Process-Oriented Subsumption Architectures in Swarm Robotic Systems

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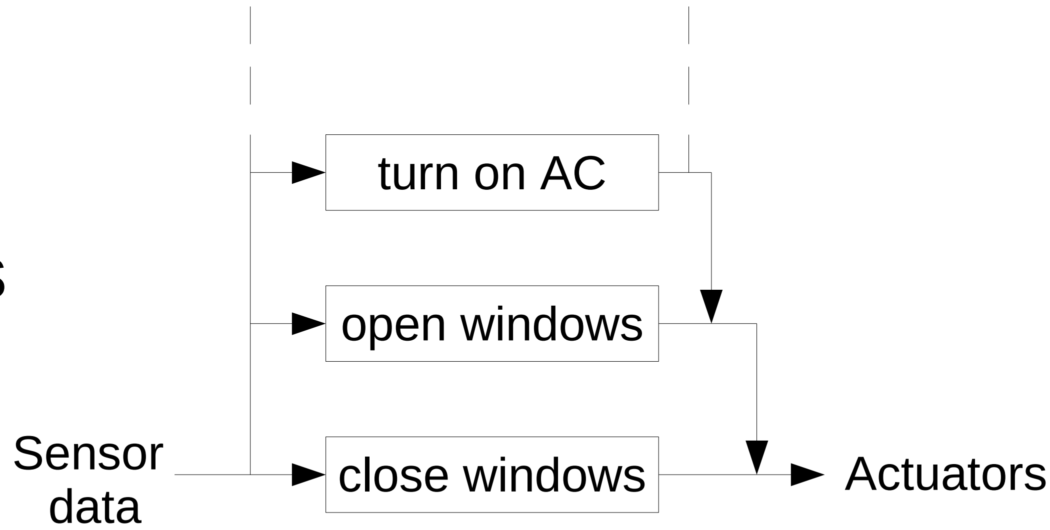
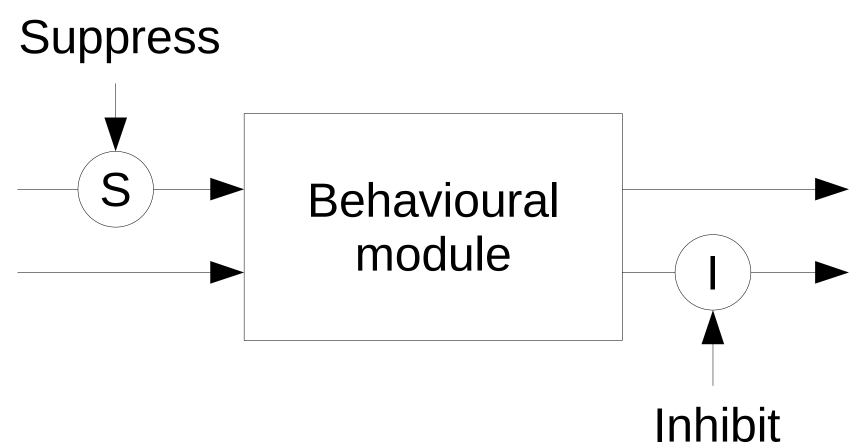
Introduction

- Jeremy Posso's MSc project at York in 2009
  - Supervised by Jon Timmis
  - Worked with Jon Simpson on architecture, and Adam Sampson on Player/Stage bindings
- Robotic control is an inherently **concurrent** problem: sensors, actuators...
- **Process-oriented programming** should be a convenient way to implement control systems
  - Transterpreter, Plumbing...

Subsumption architecture

- Layered behaviours
  - Map sensor inputs to actuator outputs
- Suppressors
- Inhibitors
- No planning – purely reactive
- Modular √ Compositional **?**





Past work

- **CPA 2006**: Simpson, Jacobsen and Jadud, "Mobile Robot Control: the Subsumption Architecture and occam-π"
  - Implemented subsumptive control components in a process-oriented system
- **CPA 2009**: Simpson and Ritson, "Toward Process Architectures for Behavioural Robotics"
  - Compared subsumption with other approaches; identified scalability problems

Swarm robotics

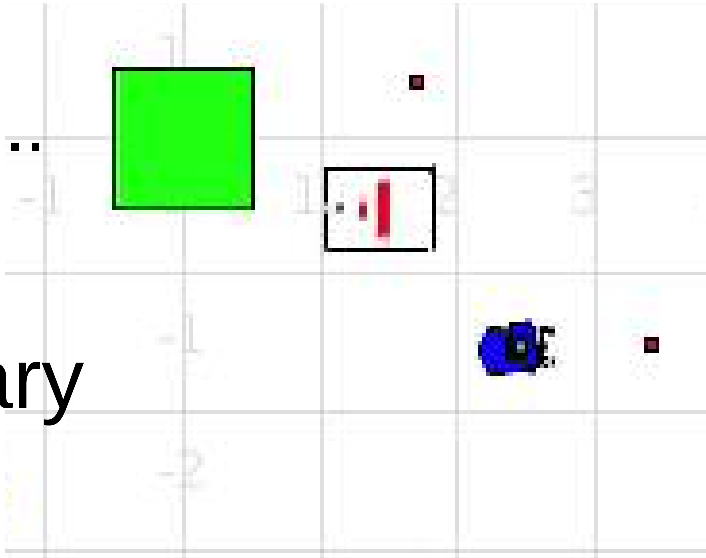
- Several robots collaborate to perform a task
  - May involve **engineering emergence**
- **Local** intelligence, not remote control
- Robustness
- Flexibility
- How can we use a process-oriented subsumptive control system in a swarm context?

The task

- Foraging: common swarm problem
- Many identical robots collect pieces of **rubbish** from a field, and deposit them in a **bin**
- Robots must coordinate to avoid collisions, while covering as much ground as possible
- Robots have limited battery life – must recharge at charging stations when low

The robot

- Pioneer platform, modelled within Stage
  - Realistic, noisy... so nondeterministic
- Gripper for collecting rubbish
- Camera for spotting rubbish, other robots, chargers and the bin
  - Rubbish is red, robots are blue...
- Sonar for avoiding walls, etc.
- All driven through the Player library
  - … which Jeremy significantly improved our bindings to

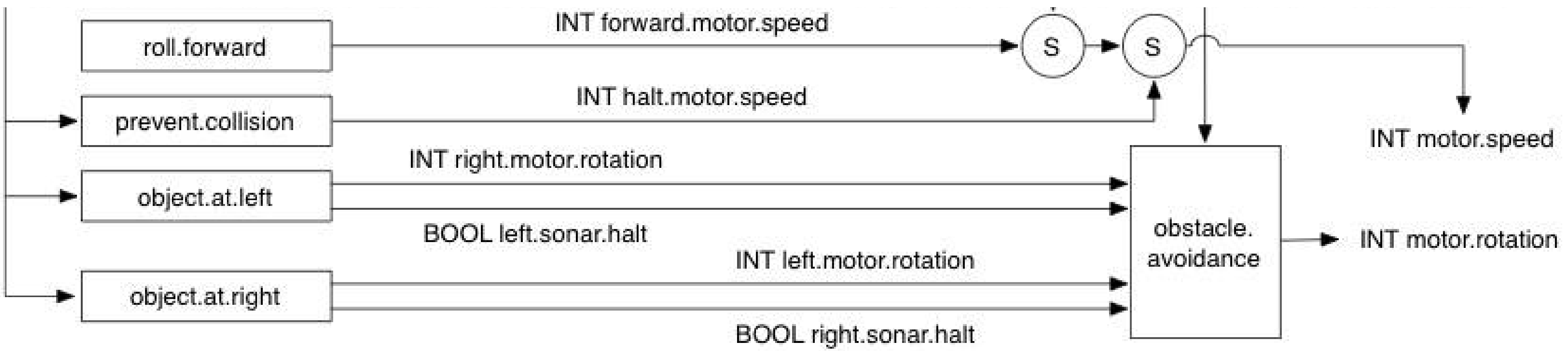


Design

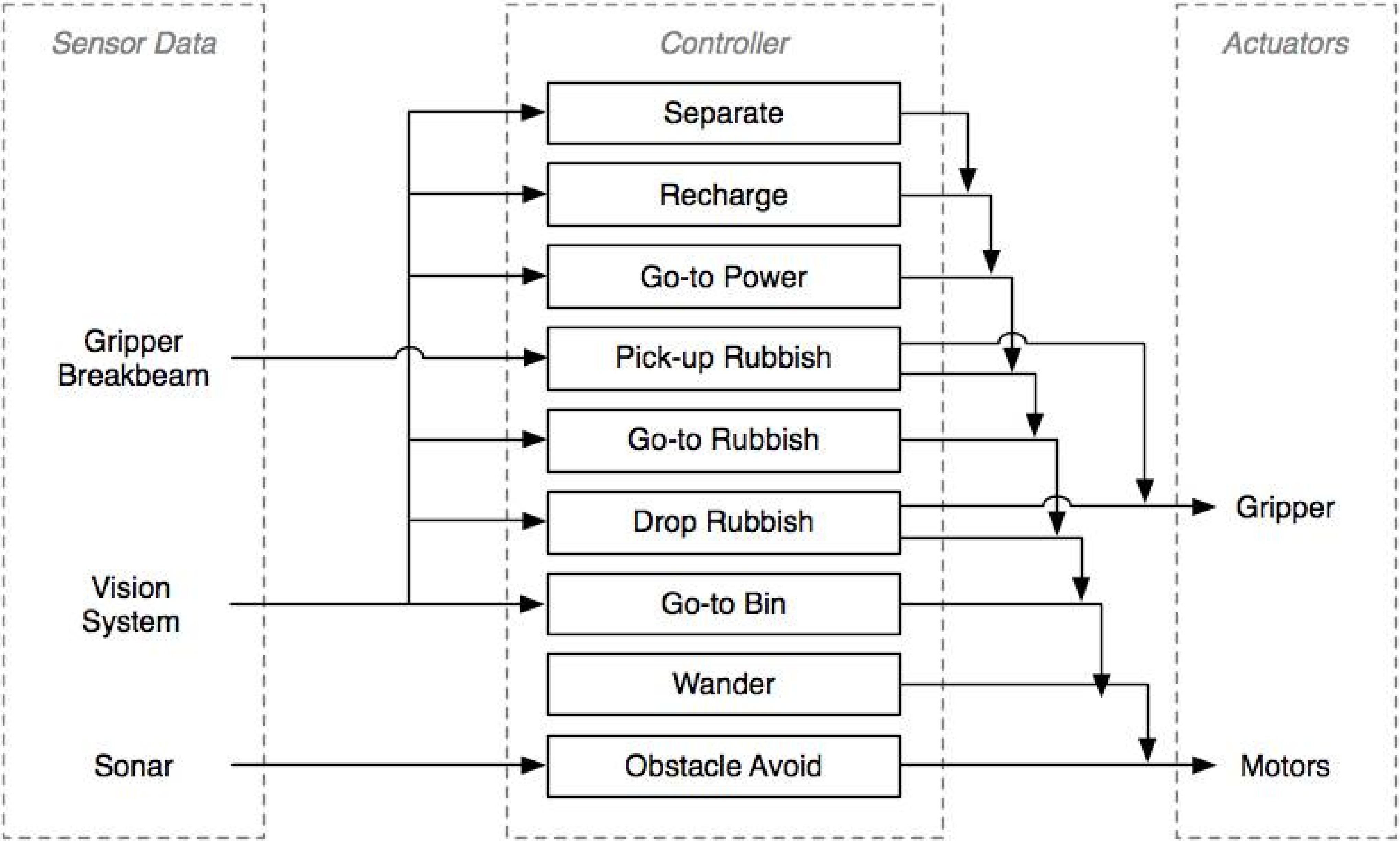
- First we identify the high-level behaviours
    - Arrange in priority order, most important last
- **Explore**
- **Avoid collisions**
- **Acquire rubbish**
- **Deposit rubbish**
- **Recharge**
- **Collaborate**

Design

- Then we can break those down into simpler behaviours, and map those to processes
- e.g. **Avoid collisions**
  - Move forwards
  - … unless you're about to run into something
  - If sonar senses something to one side, turn away from it

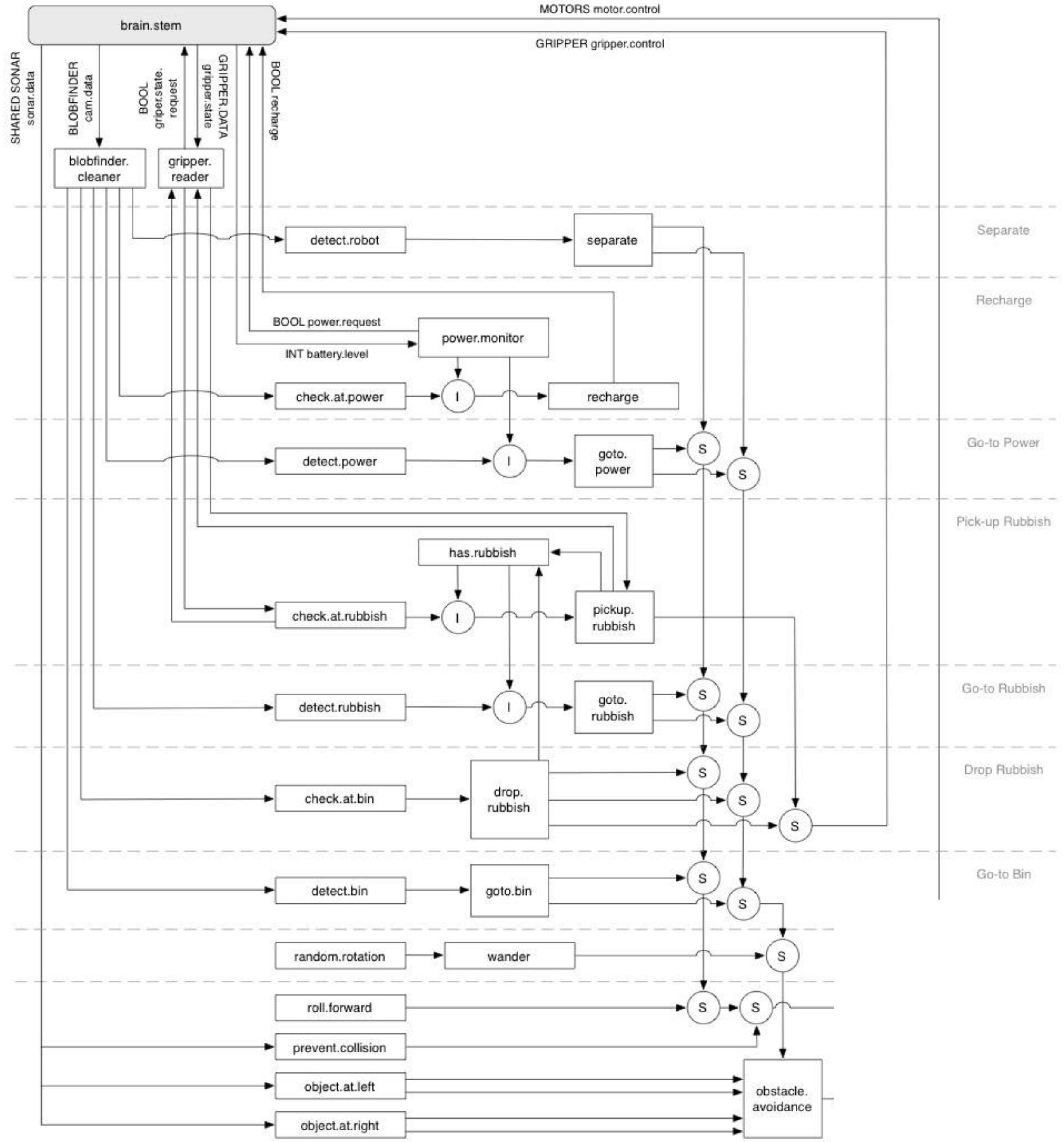


The control system



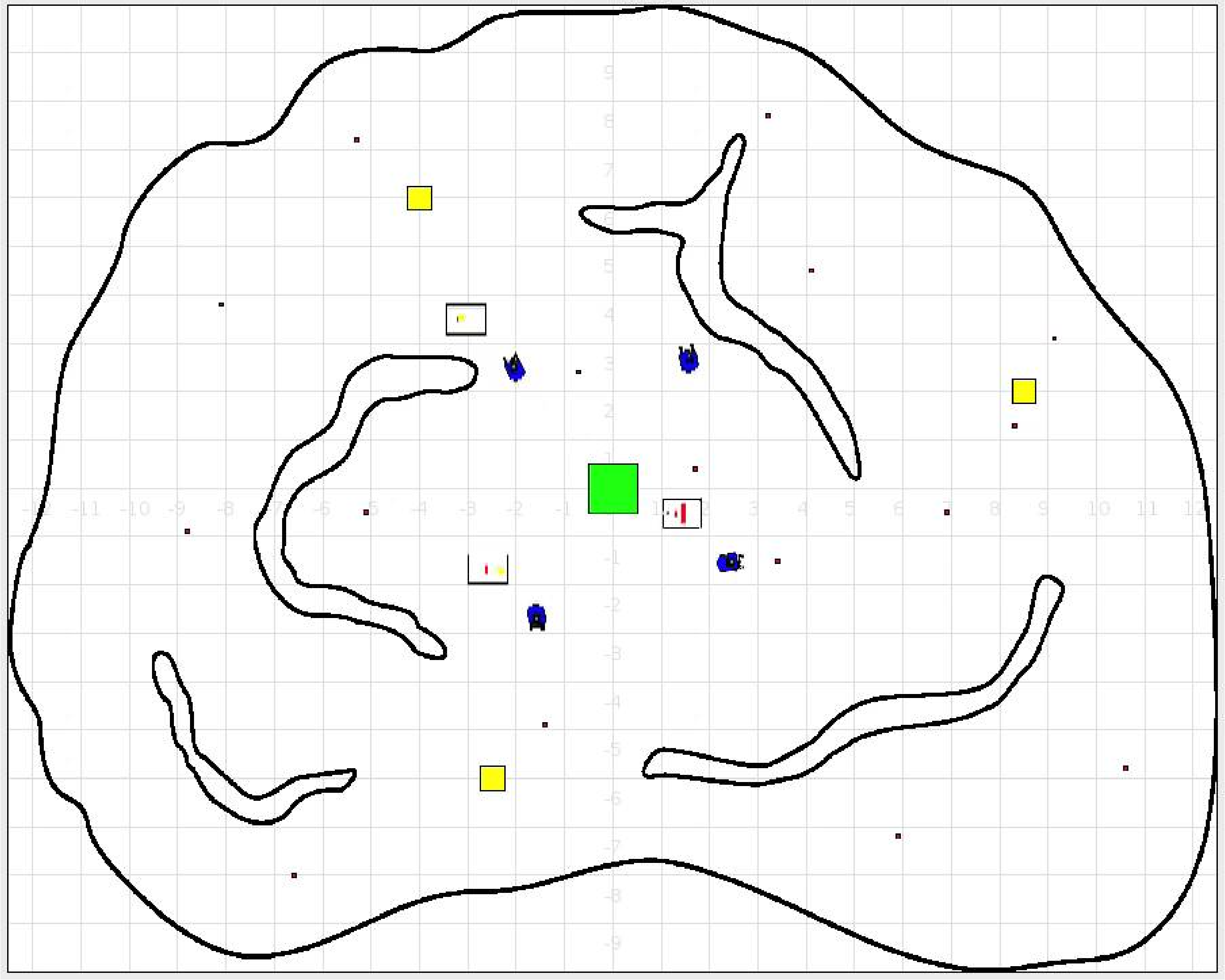
The process network

(see paper for more detail)



Trials

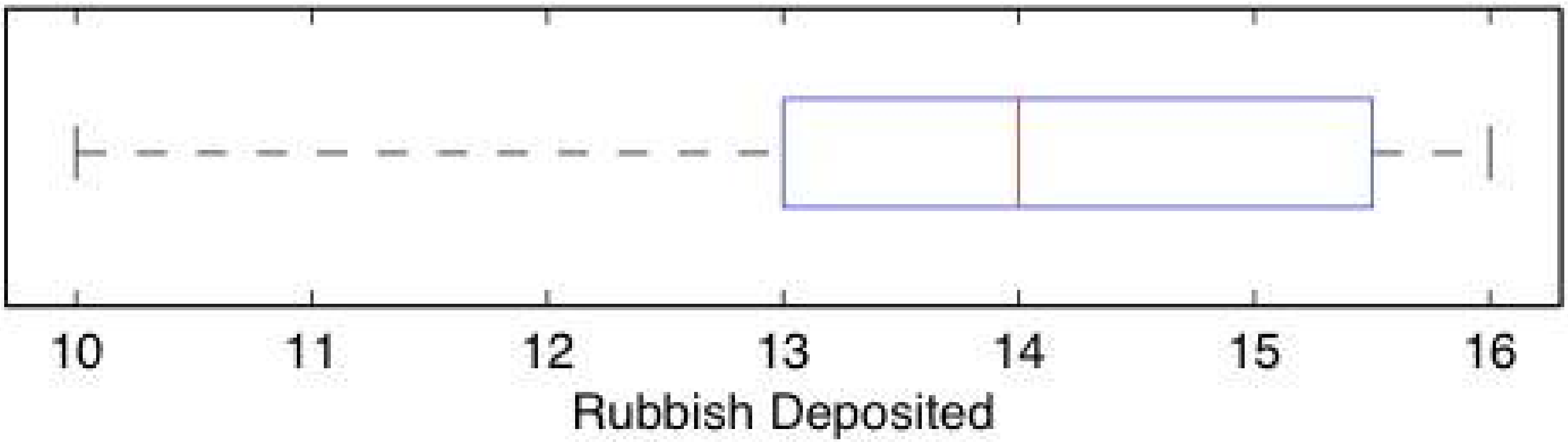
- Four robots, sixteen pieces of rubbish
- **Success** when all rubbish in bin within twenty minutes



Video

Results

- Ran **20** trials...
- … of which only **5** were completely successful



- It works sometimes – why not always?

Diagnosis

- Some robots wander around but don't pick up or put down rubbish...
- Some behaviours aren't working
- Part of the control system has **deadlocked**
- … but no way to detect this until it's used
- This appears to be a common problem with complex subsumptive controllers

Desiderata

- **Synchronous** channels aren't a good fit here – we want **overwriting-buffered** channels
  - Can we identify new design patterns for safe programming with **asynchronous** communications?
- We don't have good tools for **debugging** or **performance analysis** (e.g. tracking latency)
  - The Transterpreter can give you the data...
  - … we just need to display/explore it

Conclusion

- We've built a complex **subsumptive** control system using **process-oriented** techniques
- Design and implementation straightforward
- It works... sometimes!
  - We need better tools to tune and debug it
- Previous attempts at subsumption in occam-π built **much simpler** systems, and didn't run into these scalability problems

Future work

- Build subsumptive swarm systems that **span multiple robots**
  - e.g. allow one robot to suppress behaviours in another robot
- Investigate **other approaches** for complex problems like this
  - e.g. Colony architecture

Any questions?