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Understanding the Role of Recruitment in Collective Robot Foraging

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Foraging in nature

Solitary

Dispersed food

Collective

Food patches

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Robot foraging

- When should we invest money and time into collective robot foraging,
  - i.e., using robot-robot recruitment?
- What side effects will communication have?
- When is it NOT a good idea for robots to recruit each other?

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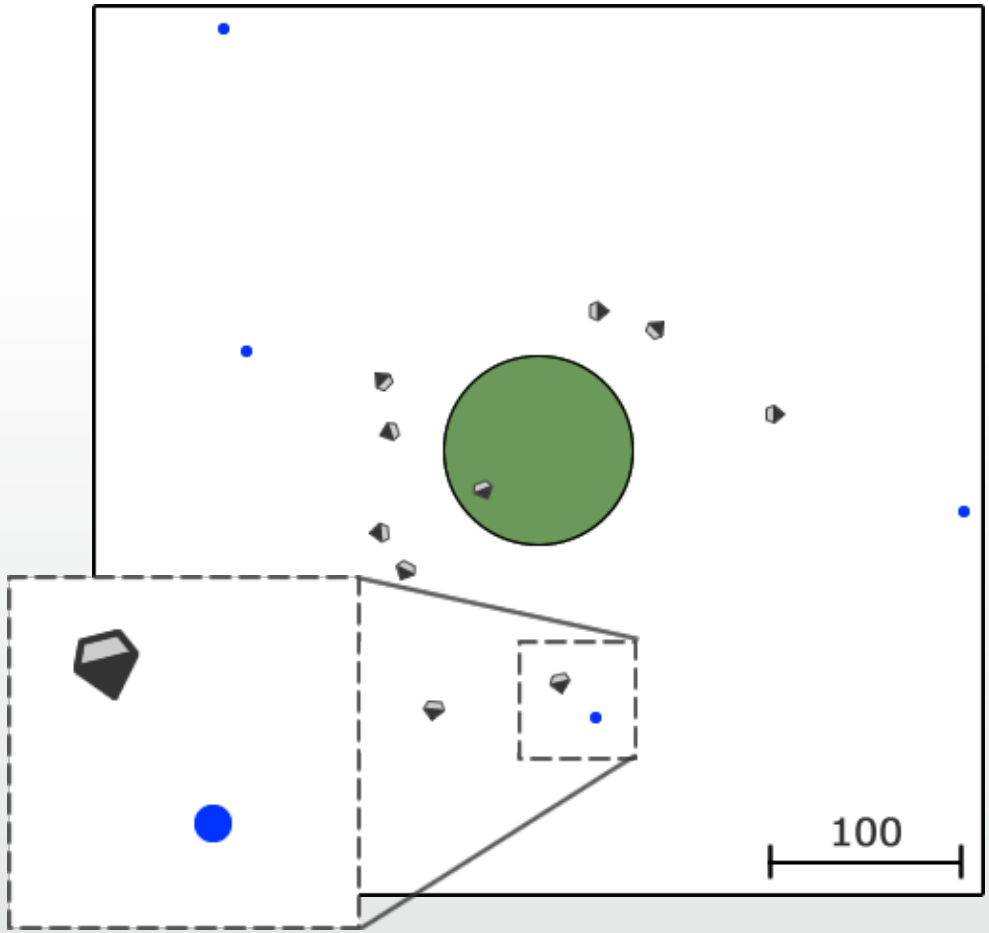
Our simulation: Environment

- Continuous space / time
- 4000×4000 units large
- Base in the middle
  - with beacon
- Deposits around

- A deposit has:
  - Volume V
  - Quality Q
  - Net return = $V \times Q$



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Our simulation: Robots

Individualists: I-Swarm

- Random walk
- Load resource and get its energy efficiency EE
- Bring it back to the base
- Return to the deposit location
  - Using odometry
  - Neighbourhood search

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Our simulation: Robots

Bee inspired recruitment: B-Swarm

- Can be recruited to another robot's deposit if it has higher EE
- Periodically make trips to the base if random walk is unsuccessful
  - Get information from successful returning foragers

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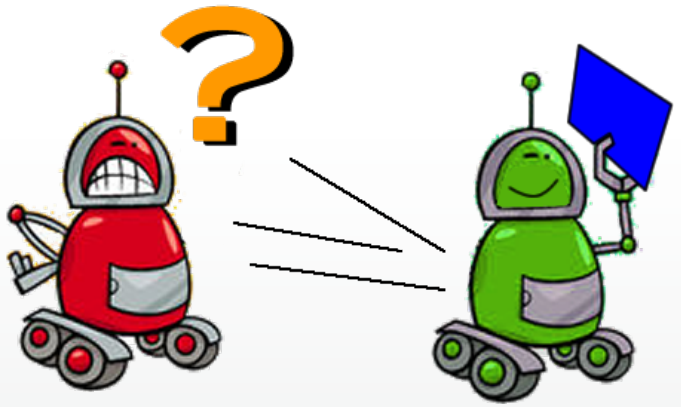
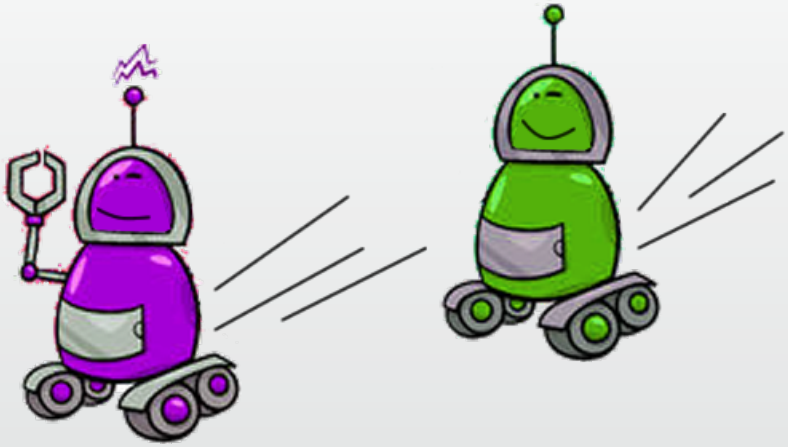
Robot-robot interference

- Physical

- Environmental



- Informational



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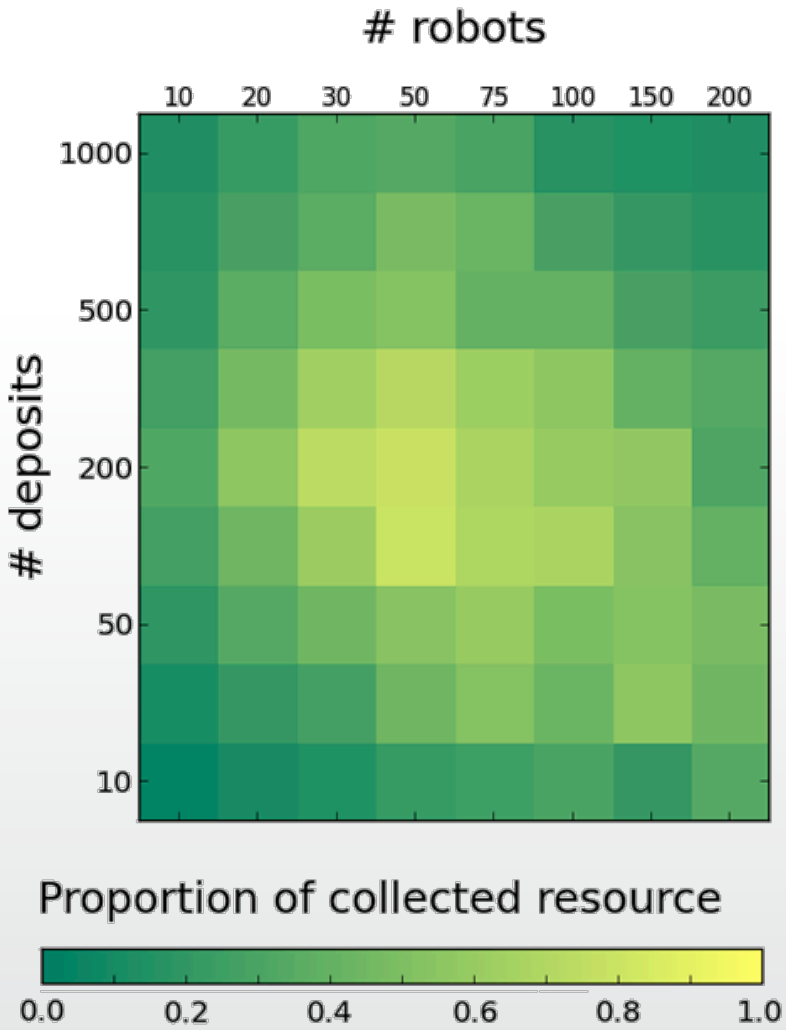
I-Swarm and the environment



- Best performance for 30-75 robots, 100-300 deposits
- Too many robots => physical interference
- Too many deposits => environmental interference
- Too few robots or deposits => hard to find anything

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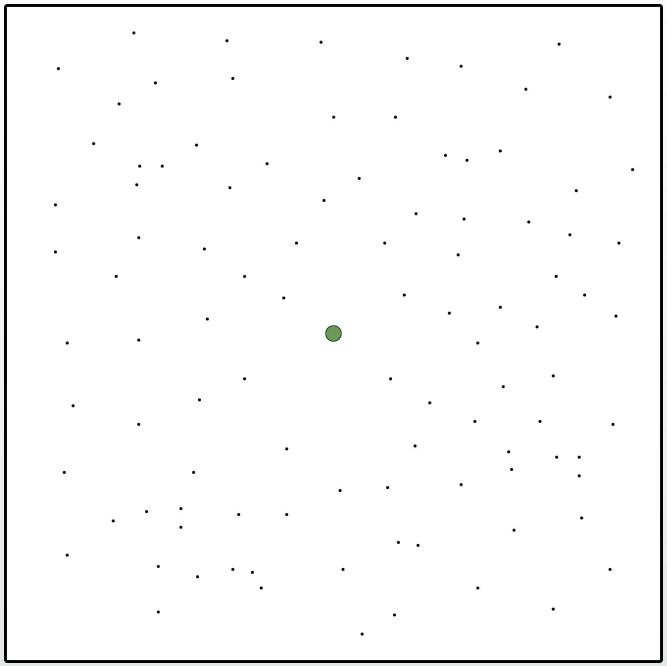
Litter and puddles

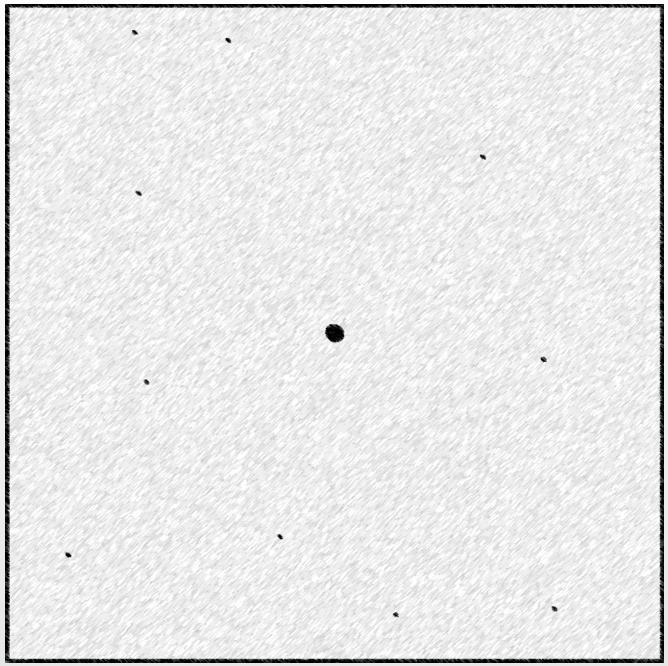
Litter

- 100 deposits, V=2
- Uniform deposit quality



Puddles

- 10 deposits, V=20
- Uniform deposit quality



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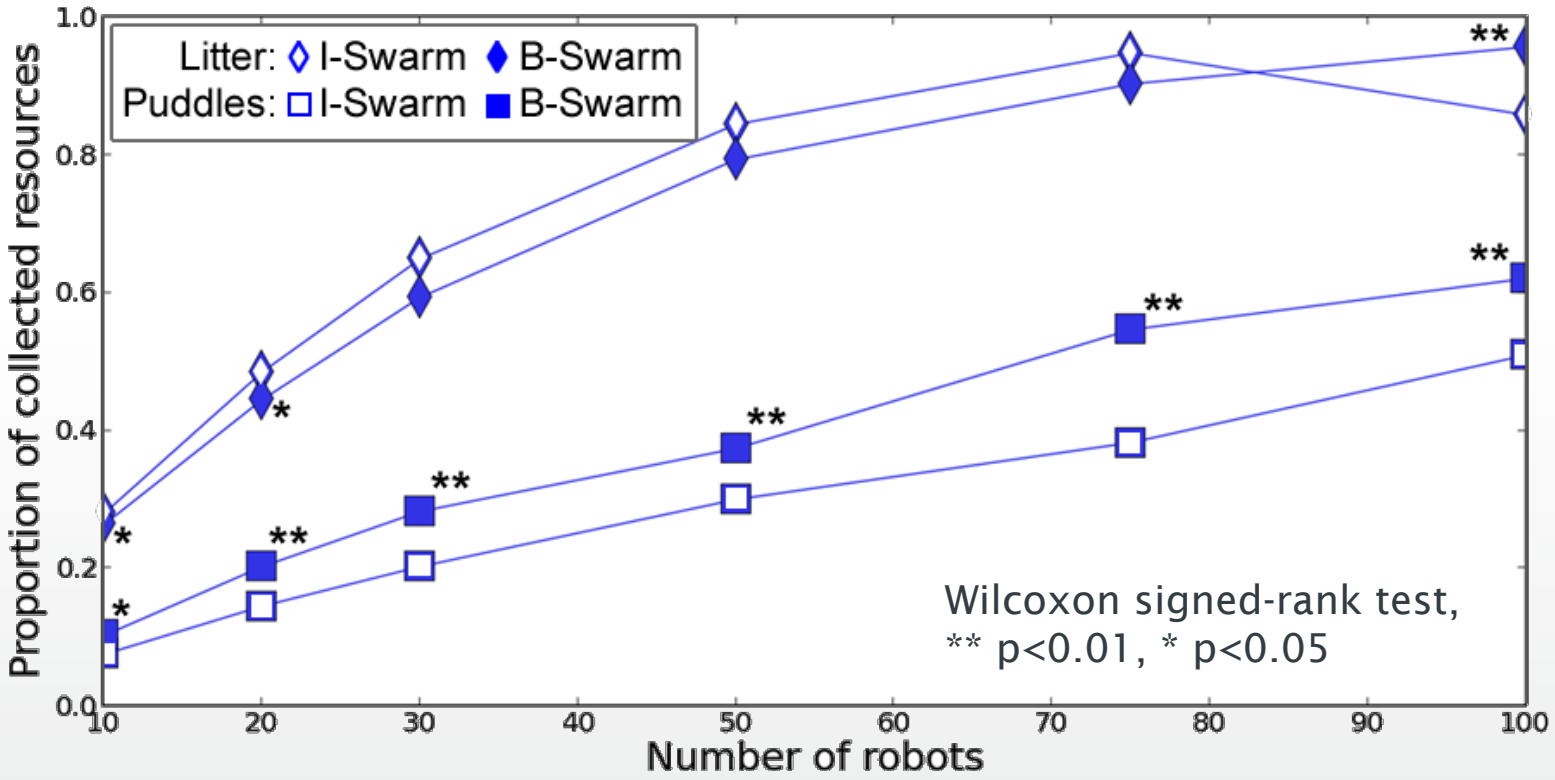
Litter and puddles



- Litter: I-Swarm consistently better <= informational interference
- Puddles: B-Swarm better <= more return trips possible

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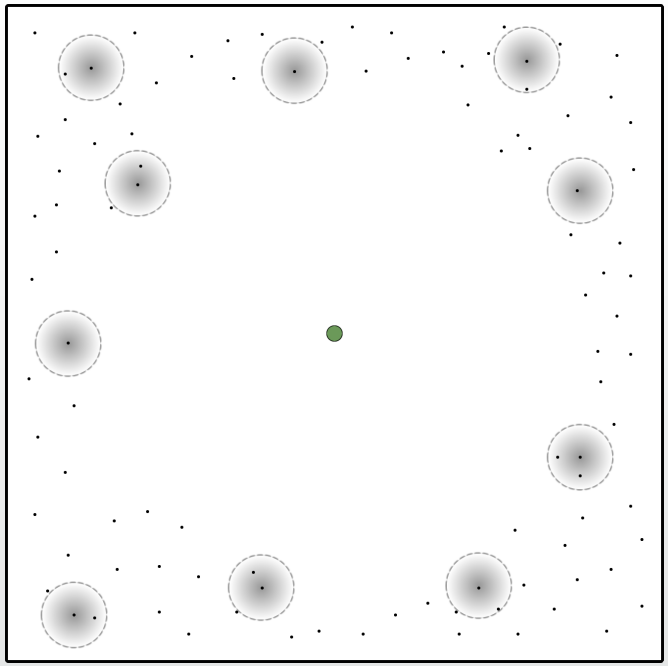
Stones and minerals

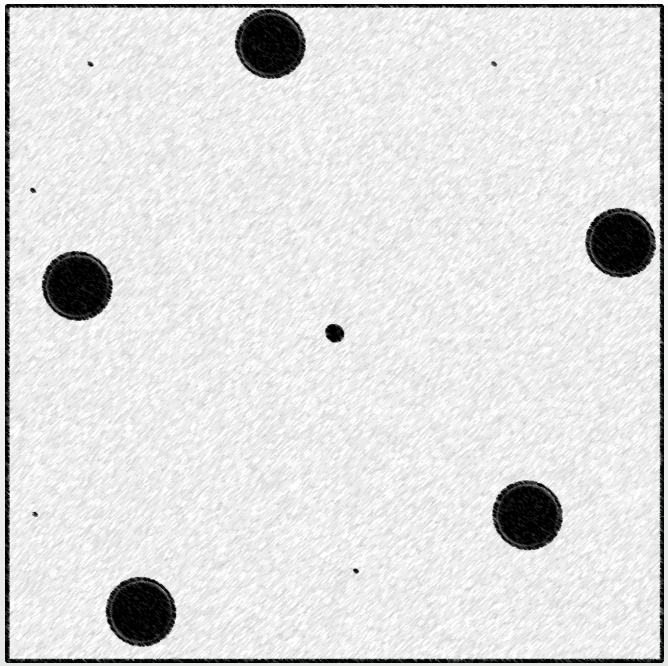
Stones

- 100 deposits, V=2
- 10 patches of better quality
- Deposits far away



Minerals

- 10 deposits, V=20
- 5 deposits of better quality
- Deposits far away



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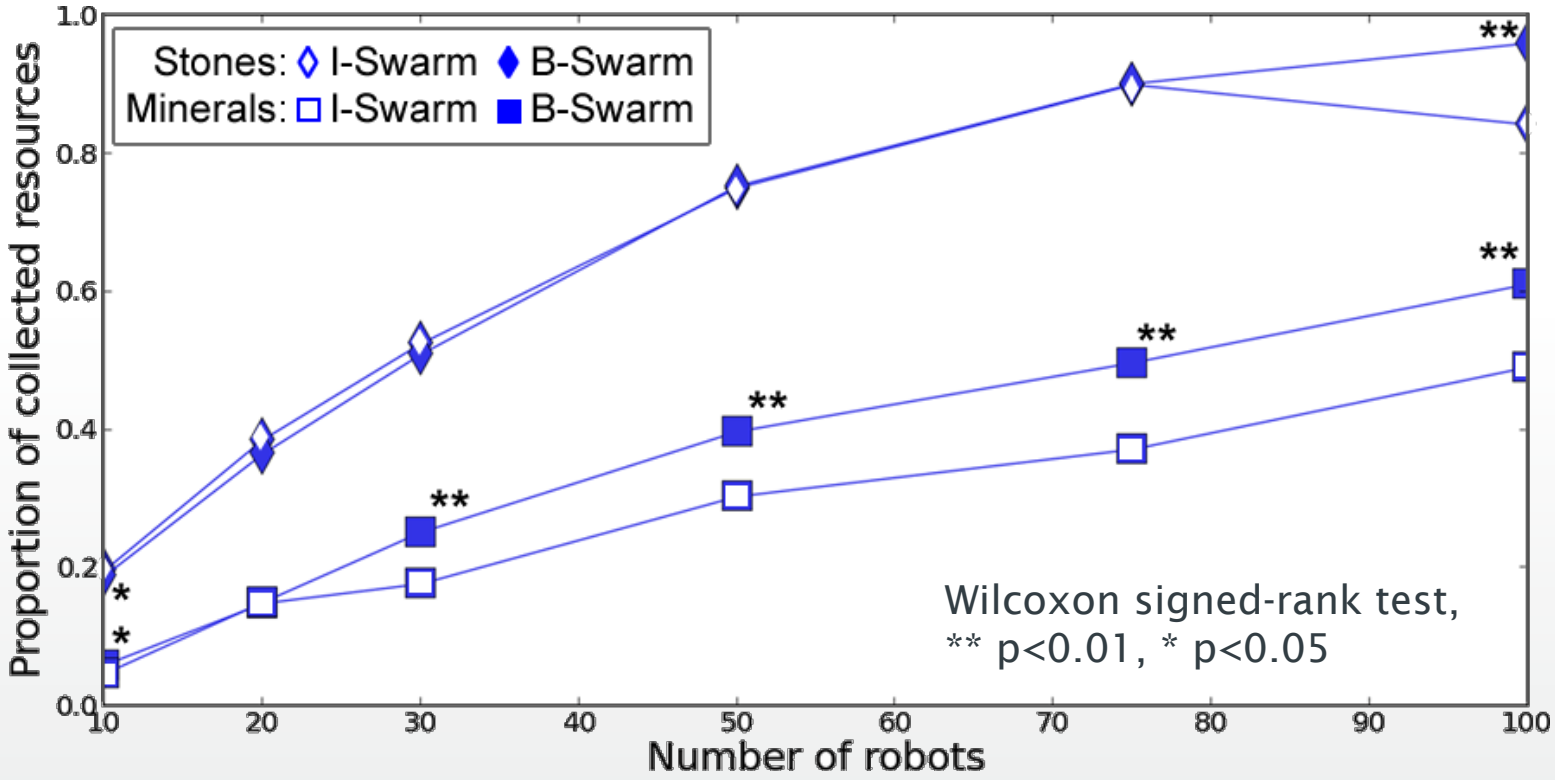
Stones and minerals



- Stones: B-Swarm slight benefit from recruitment to a general location
- Minerals: B-Swarm better but needs to be large enough

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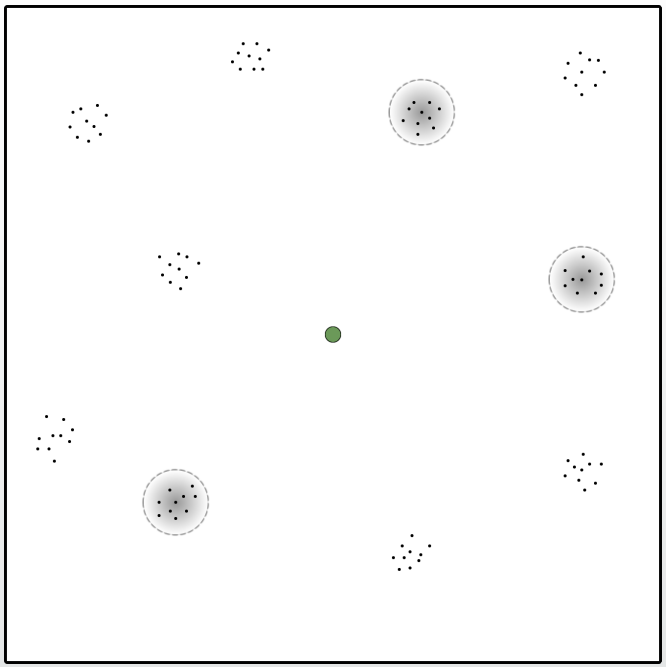
Nectar and cargo

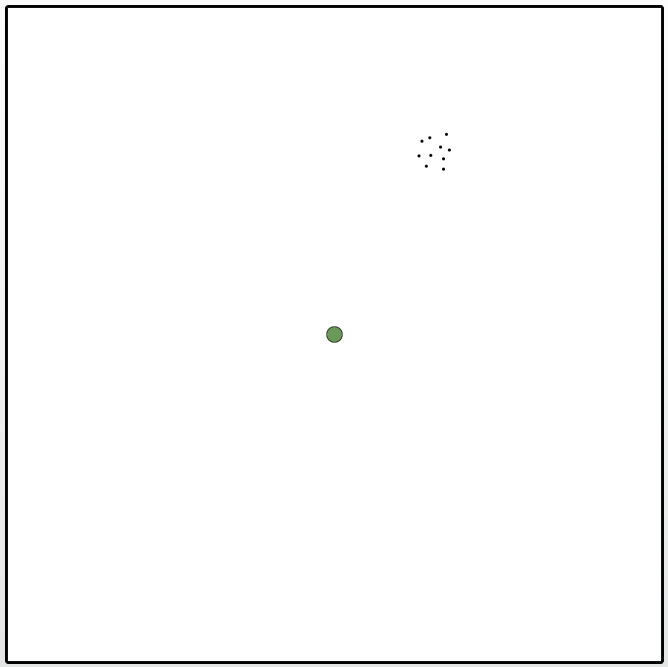
Nectar

- 100 deposits, V=2
- 10 deposit groups of 10
- 3 groups of better quality



Cargo

- 10 deposits, V=20
- Single deposit group of 10
- Uniform deposit quality



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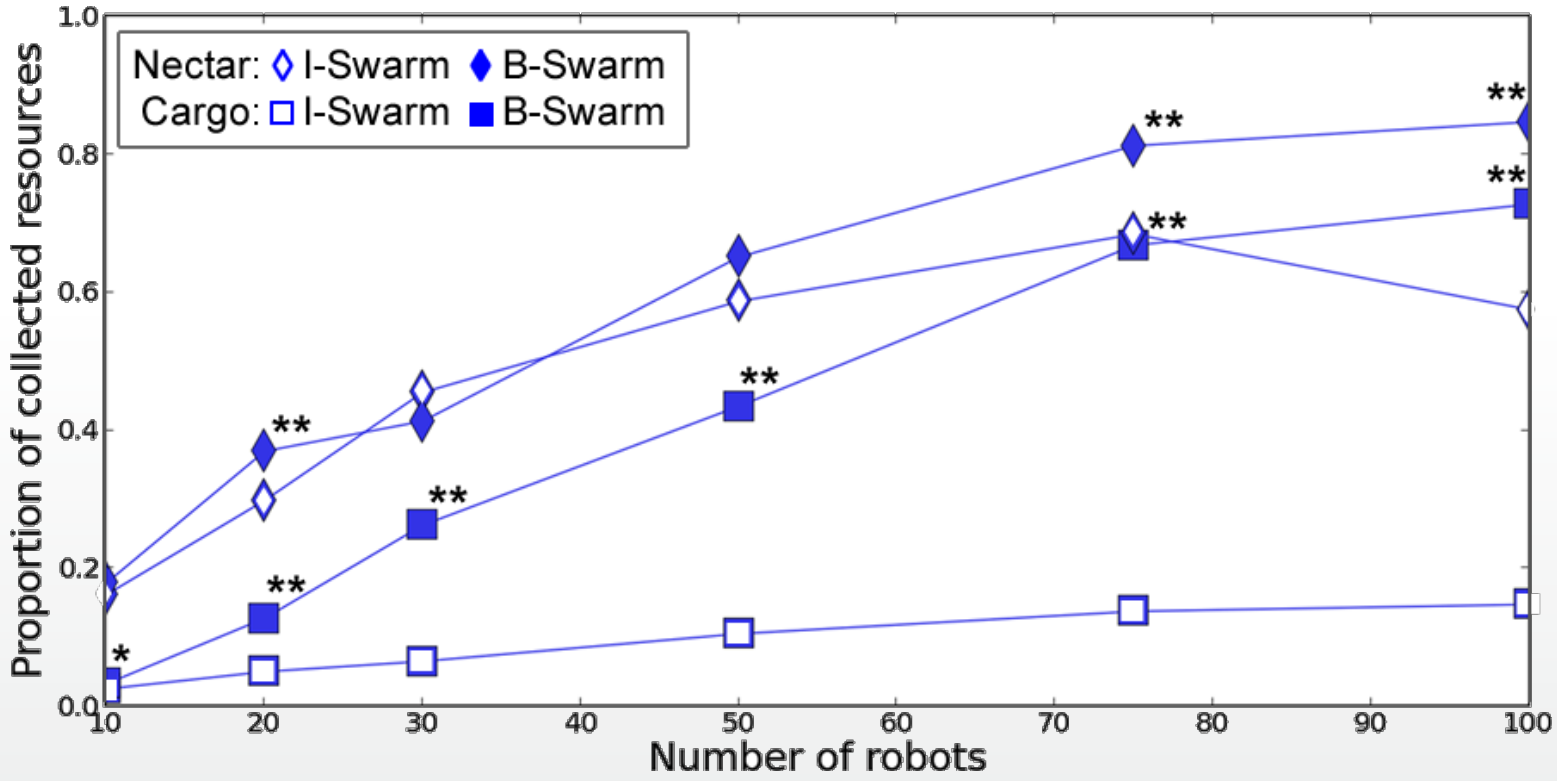
Nectar and cargo



- Nectar: B-Swarms of moderate size rapidly deplete resource groups, but find new groups hard to locate
- Cargo: Ideal for B-Swarm

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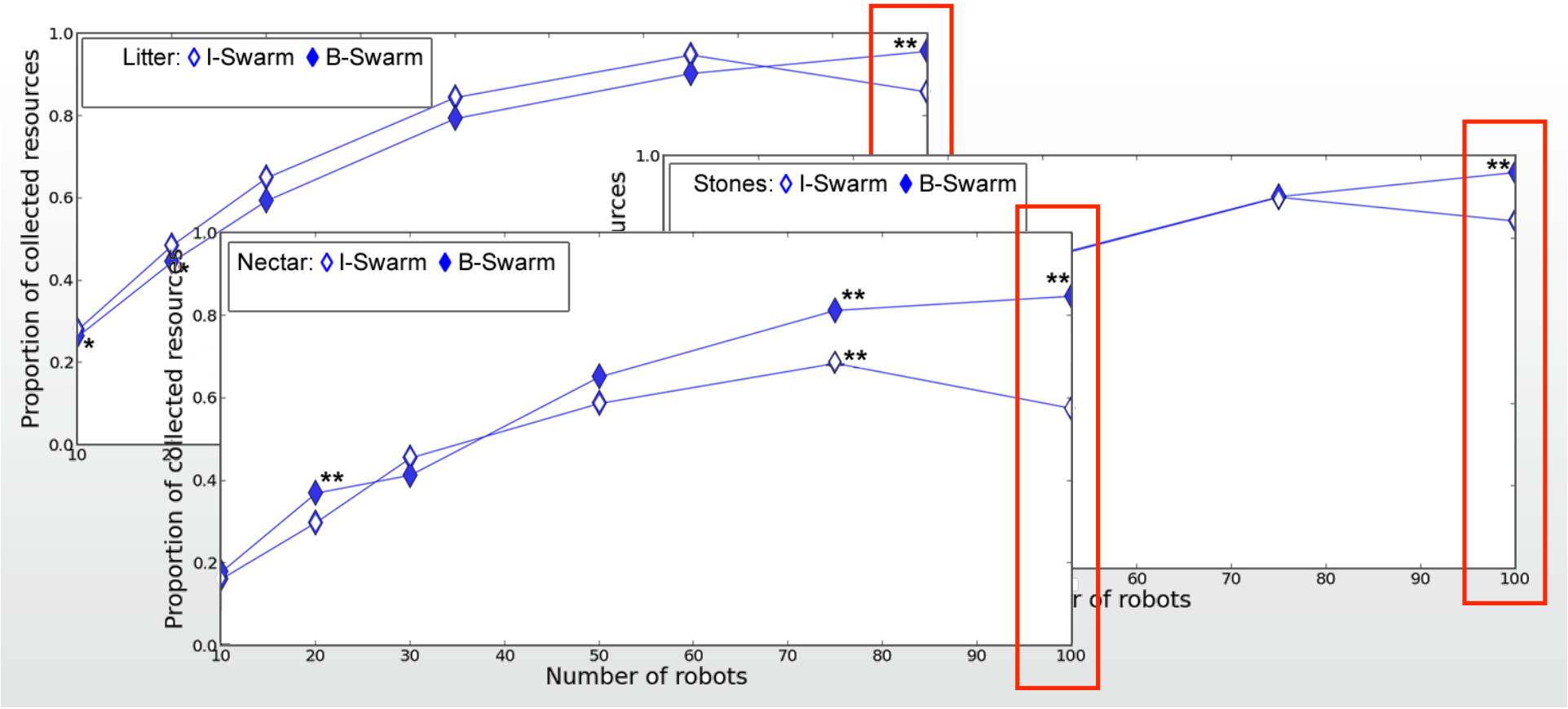
Emergent traffic management

- Congestion around the base created with I-Swarm of 100 when foraging in an environment with a lot of deposits



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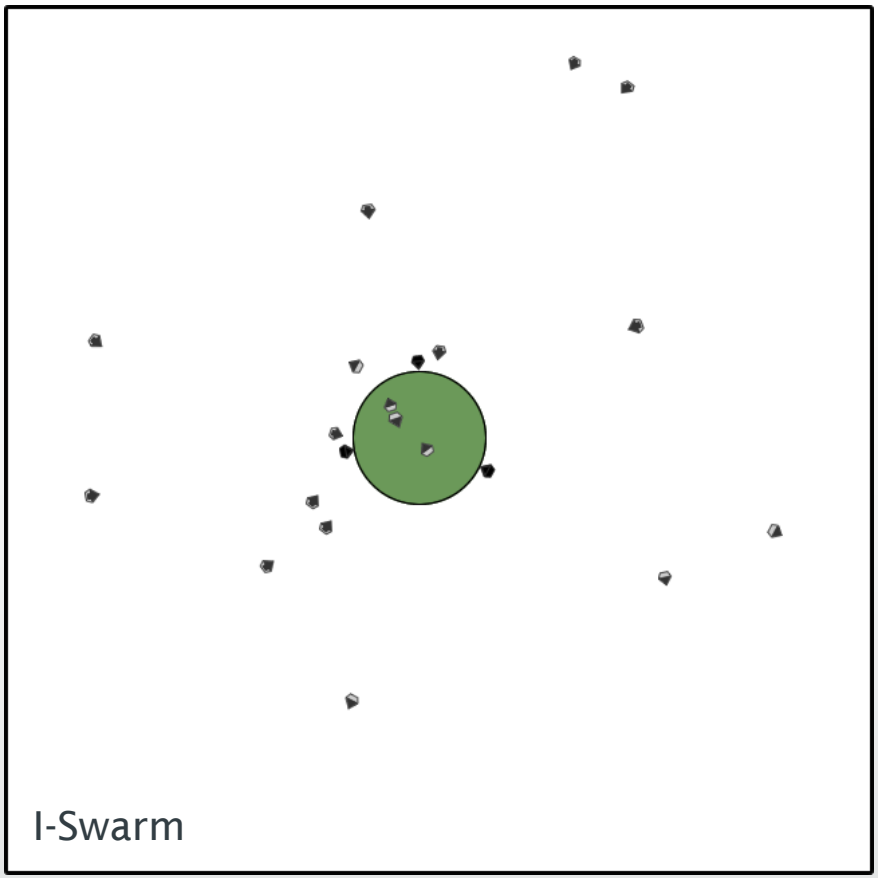
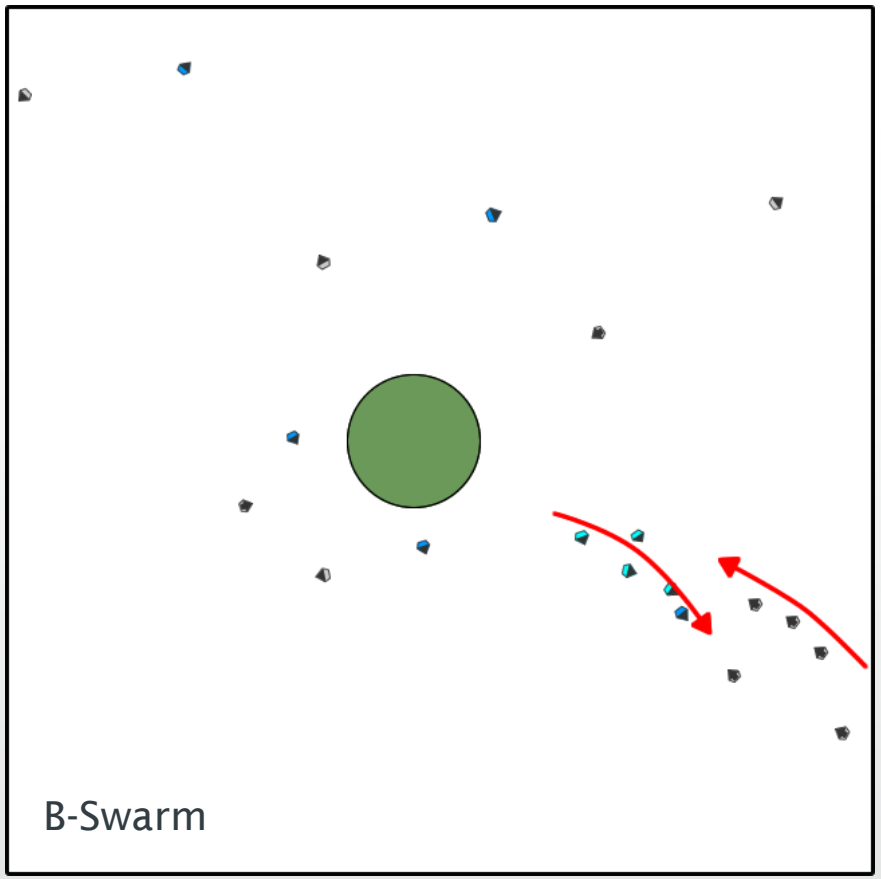
Emergent traffic management

- B-Swarm robots forage in groups => better flow of traffic





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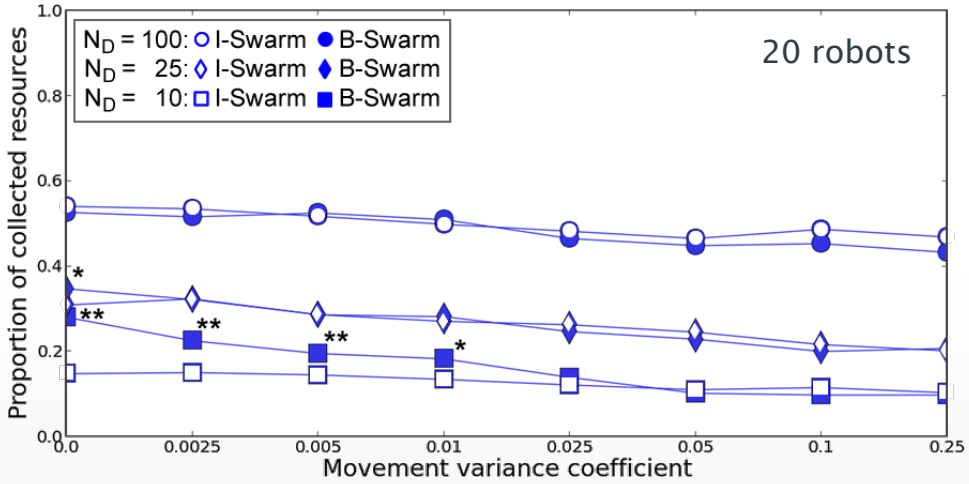
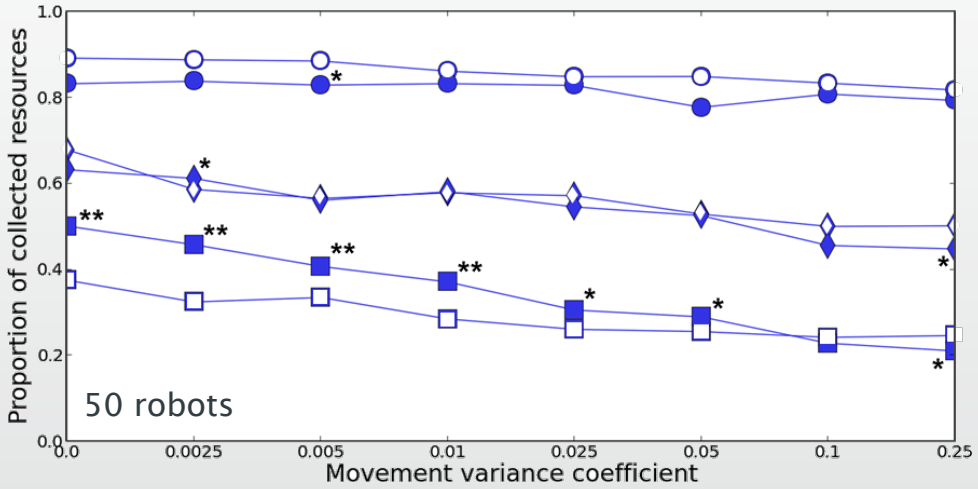
Odometry error





- Larger impact on B-Swarm when deposits are rare <= informational interference
- B-Swarm of 50 robots more susceptible than that of 20 robots
  - Harder to become an individualist

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When to forage collectively

1. **When resources are hard to find**
   - Initial collection time is important
   - Collection of rare minerals, not picking up litter from streets

2. **When congestion near the base is a problem**
   - Emergent traffic management

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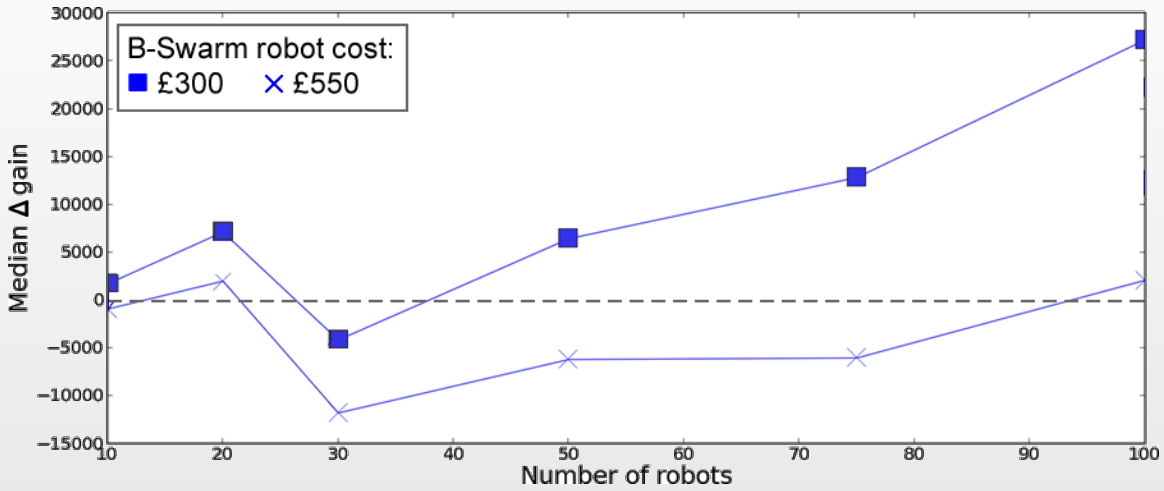
When to forage individually

1. **When resources are abundant**
2. **When reliability of information is low**
3. **Borderline cases**
   - Extra behaviour = extra cost!



Example:

- Collecting nectar
- Total gain: £100,000
- I-Swarm robot costs £300

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Current work in progress

- More realistic physical model needed
  - The ARGoS simulation platform
- B-Swarm unable to selectively forage from deposits of better energy efficiency
  - Give them a concentrated place to exchange information, like a dance floor in a bee hive?
- Dynamic environments
  - Other bee-like behaviours like scouting and inspection?

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Current work in progress

- Are there any principles related to how information flows in a swarm that are applicable across swarm sizes and environments?
- Can these be applied to similar collective behaviours, like labour division?

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Thank you!
Questions?