Robot-Assisted Discovery of Evacuation Routes in Emergency Scenarios

Ettore Ferranti

Niki Trigoni
Computing Laboratory, University of Oxford, UK

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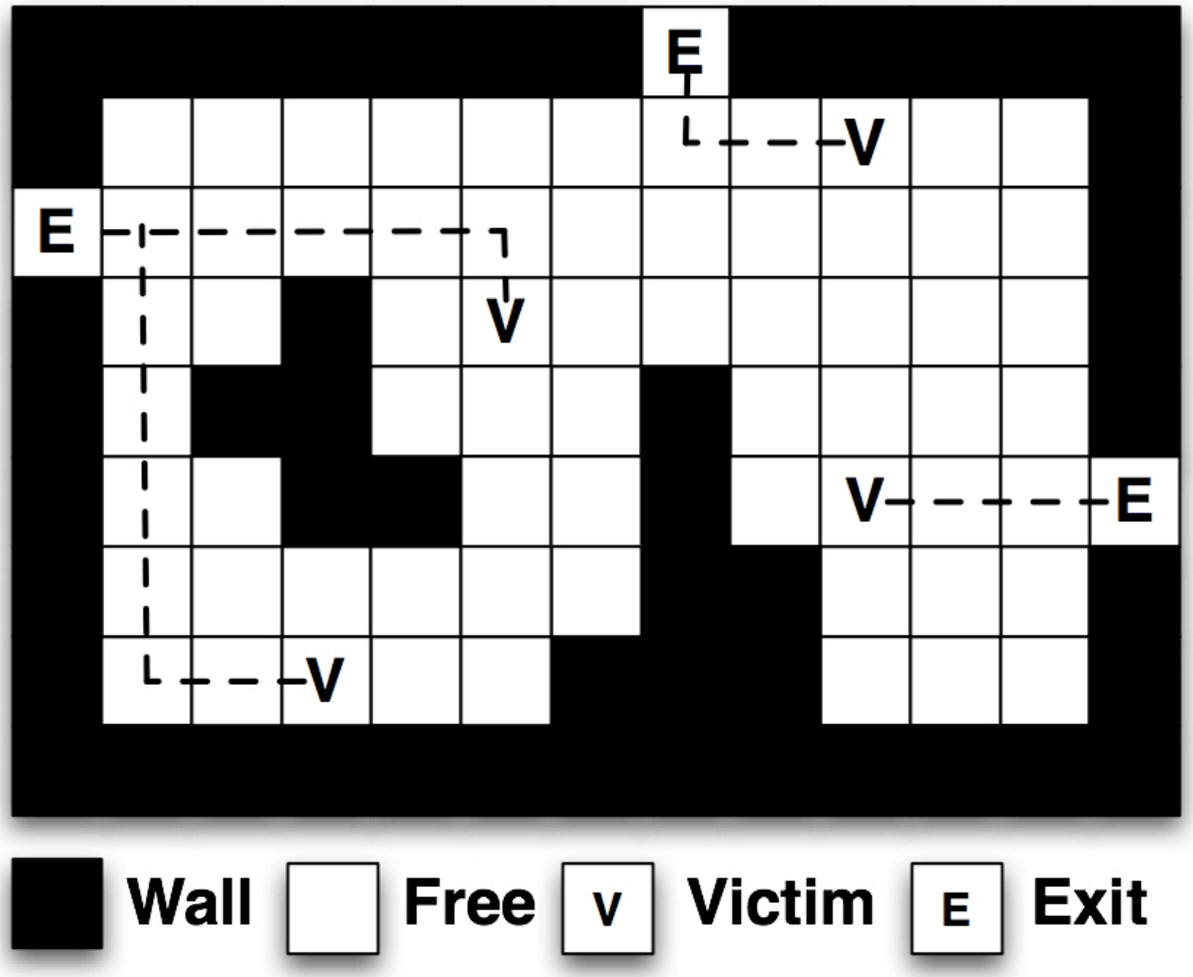
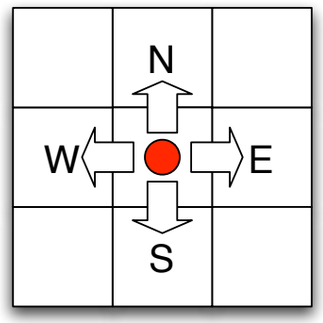
Scenario

• A Group of mini robots (agents) is exploring an area where an emergency event has just happened.

1. No prior knowledge of the area's map.
2. Lack of exact knowledge of agents' and victims' positions.

Model

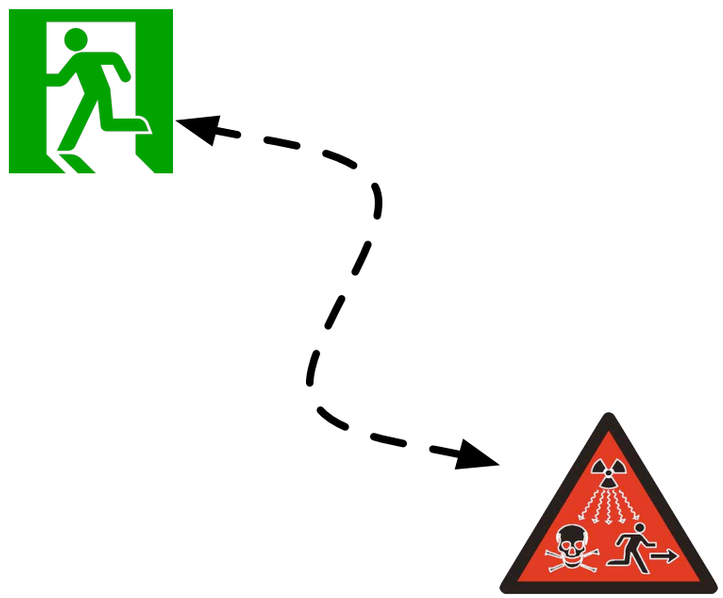




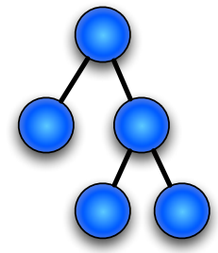
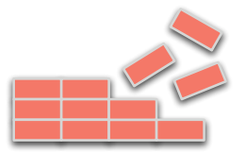
- The environment is divided into square cells.
- When an agent first moves to a cell, it deploys a stationary sensor (*tag*).
- The agent then moves into one of the four adjacent cells.

Objective

Whilst exploring an unknown area, dynamically discover and maintain short **evacuation routes** connecting emergency exits to critical points in the area.



Exploration Algorithms

- Ants* 
- Multiple Depth First Search+ 
- Brick&Mortar+ 

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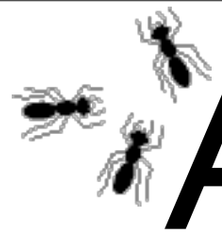

Ants*

- Each agent moves toward the least visited adjacent cell.

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0	0	0	0	0	0	0
0	0	0	0	0	0	0
		0		0	0	0
0	0	0		0	0	0
0	0	0		0	0	0
0	0	0		0	0	0
0	0	0		0	0	0

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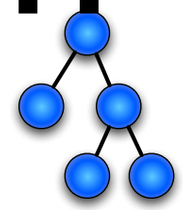
Multiple Depth First Search[+]



- Agents navigate a branch downwards to mark the cells as ***Explored***.

- Agents navigate a branch upwards to mark the cells as ***Visited***.

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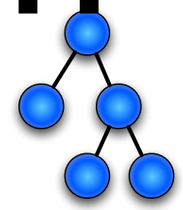

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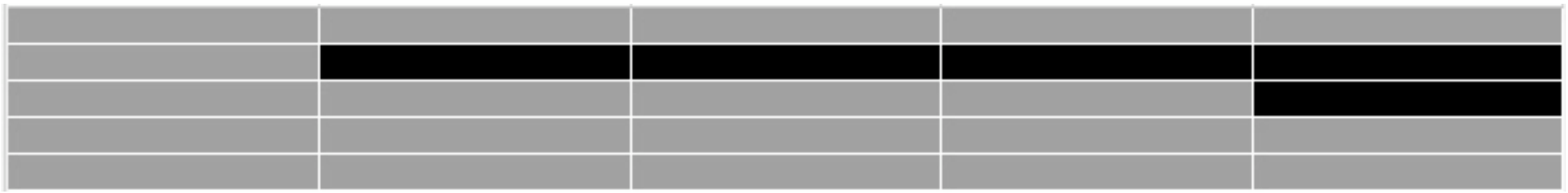

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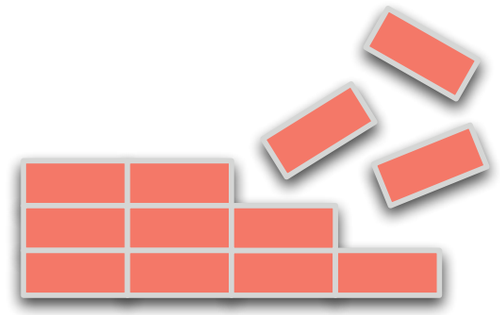
Brick&Mortar[+]



Agents thicken the existing walls of a room with virtual “bricks” (***Visited*** cells).

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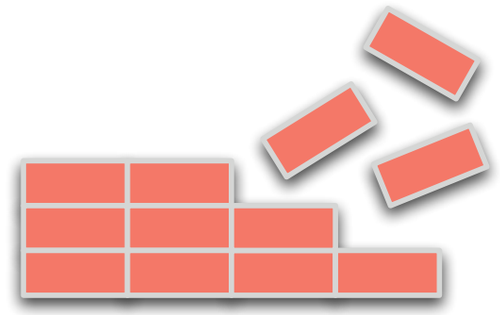

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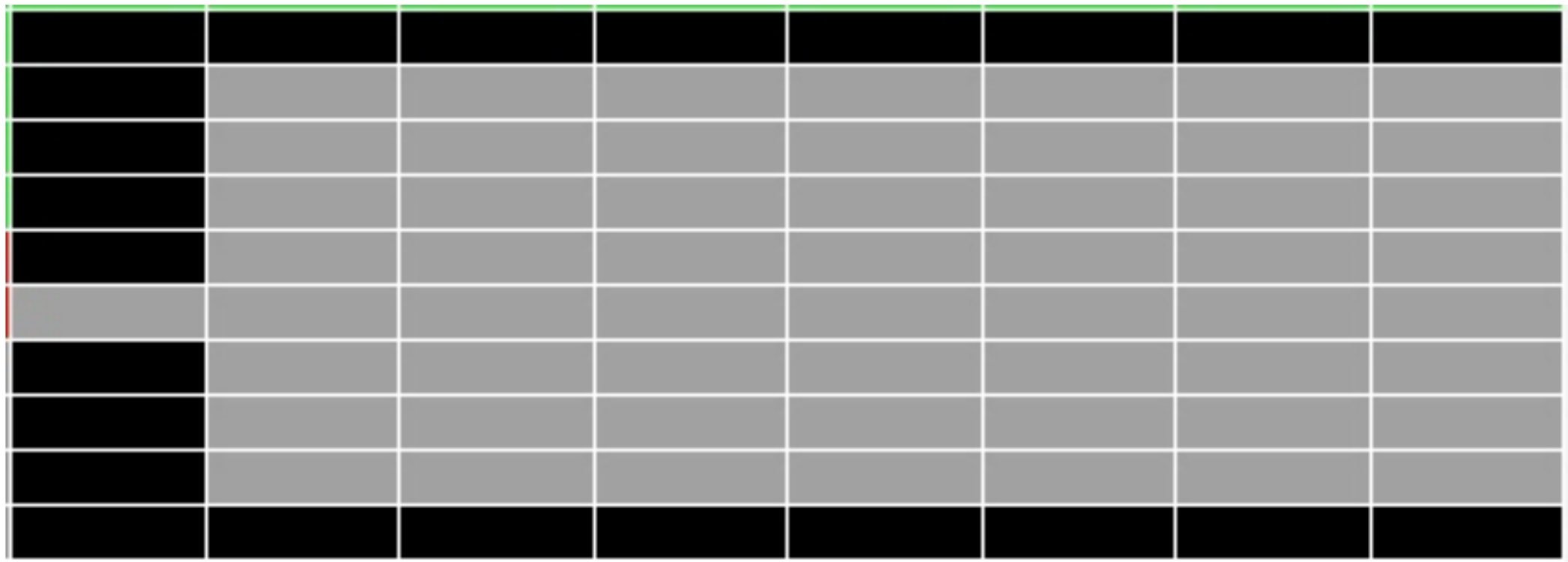

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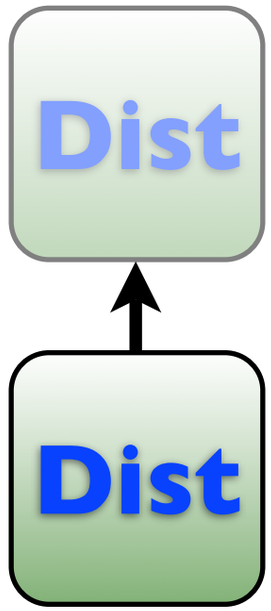
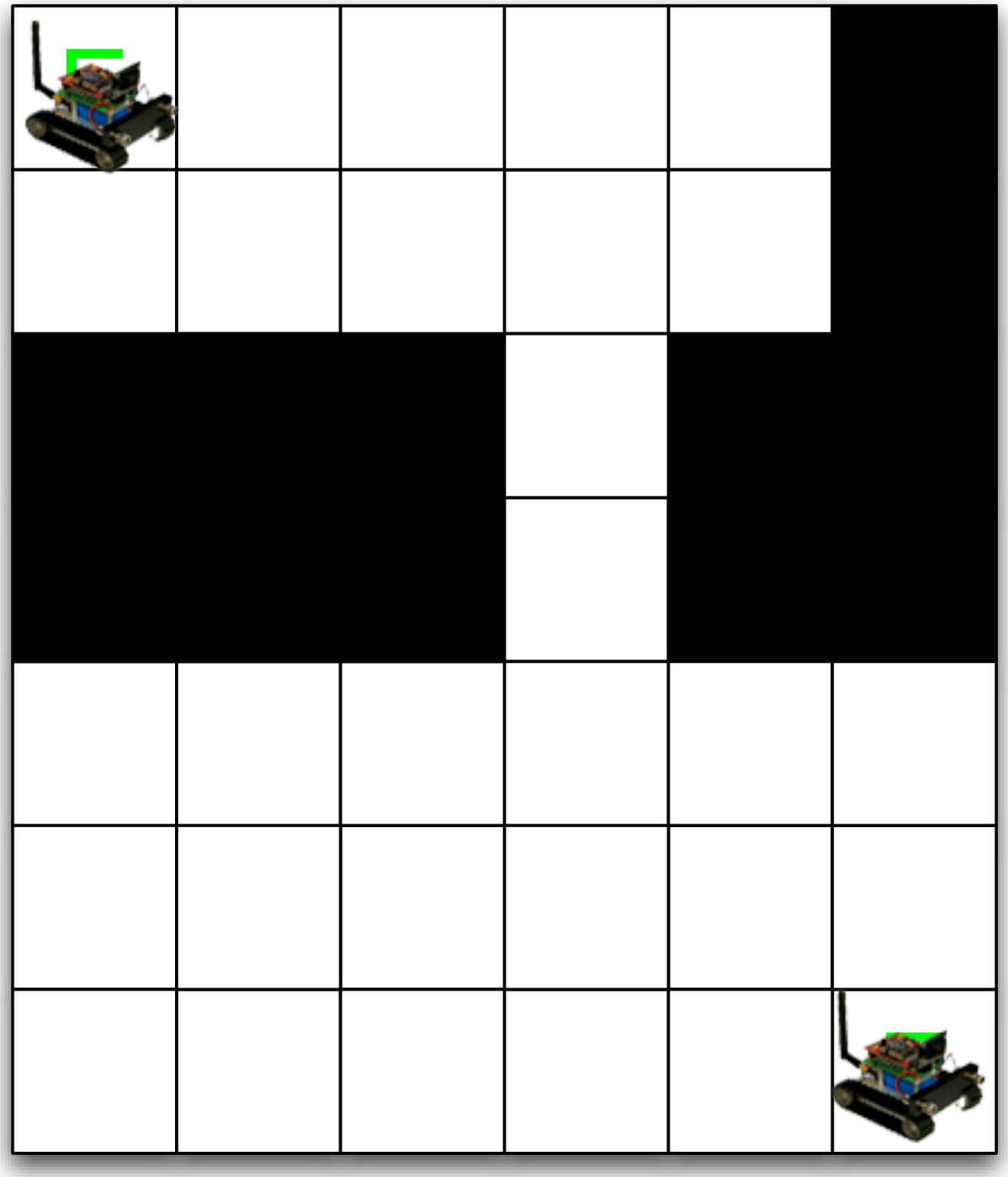
Evacuation Paths

- Each cell has a **distance** value and a **pointer** to its parent in the evacuation route.



- The distance value indicates the **number of steps** from the nearest exit, which can be reached by following the pointer to the parent cell.

Evacuation Path Mechanism



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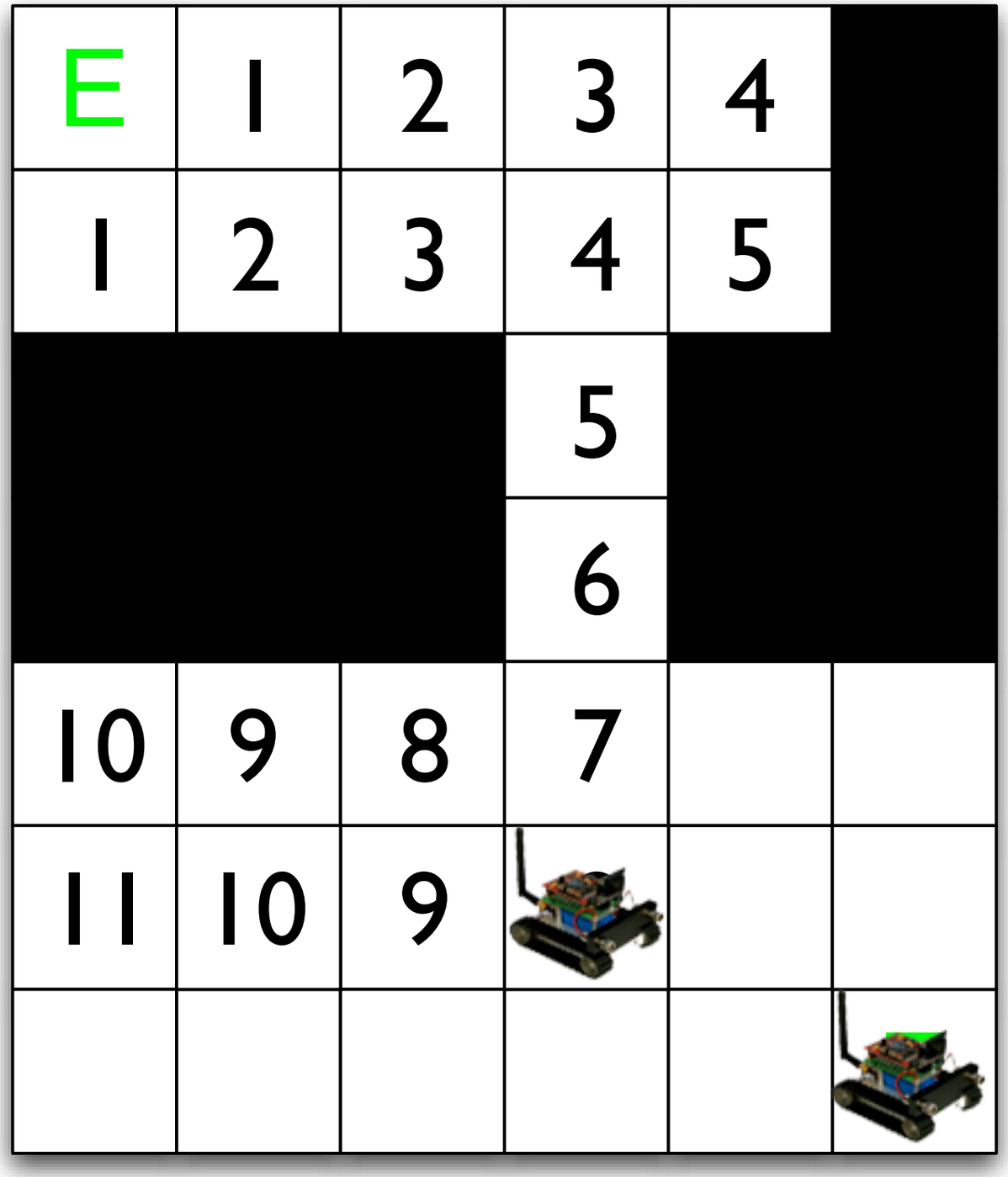

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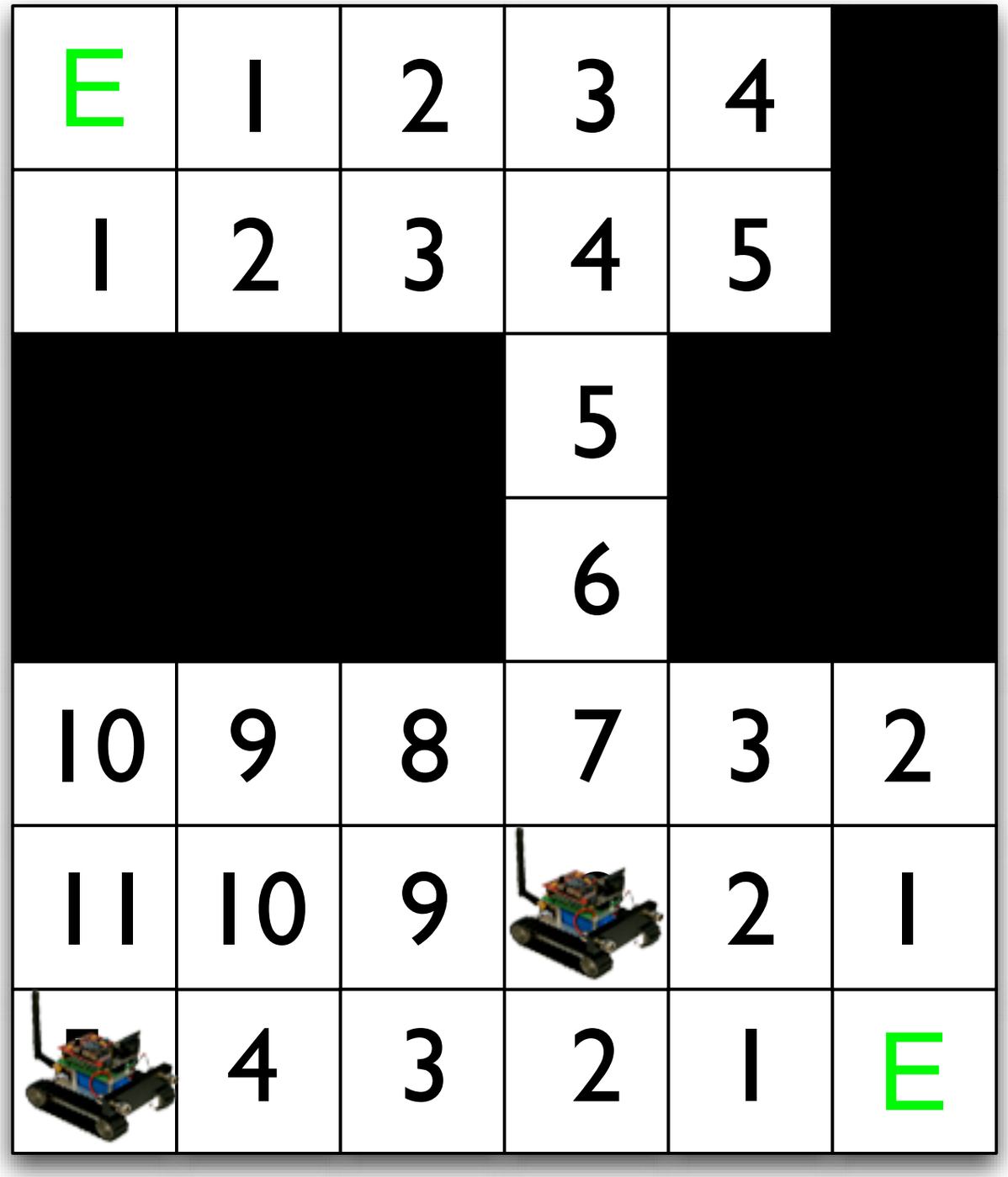

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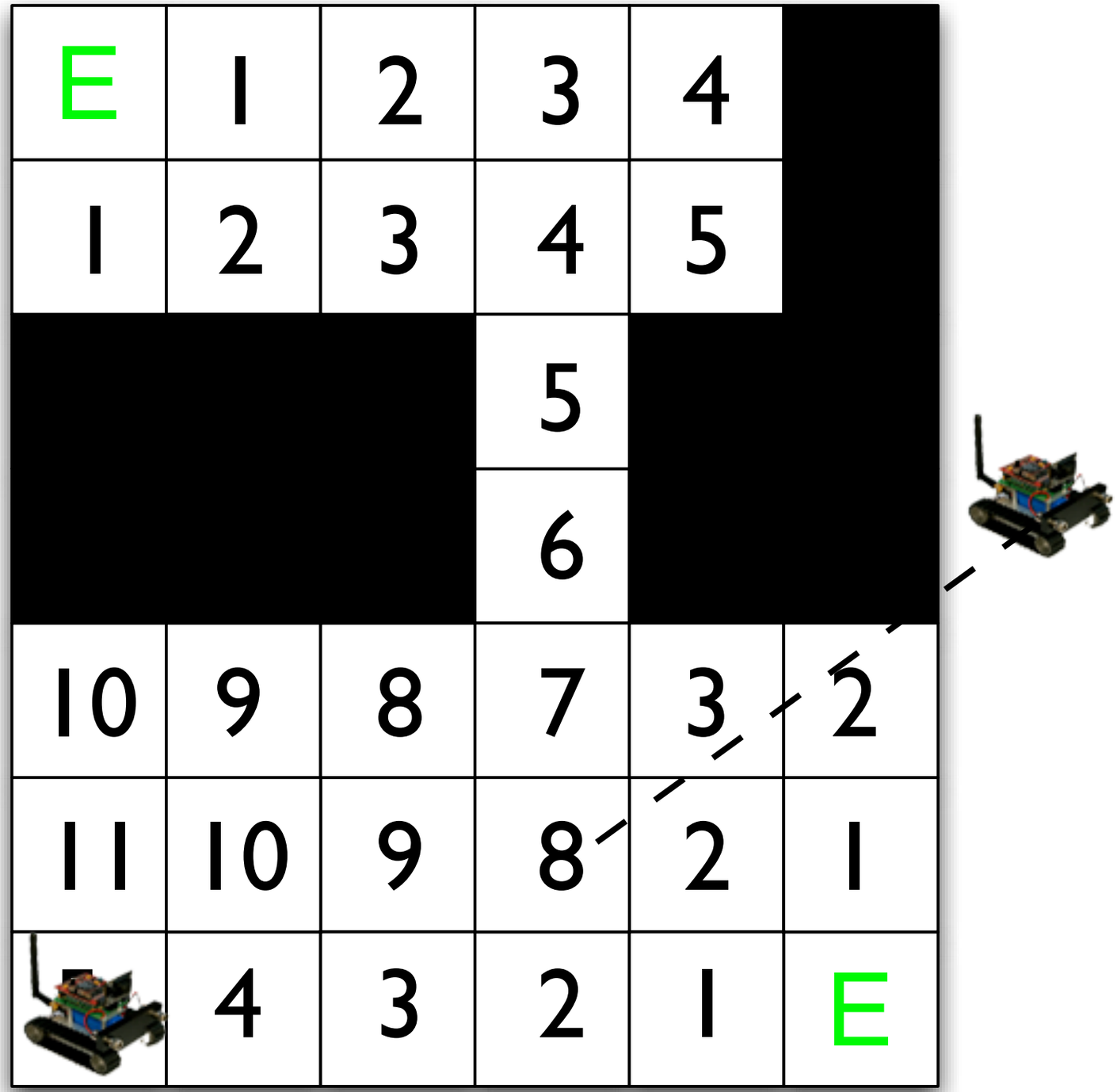

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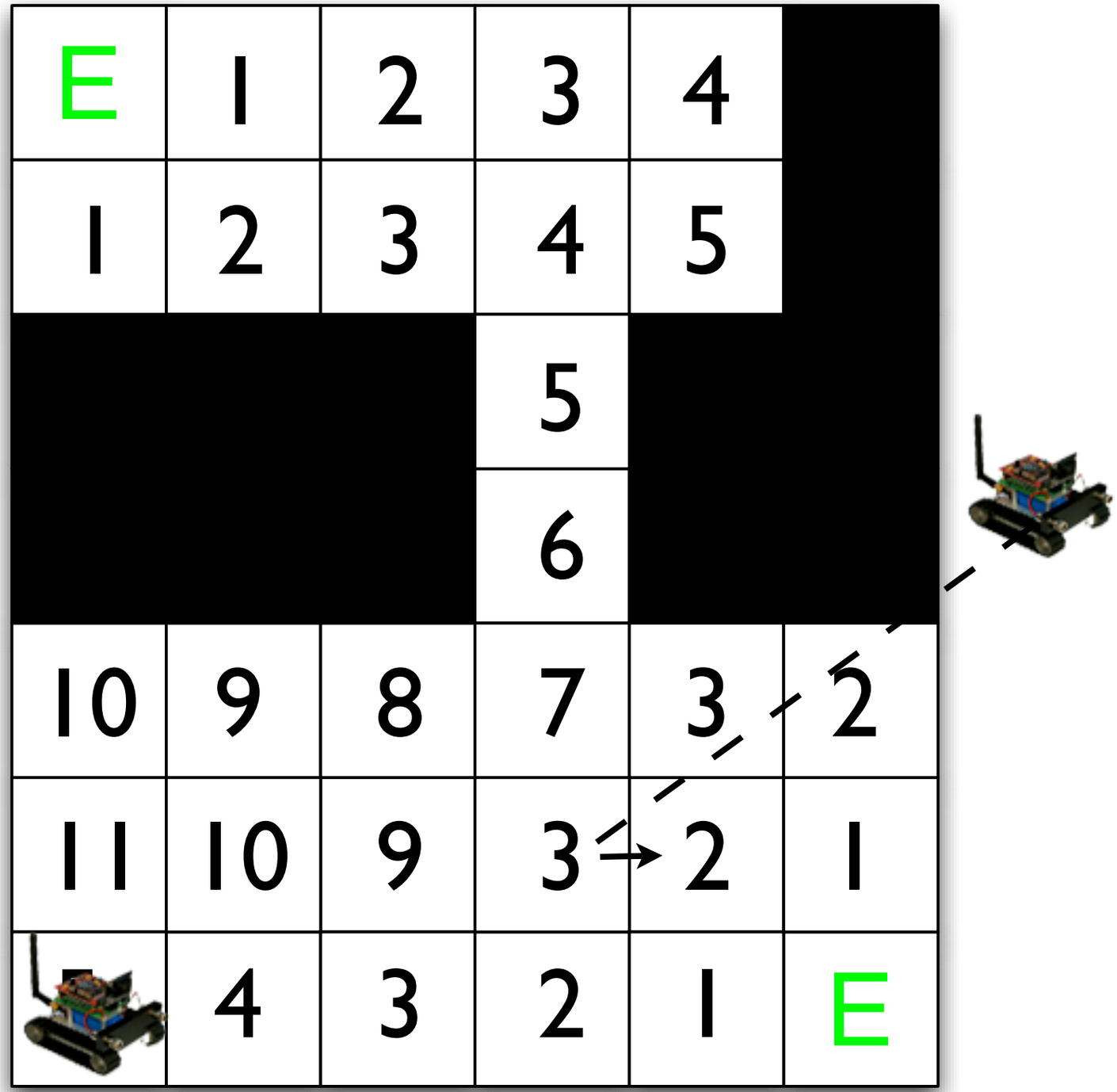

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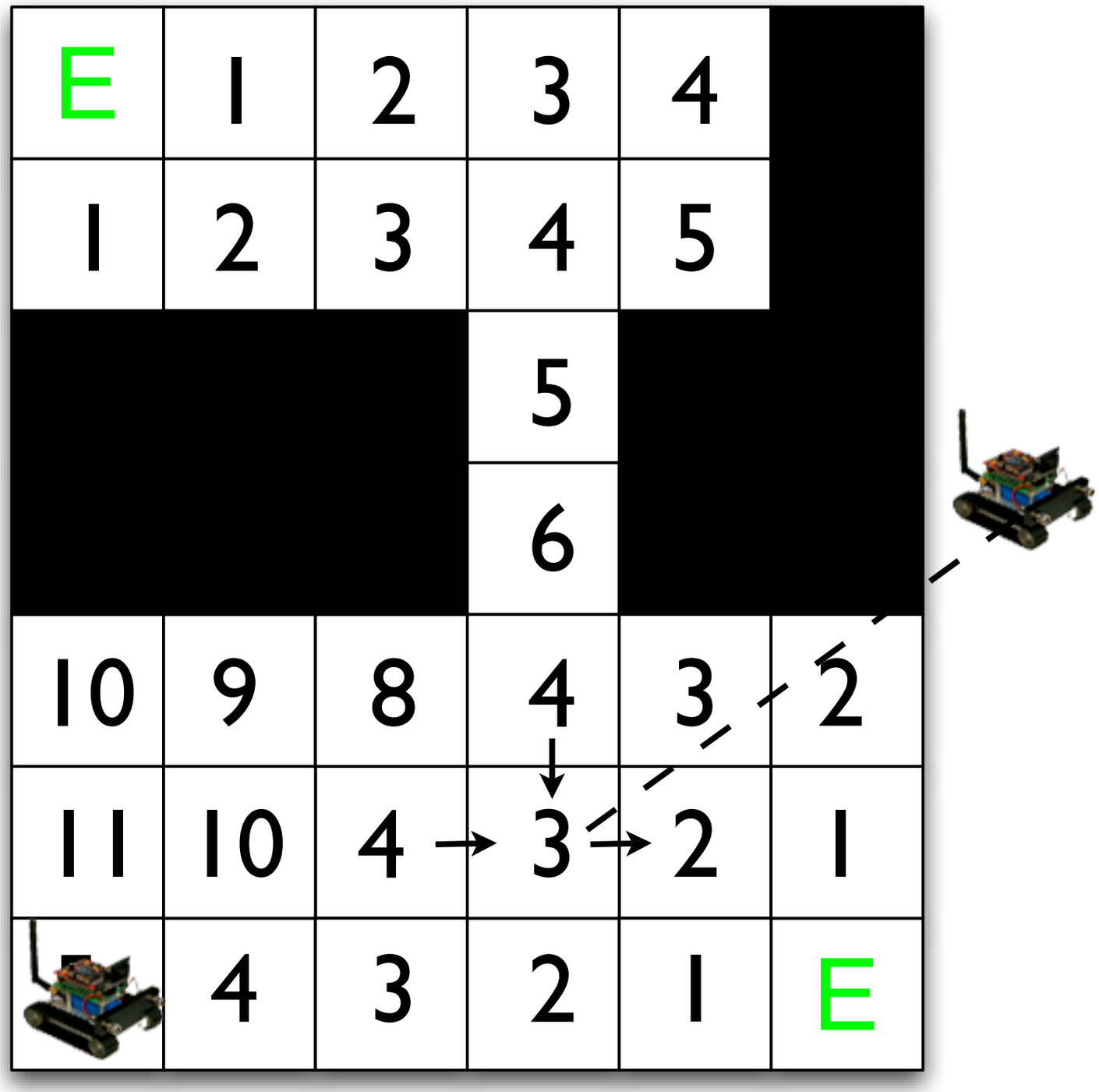
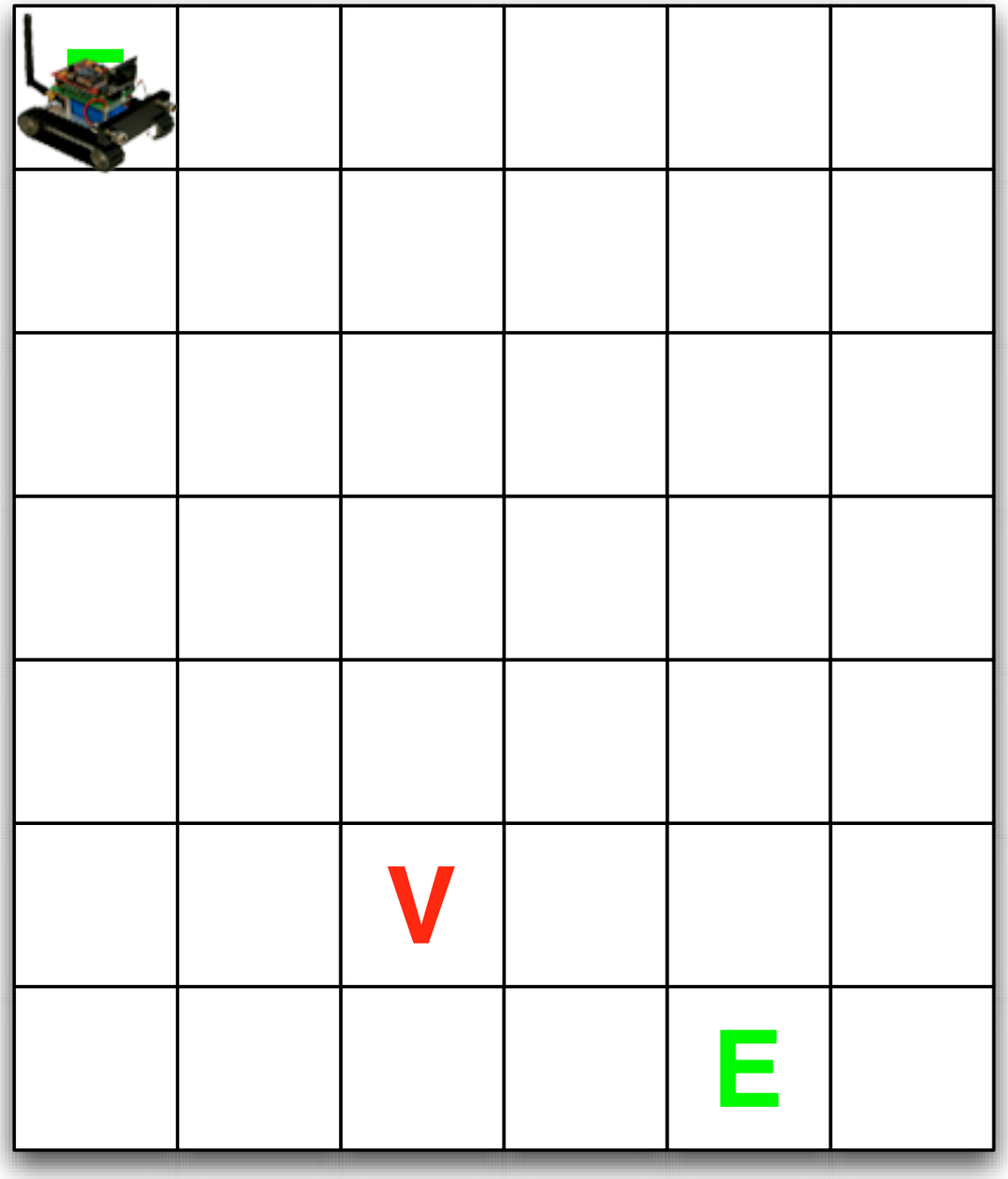
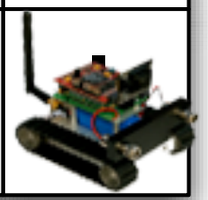


Route Discovery



Route Discovery

E	1	2	3	4	5
1	2	3	4	5	6
2	3	4	5	6	7
3	4	5	6	7	8
4	5	6	7	8	9
5	6	V	8	9	10
5	6	7	1	E	

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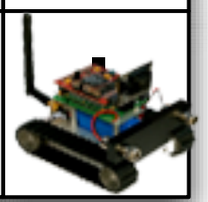
5	6	7	1	E	

- Brick&Mortar: 33 steps to find a 7 cells evacuation path.

Route Discovery

E	1	2	3	4	5
1	2	3	4	5	6
2	3	4	5	6	7
3	4	5	6	7	8
4	5	6	7	2	3
5	6		2	1	2
5	6	7	1	E	1

- Brick&Mortar: 33 steps to find a 7 cells evacuation path.
- Ants: 48 steps to find a 3 cells evacuation path.

Route Discovery

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1	2	3	4	5	6
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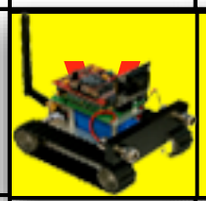
4	5	6	7	2	3
5	4		2	1	2
4	3	2	1	E	1

- Brick&Mortar: 33 steps to find a 7 cells evacuation path.
- Ants: 48 steps to find a 3 cells evacuation path.
- MDFS: 50 steps to find a 3 cells evacuation path.

What if we change our communication assumptions?

- *Agent2Tag:* agents communicate indirectly by reading and updating the state of tags.

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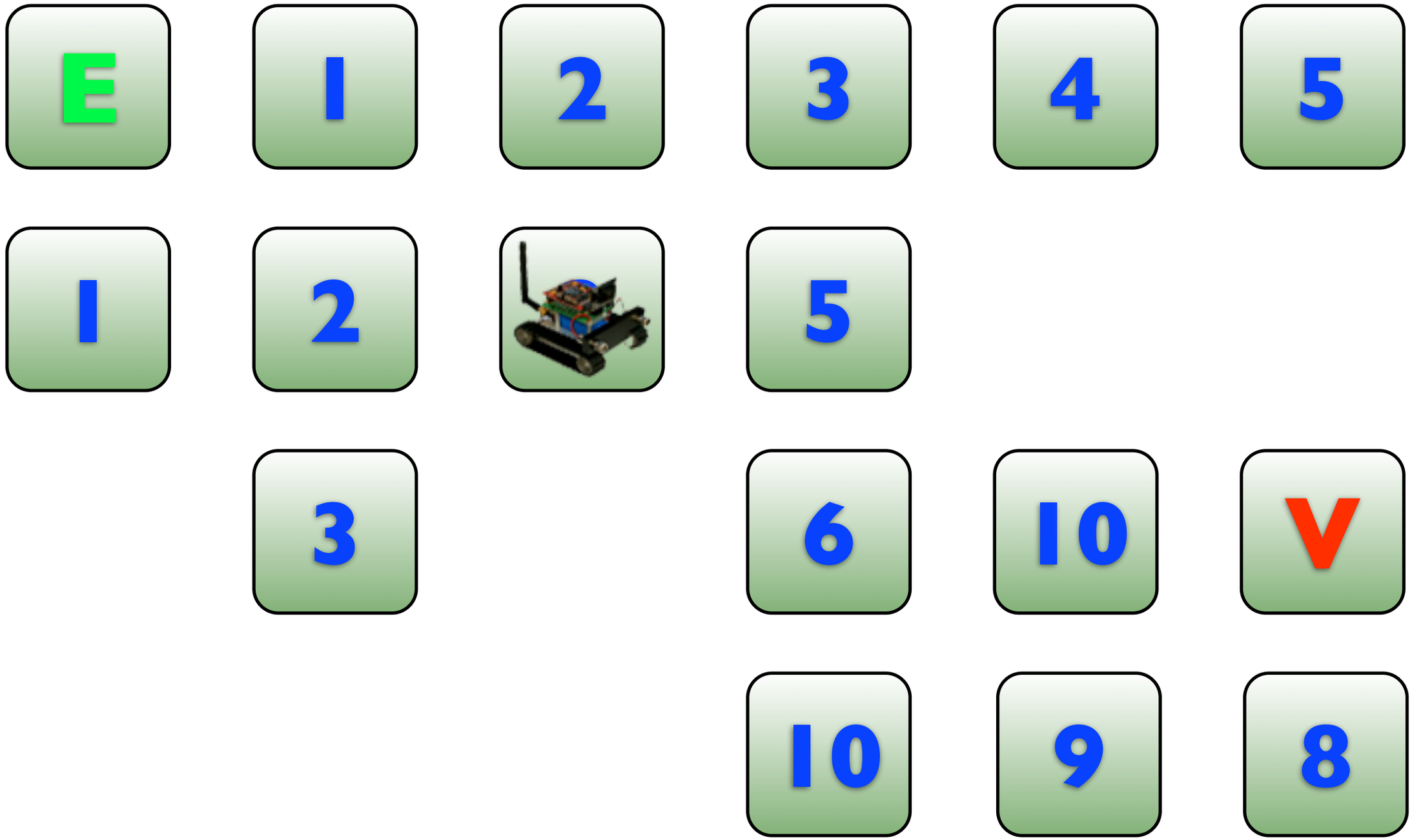
- *Tag2Tag:* tags can exchange messages to update their state.

Evacuation Paths (Tag2Tag)

- A **message** is sent to the adjacent neighbours each time the **distance** value of a cell is changed.



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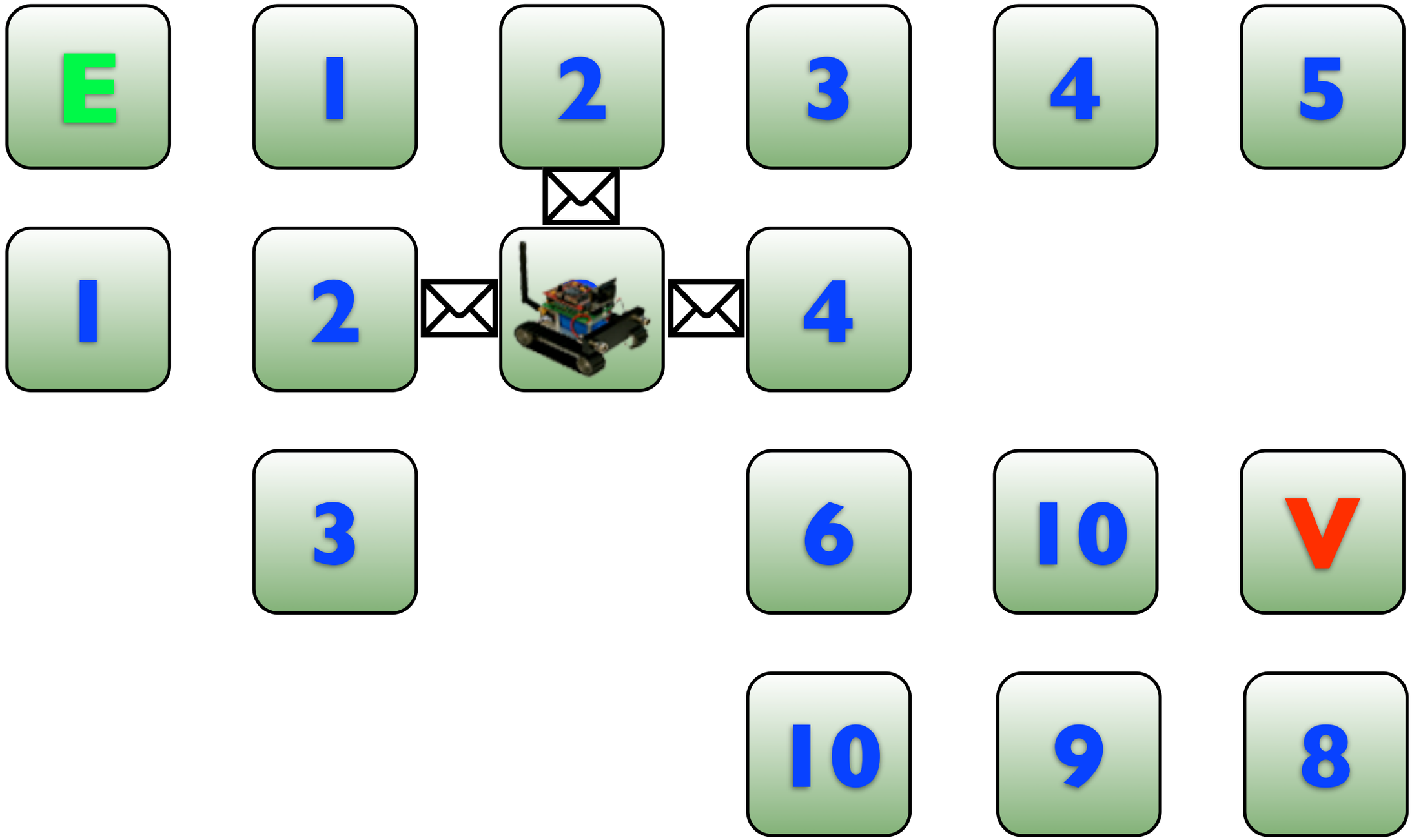

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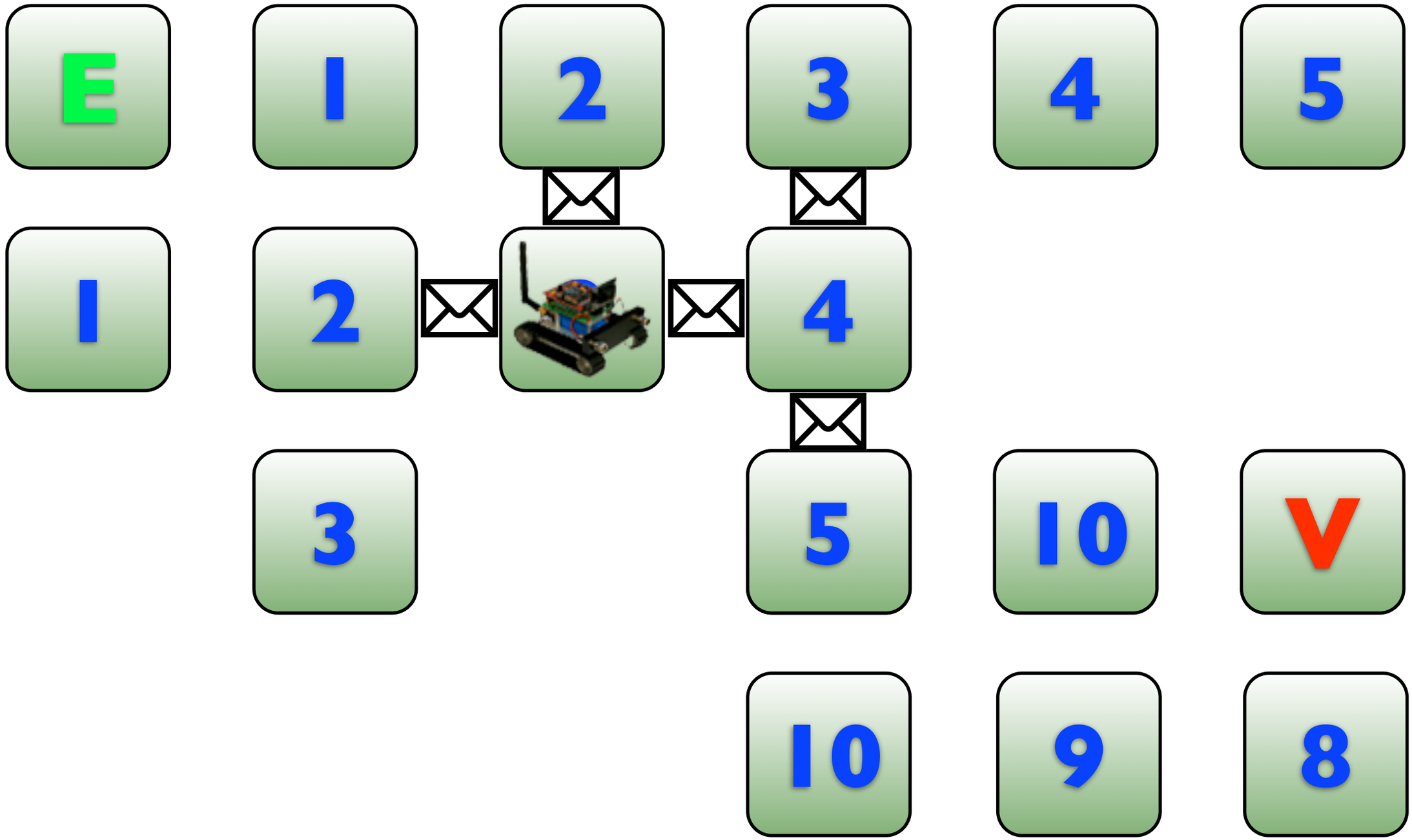

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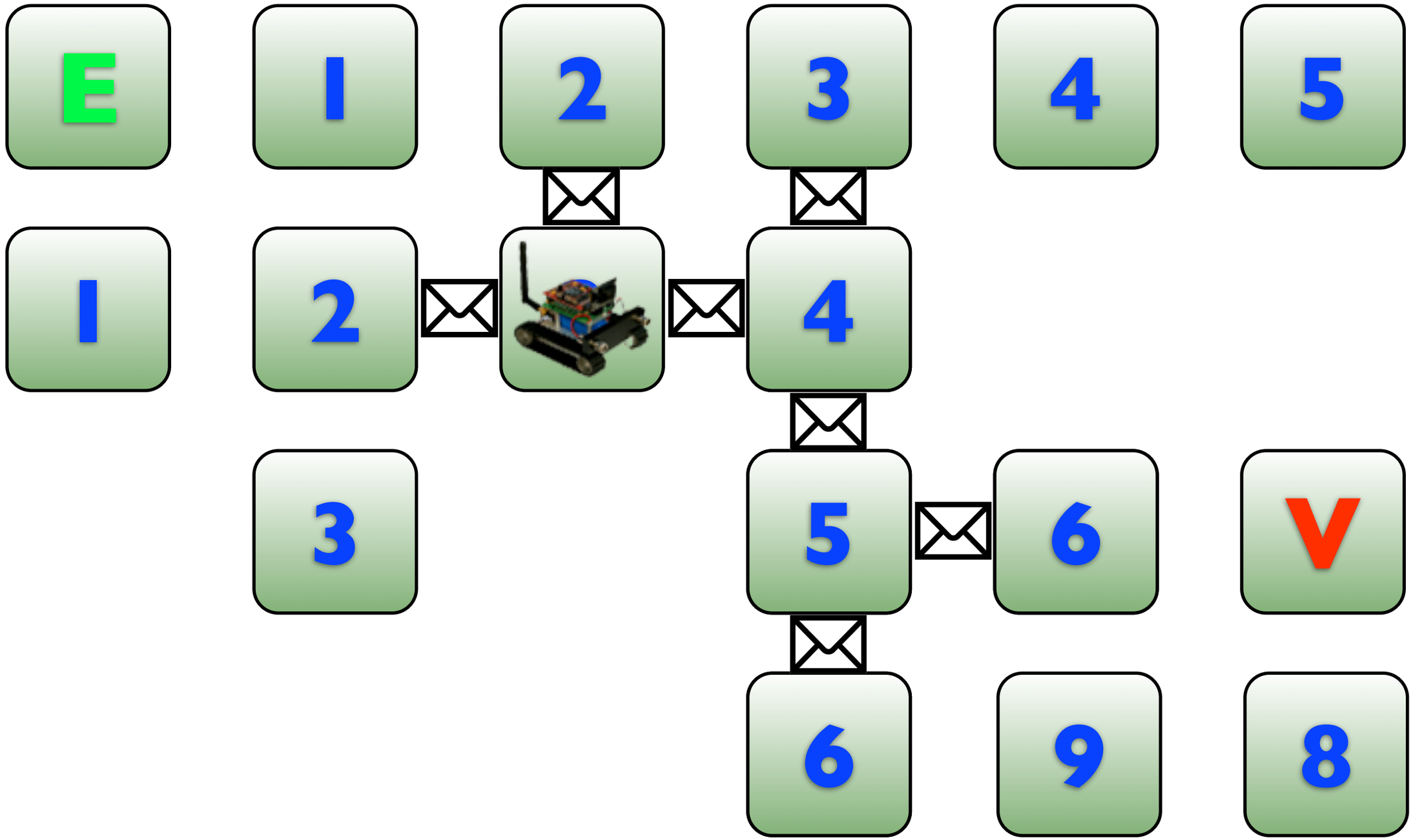

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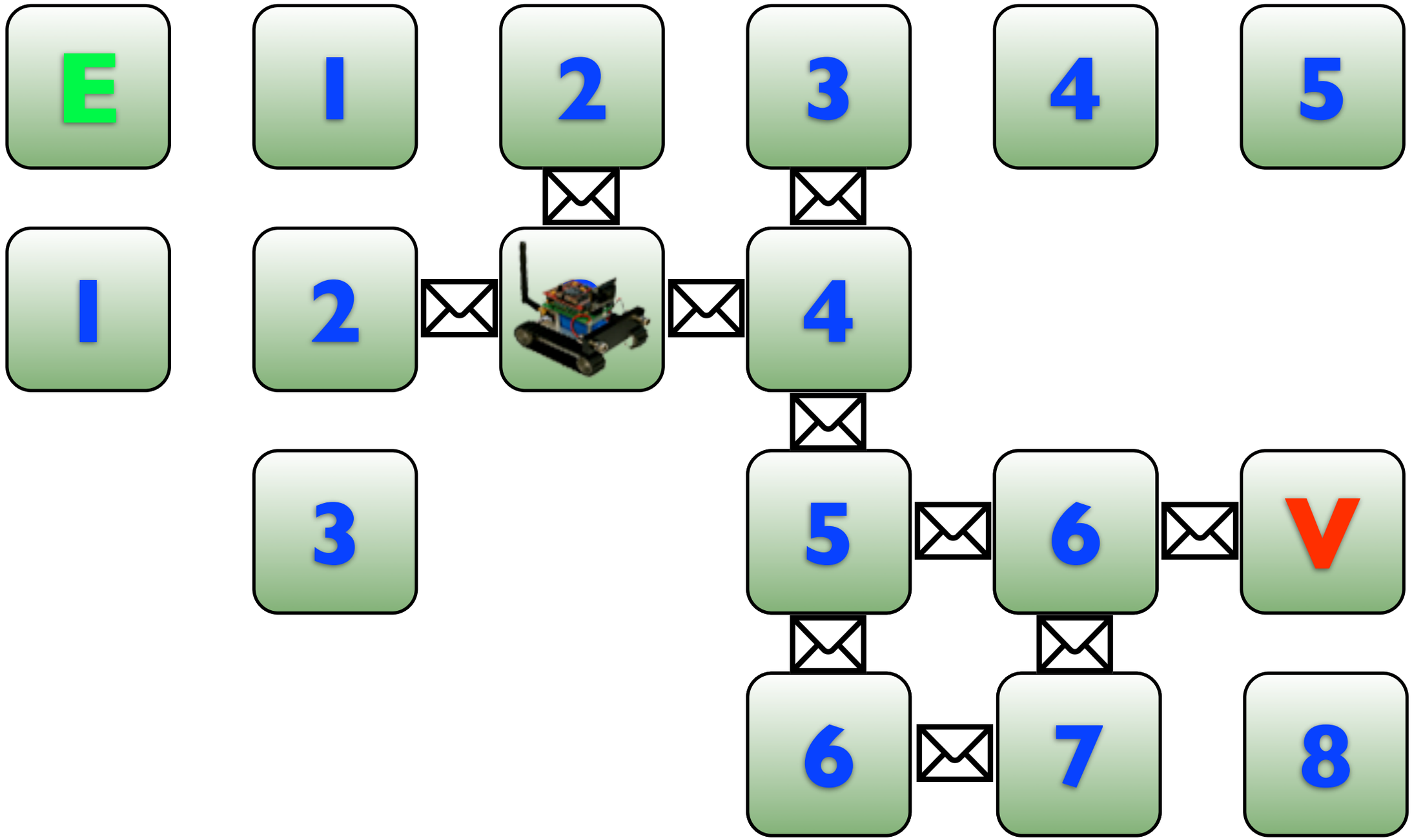
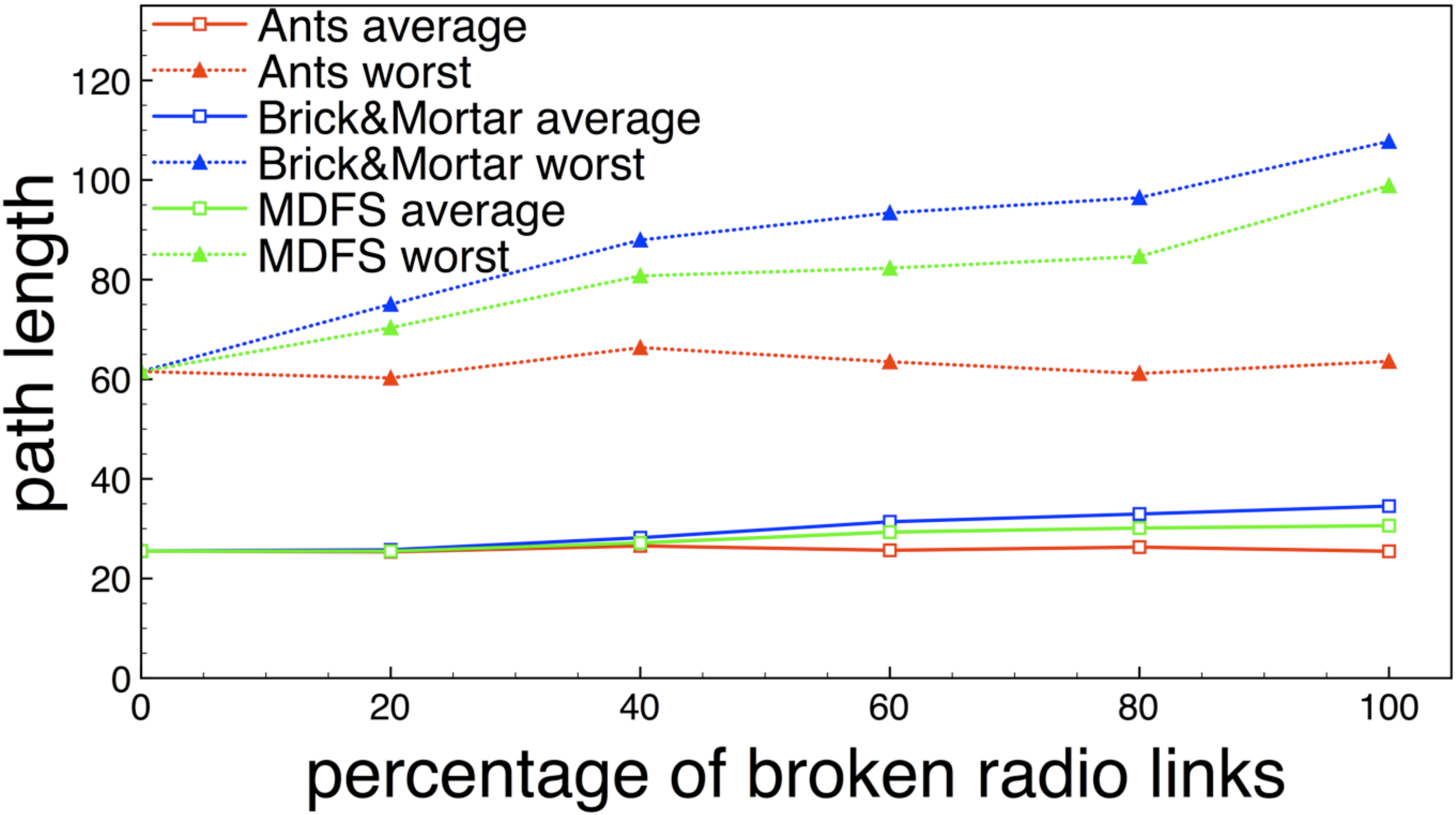
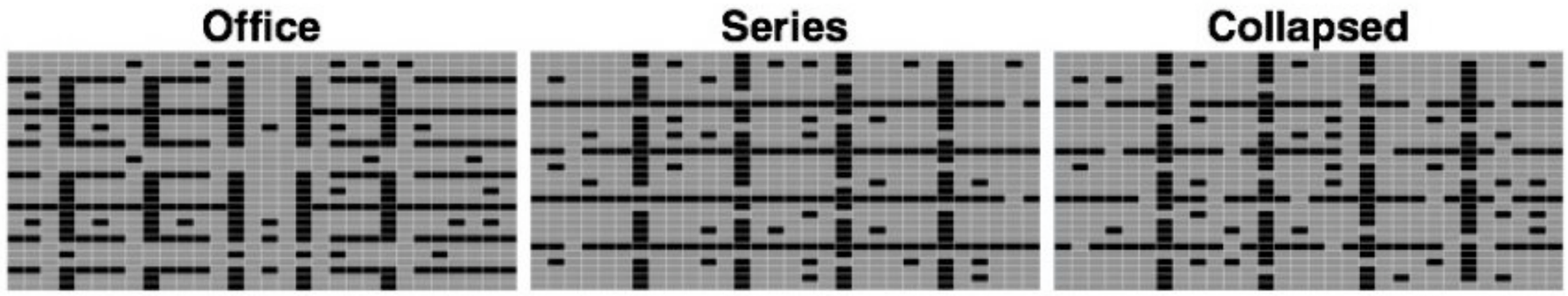


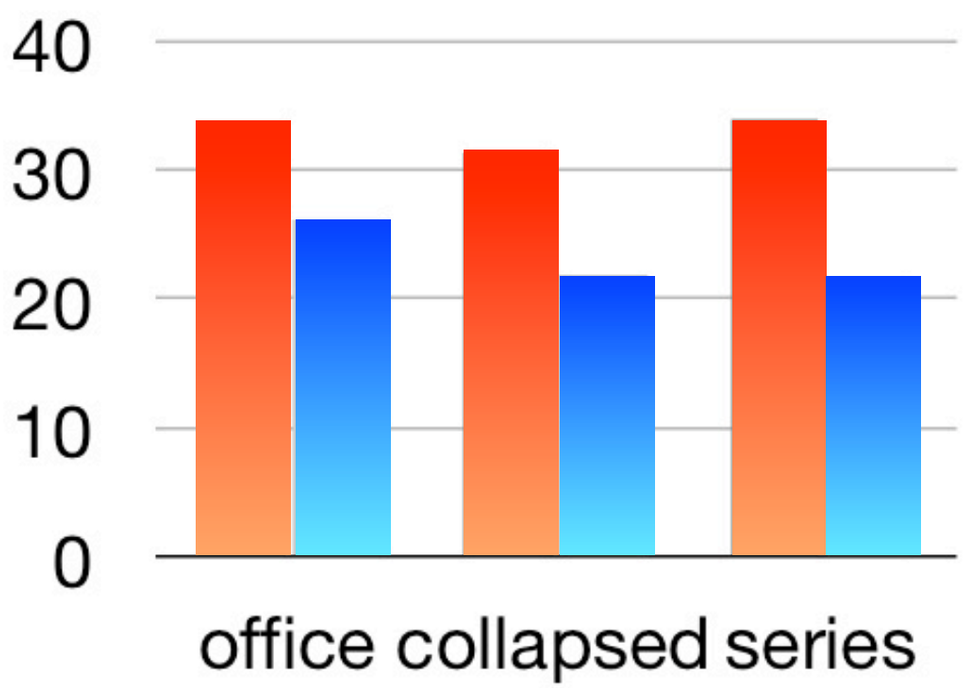
Impact of Tag2Tag



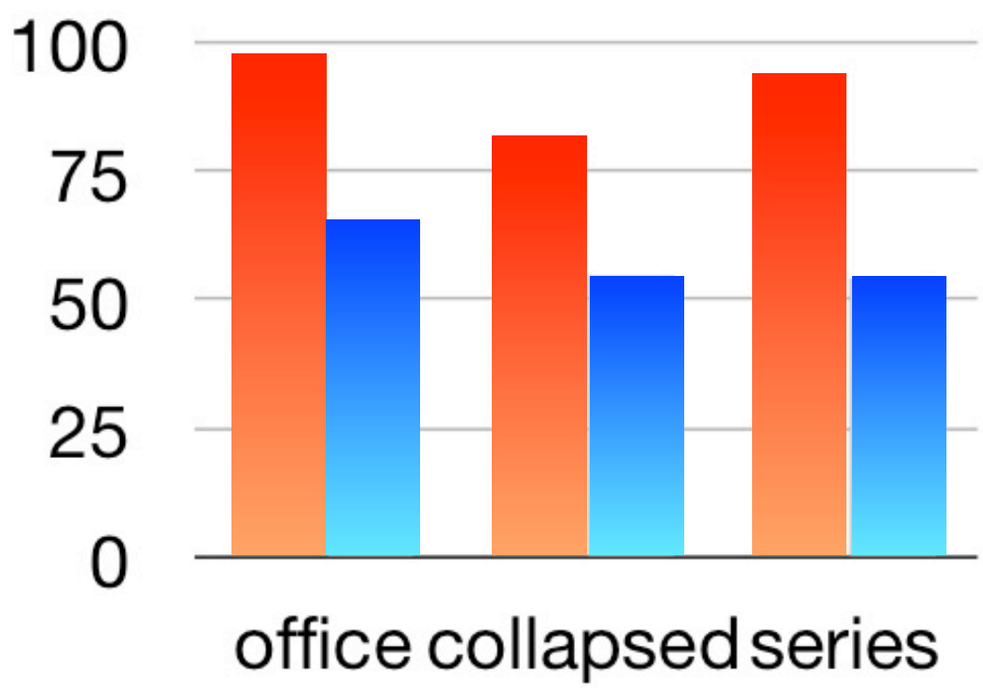
B&M in Different Scenarios



average path length



longest path length



Agent2Tag- B&M

Tag2Tag- B&M

Conclusions

- Without Tag2Tag, faster algorithms are not better in finding good evacuation paths. In particular, Brick&Mortar tends to be the fastest but yields longer evacuation paths.
- With Tag2Tag, all algorithms find shortest length evacuation paths. Among them, Brick&Mortar is preferred because it is the the fastest one.

Thank you!

...questions?