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Task Allocation in Foraging Robot Swarms: The Role of Information Sharing

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Task allocation

- **Repeatedly** adjust the number of working and idle robots in order to improve **the energy efficiency** of the swarm when **congestion** prevents robots from working

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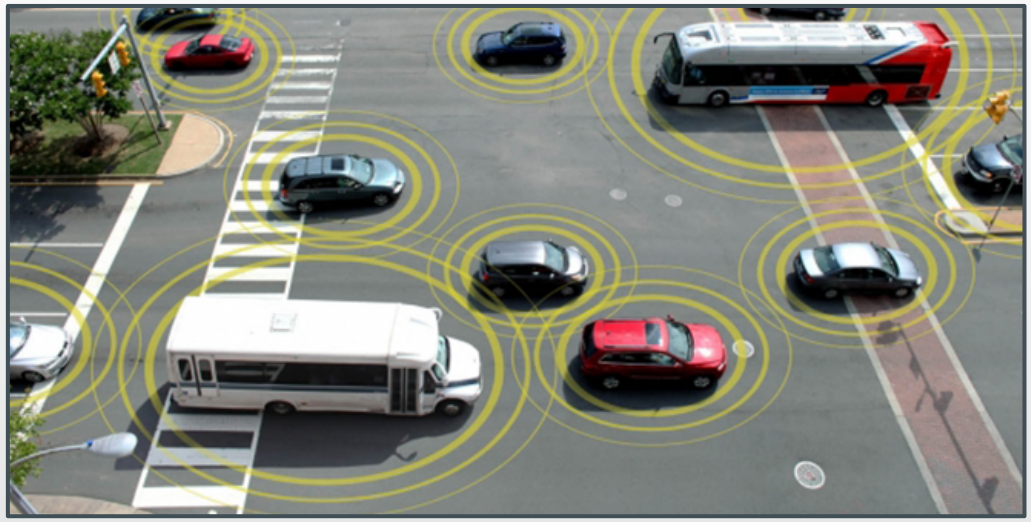
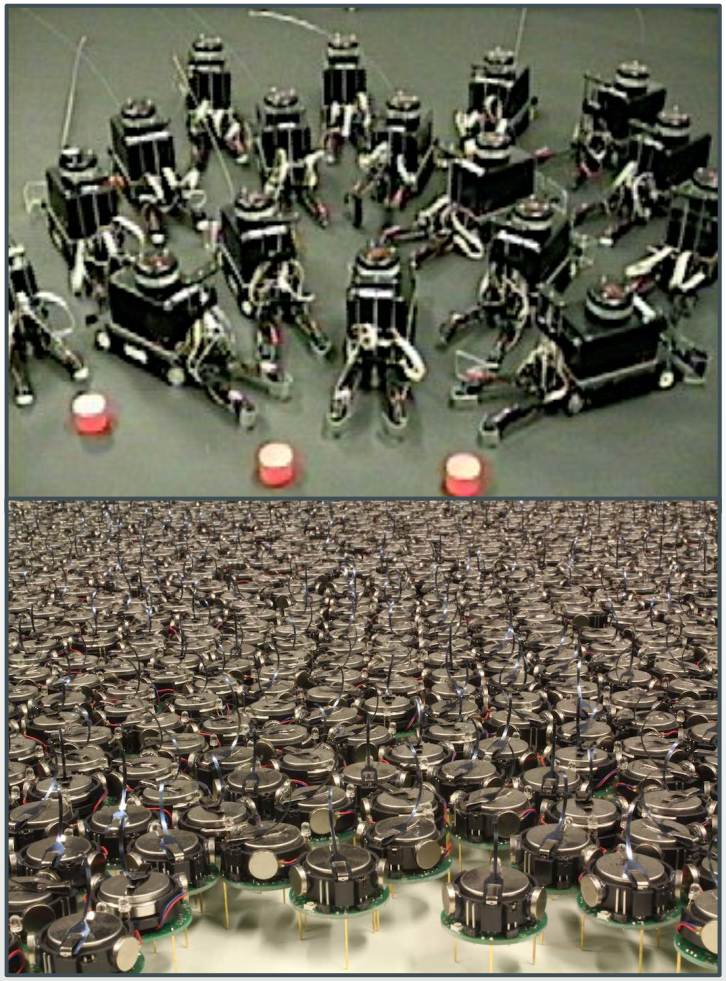
Task allocation

- Item collection and delivery
- Autonomous cars, robotic taxis
- **Congestion prevention**





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Task allocation

- Congestion can result from
  - Size of the robot swarm
  - Nature of the task

- Desired response
  - Decrease the number of workers to prevent or deal with congestion
  - Increase the number of workers when the work space has cleared out
  - **Adapt** to changing congestion conditions

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Task allocation

- How can a robot swarm prevent congestion in a **decentralised** manner?

- Why should it?
  - Save energy
  - Perform more work

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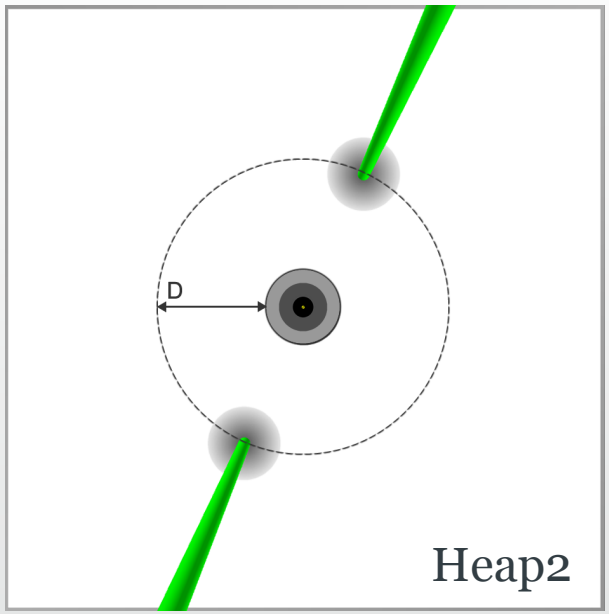
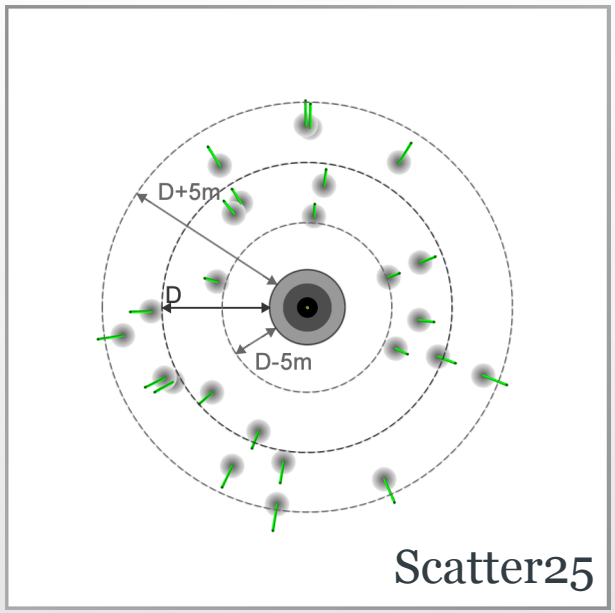
Our model

- Foraging in continuous space from deposits with unlimited volume
- Heap-N: N deposits, D m away from the base



- Scatter-N: N deposits, D±5 m away from the base



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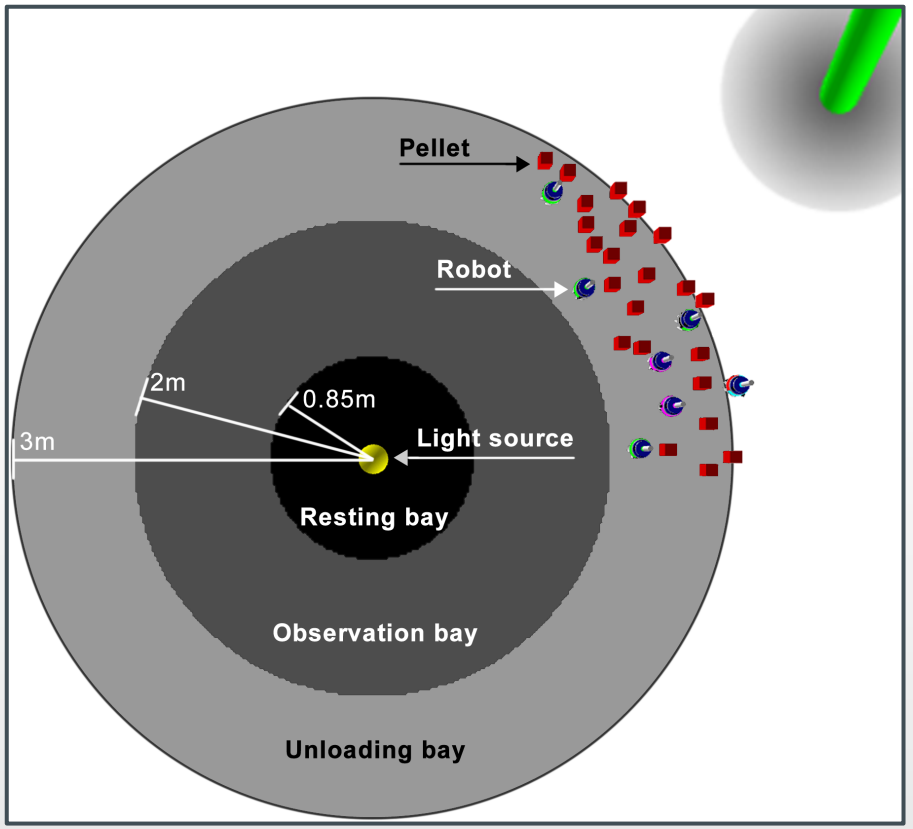
Our model

- Unloading bay
  - Robots drop off collected material
  - Material handling time t_H
- Observation bay
  - Unemployed robots wait to be recruited
- Resting bay
  - Idle robots wait there



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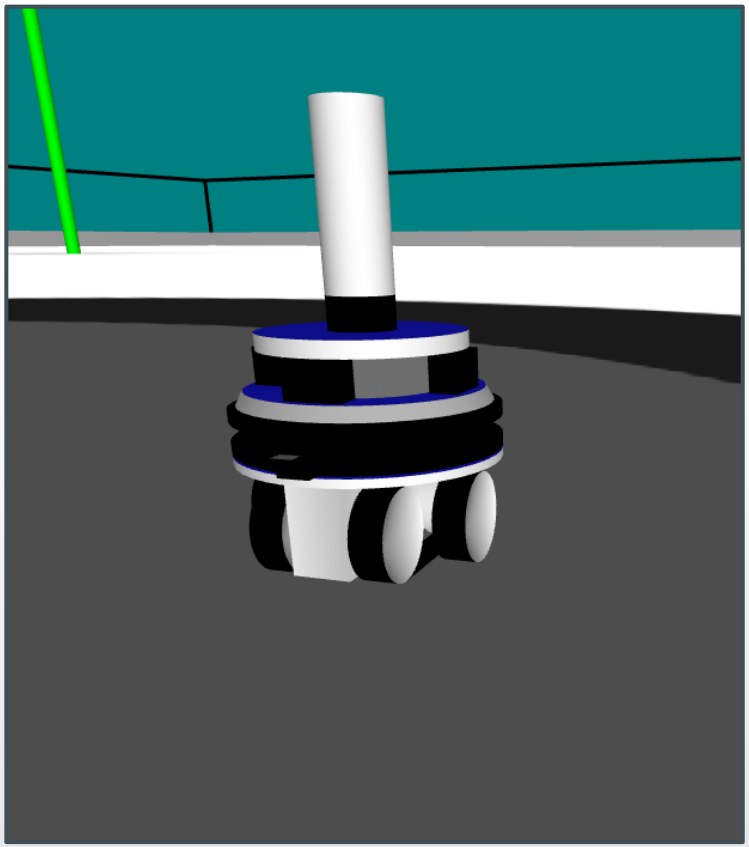
Our model

- Three swarm types:
  - Control: no self-regulation
  - Non-social self-regulation
    - Robots become idle when they sense congestion
  - Social self-regulation
    - Robots signal others to become idle upon sensing congestion



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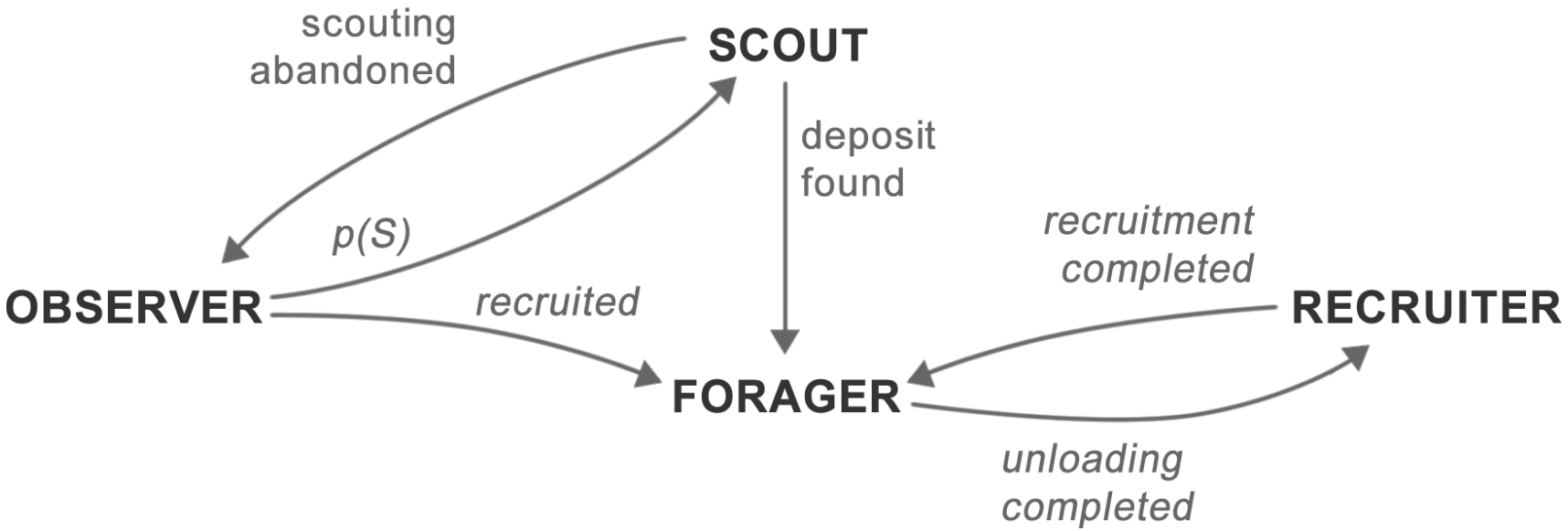
The control swarm



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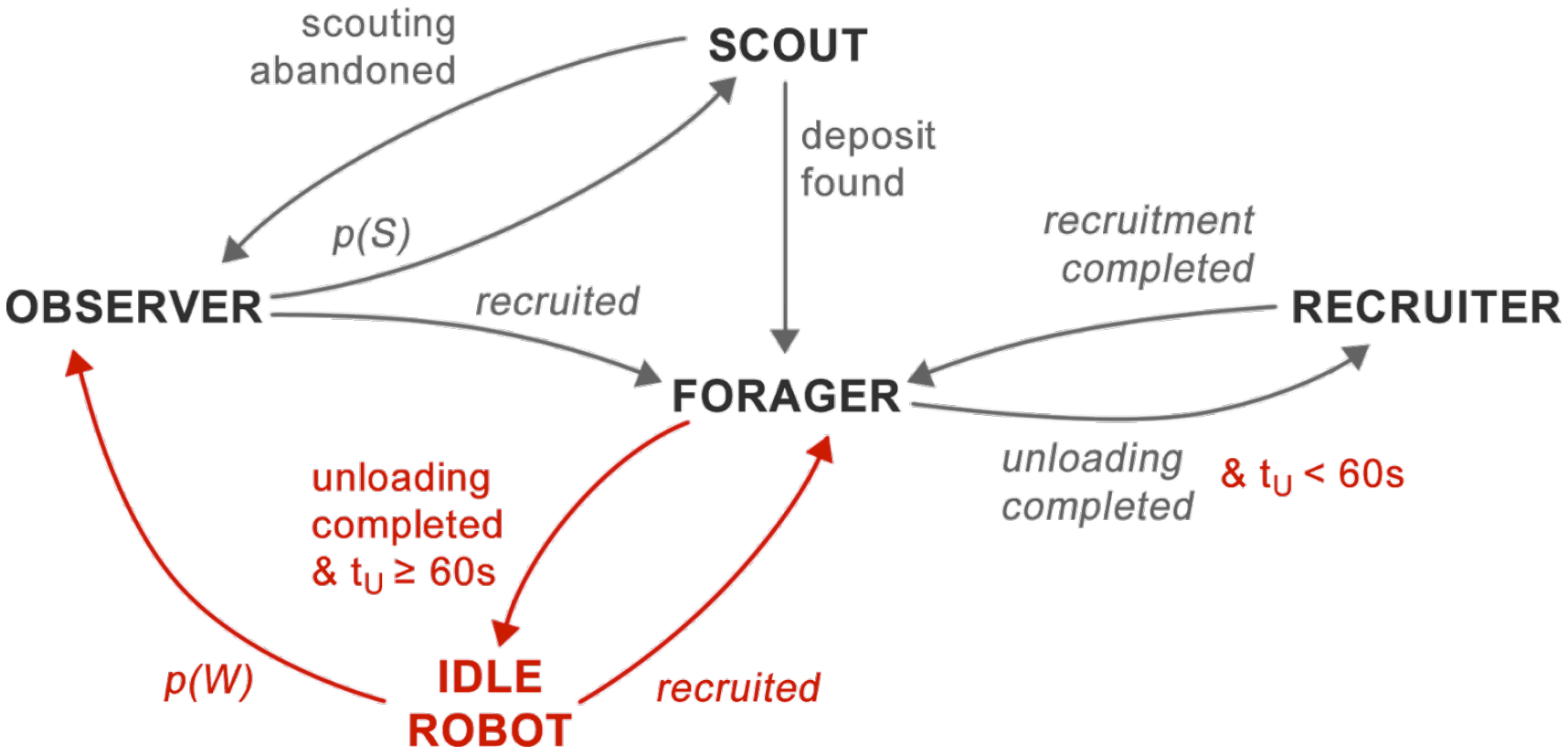
Non-social self-regulation



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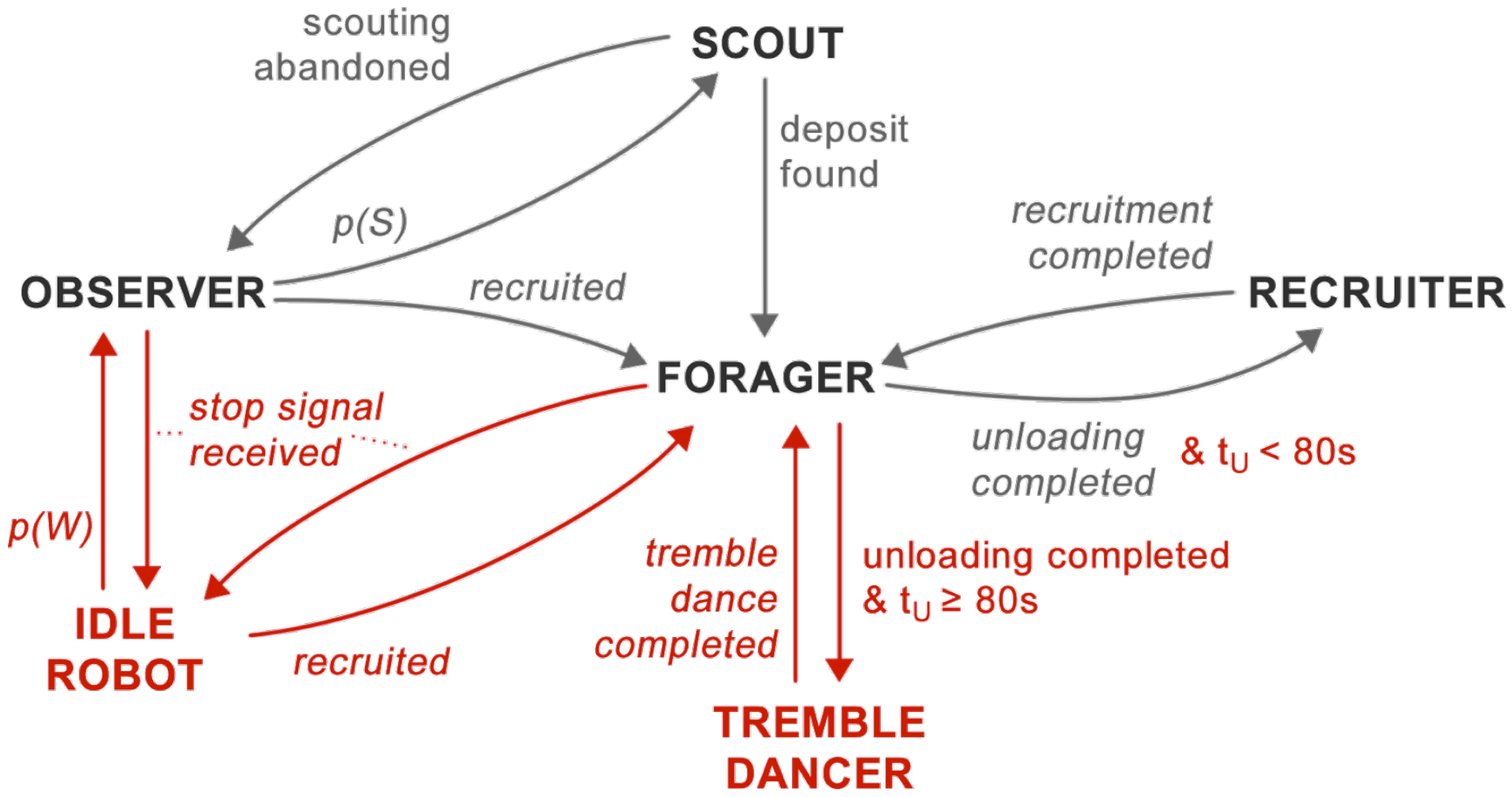
Social self-regulation



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Performance measures

- The total amount of resource collected in 4 hours
- Swarm energy efficiency

$$C = R / E$$

R: Total amount of resource collected
E: Total amount of energy spent by the swarm

- A robot normally spends 1 unit of energy per second. It spends 0 energy per second when it is idle.

The impact of congestion on foraging of control swarms

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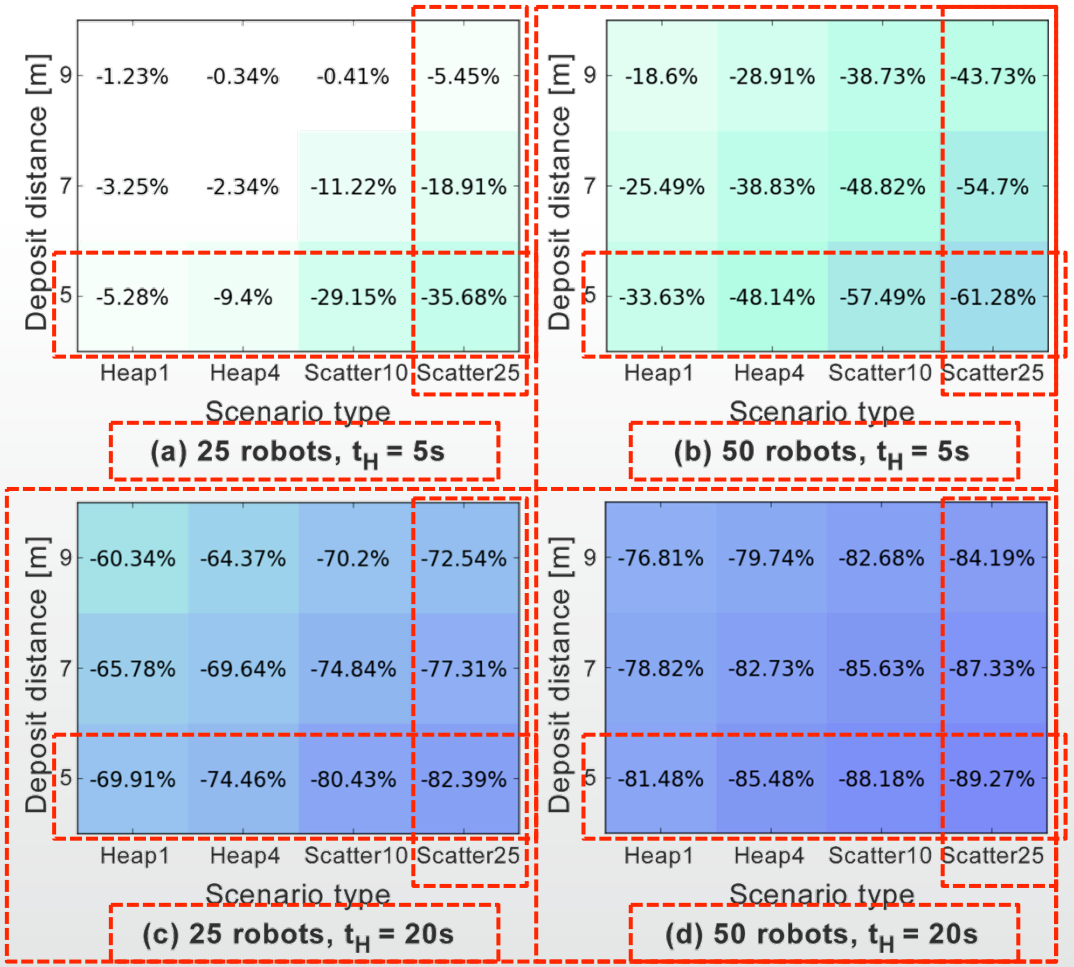
- The control swarms collect less resource due to congestion
- Performance affected more severely when:
  - More deposits
  - Smaller D
  - More robots
  - Pellets disappear slower



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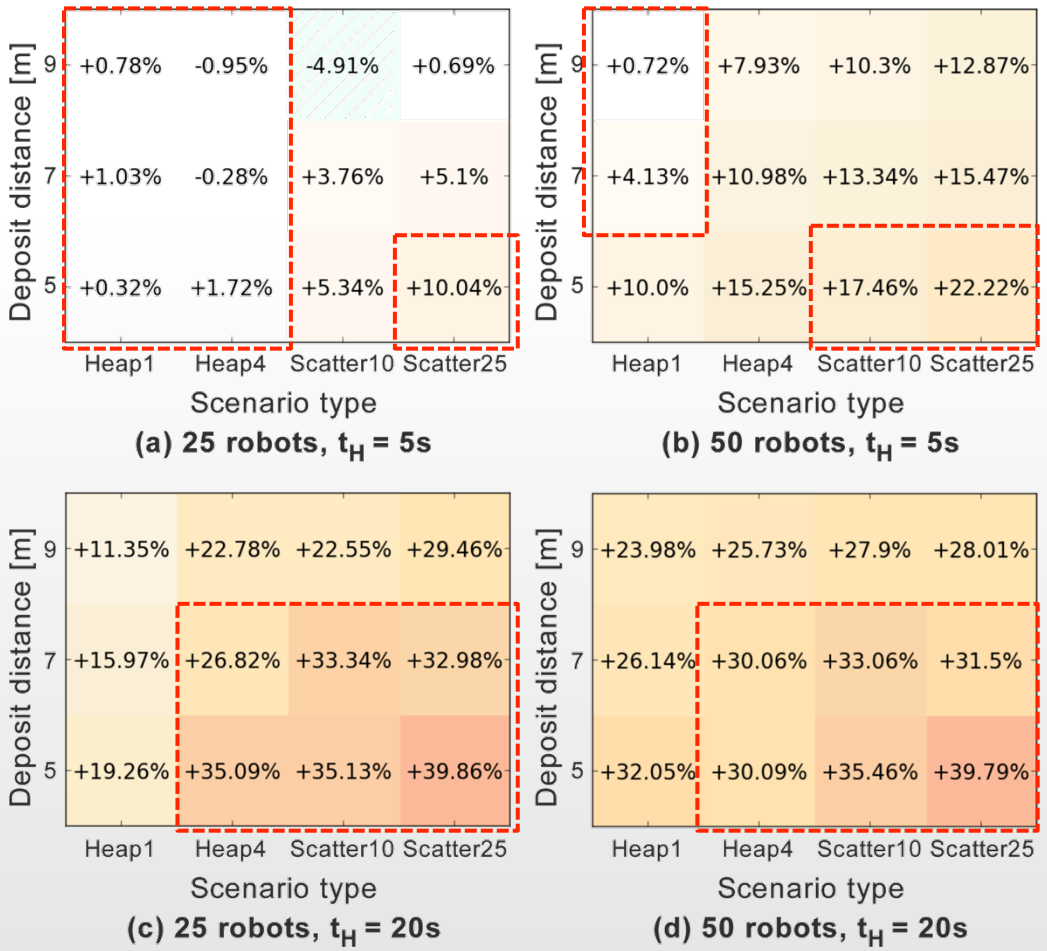
Energy efficiency
Non-social self-regulation

- Higher energy efficiency improvement over control swarms when congestion is severe
- Energy efficiency similar as control swarms when small amount of congestion



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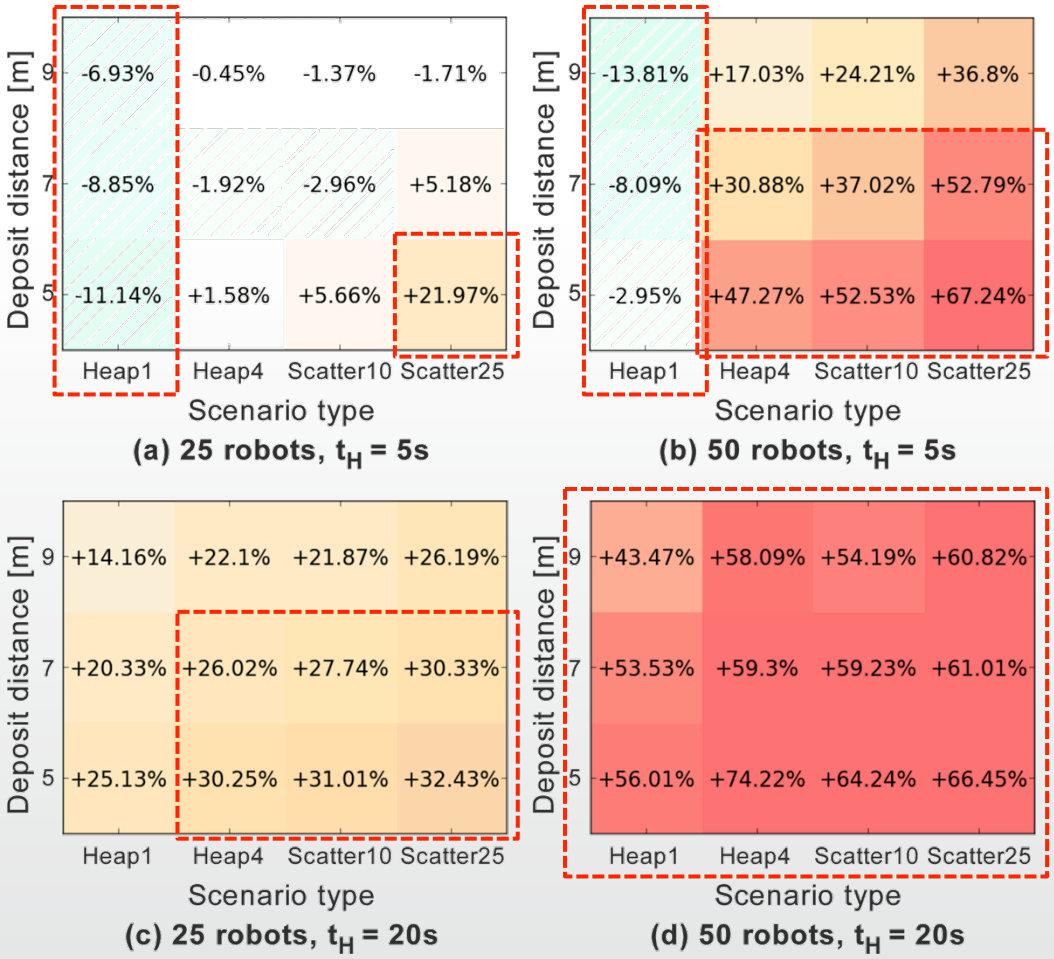
Energy efficiency
Social self-regulation

- Higher energy efficiency improvement when congestion is severe
  - More than with non-social self-regulation
- Lower energy efficiency when small amount of congestion or when there is 1 deposit



Resource collection

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- Do self-regulating swarms collect more resource than the control swarms [when swarm energy is limited]?

Resource collection

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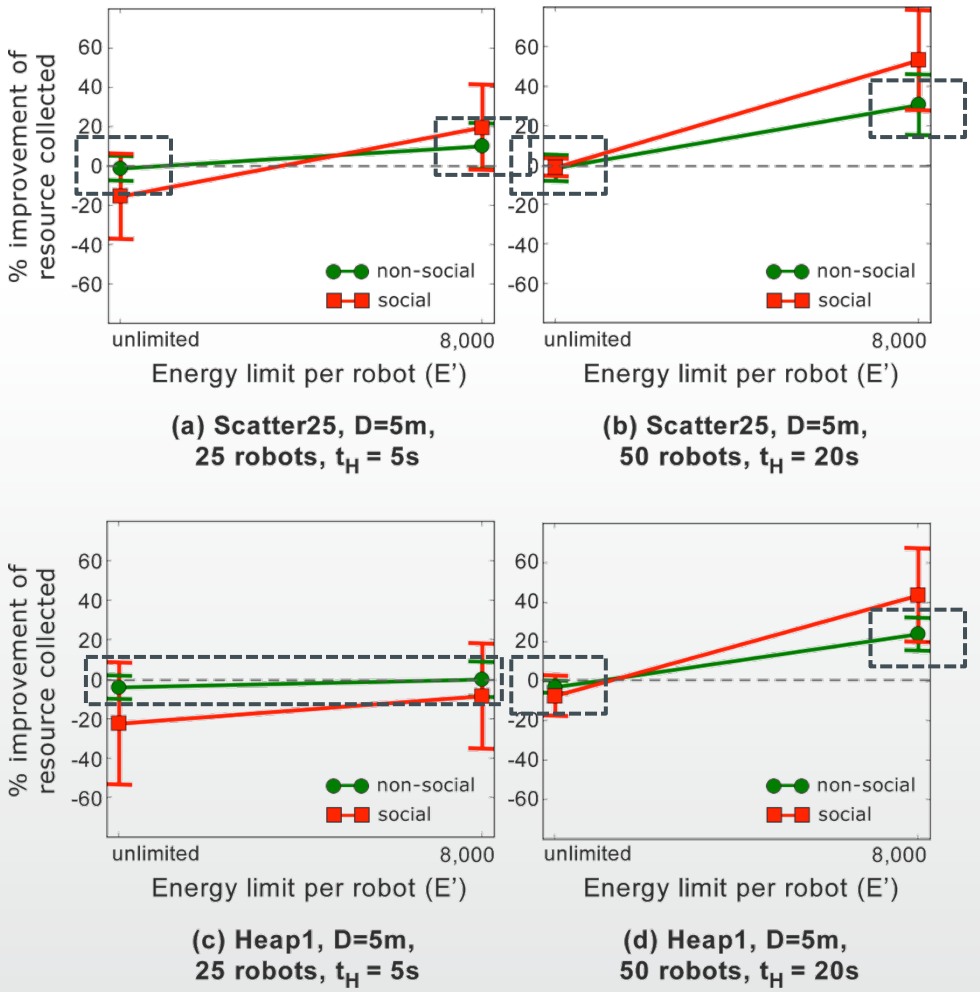
- **Non-social self-regulation:**
  - Improved performance when congestion is severe and energy is limited
  - Similar performance when congestion is mild or energy is unlimited



Resource collection

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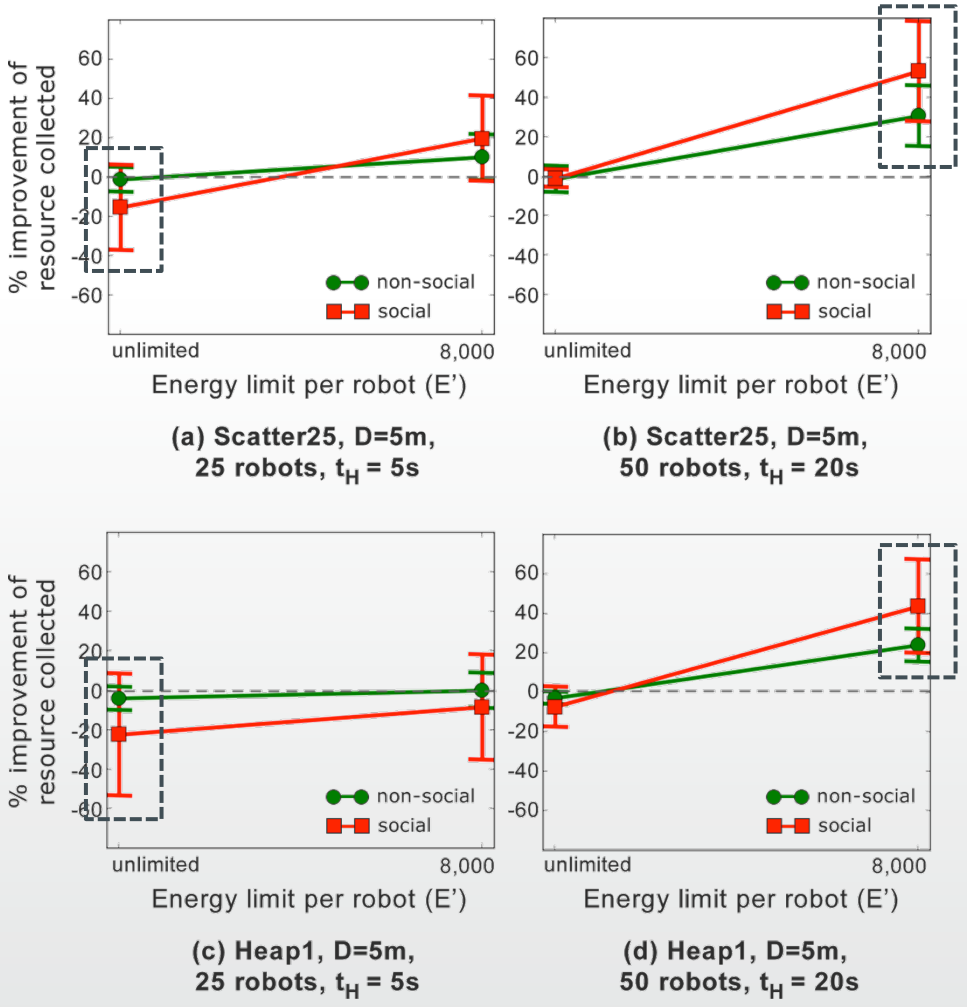
- **Social self-regulation:**
  - More improved performance when congestion is severe and energy is limited
  - Worse performance when congestion is mild and energy is unlimited



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Conclusion

- How can a foraging robot swarm prevent congestion in a **decentralised** manner?

- Non-social vs social self-regulation
  - Structure of the environment?
  - Amount of congestion?
  - Energy constraints?

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Conclusion

- Swarms with ***social*** self-regulation react **strongly**
  - Suitable in appropriate, known scenarios: severe congestion, limited energy
  - Bad performance when congestion is less severe or energy is unlimited
- Swarms with ***non-social*** self-regulation react more **subtly**
  - Suitable when we expect low congestion, unlimited swarm energy, or *when we do not know* what to expect

Information-based view

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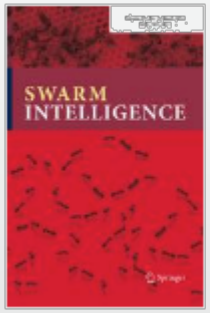
- Information flow: how fast does information [about congestion] spread across the swarm
  - Slower in swarms with non-social self-regulation, compared to swarms with social self-regulation
- ***Slow*** information flow leads to ***smaller variations*** in swarm performance
  - Reaction to congestion & deposit profitability:



Swarm Intelligence
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Information flow principles for plasticity in foraging robot swarms

Information-based view

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- **What is the appropriate information flow that fits the dynamics of the environment and of the task?**
  - Slow: mediocre improvements, rarely damages performance
  - Fast: extreme results

- Need to study information flow in **decentralised, embodied** systems
- Understand **the costs** of searching for, sharing and utilising of information

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Thank you.
Questions?