Program Structures and Algorithms - Assignment 3
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Tasks:

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:

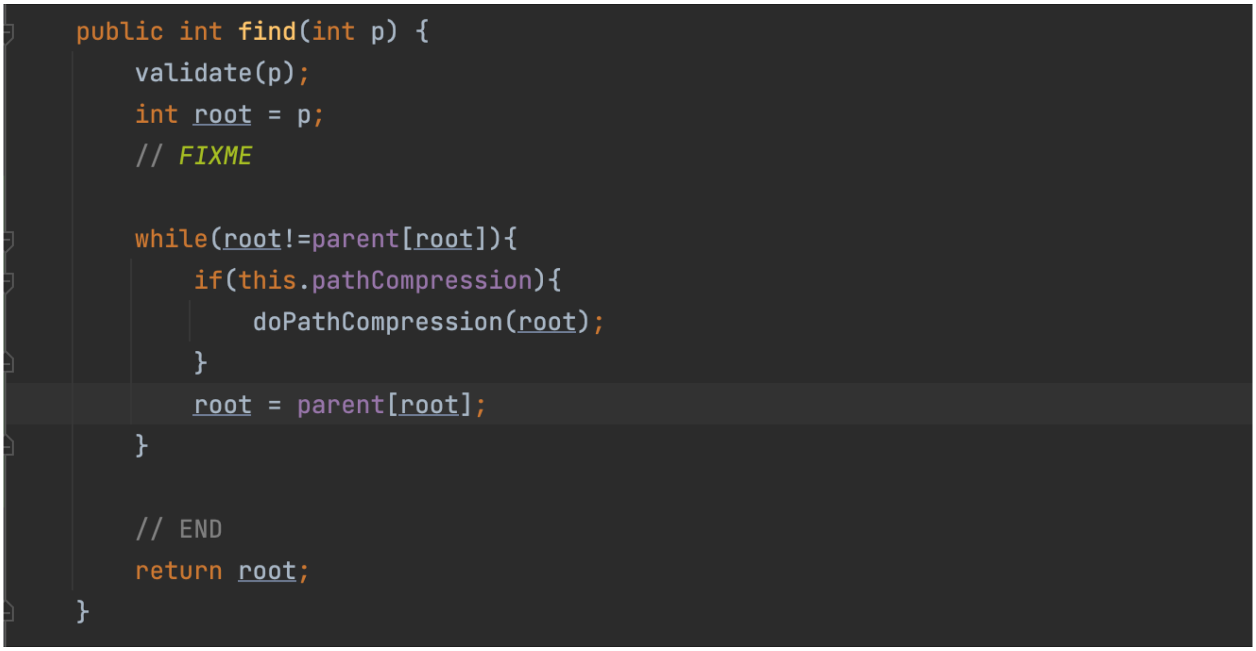
Using your implementation of UF_HWQUPC, develop a UF ("union-find") client that takes an integer value n from the command line to determine the number of "sites." Then generates random pairs of integers between 0 and n-1, calling connected() to determine if they are connected and union() if not. Loop 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:

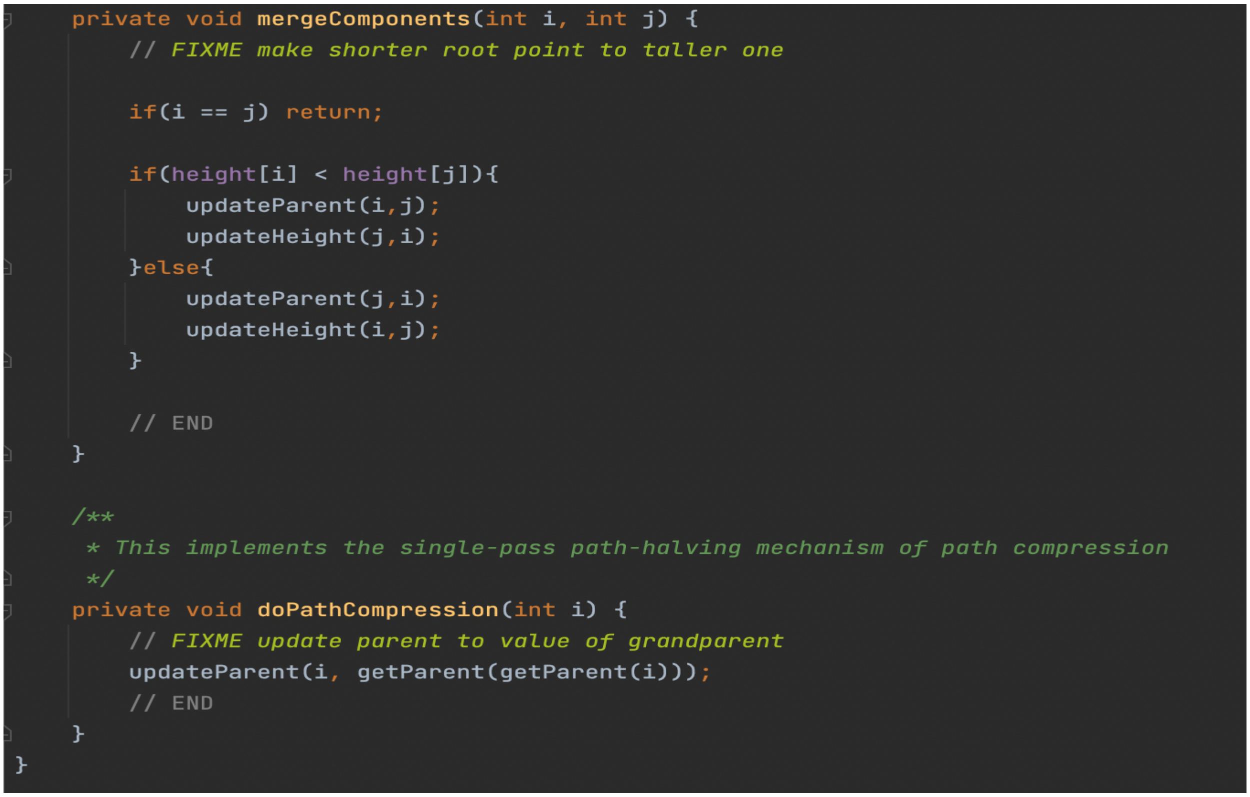
Determine the relationship between the number of objects (*n*) and the number of pairs (*m*) generated to accomplish this (i.e. to reduce the number of components from *n* to 1). Justify your conclusion in terms of your observations and what you think might be going on.

Step 1:

Code Implementation Screenshots:

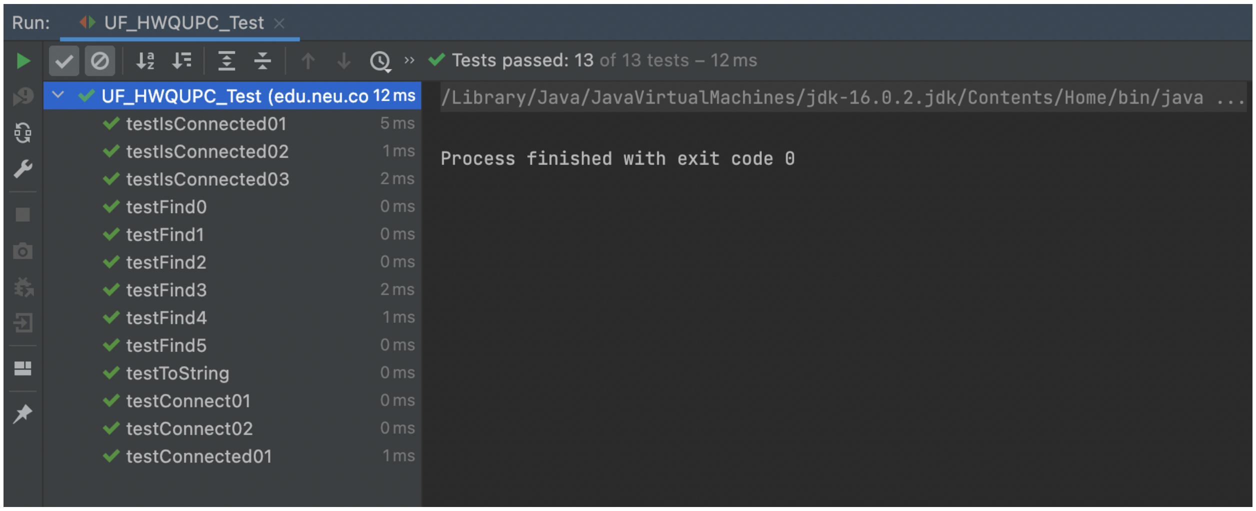


```
    public int find(int p) {
        validate(p);
        int root = p;
        // FIXME

        while(root!=parent[root]){
            if(this.pathCompression){
                doPathCompression(root);
            }
            root = parent[root];
        }

        // END
        return root;
    }
```



```
    private void mergeComponents(int i, int j) {
        // FIXME make shorter root point to taller one

        if(i == j) return;

        if(height[i] < height[j]){
            updateParent(i,j);
            updateHeight(j,i);
        }else{
            updateParent(j,i);
            updateHeight(i,j);
        }

        // END
    }

    /**
     * This implements the single-pass path-halving mechanism of path compression
     */
    private void doPathCompression(int i) {
        // FIXME update parent to value of grandparent
        updateParent(i, getParent(getParent(i)));
        // END
    }
}
```

Testing Screenshots:

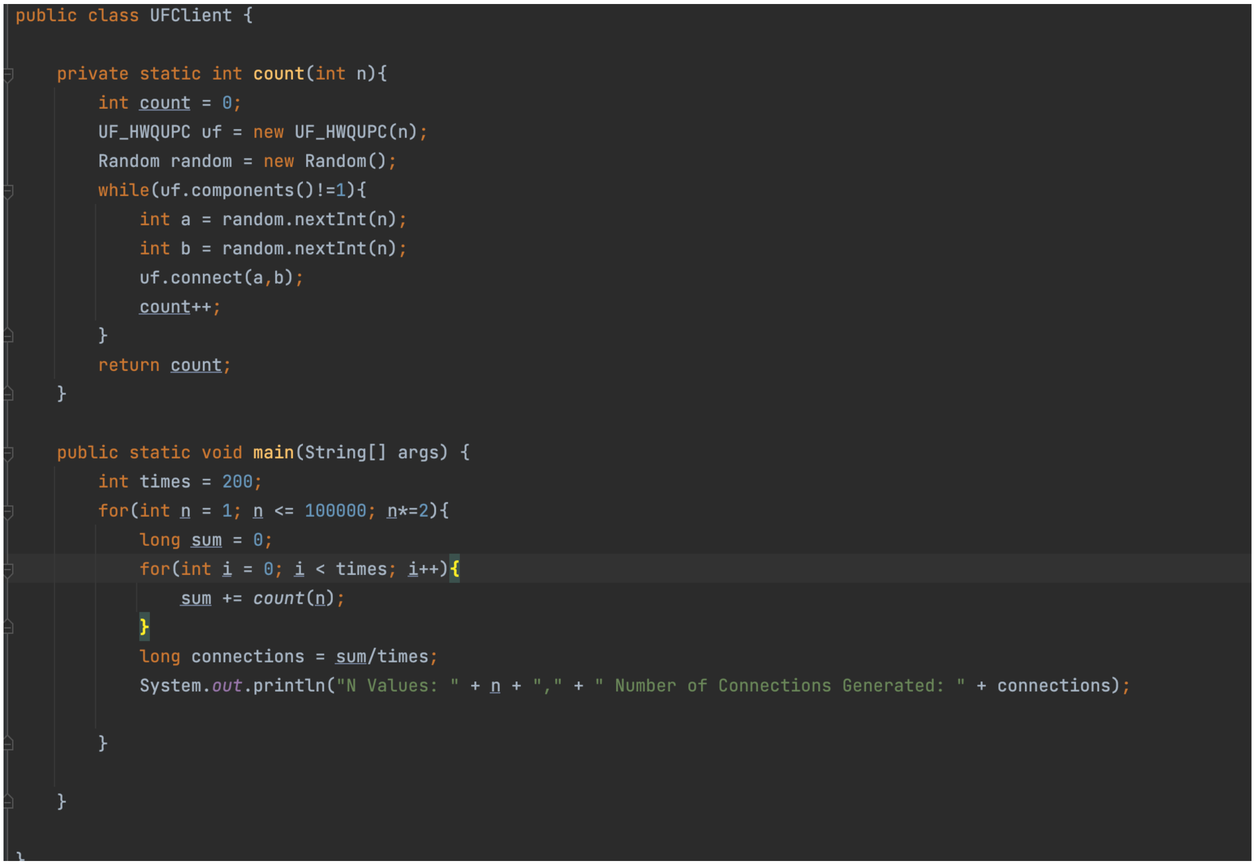


```
Tests passed: 13 of 13 tests – 12 ms

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

```
/Library/Java/JavaVirtualMachines/jdk-16.0.2.jdk/Contents/Home/bin/java ...

Process finished with exit code 0
```

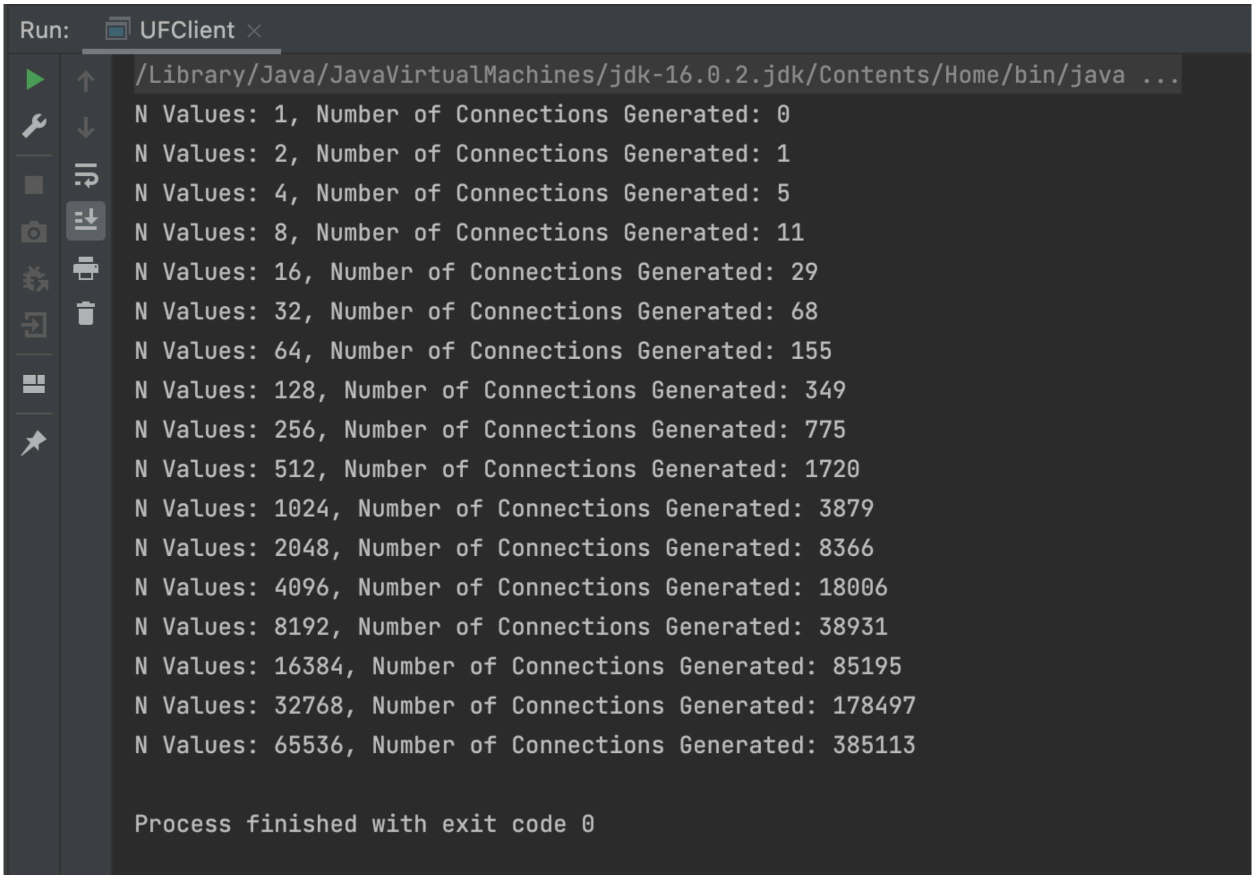
Step 2:

Code for UFClient.java



```java
public class UFClient {

    private static int count(int n){
        int count = 0;
        UF_HWQUPC uf = new UF_HWQUPC(n);
        Random random = new Random();
        while(uf.components()!=1){
            int a = random.nextInt(n);
            int b = random.nextInt(n);
            uf.connect(a,b);
            count++;
        }
        return count;
    }

    public static void main(String[] args) {
        int times = 200;
        for(int n = 1; n <= 100000; n*=2){
            long sum = 0;
            for(int i = 0; i < times; i++){
                sum += count(n);
            }
            long connections = sum/times;
            System.out.println("N Values: " + n + "," + " Number of Connections Generated: " + connections);

        }

    }

}
```

Output for UFClient.java



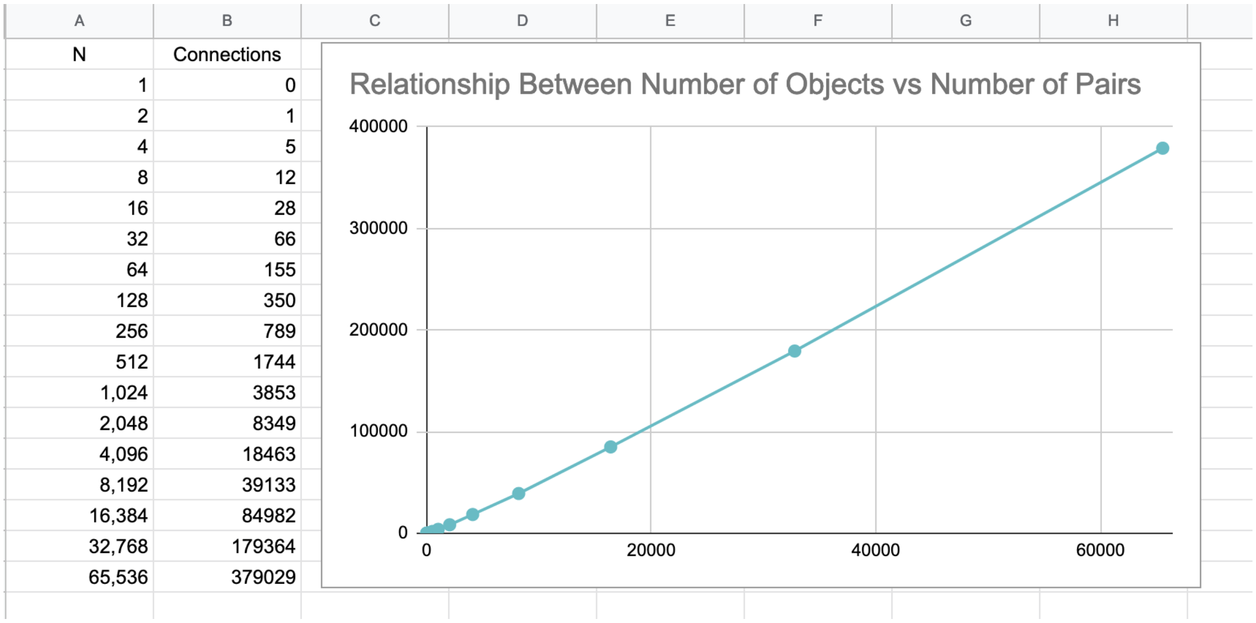
```
/Library/Java/JavaVirtualMachines/jdk-16.0.2.jdk/Contents/Home/bin/java ...
N Values: 1, Number of Connections Generated: 0
N Values: 2, Number of Connections Generated: 1
N Values: 4, Number of Connections Generated: 5
N Values: 8, Number of Connections Generated: 11
N Values: 16, Number of Connections Generated: 29
N Values: 32, Number of Connections Generated: 68
N Values: 64, Number of Connections Generated: 155
N Values: 128, Number of Connections Generated: 349
N Values: 256, Number of Connections Generated: 775
N Values: 512, Number of Connections Generated: 1720
N Values: 1024, Number of Connections Generated: 3879
N Values: 2048, Number of Connections Generated: 8366
N Values: 4096, Number of Connections Generated: 18006
N Values: 8192, Number of Connections Generated: 38931
N Values: 16384, Number of Connections Generated: 85195
N Values: 32768, Number of Connections Generated: 178497
N Values: 65536, Number of Connections Generated: 385113

Process finished with exit code 0
```

Step 3:

The relationship between the number of objects (n) and number of pairs (m) generated to reduce the number of components from n to1 is -

m = f(n) = (n * ln (n)) / 2

In union find we check if pairs are connected or disconnected (n (ln(n)), since there are only two possibilities for each pair. Hence the relationship between m and n is almost identical to 0.5 * (n * ln (n))



N	Connections
1	0
2	1
4	5
8	12
16	28
32	66
64	155
128	350
256	789
512	1744
1,024	3853
2,048	8349
4,096	18463
8,192	39133
16,384	84982
32,768	179364
65,536	379029