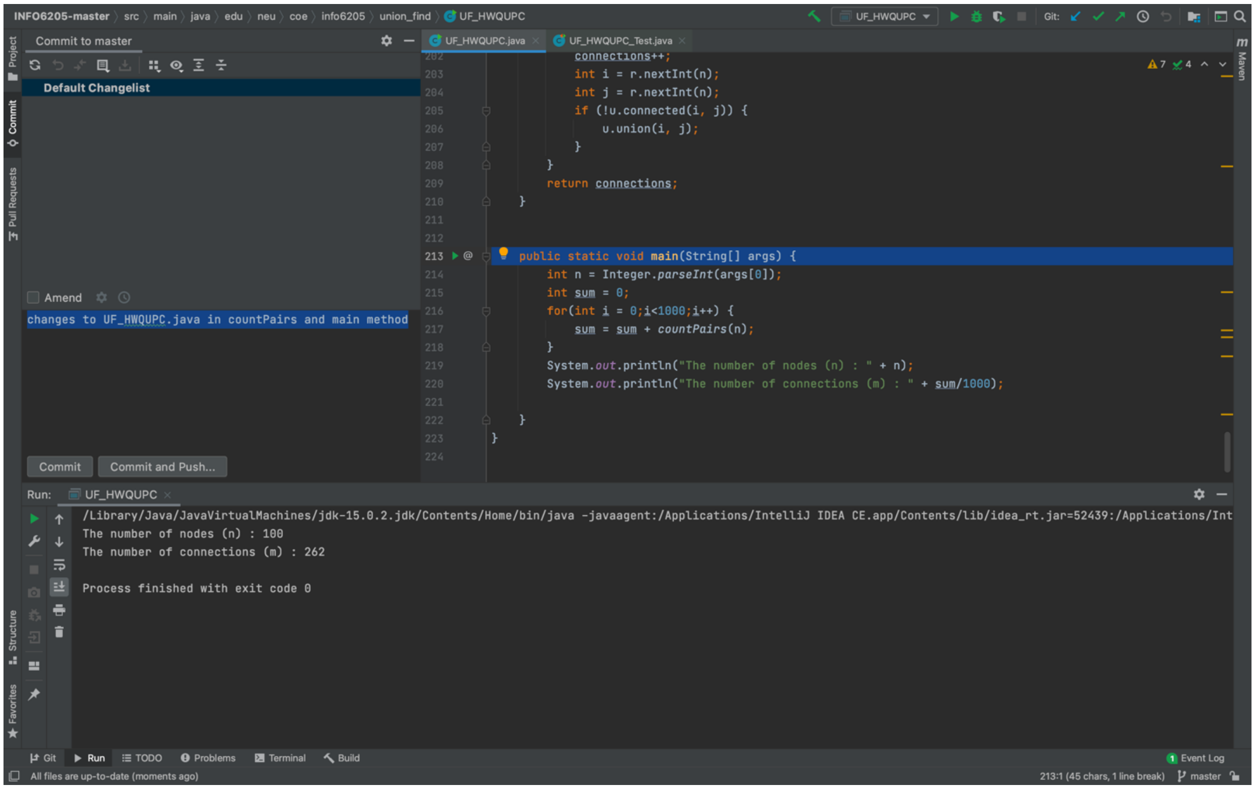
- **Task –**

- Step 1:
  (a) Implement height-weighted Quick Union with Path Compression. For this, you will flesh out the class UF_HWQUPC. All you have to do is to fill in the sections marked with // TO BE IMPLEMENTED ... // ...END IMPLEMENTATION.
- (b) Check that the unit tests for this class all work. You must show "green" test results in your submission (screenshot is OK).
- Step 2:
  Using your implementation of UF_HWQUPC, develop a UF ("union-find") client that takes an integer value n from the command line to determine the number of "sites." Then generates random pairs of integers between 0 and n-1, calling connected () to determine if they are connected and union () if not. Loop until all sites are connected then print the number of connections generated. Package your program as a static method count () that takes n as the argument and returns the number of connections; and a main () that takes n from the command line, calls count() and prints the returned value. If you prefer, you can create a main program that doesn't require any input and runs the experiment for a fixed set of n values. Show evidence of your run(s).
- Step 3:
  Determine the relationship between the number of objects (*n*) and the number of pairs (*m*) generated to accomplish this (i.e., to reduce the number of components from *n* to 1). Justify your conclusion.

- **Relationship Conclusion:**

  m = c * n.ln(n). (log to the base e)
  c ~ 1/2

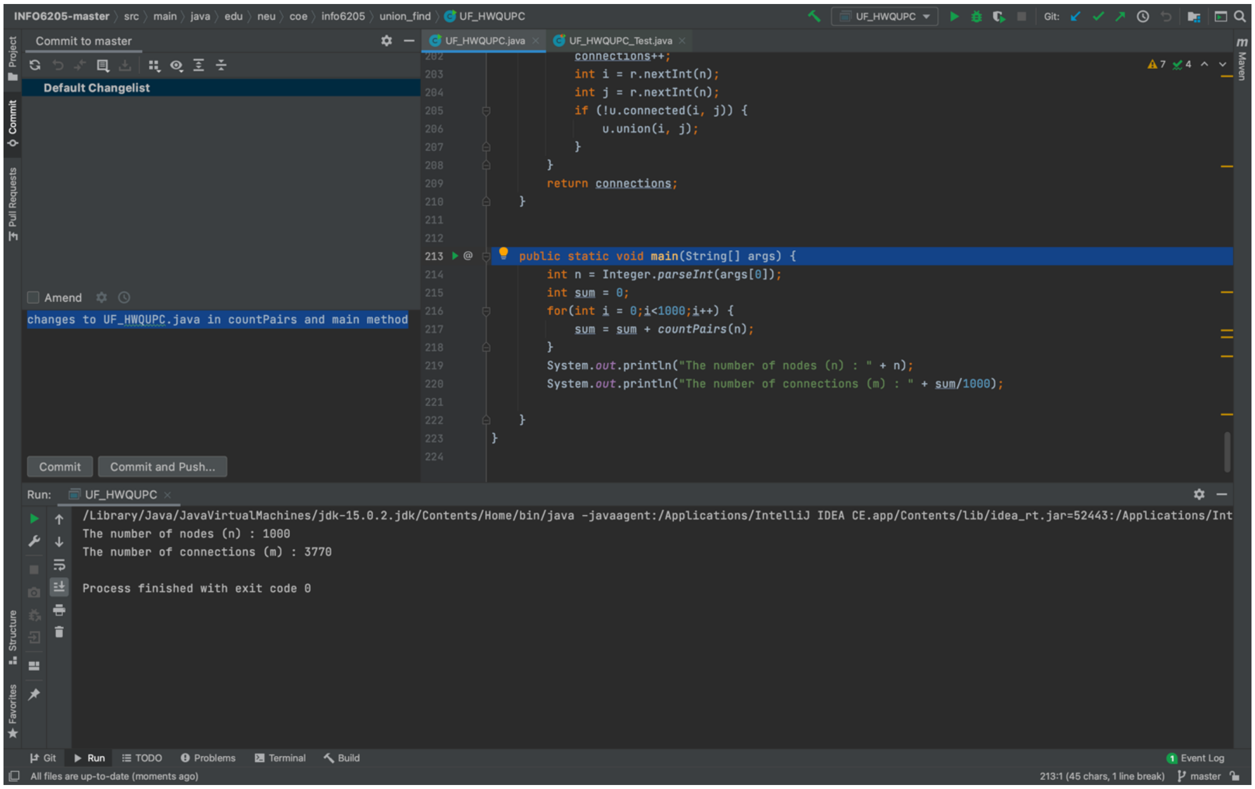
- ## Evidence to support the conclusion:



```
changes to UF_HWQUPC.java in countPairs and main method
```

```java
                connections++;
                int i = r.nextInt(n);
                int j = r.nextInt(n);
                if (!u.connected(i, j)) {
                    u.union(i, j);
                }
            }
            return connections;
        }


    public static void main(String[] args) {
            int n = Integer.parseInt(args[0]);
            int sum = 0;
            for(int i = 0;i<1000;i++) {
                sum = sum + countPairs(n);
            }
            System.out.println("The number of nodes (n) : " + n);
            System.out.println("The number of connections (m) : " + sum/1000);

        }
    }
```

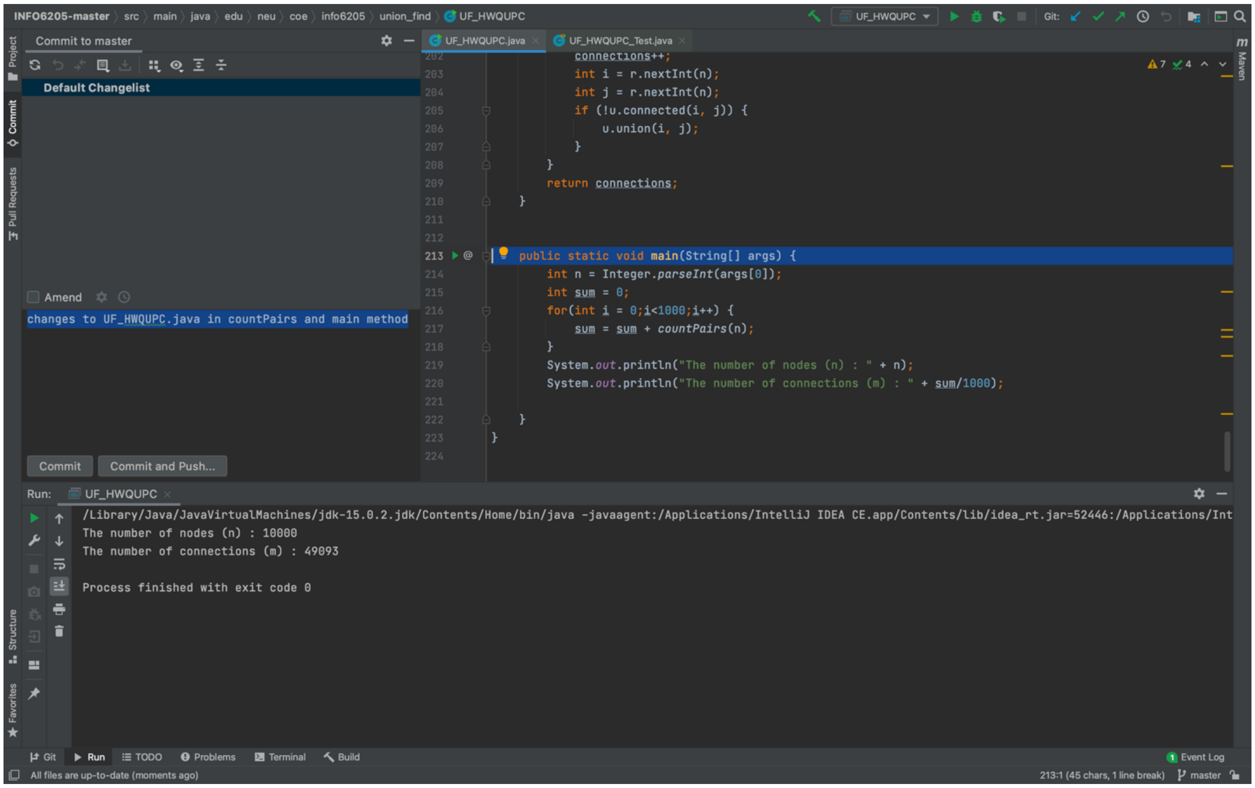
```
/Library/Java/JavaVirtualMachines/jdk-15.0.2.jdk/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.jar=52439:/Applications/Int
The number of nodes (n) : 100
The number of connections (m) : 262

Process finished with exit code 0
```



```
changes to UF_HWQUPC.java in countPairs and main method
```

```java
                connections++;
                int i = r.nextInt(n);
                int j = r.nextInt(n);
                if (!u.connected(i, j)) {
                    u.union(i, j);
                }
            }
            return connections;
        }


    public static void main(String[] args) {
            int n = Integer.parseInt(args[0]);
            int sum = 0;
            for(int i = 0;i<1000;i++) {
                sum = sum + countPairs(n);
            }
            System.out.println("The number of nodes (n) : " + n);
            System.out.println("The number of connections (m) : " + sum/1000);

        }
    }
```

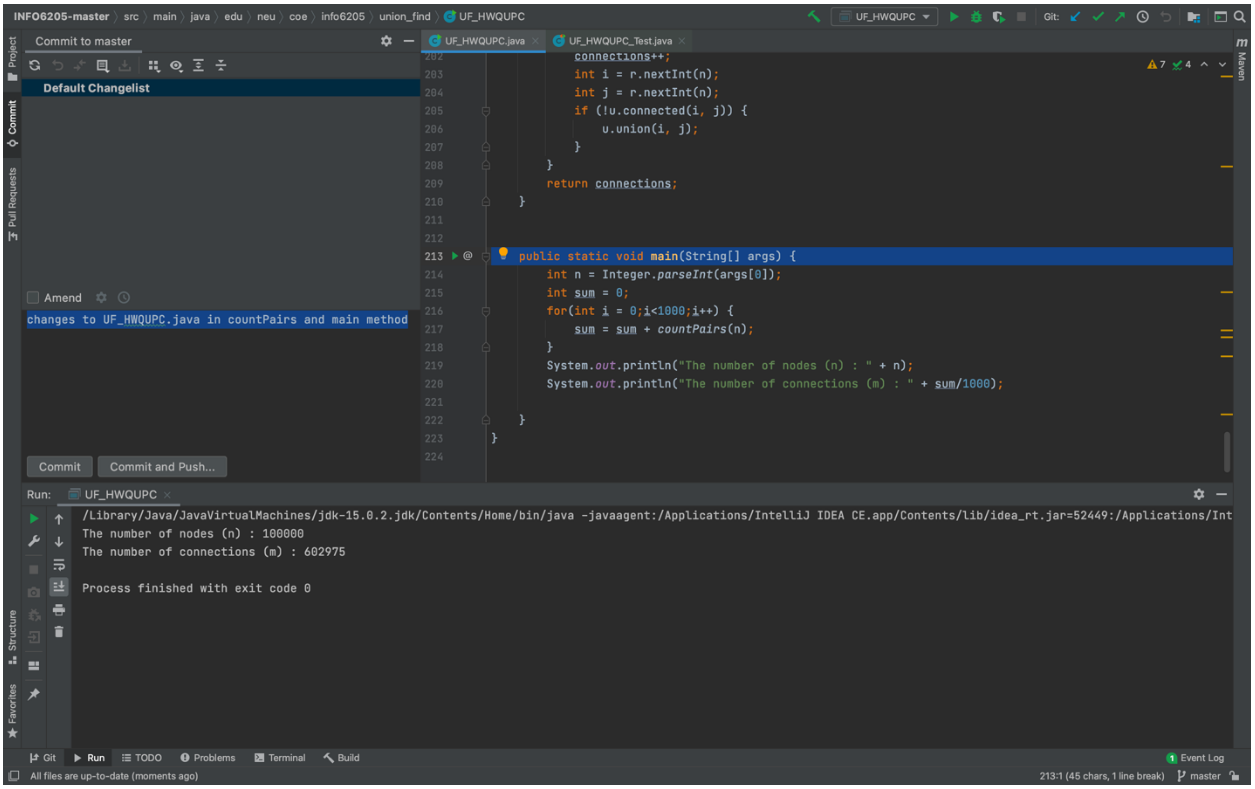
```
/Library/Java/JavaVirtualMachines/jdk-15.0.2.jdk/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.jar=52443:/Applications/Int
The number of nodes (n) : 1000
The number of connections (m) : 3770

Process finished with exit code 0
```



changes to UF_HWQUPC.java in countPairs and main method

```
            connections++;
            int i = r.nextInt(n);
            int j = r.nextInt(n);
            if (!u.connected(i, j)) {
                u.union(i, j);
            }
        }
        return connections;
    }


    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        int sum = 0;
        for(int i = 0;i<1000;i++) {
            sum = sum + countPairs(n);
        }
        System.out.println("The number of nodes (n) : " + n);
        System.out.println("The number of connections (m) : " + sum/1000);

    }
}
```

```
/Library/Java/JavaVirtualMachines/jdk-15.0.2.jdk/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.jar=52446:/Applications/Int
The number of nodes (n) : 10000
The number of connections (m) : 49093

Process finished with exit code 0
```

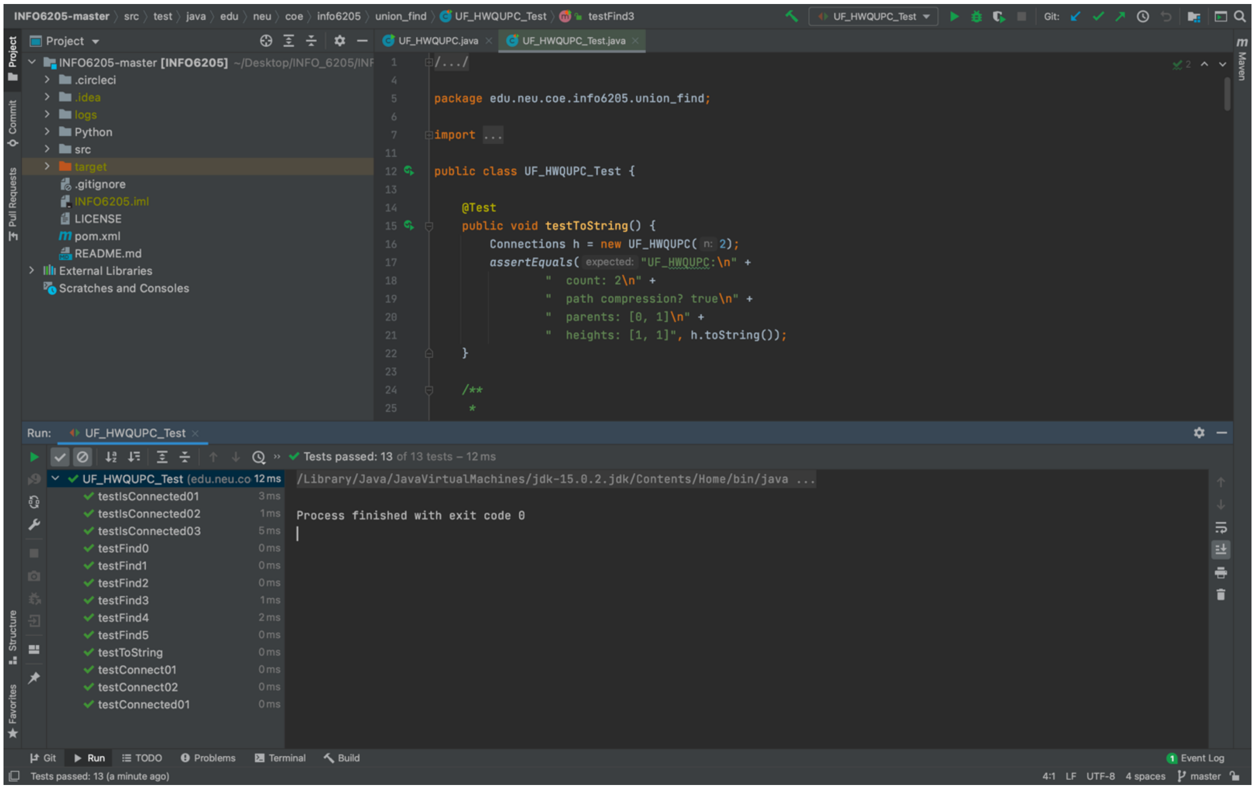


changes to UF_HWQUPC.java in countPairs and main method

```
            connections++;
            int i = r.nextInt(n);
            int j = r.nextInt(n);
            if (!u.connected(i, j)) {
                u.union(i, j);
            }
        }
        return connections;
    }


    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        int sum = 0;
        for(int i = 0;i<1000;i++) {
            sum = sum + countPairs(n);
        }
        System.out.println("The number of nodes (n) : " + n);
        System.out.println("The number of connections (m) : " + sum/1000);

    }
}
```

```
/Library/Java/JavaVirtualMachines/jdk-15.0.2.jdk/Contents/Home/bin/java -javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.jar=52449:/Applications/Int
The number of nodes (n) : 100000
The number of connections (m) : 602975

Process finished with exit code 0
```

- **Unit tests result:**



```
/.../

package edu.neu.coe.info6205.union_find;

import ...

public class UF_HWQUPC_Test {

    @Test
    public void testToString() {
        Connections h = new UF_HWQUPC( n: 2);
        assertEquals( expected: "UF_HWQUPC:\n" +
                "  count: 2\n" +
                "  path compression? true\n" +
                "  parents: [0, 1]\n" +
                "  heights: [1, 1]", h.toString());
    }

    /**
     *
```

✓ Tests passed: 13 of 13 tests – 12 ms

```
✓ UF_HWQUPC_Test (edu.neu.co 12 ms
    ✓ testIsConnected01    3 ms
    ✓ testIsConnected02    1 ms
    ✓ testIsConnected03    5 ms
    ✓ testFind0            0 ms
    ✓ testFind1            0 ms
    ✓ testFind2            0 ms
    ✓ testFind3            1 ms
    ✓ testFind4            2 ms
    ✓ testFind5            0 ms
    ✓ testToString         0 ms
    ✓ testConnect01        0 ms
    ✓ testConnect02        0 ms
    ✓ testConnected01      0 ms
```

```
/Library/Java/JavaVirtualMachines/jdk-15.0.2.jdk/Contents/Home/bin/java ...

Process finished with exit code 0
```

Tests passed: 13 (a minute ago)