

Program Structures and Algorithms  
Spring 2023(SEC – 1)

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**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 (the 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.

**Relationship Conclusion:**

The relationship between the number of objects ( $n$ ) and the number of randomly generated pairs ( $m$ ) needed to reduce the number of components/objects from  $n$  to 1 can be described as follows:

$m$  is proportional to  $n$  times the logarithm of  $n$ , with the logarithm taken to the base of 2. This relationship was determined by taking the average of  $m$  over 100 runs of a program, with the value of  $c$ , which is approximately equal to 1.22,

being determined from the results of runs with  $n$  ranging from 1000 to 512000 (doubling in each iteration).

$$m = c * n * \log(n)$$

where  $c = m/n * \log(n)$  which is approximately equal to 1.22 as observed over  $n$  ranging from 1000 to 512000(doubling)

Therefore we can summarize the relationship as

$$m \propto n * \log(n)$$

### Evidence to support that conclusion:

1. Values of  $n$  are ranging from 1000 to 2048000(doubling each time).
2. For each value of  $n$ , the program is running 100 times, and the average value of  $m$  is shown below.
3. The constant  $c = m/n * \log(n)$  can be approximated to 1.22 And therefore the relationship can be established as

$$m = c * n * \log(n) \quad \text{or} \quad m \propto n * \log(n)$$

The screenshot shows an IDE with a Java project. The code in the editor is as follows:

```
//System.out.println("the number of connections: " + count);
return count;
}

new *
public static void main(String[] args) {
    System.out.printf("%-10s %-10s \n", "n", "m");

    for (int i = 1000; i < 1000000; i *= 2) {
        int total = 0;
        for (int j = 0; j < 10; j++) {
            total += count(i);
        }
        double mean = total / 10.0;
```

The Run window displays the following output:

n	m
1000	3578
2000	8235
4000	17348
8000	37467
16000	81598
32000	163145
64000	374727
128000	848195
256000	1715281
512000	3582265

Process finished with exit code 0

No. of Connections screenshots:

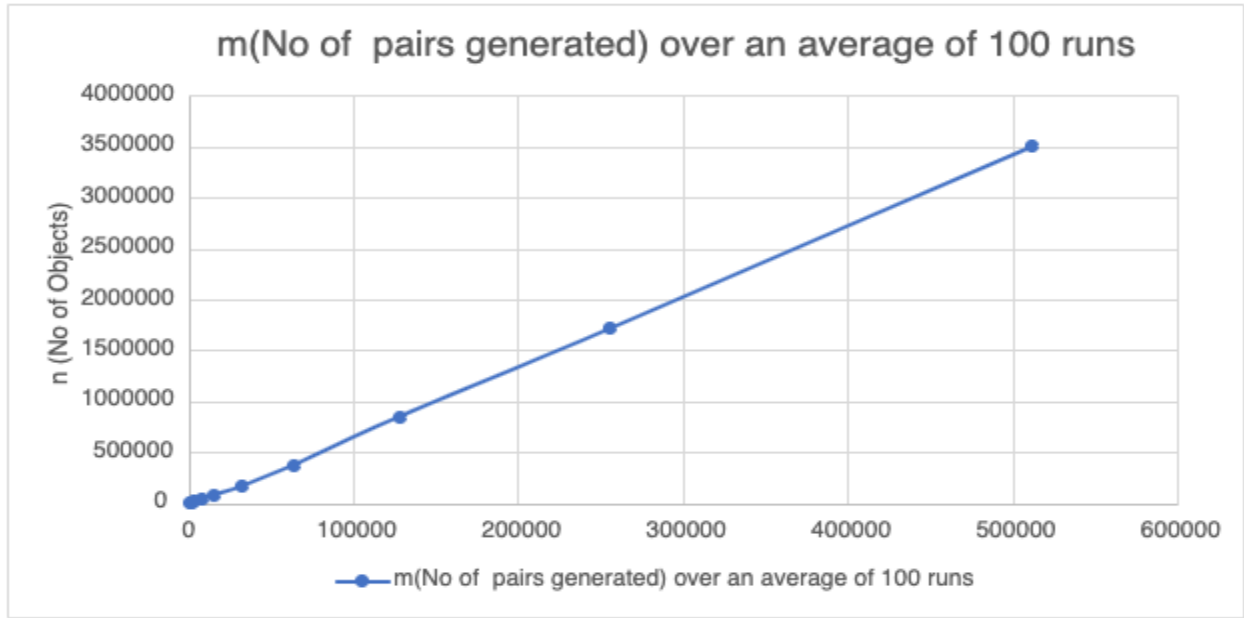
The screenshot shows an IDE with a project named 'INFO6205'. The file explorer on the left shows a package structure including 'union\_find' and 'UF\_HWQUPC'. The main editor displays the 'UF\_HWQUPC.java' file. The code defines a 'count' method that prints the number of connections and a 'main' method that runs a loop for 'n' values from 1000 to 16000 in increments of 1000, calling 'count' for each. The 'Run' console at the bottom shows the output of the program, listing the number of connections for each 'n' value.

```
INFO6205 / src / main / java / edu / neu / coe / info6205 / union_find / UF_HWQUPC / count
Project
  > runLengthEncoding
  > sort
  > symbolTable
  > threesum
  > union_find
    > Connections
    > HWQUPC_Solution
    > TypedUF
    > TypedUF_HWQUPC
    > UF
    > UF_HWQUPC
    > UFException
    > WQUPC
  > util
    > BinarySearch
    > CallByValue
    > ComparableTuple
Run: UF_HWQUPC
/Library/Java/JavaVirtualMachines/jdk-19.jdk/Contents/Home/bin/java ...
n      m
the number of connections: 3268
the number of connections: 4323
the number of connections: 3545
the number of connections: 4408
the number of connections: 2997
the number of connections: 3408
the number of connections: 4243
the number of connections: 3954
the number of connections: 4566
the number of connections: 3375
1000   3808
the number of connections: 8678
the number of connections: 7175
the number of connections: 7713
the number of connections: 13340
the number of connections: 7364
the number of connections: 9037
the number of connections: 7658
the number of connections: 6669
```

Graphical Representation:

n(No of Objects)	m(No of pairs generated) over an average of 100 runs
1000	3578
2000	8235
4000	17348
8000	37467
16000	81598

<b>32000</b>	<b>163145</b>
<b>64000</b>	<b>374727</b>
<b>128000</b>	<b>848195</b>
<b>256000</b>	<b>1715281</b>
<b>512000</b>	<b>3502265</b>



## Unit Test Screenshots:

