Aru Poleo: Reflection Lab 6

My implementation of A* has shown me that there is a bug in my DFS and BFS algorithms that I have yet to find, but alas I am running out of time to submit this lab. The following numbers show that A* is significantly worse than BFS at finding a path, but I believe that is simply because BFS often fails at finding a path when A* does find one. I believe this is especially so in the larger mazes, though I am still unsure as to why.

The benchmarks output were the following:

DFS Benchmark:
      Average Duration   : 180ms
      Average Pushes   : 64.7667
      Average Path Length : 32.5455
BFS Benchmark:
      Average Duration   : 85ms
      Average Pushes   : 32.5667
      Average Path Length : 12.4167
A Star Benchmark:
      Average Duration   : 358ms
      Average Pushes   : 93.4
      Average Path Length : 21.0667

DFS seems to be worse than BFS in terms of finding a path quickly and finding a short path. We know the first one to be highly unlikely, and repeated testing shows this behavior to be inherent to the implementation. After looking into this some more, I was able to see that often, where A* and DFS had found a path, BFS had not, and in some cases a* had found a path but neither DFS or BFS had done so. I've attached output of the behavior I found, but it can be better evidenced in the binary that is created by the project.

```
bfs version:
in string|   |   |   |   |   |   |   | x |   | x |   | x |   |   |   |   |   |   | x |   |
|   |   |   |   | x | x | x |   |   |
|   |   |   |   |   |   |   |   | x |   |   |   |   |   | x |   |   |   |   |   | x |
|   |   |   | x |   |
| x |   |   | x |   |   |   | x |   |   |   | x | x |   |   |   |   | S |   |   |   |   |
| x |   |   |   | x |
|   |   |   |   |   |   | x |   |   |   |   |   | x | x |   | x |   |   |   | x |   |   |
|   |   |   | x |   |
|   |   |   |   |   |   |   |   | x |   | x | x | x |   |   |   | x |   | x |   | x | x |
x | x |   |   |   |   |
|   | x |   |   |   |   |   | x |   |   |   |   | x |   |   |   |   | x |   | x |   |
|   |   | x |   |   |
|   |   | x |   |   |   |   |   |   |   | x |   |   |   |   |   |   |   |   |   | x |
x |   |   |   |   |   |
| x | x |   | x |   |   |   |   |   |   |   |   |   | x | x |   |   |   |   |   | x |
x |   |   |   | x |
|   |   |   | x | x |   |   | x |   |   | x |   | x |   | x | x |   | x | x |   |
|   |   | x |   |   |
| x |   |   |   |   | x |   | x | x |   |   |   |   |   | x |   | x |   | x |   |   |   |
|   | x |   |   |   |
|   |   |   |   | x |   |   | x |   | x |   |   |   | x | x |   | x |   | x | x |   |
x |   |   |   | x |
|   | x |   | x |   |   |   | x |   | x |   |   |   |   | x | x |   |   |   |   |   |
|   | x |   |   |   |
|   |   | x |   |   |   |   |   | x |   | x |   |   |   |   |   | x |   |   | x |
|   |   |   |   |   |
| x |   | x | x |   | x |   | x | x |   |   | x |   | x |   |   | x |   | x |   |
x |   |   |   | x |
| x |   |   |   |   | x |   |   |   |   |   | x | x | x |   |   |   | x |   | x |
|   |   |   |   |   |
| x |   | x | x |   | x |   | G |   |   |   |   |   |   |   |   |   | x | x |   |   |
| x |   | x |   |
| x |   |   |   | x |   | x | x |   |   |   | x |   |   | x |   | x |   |   |   |
| x |   | x |   |
|   | x | x |   | x |   | x |   | x |   | x |   |   | x |   |   |   |   |
|   |   |   |   |   |
|   |   |   | x |   | x | x |   |   |   |   | x |   |   |   |   |   |   | x |   |
|   | x |   |   |
|   | x |   | x | x | x | x |   | x |   |   | x |   | x |   | x |   |   |   |   |
| x |   | x |   |
|   |   |   |   |   |   |   |   |   |   | x |   |   | x |   |   |   |   | x | x |
| x |   |   |   |
| x | x | x |   |   | x |   | x |   | x |   |   |   |   |   |   |   |   | x |
x | x | x |   | x |
|   |   |   |   |   |   |   |   | x | x |   |   |   |   |   | x |   |   |   | x |
|   |   |   |   |
| x |   |   |   |   |   | x |   |   |   |   |   |   |   | x |   | x | x |   |
x |   |   |   |   |
|   |   |   |   |   |   | x |   |   | x |   | x |   | x | x | x |   |   |   |
x | x |   |   | x |
```

```
|   |   |   | x |   |   |   |   | x | x |   |   |   |   |   | x |   |   | x |   | x |   |   |
x |   |   |   |   |   |   |
|   | x |   | x | x |   | x |   |   |   | x |   |   |   |   |   |   |   | x |   |   |   | x |   |
|   | x | x | x |   |   |
|   |   | x |   |   | x |   | x |   |   |   |   |   | x | x | x | x |   |   |   | x | x |
| x |   | x |   |   |   |
|   |   |   |   |   |   |   |   |   |   | x |   | x |   |   | x | x |   |   |   |   |
|   |   | x |   |   |   |
|   |   |   |   |   |   |   |   |   |   | x |   |   | x |   |   |   |   |   |   | x |   | x |
x |   |   | x |   |
dfs version:
in string|   |   |   |   |   |   | x |   | x |   | x |   |   |   |   |   | x |   |
|   |   |   | x | x | x |   |
|   |   |   |   |   |   |   |   | x |   |   |   |   |   | x |   |   |   |   |   | x |
|   |   | x |   |
| x |   | x |   |   | x |   |   |   | x | x |   |   |   |   | S |   |   |   |   |
| x |   |   | x |
|   |   |   |   | x |   |   |   |   | x | x |   | x |   |   |   | x |   |
|   |   | x |   |
|   |   |   |   |   |   | x |   | x | x | x |   |   |   | x |   | x |   | x | x |
x | x |   |   |   |
|   | x |   |   |   |   | x |   |   |   |   | x |   |   |   | x |   | x |   |
|   | x |   |   |
|   |   | x |   |   |   |   |   |   | x |   |   |   |   |   |   |   |   | x |
x |   |   |   |   |
| x | x |   | x |   |   |   |   |   |   |   |   | x | x |   |   |   |   |   |
x |   |   |   | x |
|   |   | x | x |   | x |   |   | x |   | x |   | x | x |   | x | x |   |
|   | x |   |   |
| x |   |   |   | x |   | x | x |   |   |   |   | x |   | x |   | x |   |   |
|   | x |   |   |
|   |   |   | x |   |   | x |   | x |   |   | x | x |   | x |   | x | x |
x |   |   |   | x |
|   | x |   | x |   |   |   | x |   | x |   |   |   | x | x |   |   |   |
|   | x |   |   |
|   |   | x |   |   |   |   |   | x |   | x |   |   |   |   |   | x |   |   | x |
|   |   |   |   |
| x |   |   | x | x |   | x |   | x | x |   |   | x |   | x |   |   | x |   | x |
x |   |   | x |
| x |   |   |   |   | x |   |   |   |   |   | x | x | x |   |   |   | x |   | x |
|   |   |   |
| x |   | x | x |   | x |   | G |   |   |   |   |   |   |   |   |   | x | x |   |
| x |   | x |   |
| x |   |   |   | x |   | x | x |   |   |   | x |   |   | x |   | x |   |
| x | x |   |   |
|   | x | x |   | x |   | x |   | x |   | x |   |   |   | x |   |   |   |
|   |   |   |
|   |   |   | x |   | x | x |   |   |   |   | x |   |   |   |   |   |   | x |
| x |   |   |
|   | x |   | x | x | x | x |   | x |   |   | x |   | x |   | x |   |   |   |
| x |   | x |
|   |   |   |   |   |   |   |   |   | x |   |   | x |   |   |   |   | x | x |
| x |   |   |
```

```
| x | x | x |   |   |   | x |   |   | x |   |   | x |   |   |   |   |   |   |   |   |   | x |
x | x | x |   |   | x |
|   |   |   |   |   |   |   |   |   | x | x |   |   |   |   |   |   | x |   |   |   | x |   |
|   |   |   |   |   |
| x |   |   |   |   |   | x |   |   |   |   |   |   |   |   | x |   | x | x |   |
x |   |   |   |   |   |
|   |   |   |   |   |   |   | x |   |   | x |   | x |   | x | x | x |   |   |   |   |
x | x |   |   | x |
|   |   |   | x |   |   |   | x | x |   |   |   |   |   | x |   | x |   | x |   |   |
x |   |   |   |   |   |
|   | x |   | x | x |   | x |   |   | x |   |   |   |   |   | x |   |   | x |   |
|   | x | x | x |   |
|   |   | x |   | x |   | x |   |   |   |   |   | x | x | x | x |   |   | x | x |
| x |   | x |   |   |
|   |   |   |   |   |   |   |   |   |   | x |   | x |   |   | x | x |   |   |   |   |
|   | x |   |   |
|   |   |   |   |   |   |   |   |   |   | x |   |   | x |   |   |   |   |   | x |   | x |
x |   |   | x |   |
a_star version:
in string|   |   |   |   |   |   | x |   | x |   | x |   |   |   |   |   |   | x |   |
|   |   |   | x | x | x |   |
|   |   |   |   |   |   |   |   | x |   |   |   |   |   | x |   |   |   |   |   | x |
|   |   | x |   |
| x |   |   | x |   |   | x |   |   |   | x | x |   |   |   |   | S |   |   |   |
| x |   |   | x |
|   |   |   |   |   | x |   |   |   |   | x | x |   | x |   | * |   | x |   |   |
|   |   | x |   |
|   |   |   |   |   |   |   | x |   | x | x | x |   |   |   | x | * | * | x |   | x | x |
x | x |   |   |   |
|   | x |   |   |   |   | x |   |   |   | x |   |   | * | * | x |   | x |   |
|   | x |   |   |
|   |   | x |   |   |   |   |   | x |   | * | * | * | * | * |   |   |   |   | x |
x |   |   |   |
| x | x |   | x |   |   |   |   |   |   |   | * | x | x |   |   |   |   |   |
x |   |   |   | x |
|   |   | x | x |   |   | x |   |   | x | * |   | x |   | x | x |   | x | x |   |
|   | x |   |
| x |   |   |   | x |   | x | x |   |   | * |   | x |   | x |   | x |   |   |
| x |   |   |
|   |   |   | x |   |   | x |   | x |   | * |   | x | x |   | x |   | x | x |   |
x |   |   | x |
|   | x |   | x |   |   | x |   | x |   | * |   | x | x |   |   |   |   |
| x |   |   |
|   |   | x |   |   |   | x |   | x | * | * |   |   |   | x |   |   | x |
|   |   |   |
| x |   | x | x |   | x |   | x | x |   | * |   | x |   | x |   | x |   | x |
x |   |   | x |
| x |   |   |   | x |   |   |   | * |   | x | x | x |   |   | x |   | x |
|   |   |   |
| x |   | x | x |   | x |   | G | * | * | * | * |   |   |   |   | x | x |   |
| x |   | x |   |
| x |   |   |   | x |   | x | x |   |   |   | x |   | x |   | x |   |
| x |   | x |   |
```

```
|   | x | x |   | x |   |   | x |   | x |   |   | x |   |   |   | x |   |   |   |   |   |   |
|   |   |   |   |   |   |
|   |   |   | x |   |   | x | x |   |   |   |   | x |   |   |   |   |   |   |   | x |   |   |
|   | x |   |   |   |   |
|   | x |   | x | x | x | x |   | x |   |   | x |   | x |   | x |   |   |   |   |   |   |
| x |   | x |   |   |
|   |   |   |   |   |   |   |   |   |   | x |   |   | x |   |   |   |   | x | x |   |
| x |   |   |   |   |
| x | x | x |   |   | x |   | x |   | x |   | x |   |   |   |   |   |   |   |   | x |
x | x | x |   | x |
|   |   |   |   |   |   |   | x | x |   |   |   |   |   | x |   |   |   | x |   |
|   |   |   |   |   |
| x |   |   |   |   |   | x |   |   |   |   |   |   |   |   | x |   | x | x |   |
x |   |   |   |   |   |
|   |   |   |   |   |   | x |   |   | x |   | x |   | x | x | x |   |   |   |   |
x | x |   |   | x |
|   |   | x |   |   |   | x | x |   |   |   |   |   | x |   | x |   | x |   |   |
x |   |   |   |   |
|   | x |   | x | x |   | x |   |   | x |   |   |   |   |   | x |   |   | x |   |
|   | x | x | x |   |
|   |   | x |   | x |   | x |   |   |   |   | x | x | x | x |   |   | x | x |
| x |   | x |   |   |
|   |   |   |   |   |   |   |   | x |   | x |   |   | x | x |   |   |   |   |
|   | x |   |   |
|   |   |   |   |   |   |   |   | x |   |   | x |   |   |   |   |   | x |   | x |
x |   |   | x |   |
```

We are, however, able to see consistently that A* behaves as expected. It finds a path that, unlike BFS and DFS, often seems to go "directly" to the goal. Because the the heuristic path length, it is able to guess which path will take it closer to the goal and thus go to the cells that are closest to it.