

# Fundamentals of Artificial Intelligence

## Laboratory

Dr. Mauro Dragoni

Department of Information Engineering and Computer Science  
Academic Year 2022/2023

## Exercise 5.3

- LRTA\*

|   | 1        | 2 | 3        | 4 |
|---|----------|---|----------|---|
| 1 |          |   | <b>G</b> |   |
| 2 |          |   |          |   |
| 3 |          |   |          |   |
| 4 | <b>S</b> |   |          |   |

- The agent starts from S, it has to reach G. Each step costs 1. Heuristic is based on Manhattan distance.
- In case of same  $h(s)$  values, the order of possible actions are: UP, RIGHT, DOWN, LEFT

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              |   |          |   |
| 3 | 4            |   |          |   |
| 4 | <b>S (5)</b> | 4 |          |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              |   |          |   |
| 3 | <b>4</b>     |   |          |   |
| 4 | <b>S (5)</b> | 4 |          |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              |   |          |   |
| 3 | 4            |   |          |   |
| 4 | <b>S (5)</b> | 4 |          |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              |   |          |   |
| 3 | 6            |   |          |   |
| 4 | <b>S (5)</b> | 4 |          |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              |   |          |   |
| 3 | 6            |   |          |   |
| 4 | <b>S (5)</b> | 4 |          |   |

|   | 1            | 2        | 3        | 4 |
|---|--------------|----------|----------|---|
| 1 |              |          | <b>G</b> |   |
| 2 |              |          |          |   |
| 3 | 6            | 3        |          |   |
| 4 | <b>S (5)</b> | <b>4</b> | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              |   |          |   |
| 3 | 6            | 3 |          |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              |   |          |   |
| 3 | 6            | 3 |          |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              |   |          |   |
| 3 | 6            | 3 |          |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              | 2 |          |   |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2        | 3        | 4 |
|---|--------------|----------|----------|---|
| 1 |              |          | <b>G</b> |   |
| 2 |              | 2        |          |   |
| 3 | 6            | <b>3</b> | 2        |   |
| 4 | <b>S (5)</b> | 4        | 3        |   |

|   | 1            | 2        | 3        | 4 |
|---|--------------|----------|----------|---|
| 1 |              |          | <b>G</b> |   |
| 2 |              | <b>2</b> |          |   |
| 3 | 6            | 3        | 2        |   |
| 4 | <b>S (5)</b> | 4        | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              | 2 |          |   |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 1 | <b>G</b> |   |
| 2 | 3            | 2 | 1        |   |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 1 | <b>G</b> |   |
| 2 | 3            | 2 | 1        |   |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 1 | <b>G</b> |   |
| 2 | 3            | 2 | 1        |   |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1     | 2 | 3 | 4 |
|---|-------|---|---|---|
| 1 |       | 1 | G |   |
| 2 | 3     | 2 | 1 |   |
| 3 | 6     | 3 | 2 |   |
| 4 | S (5) | 4 | 3 |   |

|   | 1     | 2 | 3 | 4 |
|---|-------|---|---|---|
| 1 |       | 3 | G |   |
| 2 | 3     | 2 | 1 |   |
| 3 | 6     | 3 | 2 |   |
| 4 | S (5) | 4 | 3 |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 3 | <b>G</b> |   |
| 2 | 3            | 2 | 1        |   |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 3 | <b>G</b> |   |
| 2 | 3            | 2 | 1        |   |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 3 | <b>G</b> |   |
| 2 | 3            | 2 | 1        |   |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 3 | <b>G</b> |   |
| 2 | 3            | 2 | 1        | 2 |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 3 | <b>G</b> |   |
| 2 | 3            | 2 | 1        | 2 |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 3 | <b>G</b> |   |
| 2 | 3            | 2 | 3        | 2 |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 3 | <b>G</b> |   |
| 2 | 3            | 2 | 1        | 2 |
| 3 | 6            | 3 | 2        |   |
| 4 | <b>S (5)</b> | 4 | 3        |   |

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              | 3 | <b>G</b> | 1 |
| 2 | 3            | 2 | 3        | 2 |
| 3 | 6            | 3 | 2        | 3 |
| 4 | <b>S (5)</b> | 4 | 3        |   |

## Exercise 5.3

- LRTA\*

|   | 1            | 2 | 3        | 4        |
|---|--------------|---|----------|----------|
| 1 |              | 3 | <b>G</b> | 1        |
| 2 | 3            | 2 | 1        | <b>2</b> |
| 3 | 6            | 3 | 2        | 3        |
| 4 | <b>S (5)</b> | 4 | 3        |          |

|   | 1            | 2 | 3            | 4        |
|---|--------------|---|--------------|----------|
| 1 |              | 3 | <b>G (0)</b> | <b>1</b> |
| 2 | 3            | 2 | 3            | 2        |
| 3 | 6            | 3 | 2            | 3        |
| 4 | <b>S (5)</b> | 4 | 3            |          |

## Exercise 5.4

- LRTA\*

|   | 1        | 2 | 3        | 4 |
|---|----------|---|----------|---|
| 1 |          |   | <b>G</b> |   |
| 2 |          |   |          |   |
| 3 |          |   |          |   |
| 4 | <b>S</b> |   |          |   |

- The agent starts from S, it has to reach G.  
Each step costs:  
2 when UP  
1 otherwise.  
Heuristic is based on Manhattan distance.
- In case of same  $h(s)$  values, the order of possible actions are:  
RIGHT, DOWN, UP, LEFT

## Exercise 5.4

- LRTA\*

|   | 1            | 2 | 3        | 4 |
|---|--------------|---|----------|---|
| 1 |              |   | <b>G</b> |   |
| 2 |              |   |          |   |
| 3 | 4            |   |          |   |
| 4 | <b>S (5)</b> | 4 |          |   |

- The agent starts from S, it has to reach G.  
Each step costs:  
2 when UP  
1 otherwise.  
Heuristic is based on Manhattan distance.
- In case of same  $h(s)$  values, the order of possible actions are:  
RIGHT, DOWN, UP, LEFT

## Exercise 5.4

- LRTA\*

|   | 1     | 2 | 3 | 4 |
|---|-------|---|---|---|
| 1 | G     |   |   |   |
| 2 |       |   |   |   |
| 3 | 4     |   |   |   |
| 4 | S (5) | 4 |   |   |

|   | 1     | 2 | 3 | 4 |
|---|-------|---|---|---|
| 1 | G     |   |   |   |
| 2 |       |   |   |   |
| 3 | 4     | 3 |   |   |
| 4 | S (5) | 4 | 3 |   |

## Exercise 5.4

- LRTA\*

|   | 1        | 2        | 3 | 4 |
|---|----------|----------|---|---|
| 1 | <b>G</b> |          |   |   |
| 2 |          |          |   |   |
| 3 | 4        | 3        |   |   |
| 4 | S (5)    | <b>4</b> | 3 |   |

|   | 1        | 2 | 3        | 4 |
|---|----------|---|----------|---|
| 1 | <b>G</b> |   |          |   |
| 2 |          |   |          |   |
| 3 | 4        | 3 | 2        |   |
| 4 | S (5)    | 4 | <b>3</b> | 4 |

## Exercise 5.4

- LRTA\*

|   | 1        | 2 | 3        | 4 |
|---|----------|---|----------|---|
| 1 | <b>G</b> |   |          |   |
| 2 |          |   |          |   |
| 3 | 4        | 3 | 2        |   |
| 4 | S (5)    | 4 | <b>3</b> | 4 |

|   | 1        | 2 | 3        | 4 |
|---|----------|---|----------|---|
| 1 | <b>G</b> |   |          |   |
| 2 |          |   |          |   |
| 3 | 4        | 3 | <b>2</b> |   |
| 4 | S (5)    | 4 | 4        | 4 |

## Exercise 5.4

- LRTA\*

|   | 1     | 2 | 3 | 4 |
|---|-------|---|---|---|
| 1 | G     |   |   |   |
| 2 |       |   |   |   |
| 3 | 4     | 3 | 2 |   |
| 4 | S (5) | 4 | 4 | 4 |

|   | 1     | 2 | 3 | 4 |
|---|-------|---|---|---|
| 1 | G     |   |   |   |
| 2 |       |   |   |   |
| 3 | 4     | 3 | 4 |   |
| 4 | S (5) | 4 | 4 | 4 |

## Exercise 5.4

- LRTA\*

|   | 1     | 2 | 3 | 4 |
|---|-------|---|---|---|
| 1 | G     |   |   |   |
| 2 |       |   |   |   |
| 3 | 4     | 3 | 4 |   |
| 4 | S (5) | 4 | 4 | 4 |

|   | 1     | 2 | 3 | 4 |
|---|-------|---|---|---|
| 1 | G     |   |   |   |
| 2 |       | 2 |   |   |
| 3 | 4     | 3 | 4 |   |
| 4 | S (5) | 4 | 4 | 4 |

## Exercise 5.4

- LRTA\*

|   | 1     | 2        | 3        | 4 |
|---|-------|----------|----------|---|
| 1 |       |          | <b>G</b> |   |
| 2 |       | 2        |          |   |
| 3 | 4     | <b>3</b> | 4        |   |
| 4 | S (5) | 4        | 4        | 4 |

- The agent starts from S, it has to reach G.  
Each step costs:  
2 when UP  
1 otherwise.  
Heuristic is based on Manhattan distance.
- In case of same  $h(s)$  values, the order of possible actions are:  
RIGHT, DOWN, UP, LEFT

## Exercise 5.4

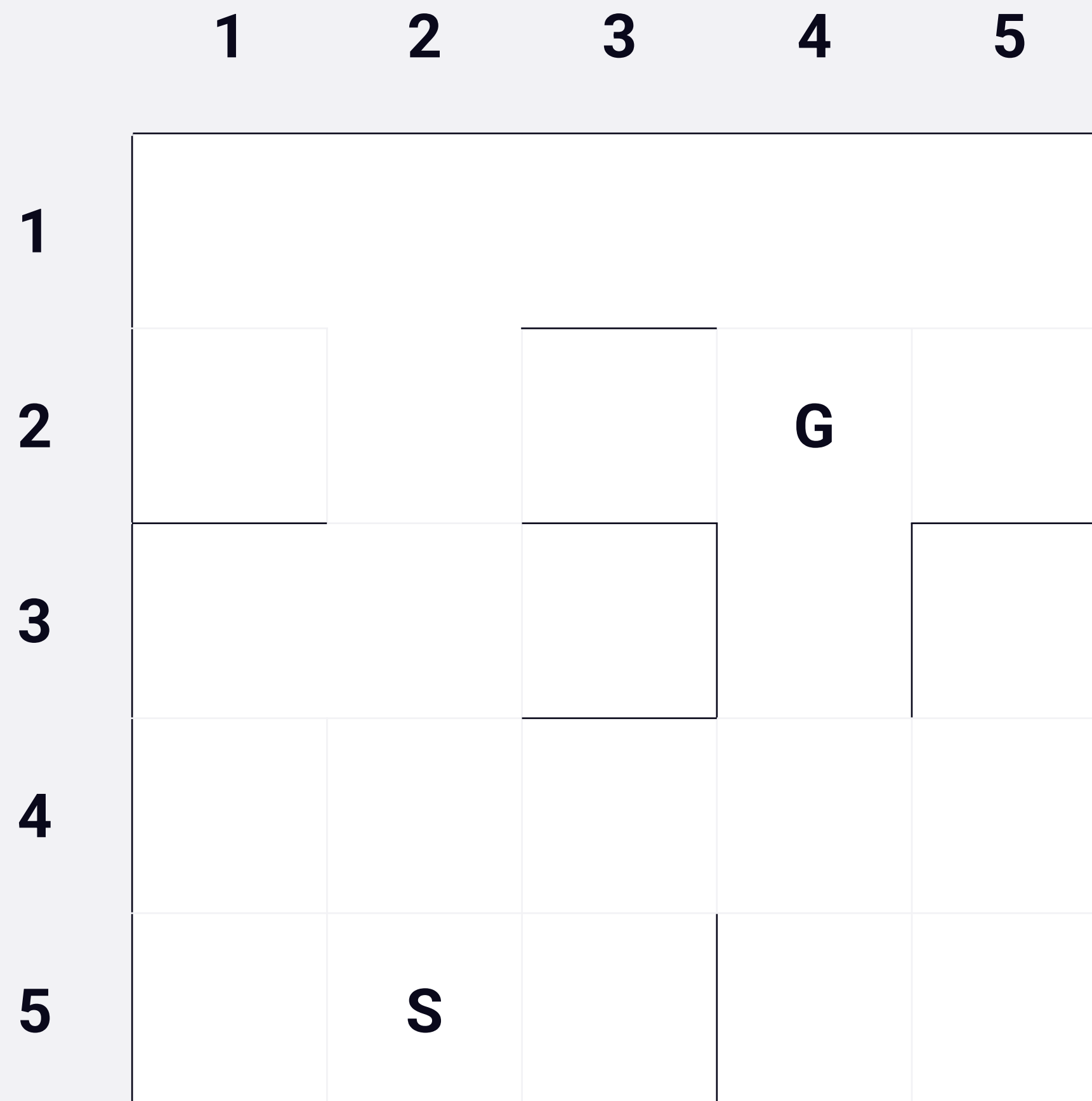
- LRTA\*

|   | 1     | 2        | 3        | 4 |
|---|-------|----------|----------|---|
| 1 |       |          | <b>G</b> |   |
| 2 |       | 2        |          |   |
| 3 | 4     | <b>3</b> | 4        |   |
| 4 | S (5) | 4        | 4        | 4 |

|   | 1     | 2        | 3        | 4        |
|---|-------|----------|----------|----------|
| 1 |       | 1        | <b>G</b> | <b>1</b> |
| 2 | 3     | <b>2</b> | <b>3</b> | <b>3</b> |
| 3 | 4     | 4        | 4        |          |
| 4 | S (5) | 4        | 4        | 4        |

## Exercise 5.5

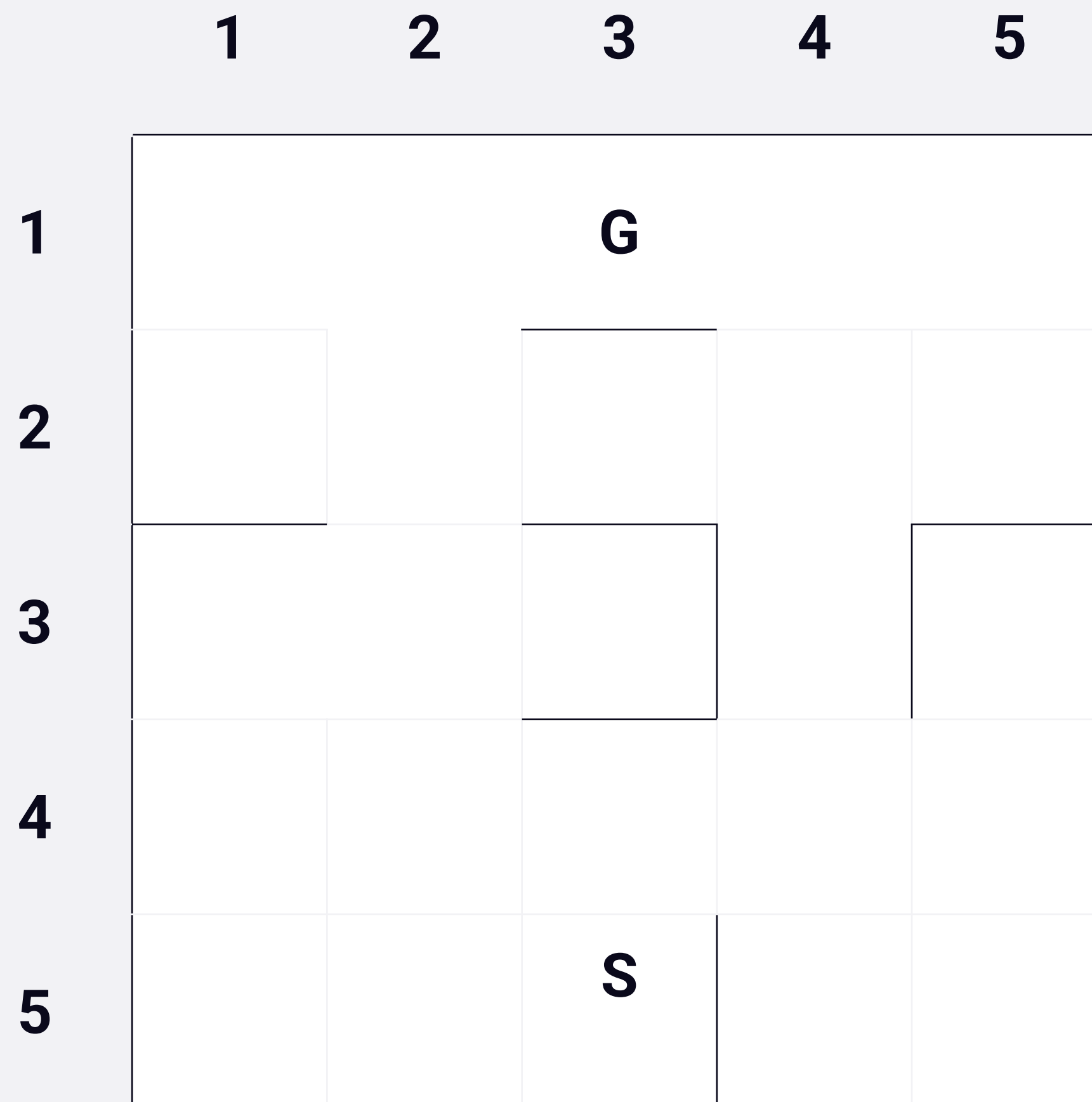
- LRTA\*



- The agent starts from S, it has to reach G.  
Each step costs:  
2 when UP  
1 otherwise.  
Heuristic is based on Manhattan distance.
- In case of same  $h(s)$  values, the order of possible actions are:  
RIGHT, DOWN, UP, LEFT

## Exercise 5.6

- LRTA\*



- The agent starts from S, it has to reach G.  
Each step costs:  
2 when UP  
1 otherwise.  
Heuristic is based on Manhattan distance.
- In case of same  $h(s)$  values, the order of possible actions are:  
LEFT, RIGHT, DOWN, UP

## Exercise 5.7

- LRTA\*

|   | 1            | 2 | 3 | 4 | 5        |
|---|--------------|---|---|---|----------|
| 1 | 3            | 3 | 2 | 4 | 2        |
| 2 | 1            | 5 | 8 | 2 | <b>G</b> |
| 3 | 8            | 8 | 6 | 9 | 6        |
| 4 | <b>S (8)</b> | 8 | 3 | 6 | 1        |
| 5 | 3            | 4 | 5 | 3 | 2        |

- The agent starts from S, it has to reach G.  
Each step costs:  
2 when UP  
1 otherwise.  
Heuristic is based on Manhattan distance.
- In case of same h(s) values, the order of possible actions are:  
RIGHT, DOWN, UP, LEFT

## Exercise 5.8

- LRTA\*

|   | 1 | 2            | 3 | 4 | 5            |
|---|---|--------------|---|---|--------------|
| 1 | 4 | 3            | 3 | 1 | 6            |
| 2 | 9 | 6            | 4 | 5 | 6            |
| 3 | 8 | 4            | 3 | 6 | <b>G (0)</b> |
| 4 | 3 | 2            | 4 | 7 | 5            |
| 5 | 7 | <b>S (8)</b> | 8 | 6 | 7            |

- The agent starts from S, it has to reach G.  
Each step costs:  
1 when RIGHT  
2 otherwise.  
Heuristic is given by the numbers included in the maze.
- In case of same **cost** values, the order of possible actions are:  
DOWN, RIGHT, UP, LEFT