TDT4136 - Exercise 3

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The A* implementation is based on the pseudo code that was given with the exercise.

Subproblem A-1

Here are the results from the four boards: The heuristic is Subproblem A-1 and A-2 is based on the euclidean distance.

Board 1-1

```
....................
....................
.........######.....
.........---A..#.-B..
.........-######.-...
.........----------...
....................
```

Board 1-2

```
....---#............
...--#-#............
..--#--#............
A--#.-#....--------B
....#--#..--#.......
.....#--#--#........
......#---#.........
```

Board 1-3

```
.........-----......
.........-#..--.....
.......##--#..--....
......#-A#-#...---..
......#-#--#.....-..
```

```
......#---#......--.
.......###........-B
```

Board 1-4

```
A-#.......#......#..
#-#.#####.#.####.#..
--#-----#.#....#....
-##-###-######.#####
--#-B#--#....#...#..
#-####-##.##.#.#.##.
.------....#...#....
```

Subproblem A-2

Board 2-1

```
mmmmmfffrrrrrrrrArrrrrrrrrrrrrrrfffmmmmm
mmmfffffffrrrrrr-------------rfffffmmmm
mmfffffffffffffffffffffffffff-ffffffmmmm
mmfffffffffffffwwwwwfffffffff-fffffffmmm
mffffffffffffwwwwwwwfffffffff-ffffffmmmm
mmfffffffffffwwwwwwwff-------rrrrrrmmmm
mmmfffffffffffwwwwwfff-fffffffrfffmmm
mmfffffffffffffffffffff-ffffffffrffffmm
mmfffffffggggggg-------ggggggggggfffmm
mmmffffgggggggggBgggggggggggggggggffmm
```

Board 2-2

```
fffffffffgggrgggggggrggggfffffffrrffff
ffAffffffgggrrgggggggrrggfffffffrrffffff
ff-fffgggggrrgggggggrrgggffffrrrrrffffff
gg----gggggrggggrrrrgggffffrrffffffffff
ggggg-------rrrrrgggggffffrrffffffffff
ggggrrggggg-gggggggggffffffrffffffffff
gggrrgggggg--ggggggffff------fffffffff
ggrrgggffggg----ggff----frff-rrrrffffff
ggrggfffffffff------ffffrff-fffrrffffff
ggrgfffffffffffffffffffrffBfffffrrffff
```

Board 2-3

```
ggggggggwwwgggggmmmmmmmmmB-------mmmmm
gggggggggwwwwggggmmmmmmmmmmmmmmmm-mgggg
ggggggggggwwwwggggmmmmmmmmmmmmmmgg-ggggg
```

```
ffgggggggggwwwwggggmmm----mm-------rgggg
ffgggggggggwwwwwwwwww-ww----gggggrrrrr
ffffgggggggggwwwwwwww-wwwwgggggggggggg
ffffff----------------wwwwwwggggggmmmmm
fA-----ffffgggggggggmmmmmmwwwwmmmmmmmmm
fffffffffffffmmmmmmmmmmmmwwwmmmmmmmmm
ffffffffffmmmmmmmmmmmmmmmmwwwmmmmmmmm
```

Board 2-4

```
wwwwwgggggggggggg----------------grrrrr
wwwwwwwgggggggggg-gggggggggwwwww--rgggg
wwwwwwwwwwwggA----gggwwwwwwwwwww-wgggg
wwwwwwwwwwwwwwwwwwwwwwwwwwwwwww-wwwww
wwwwwwwwwwwwwwwwwwwwwwwwwwwwwww-wwwww
wwwwwwwwwwwwwwwwwwwwwwwwwwwwww--wwwww
wwwwwwwwgggggBgggggwwwwwwwwwwww-wwwww
wwwwgggggfff-ffgggggggggwwwwwww-wwwww
wwgggffffff-ffffffgggggggggg--gwwwww
wgggfffrrrrr----------------ggggggg
```

Subproblem A-3

I ve chosen to use the same syntax as given in the figure. With x as open nodes and * as closed ones. To improve the A* star algorithm the heuristic function is this time the Manhattan Distance.

In general we can note that Djikstra opens more nodes than A* 2-3.

We can see that A* finds the shortest path easily, while Djikstra opens more nodes on the way. BFS explores everything until a path is found.

Board 1-1

A*

```
........********....
.......*--------*...
.......*-######-*...
......*x---Axx#--B..
.......*x#######*...
........*...........
....................
```

Djikstra

```
xxxxxxxxxxxxxxxxx..
xxxxxxxxxxxxxxxxx.
xxxxxxxxx######xxx..
xxxxxxxx---Axx#--B..
xxxxxxxx-######-xxx.
xxxxxxxx--------xxx.
xxxxxxxxxxxxxxxxx..
```

BFS

```
xxxxxxxxxxxxxxxxx*
xxxxxxxx--------xxx*
xxxxxxxx-######-xx*.
xxxxxxxx---Axx#--B..
xxxxxxxxx######xxx*.
xxxxxxxxxxxxxxxxx*
xxxxxxxxxxxxxxxx*.
```

Observations

All algorithms finds the shortest path in the problem. There is however a huge difference in how many closed nodes there are. A* barely has any, while BFS and Djikstras has both opened up most of the board.

Board 1-2

A*

```
xxxx---#...........
xxx--#-#...........
xx--#--#.**********.
A--#x-#.*----------B
xxxx#--#*-**#######.
xxxxx#--#-*#........
xxxxxx#---#.........
```

Djikstra

```
x------#xxxxxxxx....
--xxx#-#xxxxxxxxxx..
-xxx#--#xxxxxxxxxxx.
Axx#x-#xx----------B
xxxx#--#x-xx#xxxxx..
xxxxx#--#-x#xxxxx...
xxxxxx#---#xxxxxx...
```

BFS

```
-------#xxxxxxxxx*..
-xxxx#-#xxxxxxxxx*.
-xxx#--#xxxxxxxxxx*
Axx#x-#xx----------B
xxxx#--#x-xx#xxxxxx*
xxxxx#--#-x#xxxxxx*.
xxxxxx#---#xxxxxx*..
```

Observations

Again we see the same tendency that A* closes less nodes than the other algorithms. BFS opens a few more than Djikstra.

Board 1-3

A*

```
........*---*.......
........*-#--*......
.......##--#-*......
......#-A#-#-*......
......#-#--#-*......
......#---#*-******.
.......###.*-------B
```

Djikstra

```
xxxxxxxxx---xxxxxxxxx
xxxxxxxxx-#---xxxxxxx
xxxxxxx##--#x---xxxxx
xxxxxx#-A#-#xxx-xxxxx
xxxxxx#-#--#xxx-xxxxx
xxxxxx#---#xxxx-xxxxx
xxxxxxx###xxxxx-----B
```

BFS

```
xxxxxxxxx---xxxxxxxxx
xxxxxxxxx-#--xxxxxxxx
xxxxxxx##--#-xxxxxxxx
xxxxxx#-A#-#-xxxxxxxx
xxxxxx#-#--#-xxxxxxxx
xxxxxx#---#x-xxxxxxx*
xxxxxxx###xx-------B
```

Observations

Same as before

Board 1-4

A*

```
A-#.......#......#..
#-#*#####.#.####.#..
--#-----#.#....#....
-##-###-######.#####
--#-B#--#xx*.#...#..
#-####-##x##.#.#.##.
x------xxxx#...#....
```

Djikstra

```
A-#xx.....#......#..
#-#x#####.#.####.#..
--#-----#.#....#....
-##-###-######.#####
--#-B#--#xxxx#...#..
#-####-##x##x#.#.##.
x------xxxx#xx.#....
```

BFS

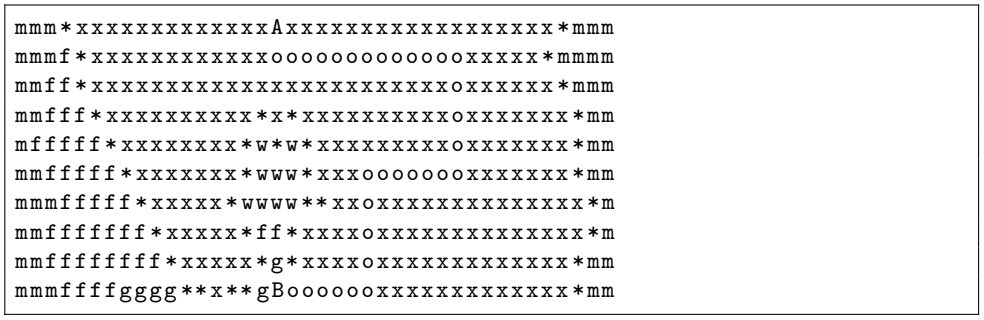
```
A-#xx*....#......#..
#-#x#####.#.####.#..
--#-----#.#....#....
-##-###-######.#####
--#-B#--#xxxx#...#..
#-####-##x##x#.#.##.
x------xxxx#xx*#....
```

Observations

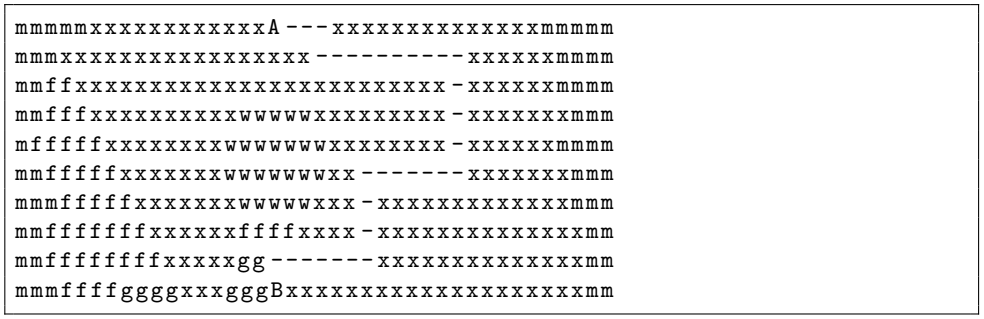
This time the algorithms are closer in performance, closing about the same amount of nodes, with A* a little better than the others.

Board 2-1

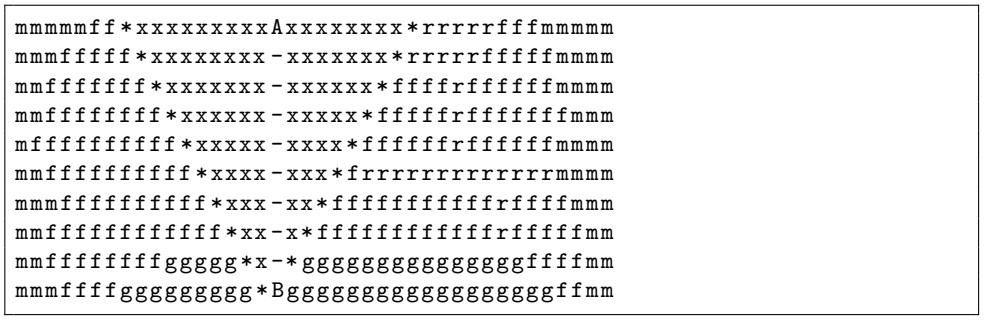
A*



Djikstra



BFS



Observations

We see now that when the cost is no longer uniform, BFS is no longer able to find the shortest path although it opens fewer nodes. Djikstra and A* is closer in performance with about the same amount of nodes closed.

Board 2-2

A*

```
xxxxxx*fffg*xxx*ggg*xxx*ggfffffffrrffffff
xxAxxxx****xxxx****xxxx*ffff*fffrrffffff
xx-xxxxxxxxxxxxxxxxxxx*fff*x*rrrffffffff
xx----xxxxxxxxxxxxxxxx*fff*xx*ffffffffff
xxxxx-------xxxxxxxxx*fff*xx*ffffffffff
xxxxxxxxxx-xxxxxxxx******x**ffffffffff
xxxxxxxxxx--xxxxx***xx------****fffffff
xxxxxxx**xxx----xxxx----xx*x-xxxx*ffffff
xxxxx**ff***xxx------xxx*x**-***x*ffffff
xxxx*fffffff**fxxxxxx*****x*fBfff*rrffff
```

Djikstra

```
xxxxxxxxxxxxxxxxxxxxxxxxxfffffffxxffffff
xxAxxxxxxxxxxxxxxxxxxxxxfffffffxxffffff
xx-xxxxxxxxxxxxxxxxxxxxfffxxxxxxffffffff
xx---xxxxxxxxxxxxxxxxxxffxxxfffffffffff
xxxx--------xxxxxxxxxxxffxxxxfffffffffff
xxxxxxxxxxx-xxxxxxxxxxfxxxxxxfffffffffff
xxxxxxxxxxx--xxxxxxxxxx------xfffffffff
xxxxxxxxxxxx----xxxx----xxxx-xxxxffffff
xxxxxxxxxxxxxx------xxxxxxf-xffxxffffff
xxxxxxxffxxxxxxxxxxxxxffxxxfBffffxxffff
```

BFS

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx*fff
xxAxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx*fff
xx-xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx*ffff
xx-xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx*fffff
xx----------xxxxxxxxxxxxxxxxxxxx*ffffff
xxxxxxxxxx-xxxxxxxxxxxxxxxxxxx*fffffff
xxxxxxxxxx--xxxxxxxxxxxxxxxxx*fffffff
xxxxxxxxxxx--------------xxxx*rrfffffff
xxxxxxxxxxxxxxxxxxxxxxx-xxx*ffrrffffff
xxxxxxxxxxxxxxxxxxxxxxx---Bffffrrffffff
```

Observations

Same as before, with A* star a little ahead with fewer nodes closed.

Board 2-3

A*

```
xxxxxxxxxxxxxxxxxxxxx*mmB-------*mmmm
xxxxxxxxxxxxxxxxxxxxx*mm******-*gggg
xxxxxxxxxxxxxxxxxxxxx*m*****x*-*gggg
```

```
xxxxxxxxxxxxxxxxxxxx----x*-------*gggg
xxxxxxxxxxxxxxxxxxxx-xx----xxxxx*rrrrr
xxxxxxxxxxxxxxxxxxxx-xxx*xxxxxx*gggggg
x---------------------xxxx**xxx*ggmmmmm
xAxxxxxxxxxxxxxxxxxxxxxxxx****mmmmmmmm
xxxxxxxxxxxxxxxxxxxxxxxxxxx*wmmmmmmmmm
xxxxxxxxxxxxxxxxxxxxxxxxxxx*wwmmmmmmmmm
```

Djikstra

```
xxxxxxxxxxxxxxxxxxxxxxmmmB-------mmmmmx
xxxxxxxxxxxxxxxxxxxxxxxmmmmmmmmm-mggggx
xxxxxxxxxxxxxxxxxxxxxxxxmmmmmmxx-xggggx
xxxxxxxxxxxxxxxxxxxxxxxxm-------xxxxxx
xxxxxxxxxxxxxxxxxxxxx-----xxxxxxxxxxx
xxxxxxxxxxxxxxxxxxxx--xwxxxxxxxxxxxxx
xxxxxx-----------------xxxwwxxxxxxmmmmx
xA-----xxxxxxxxxxxxxxxxxxxxwwmmmmmmmmmx
xxxxxxxxxxxxxxxxxxxxxxxxxxxxwwmmmmmmmmx
xxxxxxxxxxxxxxxxxxxxxxxxxxxwwwmmmmmmmmx
```

BFS

```
xxxxxxxxxxxxxxxxxxxxxxxxxBrrrrrrrmmmm
xxxxxxxxxxxxxxxxxxxxxxxx-*mmmmmrmgggg
xxxxxxxxxxxxxxxxxxxxxxxx-x*mmggrggggg
xxxxxxxxxxxxxxxxxxxxxxxx-xx*gggrrgggg
xxxxxxxxxxxxxxxxxxxx------xxx*gggrrrrr
xxxxxxxxxxxxxxxxxxxx-xxxxxxxxx*ggggggg
x---------------------xxxxxxxxx*gmmmmm
xAxxxxxxxxxxxxxxxxxxxxxxxxxxxxx*mmmmm
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx*mmmmm
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx*mmmmm
```

Observations

Same as before

Board 2-4

A*

```
wwww*xxxxxxxxxxxxx----------------xxxxxxx
wwwww*xxxxxxxxxxxx-xxxxxxxx*****--xxxxxx
wwwwww*xxxxxxxA-----xxx*****wwwww*-*xxxxx
wwwwwww****xxxxxxxxxx*wwwwwwwww*-*****x
wwwwwwwwww**********wwwwwwwwww*-*www*x
wwwwwwwwwwwwwww***wwwwwwwwwww*--*www*x
```

```
wwwwwwwwgggggB**xxx******wwwwwww*-*wwww*x
wwwwggggg****-xxxxxxxxxx********-*wwww*x
wwggggf**xxxx-xxxxxxxxxxxxxxxxx--x*www*x
wgggff*xxxxxx--------------------xxx*g*xx
```

Djikstra

```
wwwwxxxxxxxxxxxxx----------------xxxxxxx
wwwwwxxxxxxxxx-----xxxxxxxxxwwwww--xxxxxx
wwwwwwwxxxxxxxAxxxxxxxxxxxwwwwwwww-wxxxxx
wwwwwwwwwwwxxxxxxxxxxxwwwwwwwwwww-wwwwwx
wwwwwwwwwwwwwwwwwwwwwwwwwwwwwwww-wwwwwx
wwwwwwwwwwwwwwwwwwwwwwwwwwwwwww--wwwwwx
wwwwwwwwgggggBggxxxwwwwwwwwwwwww-wwwwwx
wwwwgggxxxffx-xxxxxxxxxxwwwwwww-wwwwwx
wwggggfxxxxxx-xxxxxxxxxxxxxxxxx--xwwwwx
wgggffxxxxxxx--------------------xxxxxxx
```

BFS

```
wwwwwggggg*xxxxxxx*gggggggggggggggrrrrr
wwwwwwwgg*xxxxxxxxx*ggggggggwwwwwgrrgggg
wwwwwwww*xxxx-Axxxx*ggwwwwwwwwwwwwrwgggg
wwwwwwwww*xxx-xxxx*wwwwwwwwwwwwwwwrwwwww
wwwwwwwwww*xx-xxx*wwwwwwwwwwwwwwwwrwwwww
wwwwwwwwwww*x-xx*wwwwwwwwwwwwwwwwrrwwwww
wwwwwwwwgggg*Bx*gggwwwwwwwwwwwwwwwrwwwww
wwwwgggggggffff*fgggggggggwwwwwwwwrwwwww
wwgggggfffffffffffffgggggggggggggrrgwwwww
wgggfffrrrrrrrrrrrrrrrrrrrrrrrrrgggggggg
```

Observations

Same as before.

General observations

We can see that A* and Djikstra always finds the shortest path, while BFS only finds the shortest path when the cost is the same across all nodes. A* generally outperforms Djikstra with opening less nodes, and thus is more efficient. The heuristic function of A*, as long as it is a correct one, manuever straight to the correct side of the board, while Djikstra checks out more nodes at the wrong ends.