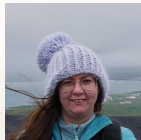


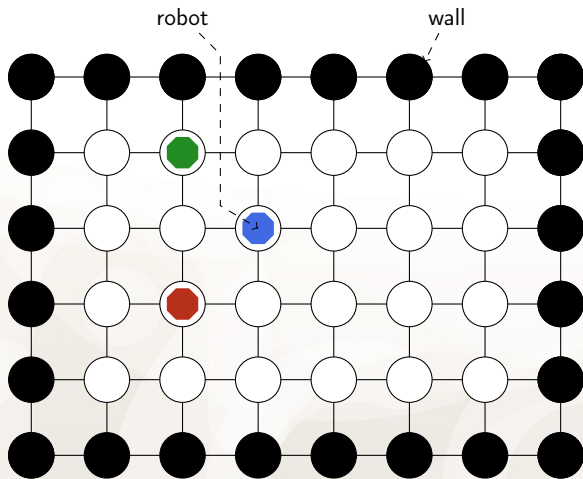
# Optimal Asynchronous Perpetual Grid Exploration

Quentin Bramas, Stéphane Devismes, **Anaïs Durand**  
Pascal Lafourcade, Anissa Lamani



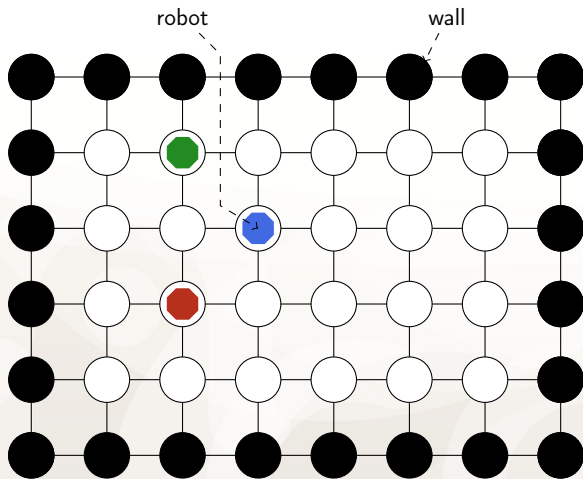
October 20th, 2024

# Computational Model



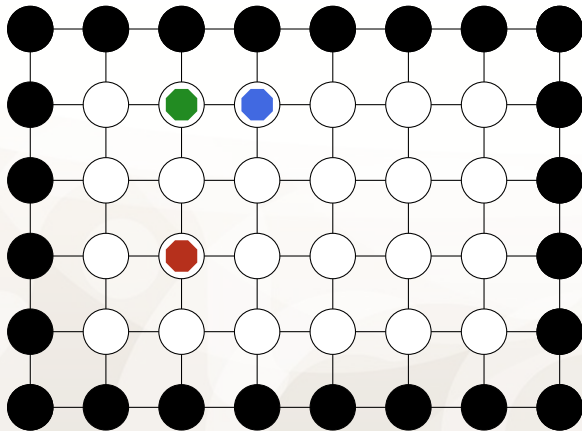
- ▶ Finite grid
- ▶ Autonomous mobile robots
- ▶ Perpetual exploration

# Computational Model



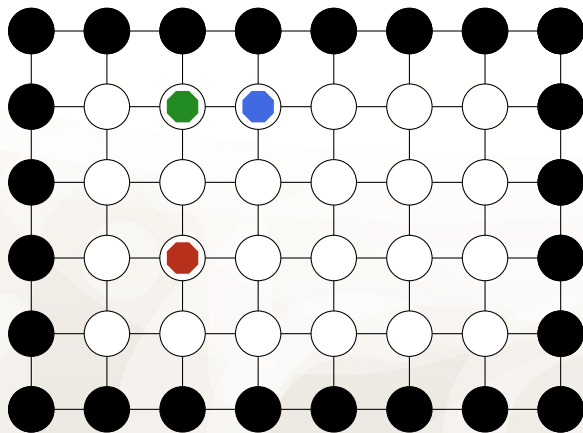
- ▶ Finite grid
- ▶ Autonomous mobile robots
- ▶ **Perpetual exploration**
- ▶ Discrete moves

# Computational Model



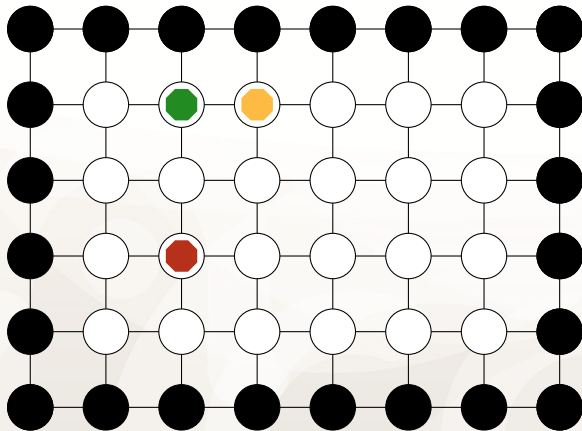
- ▶ Finite grid
- ▶ Autonomous mobile robots
- ▶ **Perpetual exploration**
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# Computational Model



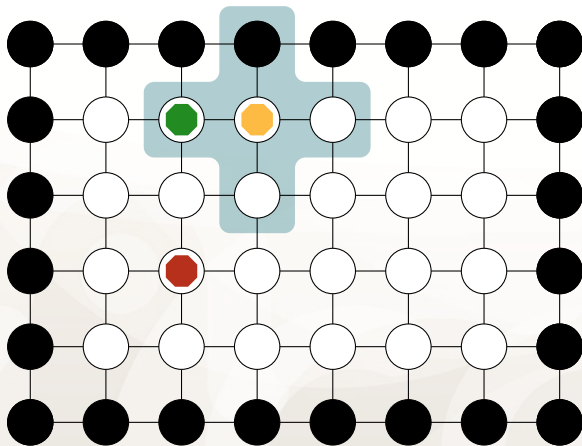
- ▶ Finite grid
- ▶ Autonomous mobile robots
- ▶ **Perpetual exploration**
- ▶ Discrete moves
- ▶ Lights of different colors

# Computational Model



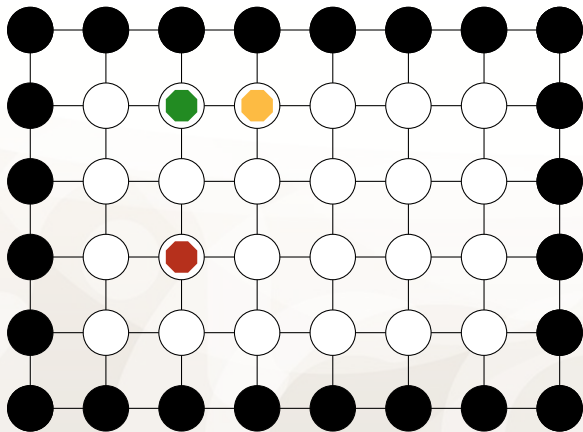
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# Computational Model



- ▶ Finite grid
- ▶ Autonomous mobile robots
- ▶ **Perpetual exploration**
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- ▶ Lights of different colors
- ▶ Limited visibility range

# Computational Model



- ▶ Finite grid
- ▶ Autonomous mobile robots
- ▶ **Perpetual exploration**
- ▶ Discrete moves
- ▶ Lights of different colors
- ▶ Limited visibility range
- ▶ No memory or direct communication



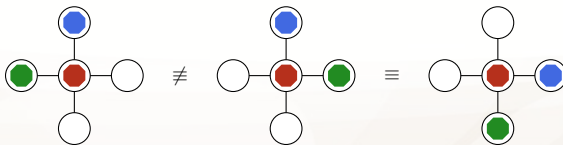
# Computational Model: Orientation System

- ▶ No compass or global coordinate system
- ▶ **With common chirality:**



# Computational Model: Orientation System

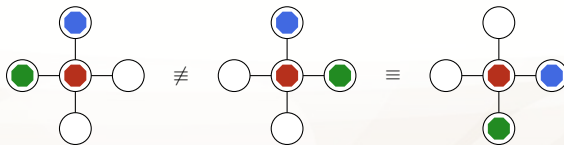
- ▶ No compass or global coordinate system
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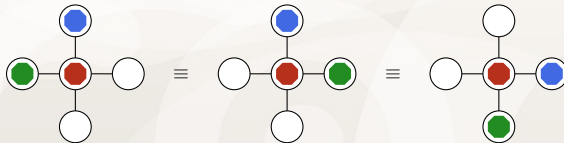
# Computational Model: Orientation System

▶ No compass or global coordinate system

▶ With common chirality:






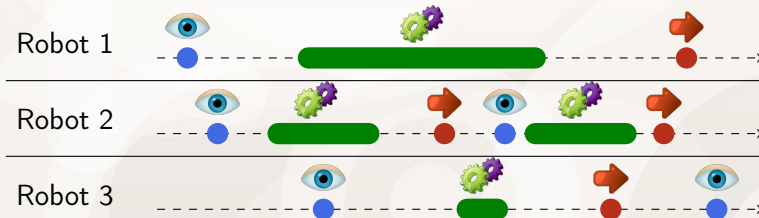
▶ Without common chirality:



# Computational Model: Asynchronous Look-Compute-Move

[Suzuki and Yamashita, 99]

- ▶ **Look** : Snapshot its surrounds within the visibility range (instantaneous)
- ▶ **Compute** : Computation of its new destination based on the snapshot & change of color
- ▶ **Move** : Move towards its destination (instantaneous)



Asynchronous perpetual grid exploration with luminous robots

Chirality	Visibility	Robots	Colors	Possible?
✓	1	finite	finite	✗

Asynchronous perpetual grid exploration with luminous robots

Chirality	Visibility	Robots	Colors	Possible?
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# Contributions

Asynchronous perpetual grid exploration with luminous robots

Chirality	Visibility	Robots	Colors	Possible?
✓	1	finite	finite	✗
	2	$\leq 3$	1	✗
	2	3	2	✓ [ <i>Bramas et al., 23</i> ]
	2	4	1	✓

# Contributions

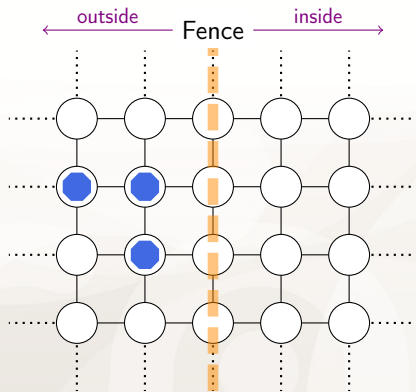
Asynchronous perpetual grid exploration with luminous robots

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	2	4	1	✓
✗	2	3	2	✓
	3	3	1	✓



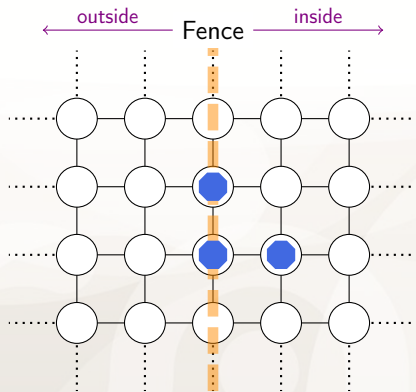
# Impossibility of Asynchronous PGE with Visibility Range 1

**Test of the fence:** A group of robots can move from outside to inside a fence without leaving a robot behind



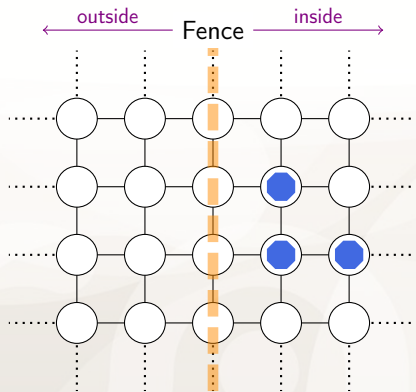
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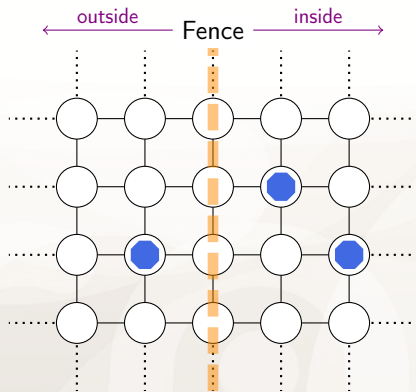
**Test of the fence:** A group of robots can move from outside to inside a fence without leaving a robot behind



Success ✓

# Impossibility of Asynchronous PGE with Visibility Range 1

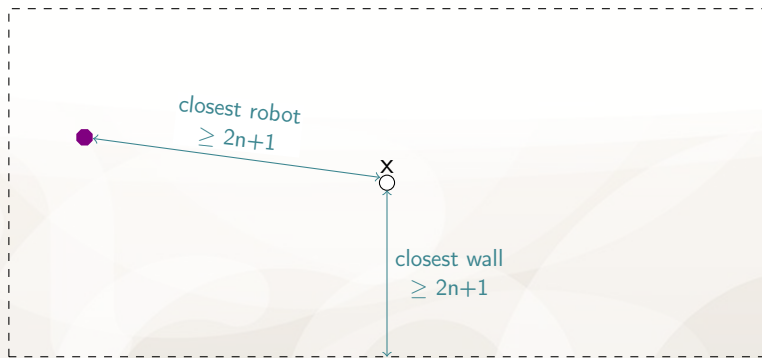
**Test of the fence:** A group of robots can move from outside to inside a fence without leaving a robot behind



Fail ❌

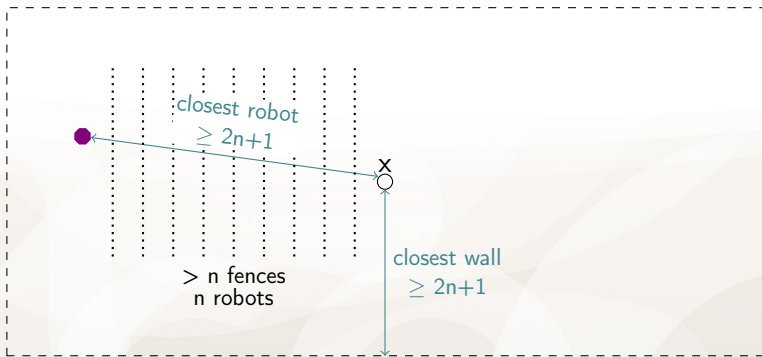
# Impossibility of Asynchronous PGE with Visibility Range 1

If an algorithm **fails** the test of the fence:



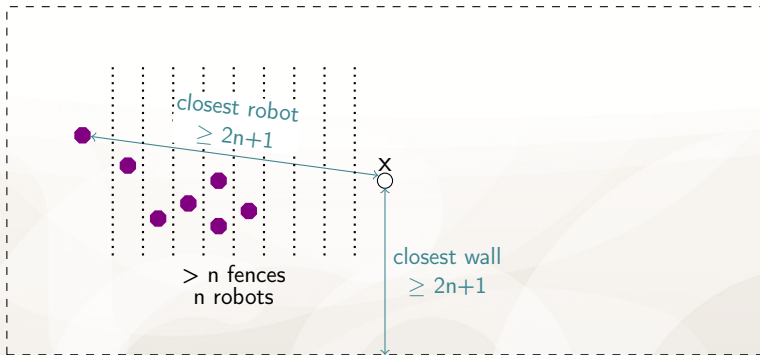
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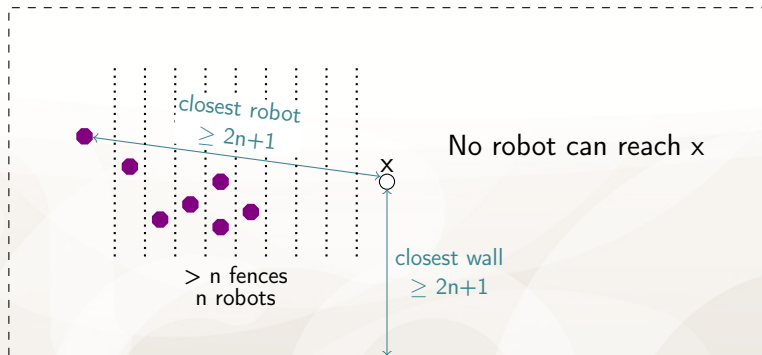
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# Impossibility of Asynchronous PGE with Visibility Range 1

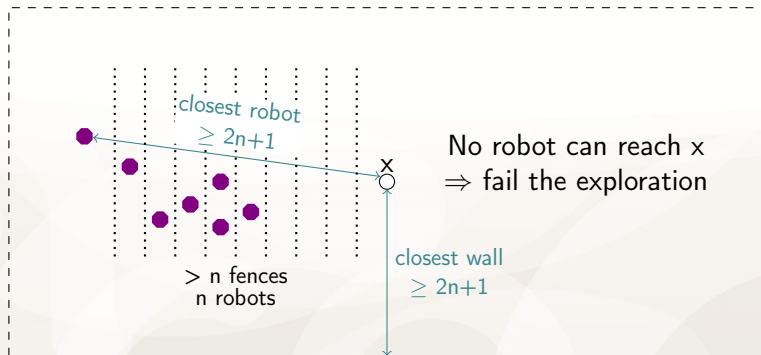
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# Impossibility of Asynchronous PGE with Visibility Range 1

**By contradiction**, assume an asynchronous PGE algorithm with visibility range 1 (whatever the number of robots, with or without common chirality)

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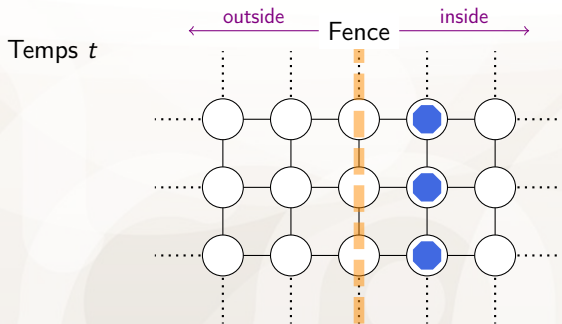
**By contradiction**, assume an asynchronous PGE algorithm with visibility range 1 (whatever the number of robots, with or without common chirality)

**Asynchronous**  $\Rightarrow$  can choose a scheduler that selects robots **one-by-one** (round-robin) for full LCM-cycle

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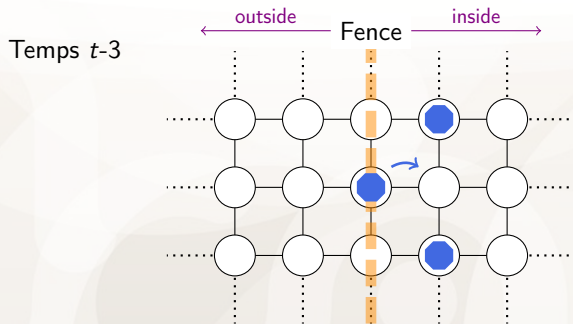
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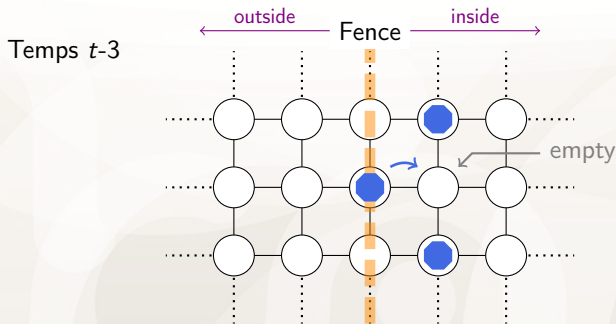
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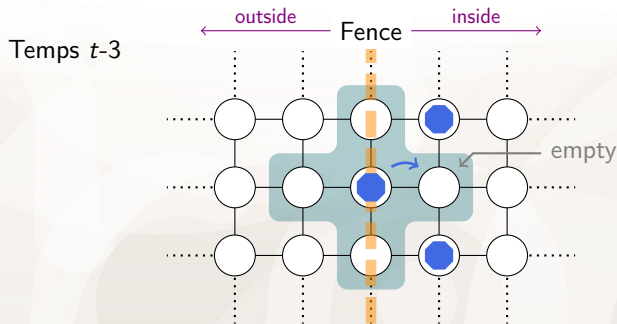
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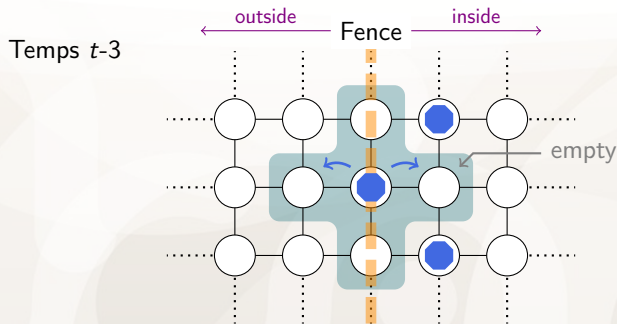
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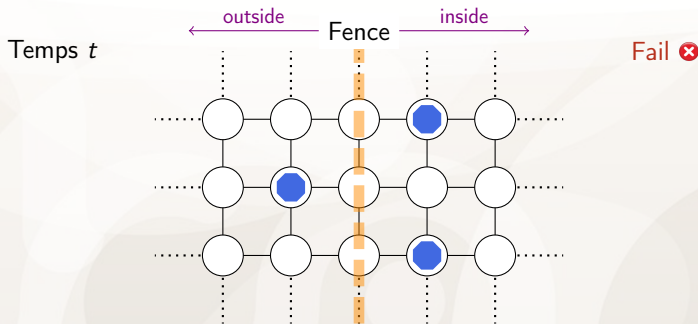




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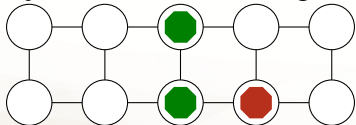
# Contributions

Asynchronous perpetual grid exploration with luminous robots

Chirality	Visibility	Robots	Colors	Possible?
✓	1	finite	finite	✗
	2	$\leq 3$	1	✗
	2	3	2	✓ [Bramas et al., 23]
	2	4	1	✓
✗	2	3	2	✓
	3	3	1	✓

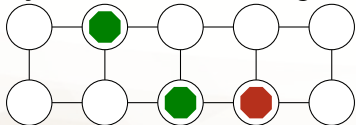
# Algorithm for 3 robots, 2 colors, visibility range 2, and without common chirality

Locally-defined Initial Configurations:



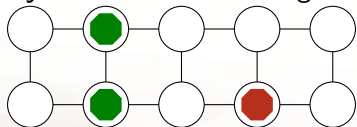
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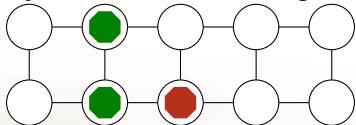
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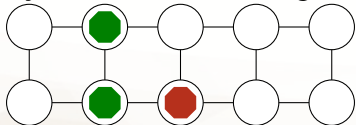
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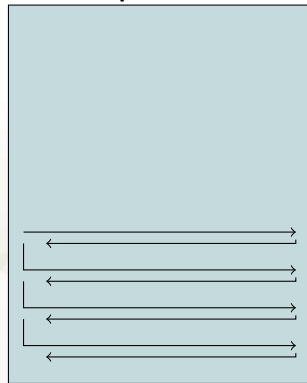


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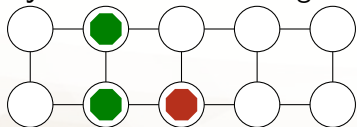


Exploration:

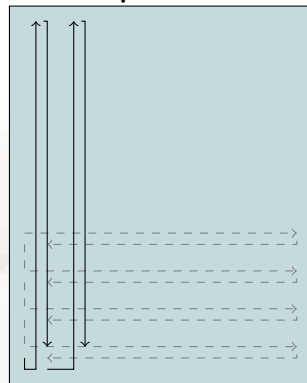


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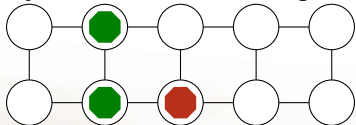
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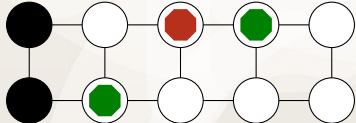


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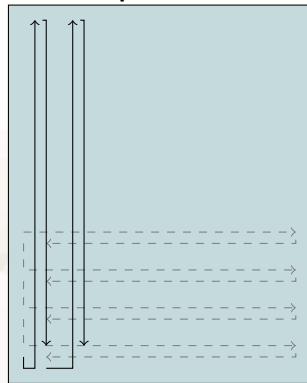
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Pattern:

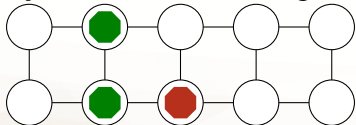


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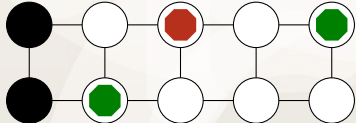


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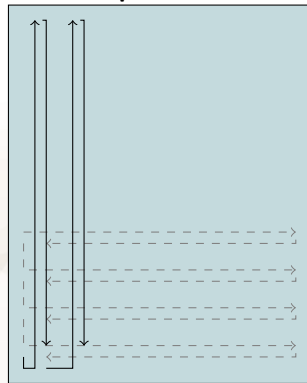
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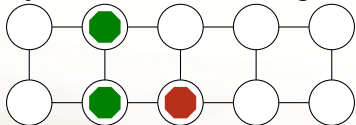


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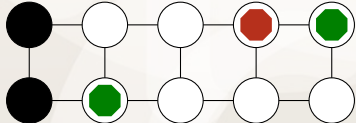


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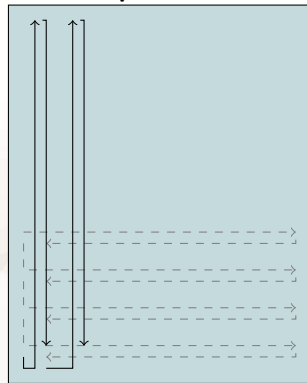
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# Conclusion

Asynchronous perpetual grid exploration with luminous robots

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} optimal

# Conclusion

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not locally defined

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assume transparency