Introduction to AI. Assignment 1. Report.

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Explanation of algorithms' flow

Backtracking algorithm

A backtracking algorithm is a recursive algorithm in which solution to problem constructs incrementally. To somehow optimize the backtracking algorithm some constraints can decrease the number of backtracking steps. In this assignment, backtracking was used to find the shortest path from start to destination (i.e. home). To decrease execution time condition was introduced that if a path is greater than the already obtained path from start to home when we can cut this path.

A* algorithm

Second algorithm to be implemented is the A* algorithm. A* algorithm is a heuristic search that is widely used to find the shortest path in a graph. In the A* algorithm cost calculated for every cell (or node in the graph) and as the next step algorithm choose the cell with minimum cost. The cost of the cell is the sum of G and H of the cell. G is the movement cost to move from the start to the cell. H is a heuristic used to estimate movement cost from a given cell to the home cell. As an actor in this assignment can move in 8 directions, the heuristic will be diagonal distance, which is the maximum between absolute values of the difference between x and x of home and difference between y and y of home.[1]

Statistical comparison of algorithms

Backtracking vs. A* algorithm. Covid feeling scenario 1.

To compare Backtracking and A* algorithms I choose sample with 30 experiments:
D - minimal distance, x_1 - Execution time of A* algorithm in ms, x_2 - execution time of Backtracking algorithm in ms.

D	8	6	9	4	6	5	7	8	2	6	5	7	7	8	4
x_1	6	3	4	3	6	4	3	4	2	3	4	4	2	3	3
x_2	2851	3840	26354	125	350	274	24048	4022	1	2201	250	17248	48	14757	71

D	8	2	6	7	5	4	3	4	6	5	8	4	3	6	2
x_1	6	2	4	4	2	2	2	3	4	4	6	4	2	3	3
x_2	34199	81410	1275	6594	14390	41226	12899	4412	543	33	29845	2	6940	62	11222

Firstly, introduce hypotheses:

- Null hypothesis h_0 : Execution time of A* algorithm and backtracking algorithm are the same.
- Alternate hypothesis h_1: Execution time of A* algorithm and backtracking algorithm are different.

To reject or fail to reject null hypothesis I will use two sample t-test. Firstly, t-value need to be calculated:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

In our case $N_1 = N_2 = 30$, hence degree of freedom $df = 29$.
Sample means: $\bar{x}_1 = 3.5, \bar{x}_2 = 11383.06667$.
Sample variances: $s_1^2 = 1.568965517, s_2^2 = 308446402.8$. Therefore, $t = -3.548922339$.
Assume that p-value is 5%. In t-table at $\boldsymbol{df = 29}$ and $\boldsymbol{p = 0.05}$ placed $t_{table} = 2.045$. $|t| > t_{table} \Rightarrow$ null hypothesis is rejected, hence execution time of A* algorithm and backtracking algorithm are different.

Backtracking vs. A* algorithm. Covid feeling scenario 2.

To compare Backtracking and A* algorithms I choose sample with 30 experiments:
D - minimal distance, x_1 - Execution time of A* algorithm in ms, x_2 - execution time of Backtracking algorithm in ms.

D	8	6	9	4	6	5	7	8	2	6	5	7	7	8	4
x_1	4	5	4	4	4	4	4	2	4	4	4	6	4	5	4
x_2	3844	5064	43041	201	468	403	32702	5761	2	3147	390	22365	32	19188	97

D	8	2	6	7	5	4	3	4	6	5	8	4	3	6	2
x_1	7	3	5	5	2	3	2	3	2	5	6	3	4	3	3
x_2	76273	99925	1688	8761	18988	54262	16811	5912	735	43	42231	4	9097	78	14512

Firstly, introduce hypotheses:

- Null hypothesis h_0 : Execution time of A* algorithm and backtracking algorithm are the same.
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To reject or fail to reject null hypothesis I will use two sample t-test. Firstly, t-value need to be calculated:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

In our case $N_1 = N_2 = 30$, hence degree of freedom $df = 29$.
Sample means: $\bar{x}_1 = 3.933333333, \bar{x}_2 = 16200.83333$.
Sample variances: $s_1^2 = 1.512643678, s_2^2 = 606290294$. Therefore, $t = -3.602900096$.
Assume that p-value is 5%. In t-table at $\boldsymbol{df = 29}$ and $\boldsymbol{p = 0.05}$ placed $t_{table} = 2.045$. $|t| > t_{table} \Rightarrow$ null hypothesis is rejected, hence execution time of A* algorithm and backtracking algorithm are different.

Backtracking scenario 1 vs. Backtracking scenario 2.

To compare Backtracking scenario 1 and Backtracking scenario 2 I choose sample with 30 experiments:
D - minimal distance, x_1 - Execution time of Backtracking algorithm in scenario 1 in ms, x_2 - execution time of Backtracking algorithm in scenario 2 in ms.

D	8	6	9	4	6	5	7	8	2	6	5	7	7	8	4
x_1	2851	3840	26354	125	350	274	24048	4022	1	2201	250	17248	48	14757	71
x_2	3844	5064	43041	201	468	403	32702	5761	2	3147	390	22365	32	19188	97

D	8	2	6	7	5	4	3	4	6	5	8	4	3	6	2
x_1	34199	81410	1275	6594	14390	41226	12899	4412	543	33	29845	2	6940	62	11222
x_2	76273	99925	1688	8761	18988	54262	16811	5912	735	43	42231	4	9097	78	14512

Firstly, introduce hypotheses:

- Null hypothesis h_0 : Execution time of Backtracking algorithm in scenario 1 and Backtracking algorithm in scenario 2 are the same.

- Alternate hypothesis h_1: Execution time of Backtracking algorithm in scenario 1 and Backtracking algorithm in scenario 2 are different.

To reject or fail to reject null hypothesis I will use two sample t-test. Firstly, t-value need to be calculated:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

In our case $N_1 = N_2 = 30$, hence degree of freedom $df = 29$.
Sample means: $\bar{x}_1 = 11383.06667, \bar{x}_2 = 16200.83333$.
Sample variances: $s_1^2 = 308446402.8, s_2^2 = 606290294$. Therefore, $t = -0.8724857425$.
Assume that p-value is 5%. In t-table at $\boldsymbol{df = 29}$ and $\boldsymbol{p = 0.05}$ placed $t_{table} = 2.045$. $|t| < t_{table} \Rightarrow$ null hypothesis is fail to be rejected.

A* search scenario 1 vs. A* search scenario 2.

To compare A* search scenario 1 and A* search scenario 2 I choose sample with 30 experiments:
D - minimal distance, x_1 - Execution time of A* search scenario 1 in ms, x_2 - execution time of A* search in scenario 2 in ms.

D	8	6	9	4	6	5	7	8	2	6	5	7	7	8	4
x_1	6	3	4	3	6	4	3	4	2	3	4	4	2	3	3
x_2	4	5	4	4	4	4	4	2	4	4	4	6	4	5	4

D	8	2	6	7	5	4	3	4	6	5	8	4	3	6	2
x_1	6	2	4	4	2	2	2	3	4	4	6	4	2	3	3
x_2	7	3	5	5	2	3	2	3	2	5	6	3	4	3	3

Firstly, introduce hypotheses:

- Null hypothesis h_0 : Execution time of A* search in scenario 1 and A* search in scenario 2 are the same.
- Alternate hypothesis h_1: Execution time of A* search in scenario 1 and A* search in scenario 2 are different.

To reject or fail to reject the null hypothesis I will use two sample t-test. Firstly, t-value need to be calculated:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

In our case $N_1 = N_2 = 30$, hence degree of freedom $df = 29$.
Sample means: $\bar{x}_1 = 3.5, \bar{x}_2 = 3.933333333$.
Sample variances: $s_1^2 = 1.568965517, s_2^2 = 1.512643678$. Therefore, $t = -1.35205371$.
Assume that p-value is 5%. In t-table at $\boldsymbol{df = 29}$ and $\boldsymbol{p = 0.05}$ placed $t_{table} = 2.045$. $|t| < t_{table} \Rightarrow$ null hypothesis is fail to be rejected.

PEAS description

P - performance measure:
win - actor reaches home, lose - actor is infected by covid
E - environment:
map, covids, mask, doctor, home, rules of movement
Environment is:

- Partially observable (as actor cannot see whole environment)
- Single agent (there is no other agent in the environment)
- Deterministic (next state can be determined with previous state and action on it)

- Sequential (current decision will have consequences in future)
- Static (environment does not change while agent choose next action)
- Discrete (environment have states and does not smoothly behave over time)
- Known (creator of agent have full knowledge about environment)

A - actuators:
take mask, visit doctor
S - sensors:
feeling covid, see doctor, see mask

Impossible maps

Legend for all maps:
C - covid
i - infected cell
M - mask
D - doctor
H - home
A - actor at starting cell

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covid(1, 2); covid(3, 1); doctor(3, 7); mask(8, 6); home(5, 8).

8						H			
7				D					
6									M
5									
4									
3	i	i	i						
2	i	C	i	i	i				
1	i	i	i	C	i				
0	A		i	i	i				
	0	1	2	3	4	5	6	7	8

---

covid(0,2); covid(3,1); doctor(5,5); mask(2,6); home(7,4).

8									
7									
6			M						
5						D			
4								H	
3	i	i							
2	C	i	i	i	i				
1	i	i	i	C	i				
0	A		i	i	i				
	0	1	2	3	4	5	6	7	8

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covid(0,4); covid(2,1); doctor(5,5); mask(2,6); home(7,4).

8									
7									
6			M						
5	i	i				D			
4	C	i						H	
3	i	i							
2		i	i	i					
1		i	C	i					
0	A	i	i	i					
	0	1	2	3	4	5	6	7	8

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covid(5,8); covid(7,5); doctor(7,7); mask(7,8); home(8,8).

8					i	C	i	M	H
7					i	i	i	D	
6							i	i	i
5							i	C	i
4							i	i	i
3									
2									
1									
0	A								
	0	1	2	3	4	5	6	7	8

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covid(8,5); covid(5,7); doctor(7,7); mask(7,8); home(8,8).

8					i	i	i	M	H
7					i	C	i	D	
6					i	i	i	i	i
5								i	C
4								i	i
3									
2									
1									
0	A								
	0	1	2	3	4	5	6	7	8

Maps used for statistical analysis

covid(5,1). covid(5,6). doctor(0,2). mask(0,6). home(8,4).

A* scenario 1:

Road: [[0,0],[1,1],[2,2],[3,2],[4,3],[5,4],[6,3],[7,4],[8,4]]

Distance: 8

Execution time: 6ms

Backtracking scenario 1:

Road: [[0,0],[1,0],[2,1],[3,2],[4,3],[5,3],[6,3],[7,3],[8,4]]

Distance: 8

Execution time: 2851ms

A* scenario 2:

Road: [[0,0],[1,1],[2,2],[3,2],[4,3],[5,4],[6,3],[7,4],[8,4]]

Distance: 8
Execution time: 4ms

Backtracking scenario 2:
Road: [[0,0],[1,0],[2,1],[3,2],[4,3],[5,3],[6,3],[7,3],[8,4]]
Distance: 8
Execution time: 3844ms

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covid(4,6). covid(7,8). doctor(3,4). mask(7,2). home(2,6).

A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3],[0,4],[1,5],[2,6]]
Distance: 6
Execution time: 3ms

Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[1,5],[2,6]]
Distance: 6
Execution time: 3840ms

A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[0,4],[1,5],[2,6]]
Distance: 6
Execution time: 5ms

Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[1,5],[2,6]]
Distance: 6
Execution time: 5064ms

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covid(6,2). covid(0,2). doctor(6,8). mask(3,4). home(0,8).

A* scenario 1:
Road: [[0,0],[1,0],[2,1],[3,2],[2,3],[1,4],[0,5],[1,6],[0,7],[0,8]]
Distance: 9
Execution time: 4ms

Backtracking scenario 1:
Road: [[0,0],[1,0],[2,1],[2,2],[2,3],[2,4],[2,5],[2,6],[1,7],[0,8]]
Distance: 9
Execution time: 26354ms

A* scenario 2:
Road: [[0,0],[1,0],[2,1],[3,2],[2,3],[1,4],[0,5],[1,6],[0,7],[0,8]]
Distance: 9
Execution time: 4ms

Backtracking scenario 2:
Road: [[0,0],[1,0],[2,1],[2,2],[2,3],[2,4],[2,5],[2,6],[1,7],[0,8]]
Distance: 9
Execution time: 34041ms

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covid(5,2). covid(3,8). doctor(2,4). mask(3,4). home(4,4)

A* scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 3ms

Backtracking scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 125ms

A* scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 4ms

Backtracking scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 201ms

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covid(6,1). covid(4,1). doctor(7,6). mask(2,6). home(3,6).
A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3],[2,4],[3,5],[3,6]]
Distance: 6
Execution time: 6ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[1,4],[2,5],[3,6]]
Distance: 6
Execution time: 305ms
A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[2,4],[3,5],[3,6]]
Distance: 6
Execution time: 4ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[1,4],[2,5],[3,6]]
Distance: 6
Execution time: 468ms

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covid(8,5). covid(2,6). doctor(4,1). mask(6,6). home(5,4).
A* scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,4]]
Distance: 5
Execution time: 4ms
Backtracking scenario 1:
Road: [[0,0],[1,0],[2,1],[3,2],[4,3],[5,4]]
Distance: 5
Execution time: 274ms
A* scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,4]]
Distance: 5
Execution time: 4ms
Backtracking scenario 2:
Road: [[0,0],[1,0],[2,1],[3,2],[4,3],[5,4]]
Distance: 5
Execution time: 403ms

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covid(4,2). covid(2,1). doctor(4,8). mask(2,3). home(0,7).
A* scenario 1:
Road: [[0,0],[0,1],[0,2],[1,3],[0,4],[1,5],[0,6],[0,7]]
Distance: 7
Execution time: 3ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[0,5],[0,6],[0,7]]
Distance: 7
Execution time: 24048ms
A* scenario 2:
Road: [[0,0],[0,1],[0,2],[1,3],[0,4],[1,5],[0,6],[0,7]]
Distance: 7
Execution time: 4ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[0,5],[0,6],[0,7]]

Distance: 7
Execution time: 32702ms

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covid(2,6). covid(1,3). doctor(7,4). mask(5,4). home(6,7).
A* scenario 1:
Road: [[0,0],[1,1],[2,1],[3,2],[4,3],[3,4],[4,5],[5,6],[6,7]]
Distance: 8
Execution time: 4ms
Backtracking scenario 1:
Road: [[0,0],[1,0],[2,1],[3,2],[3,3],[3,4],[4,5],[5,6],[6,7]]
Distance: 8
Execution time: 4022ms
A* scenario 2:
Road: [[0,0],[1,1],[2,1],[3,2],[4,3],[3,4],[4,5],[5,6],[6,7]]
Distance: 8
Execution time: 2ms
Backtracking scenario 2:
Road: [[0,0],[1,0],[2,1],[3,2],[3,3],[3,4],[4,5],[5,6],[6,7]]
Distance: 8
Execution time: 5761ms

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covid(4,2). covid(2,4). doctor(1,1). mask(0,6). home(2,0).
A* scenario 1:
Road: [[0,0],[1,1],[2,0]]
Distance: 2
Execution time: 2ms
Backtracking scenario 1:
Road: [[0,0],[1,0],[2,0]]
Distance: 2
Execution time: 1ms
A* scenario 2:
Road: [[0,0],[1,1],[2,0]]
Distance: 2
Execution time: 4ms
Backtracking scenario 2:
Road: [[0,0],[1,0],[2,0]]
Distance: 2
Execution time: 2ms

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covid(5,4). covid(6,5). doctor(0,1). mask(5,8). home(3,6).
A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3],[2,4],[3,5],[3,6]]
Distance: 6
Execution time: 3ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[1,4],[2,5],[3,6]]
Distance: 6
Execution time: 2201ms
A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[2,4],[3,5],[3,6]]
Distance: 6
Execution time: 4ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[1,4],[2,5],[3,6]]
Distance: 6
Execution time: 3147ms

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covid(7,8). covid(2,7). doctor(7,1). mask(4,1). home(5,5).

A* scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5]]
Distance: 5
Execution time: 4ms

Backtracking scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5]]
Distance: 5
Execution time: 250ms

A* scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5]]
Distance: 5
Execution time: 4ms

Backtracking scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5]]
Distance: 5
Execution time: 390ms

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covid(0,6). covid(4,5). doctor(8,4). mask(5,7). home(7,1).

A* scenario 1:
Road: [[0,0],[1,1],[2,0],[3,1],[4,0],[5,1],[6,0],[7,1]]
Distance: 7
Execution time: 4ms

Backtracking scenario 1:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0],[5,0],[6,0],[7,1]]
Distance: 7
Execution time: 17248ms

A* scenario 2:
Road: [[0,0],[1,1],[2,0],[3,1],[4,0],[5,1],[6,0],[7,1]]
Distance: 7
Execution time: 6ms

Backtracking scenario 2:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0],[5,0],[6,0],[7,1]]
Distance: 7
Execution time: 22365ms

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covid(7,4). covid(2,1). doctor(2,8). mask(2,3). home(5,3).

A* scenario 1:
Road: [[0,0],[0,1],[0,2],[1,3],[2,4],[3,3],[4,2],[5,3]]
Distance: 7
Execution time: 2ms

Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[1,3],[2,3],[3,3],[4,3],[5,3]]
Distance: 7
Execution time: 48ms

A* scenario 2:
Road: [[0,0],[0,1],[0,2],[1,3],[2,4],[3,3],[4,2],[5,3]]
Distance: 7
Execution time: 4ms

Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[1,3],[2,3],[3,3],[4,3],[5,3]]
Distance: 7
Execution time: 32ms

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covid(4,6). covid(7,2). doctor(2,6). mask(2,8). home(4,8).

A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3],[0,4],[1,5],[2,6],[3,7],[4,8]]
Distance: 8
Execution time: 3ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[1,5],[2,6],[3,7],[4,8]]
Distance: 8
Execution time: 14757ms
A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[0,4],[1,5],[2,6],[3,7],[4,8]]
Distance: 8
Execution time: 5ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[1,5],[2,6],[3,7],[4,8]]
Distance: 8
Execution time: 19188

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covid(7,6). covid(6,6). doctor(1,4). mask(4,5). home(4,4).
A* scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 3ms
Backtracking scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 71ms
A* scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 4ms
Backtracking scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 97ms

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covid(2,7). covid(2,8). doctor(4,6). mask(5,1). home(4,8).
A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3],[2,4],[3,5],[4,6],[5,7],[4,8]]
Distance: 8
Execution time: 6ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[1,3],[2,4],[3,5],[4,6],[4,7],[4,8]]
Distance: 8
Execution time: 34199ms
A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[2,4],[3,5],[4,6],[5,7],[4,8]]
Distance: 8
Execution time: 7ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[1,3],[2,4],[3,5],[4,6],[4,7],[4,8]]
Distance: 8
Execution time: 76273ms

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covid(6,6). covid(5,8). doctor(4,5). mask(3,4). home(2,1).
A* scenario 1:
Road: [[0,0],[1,1],[2,1]]

Distance: 2
Execution time: 2ms

Backtracking scenario 1:
Road: [[0,0],[1,0],[2,1]]
Distance: 2
Execution time: 81410ms

A* scenario 2:
Road: [[0,0],[1,1],[2,1]]
Distance: 2
Execution time: 3ms

Backtracking scenario 2:
Road: [[0,0],[1,0],[2,1]]
Distance: 2
Execution time: 99925ms

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covid(8,0). covid(8,1). doctor(0,2). mask(7,5). home(6,6).

A* scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5],[6,6]]
Distance: 6
Execution time: 4ms

Backtracking scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5],[6,6]]
Distance: 6
Execution time: 1275ms

A* scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5],[6,6]]
Distance: 6
Execution time: 5ms

Backtracking scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5],[6,6]]
Distance: 6
Execution time: 1688ms

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covid(2,4). covid(0,4). doctor(2,2). mask(3,6). home(3,7).

A* scenario 1:
Road: [[0,0],[1,1],[2,2],[1,3],[0,4],[1,5],[2,6],[3,7]]
Distance: 7
Execution time: 4ms

Backtracking scenario 1:
Road: [[0,0],[1,1],[2,2],[2,3],[2,4],[2,5],[2,6],[3,7]]
Distance: 7
Execution time: 6594ms

A* scenario 2:
Road: [[0,0],[1,1],[2,2],[1,3],[0,4],[1,5],[2,6],[3,7]]
Distance: 7
Execution time: 5ms

Backtracking scenario 2:
Road: [[0,0],[1,1],[2,2],[2,3],[2,4],[2,5],[2,6],[3,7]]
Distance: 7
Execution time: 8761ms

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covid(6,6). covid(2,6). doctor(4,3). mask(6,1). home(0,5).

A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3],[0,4],[0,5]]
Distance: 5
Execution time: 2ms

Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[0,5]]
Distance: 5
Execution time: 14390ms
A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[0,4],[0,5]]
Distance: 5
Execution time: 2ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[0,5]]
Distance: 5
Execution time: 18988ms

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covid(0,6). covid(4,8). doctor(8,7). mask(0,3). home(0,4).
A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3],[0,4]]
Distance: 4
Execution time: 2ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4]]
Distance: 4
Execution time: 41226ms
A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[0,4]]
Distance: 4
Execution time: 3ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4]]
Distance: 4
Execution time: 54262ms

---

covid(6,4). covid(1,7). doctor(8,5). mask(4,4). home(3,1).
A* scenario 1:
Road: [[0,0],[1,1],[2,0],[3,1]]
Distance: 3
Execution time: 2ms
Backtracking scenario 1:
Road: [[0,0],[1,0],[2,0],[3,1]]
Distance: 3
Execution time: 12899ms
A* scenario 2:
Road: [[0,0],[1,1],[2,0],[3,1]]
Distance: 3
Execution time: 2ms
Backtracking scenario 2:
Road: [[0,0],[1,0],[2,0],[3,1]]
Distance: 3
Execution time: 16811ms

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covid(3,1). covid(1,7). doctor(4,5). mask(6,3). home(1,4).
A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3],[1,4]]
Distance: 4
Execution time: 3ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[1,4]]

Distance: 4
Execution time: 4412ms

A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[1,4]]
Distance: 4
Execution time: 3ms

Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[1,4]]
Distance: 4
Execution time: 5912ms

---

covid(4,8). covid(6,1). doctor(1,3). mask(1,5). home(4,6).

A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3],[2,4],[3,5],[4,6]]
Distance: 6
Execution time: 4ms

Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[1,3],[2,4],[3,5],[4,6]]
Distance: 6
Execution time: 543ms

A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[2,4],[3,5],[4,6]]
Distance: 6
Execution time: 2ms

Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[1,3],[2,4],[3,5],[4,6]]
Distance: 6
Execution time: 735ms

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covid(3,5). covid(0,6). doctor(7,6). mask(5,1). home(5,0).

A* scenario 1:
Road: [[0,0],[1,1],[2,0],[3,1],[4,0],[5,0]]
Distance: 5
Execution time: 4ms

Backtracking scenario 1:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0],[5,0]]
Distance: 5
Execution time: 33ms

A* scenario 2:
Road: [[0,0],[1,1],[2,0],[3,1],[4,0],[5,0]]
Distance: 5
Execution time: 5ms

Backtracking scenario 2:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0],[5,0]]
Distance: 5
Execution time: 43ms

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covid(2,6). covid(6,7). doctor(5,4). mask(0,8). home(3,8).

A* scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[3,4],[4,5],[4,6],[4,7],[3,8]]
Distance: 8
Execution time: 6ms

Backtracking scenario 1:
Road: [[0,0],[0,1],[1,2],[2,3],[3,4],[4,5],[4,6],[4,7],[3,8]]
Distance: 8
Execution time: 29845ms

A* scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[3,4],[4,5],[4,6],[4,7],[3,8]]
Distance: 8
Execution time: 6ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[1,2],[2,3],[3,4],[4,5],[4,6],[4,7],[3,8]]
Distance: 8
Execution time: 42231ms

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covid(7,7). covid(4,2). doctor(4,0). mask(6,1). home(4,0).
A* scenario 1:
Road: [[0,0],[1,1],[2,0],[3,0],[4,0]]
Distance: 4
Execution time: 4ms
Backtracking scenario 1:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0]]
Distance: 4
Execution time: 2ms
A* scenario 2:
Road: [[0,0],[1,1],[2,0],[3,0],[4,0]]
Distance: 4
Execution time: 3ms
Backtracking scenario 2:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0]]
Distance: 4
Execution time: 4ms

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covid(8,0). covid(8,8). doctor(7,2). mask(4,1). home(1,3).
A* scenario 1:
Road: [[0,0],[1,1],[0,2],[1,3]]
Distance: 3
Execution time: 2ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[1,3]]
Distance: 3
Execution time: 6940ms
A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3]]
Distance: 3
Execution time: 4ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[1,3]]
Distance: 3
Execution time: 9097ms

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covid(8,7). covid(3,3). doctor(3,5). mask(8,2). home(6,0).
A* scenario 1:
Road: [[0,0],[1,1],[2,0],[3,1],[4,0],[5,1],[6,0]]
Distance: 6
Execution time: 3ms
Backtracking scenario 1:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0],[5,0],[6,0]]
Distance: 6
Execution time: 62ms
A* scenario 2:
Road: [[0,0],[1,1],[2,0],[3,1],[4,0],[5,1],[6,0]]

Distance: 6
Execution time: 3ms

Backtracking scenario 2:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0],[5,0],[6,0]]
Distance: 6
Execution time: 78ms

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covid(4,8). covid(2,6). doctor(4,1). mask(8,6). home(1,2).

A* scenario 1:
Road: [[0,0],[1,1],[1,2]]
Distance: 2
Execution time: 3ms

Backtracking scenario 1:
Road: [[0,0],[0,1],[1,2]]
Distance: 2
Execution time: 11222ms

A* scenario 2:
Road: [[0,0],[1,1],[1,2]]
Distance: 2
Execution time: 3ms

Backtracking scenario 2:
Road: [[0,0],[0,1],[1,2]]
Distance: 2
Execution time: 14512ms

References:

[1]. Prolog Tutorial – 5.1. [Online]. Available: `https://www.cpp.edu/~jrfisher/www/prolog_tutorial/5_1.html`. [Accessed: 15-Mar-2021].