Mohamed Hamdy – B20-06 – AI Assignment 1 Report.

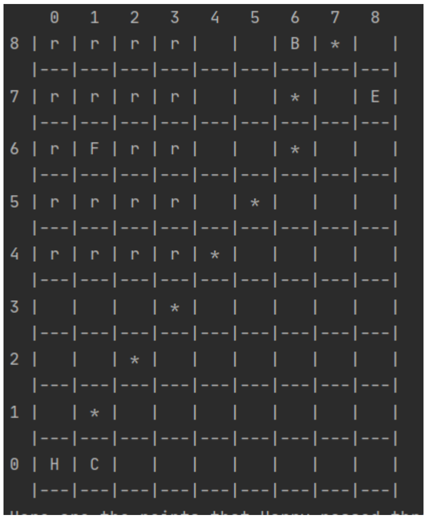
- **Algorithms' description:**
    - **Backtracking search:**
        - The idea was to use a recursive method $\text{visit(int x, int y, String target)}$ that explores the map, by trying all possible valid paths while counting the number of steps along the way, minimizing $path\ length$, keeping the state of actor, and storing the Path list.
        - Since the number of recursive calls will be huge (even for 9*9 lattice, the unguided search is expensive and better algorithms exist for shortest path problems), some optimizations were implemented to make it faster for typical cases, but the upper-bound complexity didn't change.
        - Example of such optimizations was to start exploring paths, and compare their values with the shortest length so far, and if it was found that the length of the path, we are currently exploring exceeds the shortest found path, we stop searching in that direction.
    - **A* search:**
        - The algorithm uses the diagonal distance heuristic $\max(|actor_x - home_x|, |actor_y - home_y|)$ to determine the best next move (because the actor can move in max. 8 directions)
        - Since the problem is not pure shortest path, and is more like a maze-door-keys problem, the algorithm is modified to consider 3 possible cases.
            - Actor can find the book and exit in the shortest number of steps without the cloak.
            - It gives shorter path to take the cloak and use it.
            - It is impossible to solve without getting the cloak
- **PEAS description with respect to the actor agent.**
    - **Performance measure:** the number of steps needed to find the book, whether the actors can reach it or not.
    - **Environment:** 9*9 square lattice, representing physical spots, partially visible.
    - **Actuators:** the actor can **move** using his legs horizontally, vertically, and diagonally.
    - **Sensors:** the actor can **perceive** with his eye objects around him, from different distances.

- **Statistical analysis** (for random samples of maps)
    - Note that variants didn't introduce any output difference; the actor perceiving inspectors from a larger distance may affect his decision of going in a certain direction, but will never affect the final shortest path length, as it's unique.
    - Running 8 randomly generated maps and collecting the running time results (in milli seconds)

#	A*	BT
1	57	2988
2	59	426
3	60	62
4	58	227
5	68	17
6	88	-
7	90	1056
8	-	-
Σ	**480msec**	**4776msec**

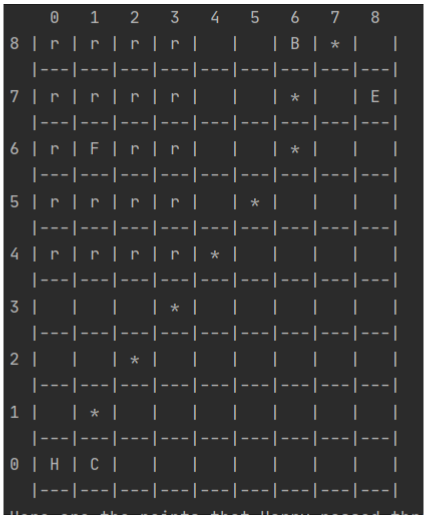
Map1:

Backtracking:



```
    0   1   2   3   4   5   6   7   8
8 | r | r | r | r |   |   | B | * |   |
  |---|---|---|---|---|---|---|---|---|
7 | r | r | r | r |   |   | * |   | E |
  |---|---|---|---|---|---|---|---|---|
6 | r | F | r | r |   |   | * |   |   |
  |---|---|---|---|---|---|---|---|---|
5 | r | r | r | r |   | * |   |   |   |
  |---|---|---|---|---|---|---|---|---|
4 | r | r | r | r | * |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
3 |   |   |   | * |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 |   |   | * |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
1 |   | * |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H | C |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

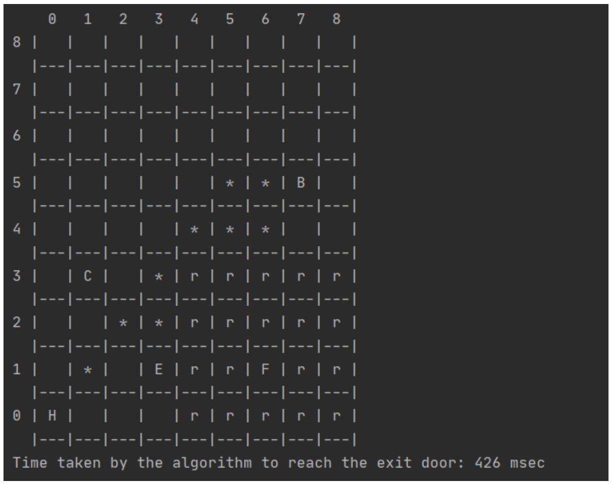
A*:



```
    0   1   2   3   4   5   6   7   8
8 | r | r | r | r |   |   | B | * |   |
  |---|---|---|---|---|---|---|---|---|
7 | r | r | r | r |   |   | * |   | E |
  |---|---|---|---|---|---|---|---|---|
6 | r | F | r | r |   |   | * |   |   |
  |---|---|---|---|---|---|---|---|---|
5 | r | r | r | r |   | * |   |   |   |
  |---|---|---|---|---|---|---|---|---|
4 | r | r | r | r | * |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
3 |   |   |   | * |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 |   |   | * |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
1 |   | * |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H | C |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

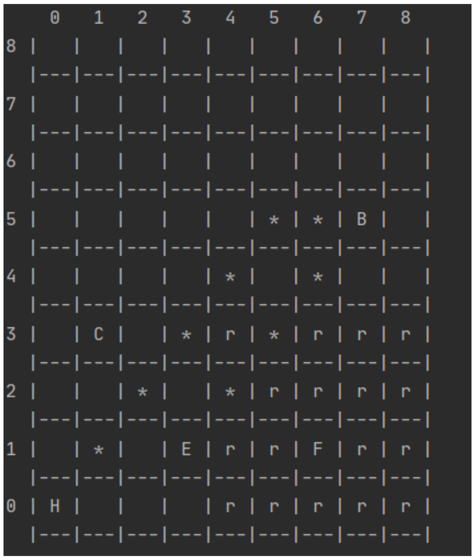
Map 2:

Backtracking:



```
    0   1   2   3   4   5   6   7   8
8 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
7 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
5 |   |   |   |   |   | * | * | B |   |
  |---|---|---|---|---|---|---|---|---|
4 |   |   |   |   | * | * | * |   |   |
  |---|---|---|---|---|---|---|---|---|
3 |   | C |   | * | r | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
2 |   |   | * | * | r | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
1 |   | * |   | E | r | r | F | r | r |
  |---|---|---|---|---|---|---|---|---|
0 | H |   |   |   | r | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
Time taken by the algorithm to reach the exit door: 426 msec
```

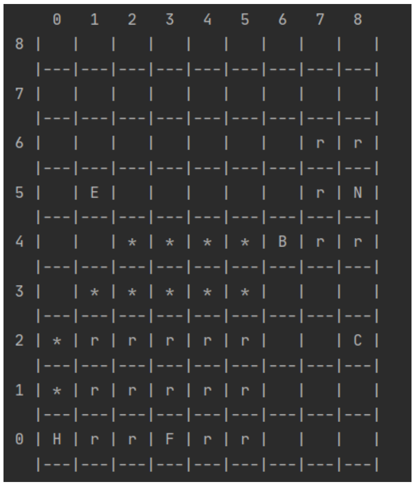
A*:



```
    0   1   2   3   4   5   6   7   8
8 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
7 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
5 |   |   |   |   |   | * | * | B |   |
  |---|---|---|---|---|---|---|---|---|
4 |   |   |   |   | * |   | * |   |   |
  |---|---|---|---|---|---|---|---|---|
3 |   | C |   | * | r | * | r | r | r |
  |---|---|---|---|---|---|---|---|---|
2 |   |   | * |   | * | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
1 |   | * |   | E | r | r | F | r | r |
  |---|---|---|---|---|---|---|---|---|
0 | H |   |   |   | r | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
```

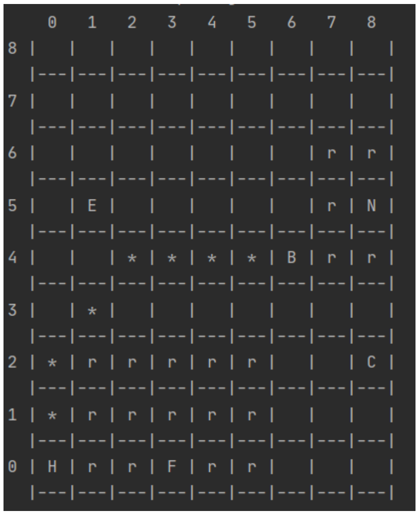
Map 3:

Backtracking:



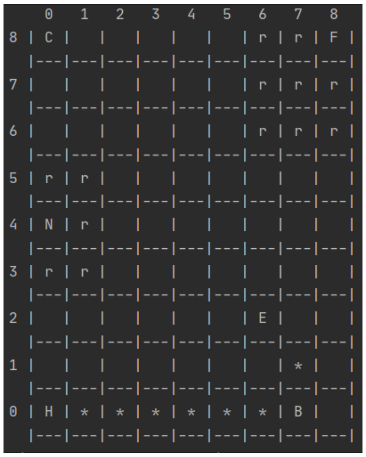
```
    0   1   2   3   4   5   6   7   8
8 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
7 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   |   |   | r | r |
  |---|---|---|---|---|---|---|---|---|
5 |   | E |   |   |   |   |   | r | N |
  |---|---|---|---|---|---|---|---|---|
4 |   |   | * | * | * | * | B | r | r |
  |---|---|---|---|---|---|---|---|---|
3 |   | * | * | * | * | * |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 | * | r | r | r | r | r |   |   | C |
  |---|---|---|---|---|---|---|---|---|
1 | * | r | r | r | r | r |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H | r | r | F | r | r |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

A* :

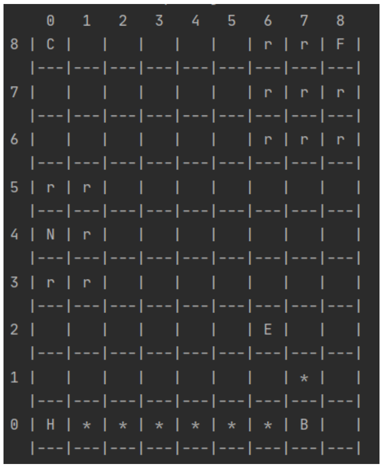


```
    0   1   2   3   4   5   6   7   8
8 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
7 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   |   |   | r | r |
  |---|---|---|---|---|---|---|---|---|
5 |   | E |   |   |   |   |   | r | N |
  |---|---|---|---|---|---|---|---|---|
4 |   |   | * | * | * | * | B | r | r |
  |---|---|---|---|---|---|---|---|---|
3 |   | * |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 | * | r | r | r | r | r |   |   | C |
  |---|---|---|---|---|---|---|---|---|
1 | * | r | r | r | r | r |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H | r | r | F | r | r |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

Map 4:



```
    0   1   2   3   4   5   6   7   8
8 | C |   |   |   |   |   | r | r | F |
  |---|---|---|---|---|---|---|---|---|
7 |   |   |   |   |   |   | r | r | r |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   |   | r | r | r |
  |---|---|---|---|---|---|---|---|---|
5 | r | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
4 | N | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
3 | r | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 |   |   |   |   |   |   | E |   |   |
  |---|---|---|---|---|---|---|---|---|
1 |   |   |   |   |   |   |   | * |   |
  |---|---|---|---|---|---|---|---|---|
0 | H | * | * | * | * | * | * | B |   |
  |---|---|---|---|---|---|---|---|---|
```



```
    0   1   2   3   4   5   6   7   8
8 | C |   |   |   |   |   | r | r | F |
  |---|---|---|---|---|---|---|---|---|
7 |   |   |   |   |   |   | r | r | r |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   |   | r | r | r |
  |---|---|---|---|---|---|---|---|---|
5 | r | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
4 | N | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
3 | r | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 |   |   |   |   |   |   | E |   |   |
  |---|---|---|---|---|---|---|---|---|
1 |   |   |   |   |   |   |   | * |   |
  |---|---|---|---|---|---|---|---|---|
0 | H | * | * | * | * | * | * | B |   |
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```
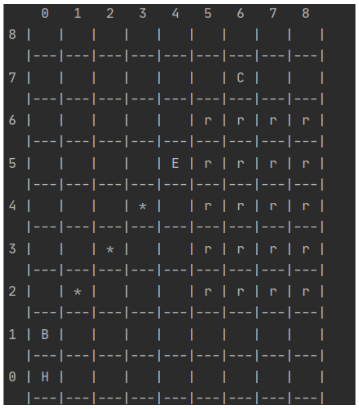
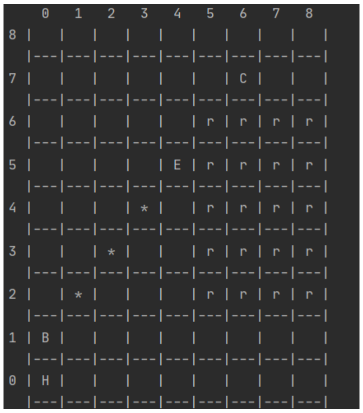

Map 5:

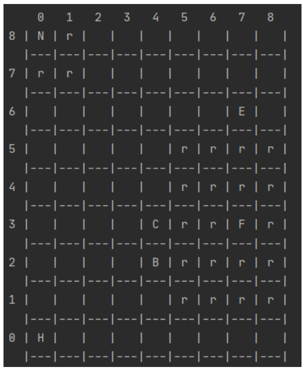


```
    0   1   2   3   4   5   6   7   8
8 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
7 |   |   |   |   |   |   | C |   |   |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
5 |   |   |   |   | E | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
4 |   |   |   | * |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
3 |   |   | * |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
2 |   | * |   |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
1 | B |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

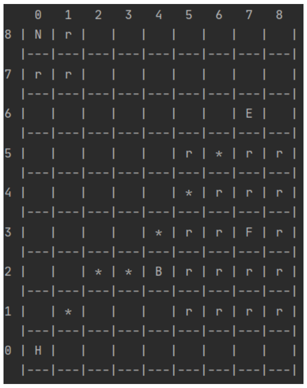


```
    0   1   2   3   4   5   6   7   8
8 |   |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
7 |   |   |   |   |   |   | C |   |   |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
5 |   |   |   |   | E | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
4 |   |   |   | * |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
3 |   |   | * |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
2 |   | * |   |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
1 | B |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

Map 6:



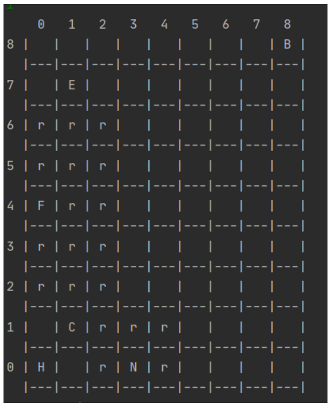
```
    0   1   2   3   4   5   6   7   8
8 | N | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
7 | r | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   |   |   | E |   |
  |---|---|---|---|---|---|---|---|---|
5 |   |   |   |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
4 |   |   |   |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
3 |   |   |   |   | C | r | r | F | r |
  |---|---|---|---|---|---|---|---|---|
2 |   |   |   |   | B | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
1 |   |   |   |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
0 | H |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```



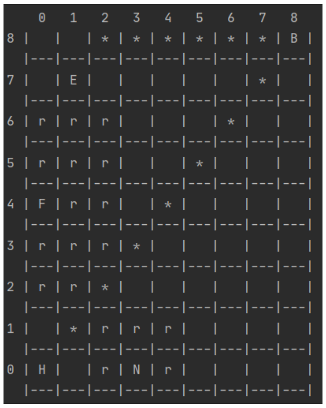
```
    0   1   2   3   4   5   6   7   8
8 | N | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
7 | r | r |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
6 |   |   |   |   |   |   |   | E |   |
  |---|---|---|---|---|---|---|---|---|
5 |   |   |   |   |   | r | * | r | r |
  |---|---|---|---|---|---|---|---|---|
4 |   |   |   |   |   | * | r | r | r |
  |---|---|---|---|---|---|---|---|---|
3 |   |   |   |   | * | r | r | F | r |
  |---|---|---|---|---|---|---|---|---|
2 |   |   | * | * | B | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
1 |   | * |   |   |   | r | r | r | r |
  |---|---|---|---|---|---|---|---|---|
0 | H |   |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

Map 7:

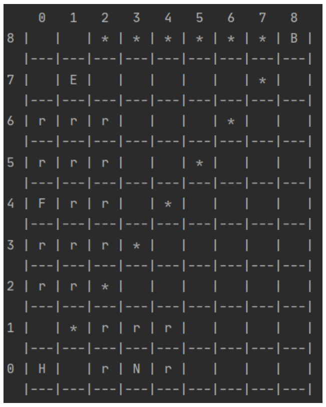
Initial map:



```
    0   1   2   3   4   5   6   7   8
8 |   |   |   |   |   |   |   |   | B |
  |---|---|---|---|---|---|---|---|---|
7 |   | E |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
6 | r | r | r |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
5 | r | r | r |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
4 | F | r | r |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
3 | r | r | r |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 | r | r | r |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
1 |   | C | r | r | r |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H |   | r | N | r |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

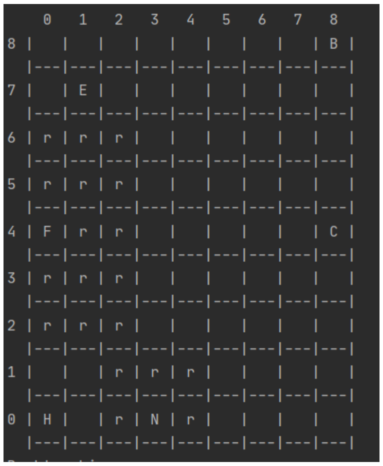


```
    0   1   2   3   4   5   6   7   8
8 |   |   | * | * | * | * | * | * | B |
  |---|---|---|---|---|---|---|---|---|
7 |   | E |   |   |   |   |   | * |   |
  |---|---|---|---|---|---|---|---|---|
6 | r | r | r |   |   |   | * |   |   |
  |---|---|---|---|---|---|---|---|---|
5 | r | r | r |   |   | * |   |   |   |
  |---|---|---|---|---|---|---|---|---|
4 | F | r | r |   | * |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
3 | r | r | r | * |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 | r | r | * |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
1 |   | * | r | r | r |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H |   | r | N | r |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```



```
    0   1   2   3   4   5   6   7   8
8 |   |   | * | * | * | * | * | * | B |
  |---|---|---|---|---|---|---|---|---|
7 |   | E |   |   |   |   |   | * |   |
  |---|---|---|---|---|---|---|---|---|
6 | r | r | r |   |   |   | * |   |   |
  |---|---|---|---|---|---|---|---|---|
5 | r | r | r |   |   | * |   |   |   |
  |---|---|---|---|---|---|---|---|---|
4 | F | r | r |   | * |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
3 | r | r | r | * |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 | r | r | * |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
1 |   | * | r | r | r |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H |   | r | N | r |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

Map 8:



```
    0   1   2   3   4   5   6   7   8
8 |   |   |   |   |   |   |   |   | B |
  |---|---|---|---|---|---|---|---|---|
7 |   | E |   |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
6 | r | r | r |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
5 | r | r | r |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
4 | F | r | r |   |   |   |   |   | C |
  |---|---|---|---|---|---|---|---|---|
3 | r | r | r |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
2 | r | r | r |   |   |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
1 |   |   | r | r | r |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
0 | H |   | r | N | r |   |   |   |   |
  |---|---|---|---|---|---|---|---|---|
```

- **Statistical analysis for custom maps:**
  - **Map 1:**
    - Backtracking: success, 10 steps, in 2988 msec
    - A*: success, 10 steps, in 57 msec
  - **Map 2:**
    - Backtracking: success, 13 steps, in 426 msec
    - A*: success, 11 steps, in 59 msec
  - **Map 3:**
    - Backtracking: success, 13 steps, in 60 msec
    - A*: success, 13 steps, in 62 msec
  - **Map 4:**
    - Backtracking: success, 9 steps, in 227msec
    - A*: success, 9 steps, in 58 msec
  - **Map 5:**
    - Backtracking: success, 5 steps, in 17 msec
    - A*: success, 5 steps, in 68 msec
  -
  - **Map 6:**
    - Backtracking: will eventually succeed, although taking a lot of time.
    - A*: success, 8 steps, in 88 msec

    Map 7:

    - Backtracking: success, 15 steps, in 1056 msec

- A*: success, 15 steps, in 90 msec

Map 8:

- Backtracking: lost
- A*: lost
- Note: the map is impossible to solve

Notes:

- **As we can see, A* was faster more precise in finding the shortest path, and worked in more cases than backtracking algorithm, also if we look at the time it took for A* to find the shortest path, it is almost consistent compered to backtracking which had a fluctuating timing result.**
- **The maps which are impossible to solve are the one where the book or the exit and the cloak are trapped inside a zone cornered by the perception of the inspectors.**
- **There is no difference in the results between variants, so I didn't include it here, I only compared between the algorithms.**