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.

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	9	4
x_1	8	3	7	3	6	7	5	6	2	3	7	7	2	15	3
x_2	3139	6066	38383	126	316	131	24453	4628	1	1726	301	2404	37	86098	73

D	8	2	6	8	5	4	3	4	6	5	8	4	3	6	2
x_1	9	4	8	8	2	2	4	3	6	4	9	4	3	6	3
x_2	63402	2025	1044	4239	22263	46689	5083	6439	495	28	54759	4	5661	42	6444

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 prove or disprove 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: $\bar{x}_1 = 5.3, \bar{x}_2 = 12883.3$.
Sample variances: $s_1^2 = 8.424137931, s_2^2 = 497927103.3$. Therefore, $t = -3.161$.
Assume that p-value is 5%. In t-table at $df = 29$ and $p = 0.05$ placed $t_{table} = 2.045$. $|t| > t_{table} \Rightarrow$ null hypothesis is false, hence execution time of A* algorithm and backtracking algorithm are different.
As $t < 0$, we can claim that mean value of population of execution time of A* algorithm is less than mean value of population of Backtracking algorithm, therefore A* algorithm is faster than Backtracking algorithm.

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	9	4
x_1	8	5	6	4	6	4	4	7	4	4	4	6	4	11	5
x_2	4154	8522	45620	185	421	167	26388	4725	1	2329	396	3606	48	127336	99

D	8	2	6	8	5	4	3	4	6	5	8	4	3	6	2
x_1	9	3	5	9	2	3	4	4	5	5	9	3	4	3	3
x_2	76273	2580	1311	6326	27559	50027	7668	8850	653	32	43079	9	6575	62	7480

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 prove or disprove 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: $\bar{x}_1 = 5.1, \bar{x}_2 = 15416.033$.
Sample variances: $s_1^2 = 4.782758621, s_2^2 = 800485634.2$. Therefore, $t = -2.98$.
Assume that p-value is 5%. In t-table at $df = 29$ and $p = 0.05$ placed $t_{table} = 2.045$. $|t| > t_{table} \Rightarrow$ null hypothesis is false, hence execution time of A* algorithm and backtracking algorithm are different.
As $t < 0$, we can claim that mean value of population of execution time of A* algorithm is less than mean value of population of Backtracking algorithm, therefore A* algorithm is faster than Backtracking algorithm.

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	9	4
x_1	3139	6066	38383	126	316	131	24453	4628	1	1726	301	2404	37	86098	73
x_2	4154	8522	45620	185	421	167	26388	4725	1	2329	396	3606	48	127336	99

D	8	2	6	8	5	4	3	4	6	5	8	4	3	6	2
x_1	63402	2025	1044	4239	22263	46689	5083	6439	495	28	54759	4	5661	42	6444
x_2	76273	2580	1311	6326	27559	50027	7668	8850	653	32	43079	9	6575	62	7480

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 prove or disprove 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: $\bar{x}_1 = 12883.3, \bar{x}_2 = 15416.033$.
Sample variances: $s_1^2 = 497927103.3, s_2^2 = 800485634.2$. Therefore, $t = -0.385$.
Assume that p-value is 5%. In t-table at $df = 29$ and $p = 0.05$ placed $t_{table} = 2.045$. $|t| < t_{table} \Rightarrow$ null hypothesis is true, hence execution time of Backtracking algorithm in scenario 1 and Backtracking algorithm in scenario 2 are the same.

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	9	4
x_1	8	3	7	3	6	7	5	6	2	3	7	7	2	15	3
x_2	8	5	6	4	6	4	4	7	4	4	4	6	4	11	5

D	8	2	6	8	5	4	3	4	6	5	8	4	3	6	2
x_1	9	4	8	8	2	2	4	3	6	4	9	4	3	6	3
x_2	9	3	5	9	2	3	4	4	5	5	9	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 prove or disprove 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: $\bar{x}_1 = 5.3, \bar{x}_2 = 5.1$.
Sample variances: $s_1^2 = 8.424137931, s_2^2 = 4.782758621$. Therefore, $t = 0.3014$.
Assume that p-value is 5%. In t-table at $df = 29$ and $p = 0.05$ placed $t_{table} = 2.045$. $|t| < t_{table} \Rightarrow$ null hypothesis is true, hence execution time of A* search in scenario 1 and A* search in scenario 2 are the same.

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

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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: 8ms

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: 3139ms

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: 8ms

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: 4154ms

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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: 6066ms

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: 8522ms

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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: 7ms

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: 38383ms

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: 6ms

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: 45620ms

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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: 126ms

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: 185ms

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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: 316ms
A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[2,4],[3,5],[3,6]]
Distance: 6
Execution time: 6ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[1,4],[2,5],[3,6]]
Distance: 6
Execution time: 421ms

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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: 7ms
Backtracking scenario 1:
Road: [[0,0],[1,0],[2,1],[3,2],[4,3],[5,4]]
Distance: 5
Execution time: 131ms
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: 167ms

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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: 5ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[0,5],[0,6],[0,7]]
Distance: 7
Execution time: 24453ms
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: 26388ms

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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: 6ms
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: 4628ms
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: 7ms
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: 4725ms

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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: 1ms

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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: 1726ms
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: 2329ms

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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: 7ms

Backtracking scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5]]
Distance: 5
Execution time: 301ms

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: 396ms

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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: 7ms

Backtracking scenario 1:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0],[5,0],[6,0],[7,1]]
Distance: 7
Execution time: 2404ms

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: 3606ms

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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: 37ms

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: 48ms

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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],[2,7],[3,8],[4,8]]
Distance: 9
Execution time: 15ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[0,5],[1,6],[2,7],[3,8],[4,8]]
Distance: 9
Execution time: 86098ms
A* scenario 2:
Road: [[0,0],[1,1],[0,2],[1,3],[0,4],[1,5],[2,6],[2,7],[3,8],[4,8]]
Distance: 9
Execution time: 11ms
Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[0,4],[0,5],[1,6],[2,7],[3,8],[4,8]]
Distance: 9
Execution time: 127336ms

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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: 73ms
A* scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 5ms
Backtracking scenario 2:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4]]
Distance: 4
Execution time: 99ms

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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: 9ms
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: 63402ms
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: 9ms
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: 4ms

Backtracking scenario 1:
Road: [[0,0],[1,0],[2,1]]
Distance: 2
Execution time: 2025ms

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: 2580ms

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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: 8ms

Backtracking scenario 1:
Road: [[0,0],[1,1],[2,2],[3,3],[4,4],[5,5],[6,6]]
Distance: 6
Execution time: 1044ms

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: 1311ms

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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],[3,2],[4,3],[5,4],[4,5],[3,6],[3,7]]
Distance: 8
Execution time: 8ms

Backtracking scenario 1:
Road: [[0,0],[1,0],[2,1],[3,2],[4,3],[4,4],[4,5],[4,6],[3,7]]
Distance: 8
Execution time: 4239ms

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

Backtracking scenario 2:
Road: [[0,0],[1,0],[2,1],[3,2],[4,3],[4,4],[4,5],[4,6],[3,7]]
Distance: 8
Execution time: 6326ms

---

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: 22263ms
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: 27559ms

---

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: 46689ms
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: 50027ms

---

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: 4ms
Backtracking scenario 1:
Road: [[0,0],[1,0],[2,0],[3,1]]
Distance: 3
Execution time: 5083ms
A* scenario 2:
Road: [[0,0],[1,1],[2,0],[3,1]]
Distance: 3
Execution time: 4ms
Backtracking scenario 2:
Road: [[0,0],[1,0],[2,0],[3,1]]
Distance: 3
Execution time: 7668ms

---

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: 6439ms

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

Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[0,3],[1,4]]
Distance: 4
Execution time: 8850ms

---

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: 6ms

Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[1,3],[2,4],[3,5],[4,6]]
Distance: 6
Execution time: 495ms

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

Backtracking scenario 2:
Road: [[0,0],[0,1],[0,2],[1,3],[2,4],[3,5],[4,6]]
Distance: 6
Execution time: 653ms

---

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: 28ms

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: 32ms

---

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: 9ms

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: 54759ms

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: 9ms
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: 43079ms

---

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: 4ms
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: 9ms

---

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: 3ms
Backtracking scenario 1:
Road: [[0,0],[0,1],[0,2],[1,3]]
Distance: 3
Execution time: 5661ms
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: 6575ms

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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: 6ms
Backtracking scenario 1:
Road: [[0,0],[1,0],[2,0],[3,0],[4,0],[5,0],[6,0]]
Distance: 6
Execution time: 42ms
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: 62ms

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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: 6444ms

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: 7480ms