



# Evolving Societies of Learning Autonomous Systems

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DFG SPP 1183 Organic Computing



## Project Goal

### Self-organization of individually learning robots in groups

#### How to achieve a specified goal?

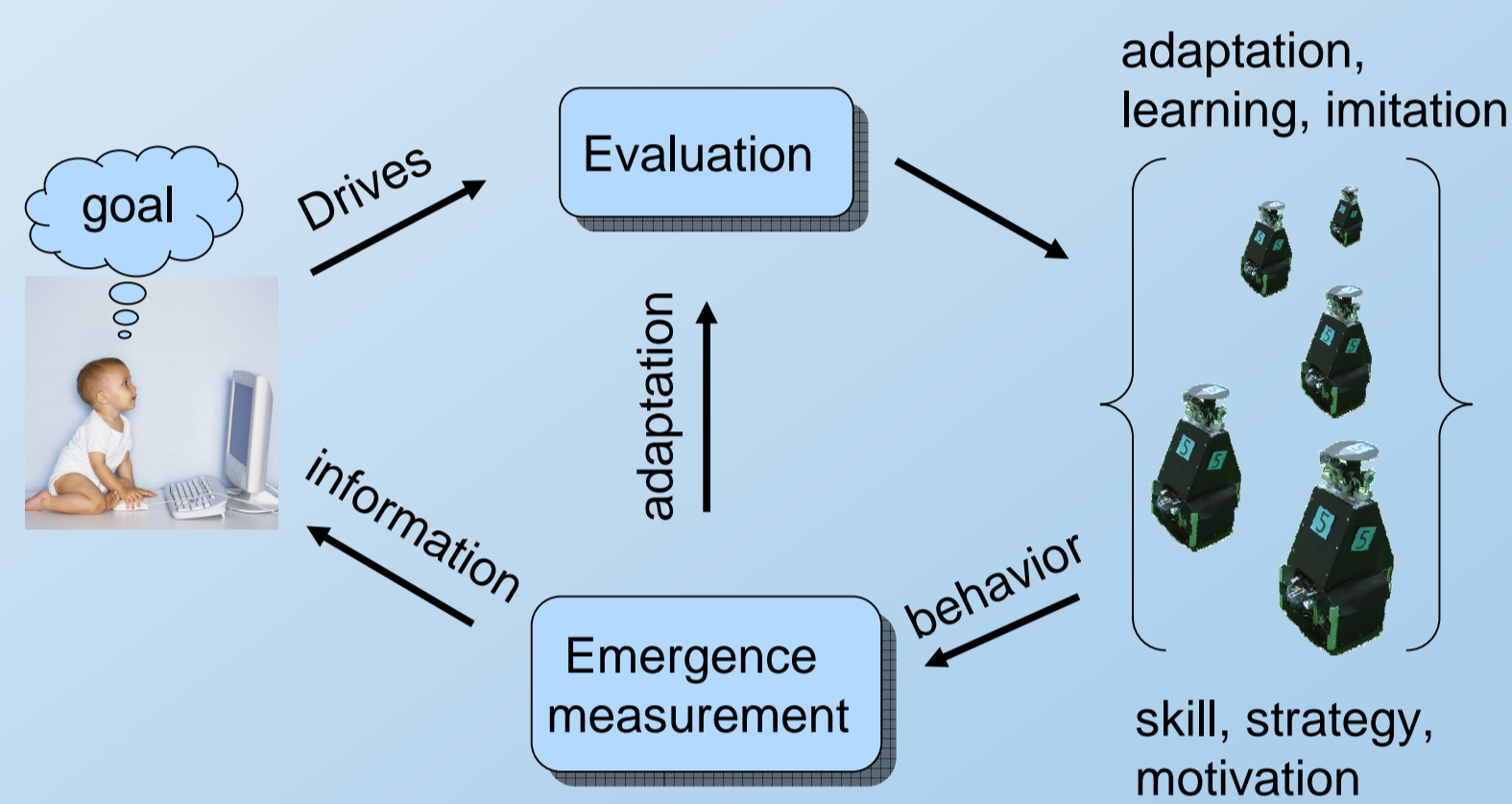
→ self-exploration, individual learning

#### How to converge to group behavior?

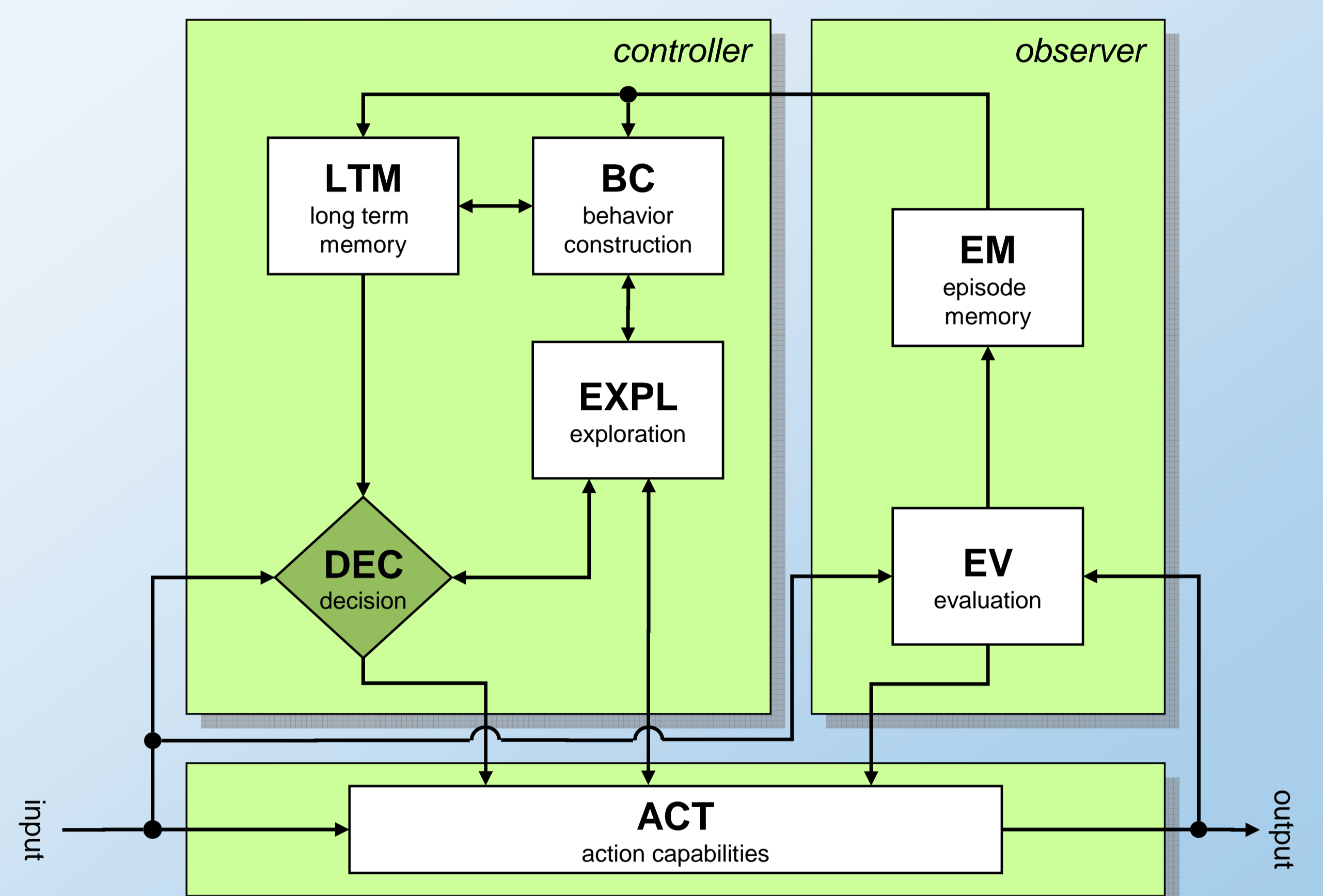
→ imitation

#### How to control emergent behavior?

→ decentralized evaluation functions inspired by biological principles



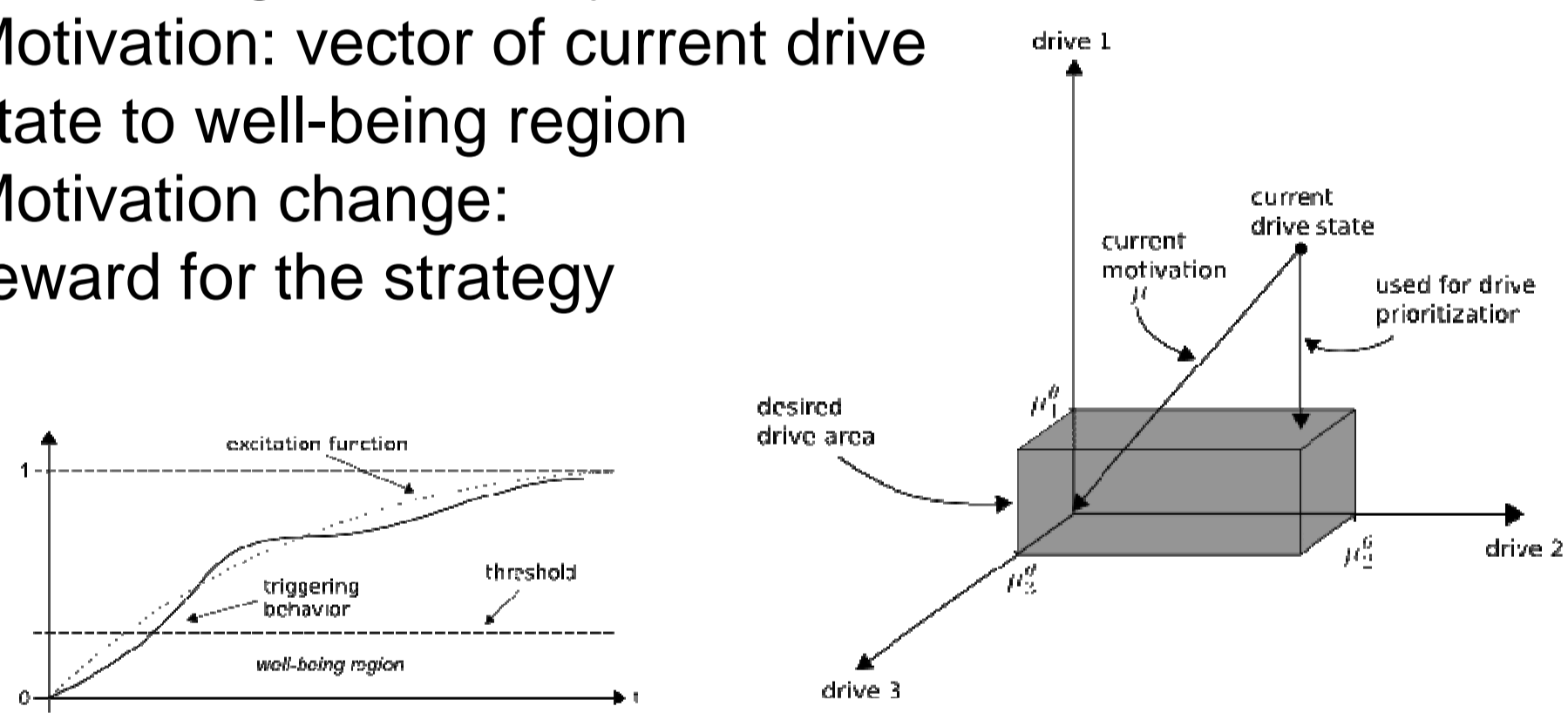
## Architecture



## Individual Learning

### Motivation

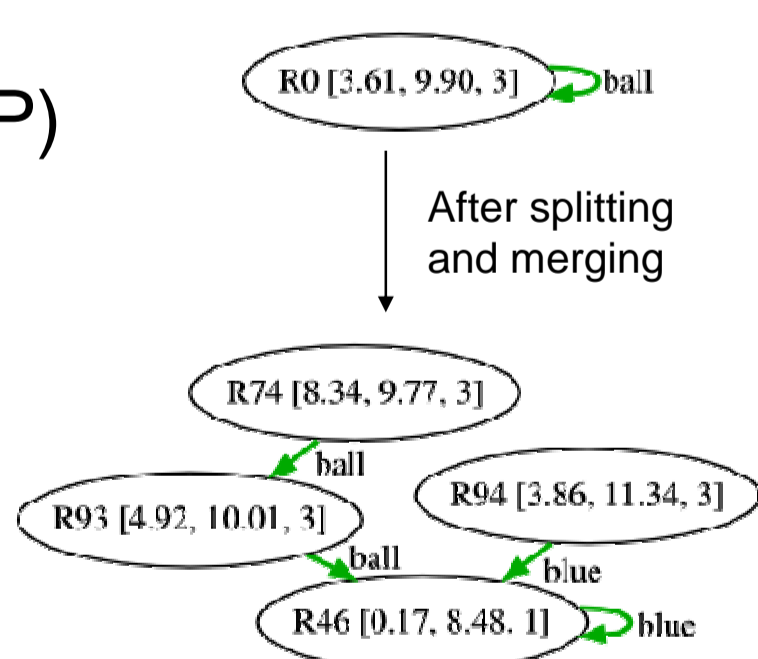
- High-level goals are modeled by drives
- Depend on time and perception
- „well-being“ defined by thresholds
- Motivation: vector of current drive state to well-being region
- Motivation change: reward for the strategy



Motivation change as reward

### Strategy

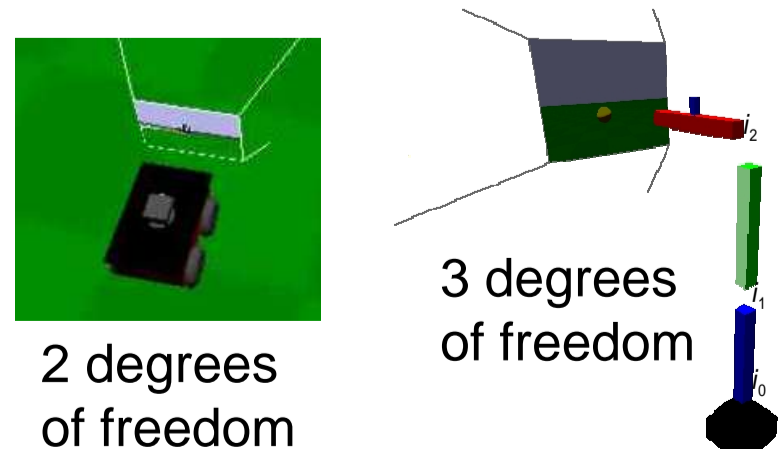
- Model-based Reinforcement Learning (Value Iteration, SMDP)
- Dynamically abstracting state space
- Actions: goal functions for the skill layer
- For each drive one separate SMDP



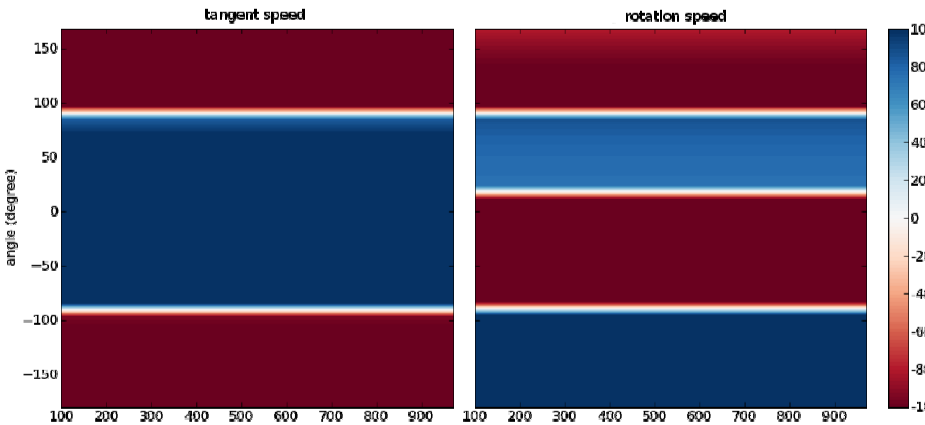
Action as goal function

### Skill

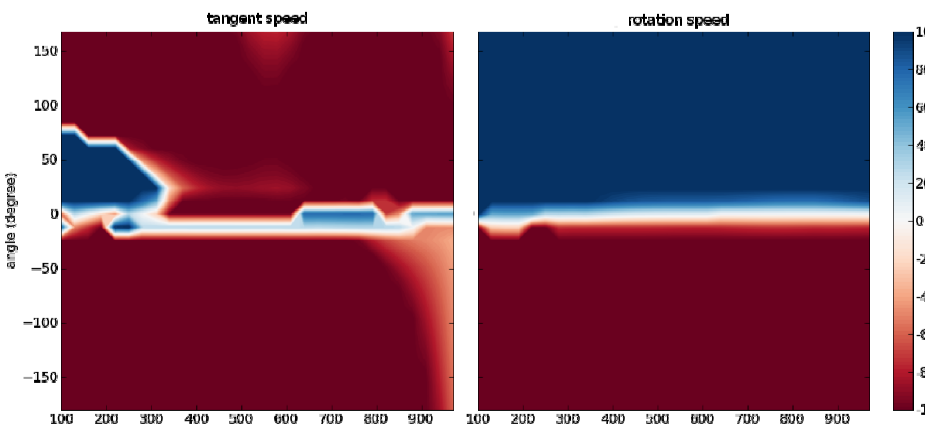
- Learns which skills are learnable
- A skill can detect itself in observations
- Independent of morphology



Learned skill: minimizing the distance



Learned skill: minimizing the angle

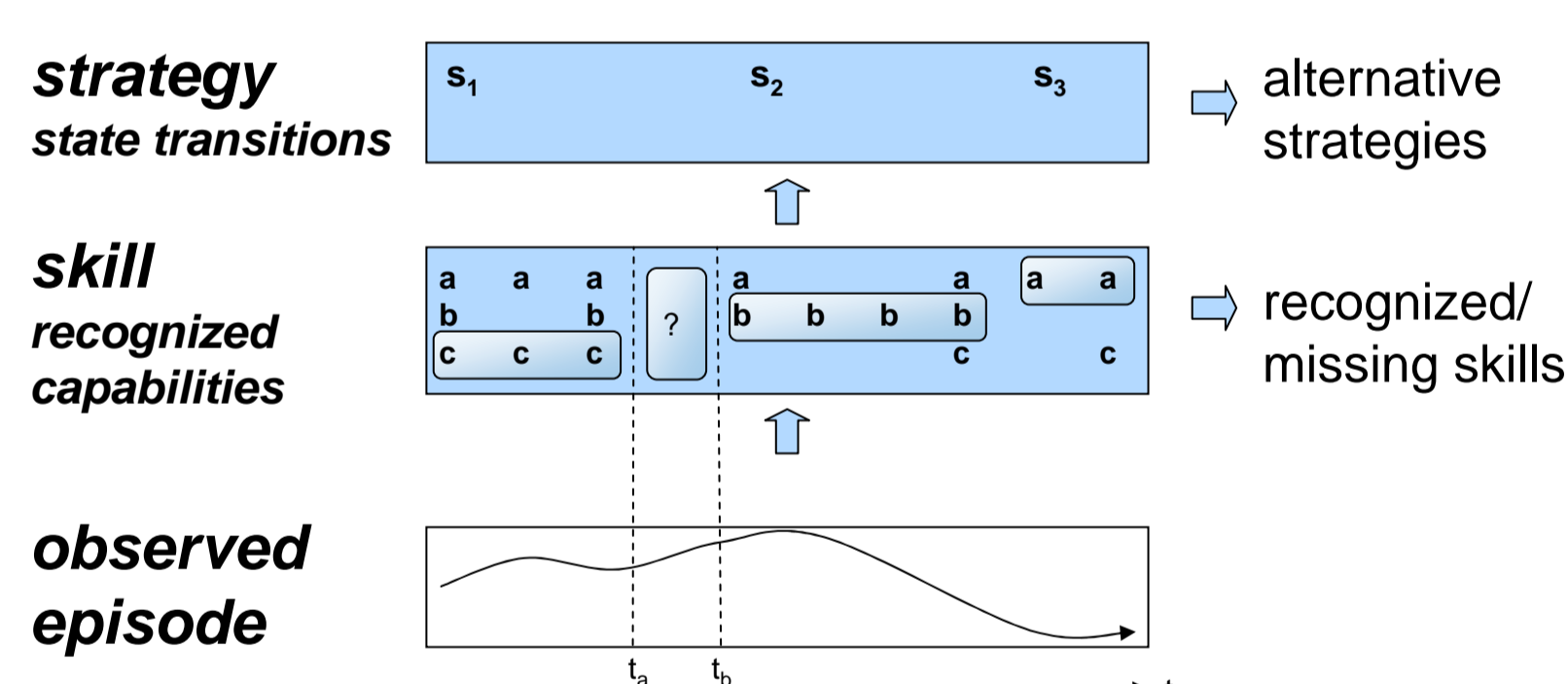


## Imitation

**Problem:** Repetitive observation is too seldom in multi-robot scenarios to allow for a real copying process.

**Solution:** See imitation as understanding

### Recognition of Observed Behavior

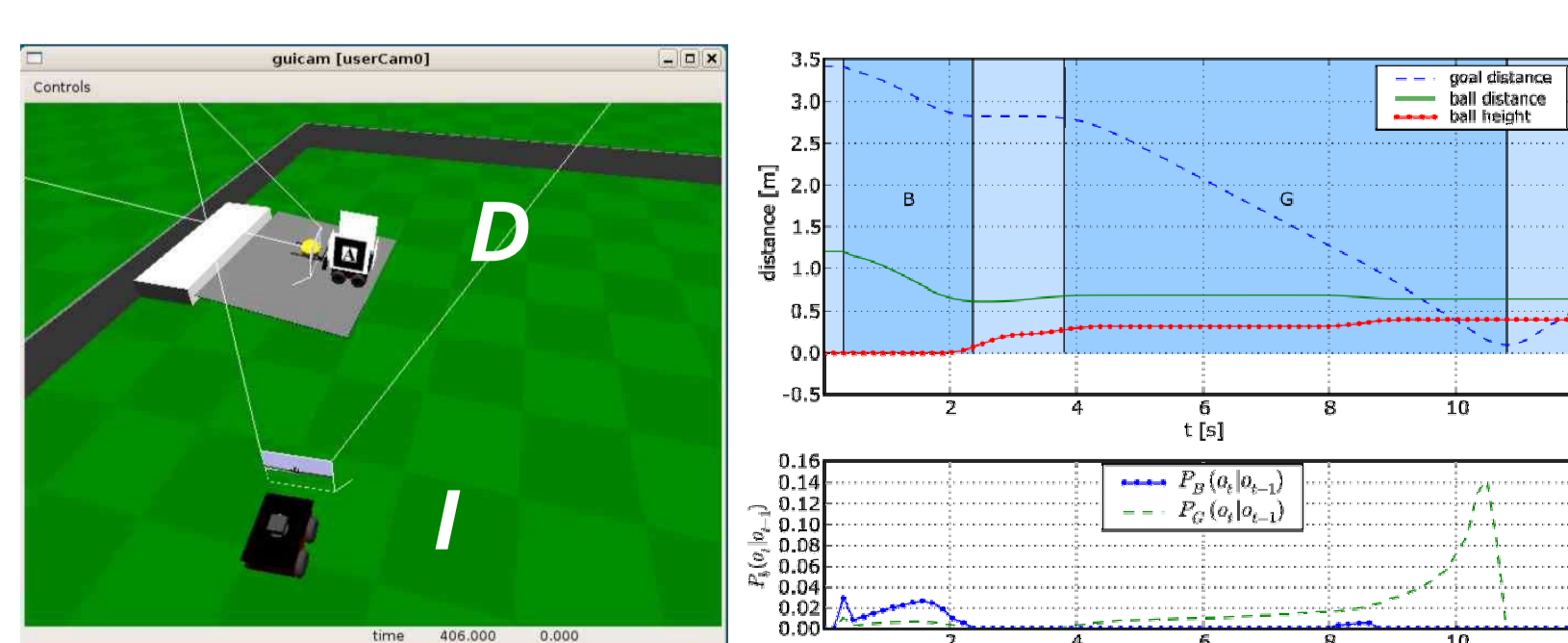


### Experimental Results

Scenario: Robot I tries to imitate robot D.  
Goal: Learn new behaviors to transport the ball to the ramp

Independent of the actual behavior and strategy repertoire of D the imitator correctly understands the observed behavior it is familiar with (right chart):

- “B”: behavior “move to ball”
- “G”: behavior “move to goal”
- Not recognized: the lifting of the ball



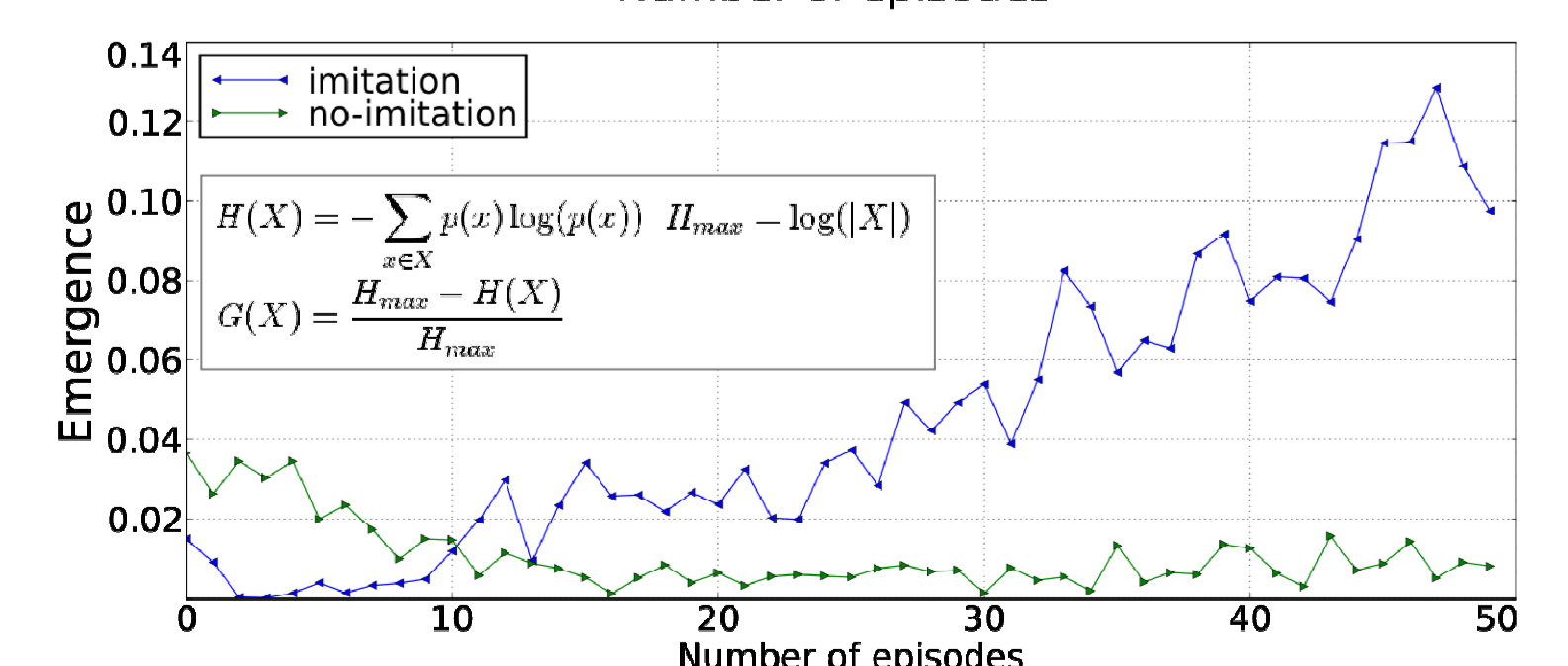
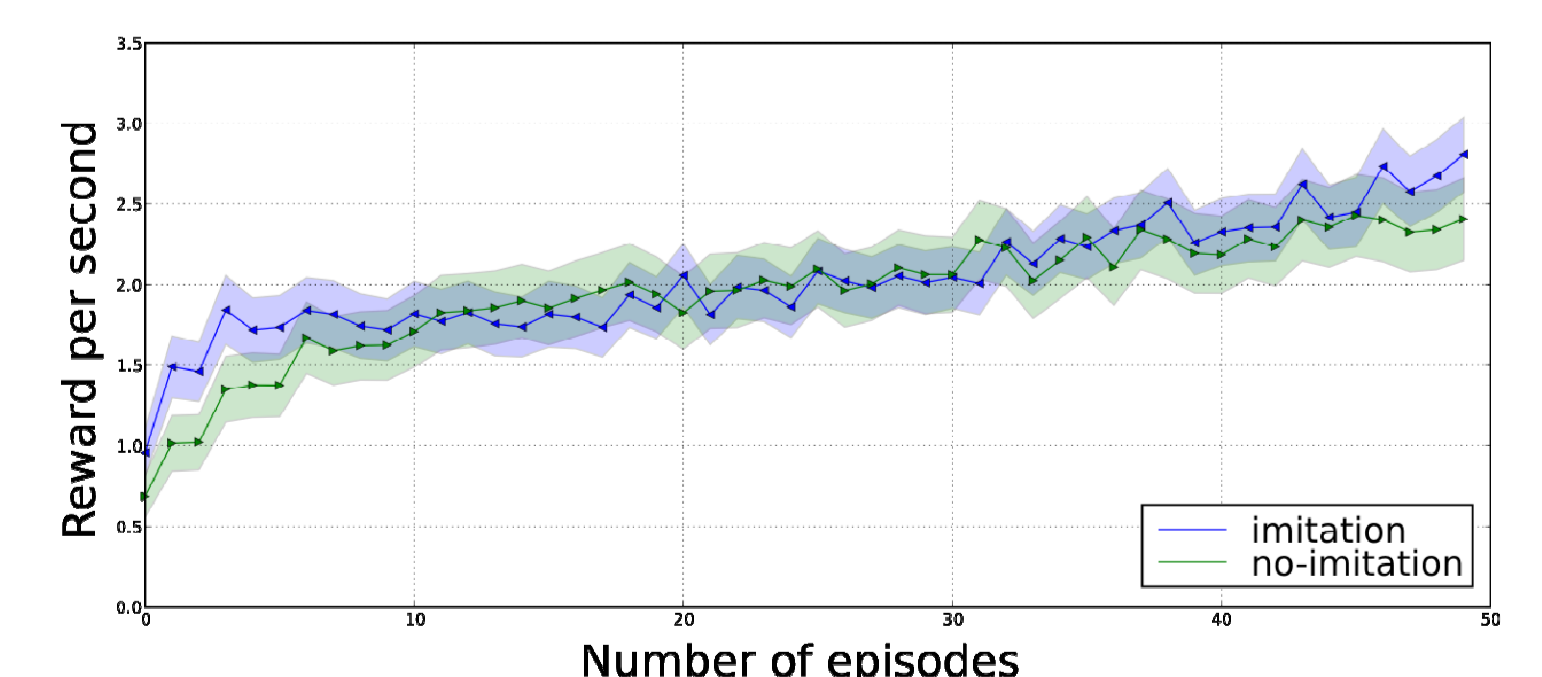
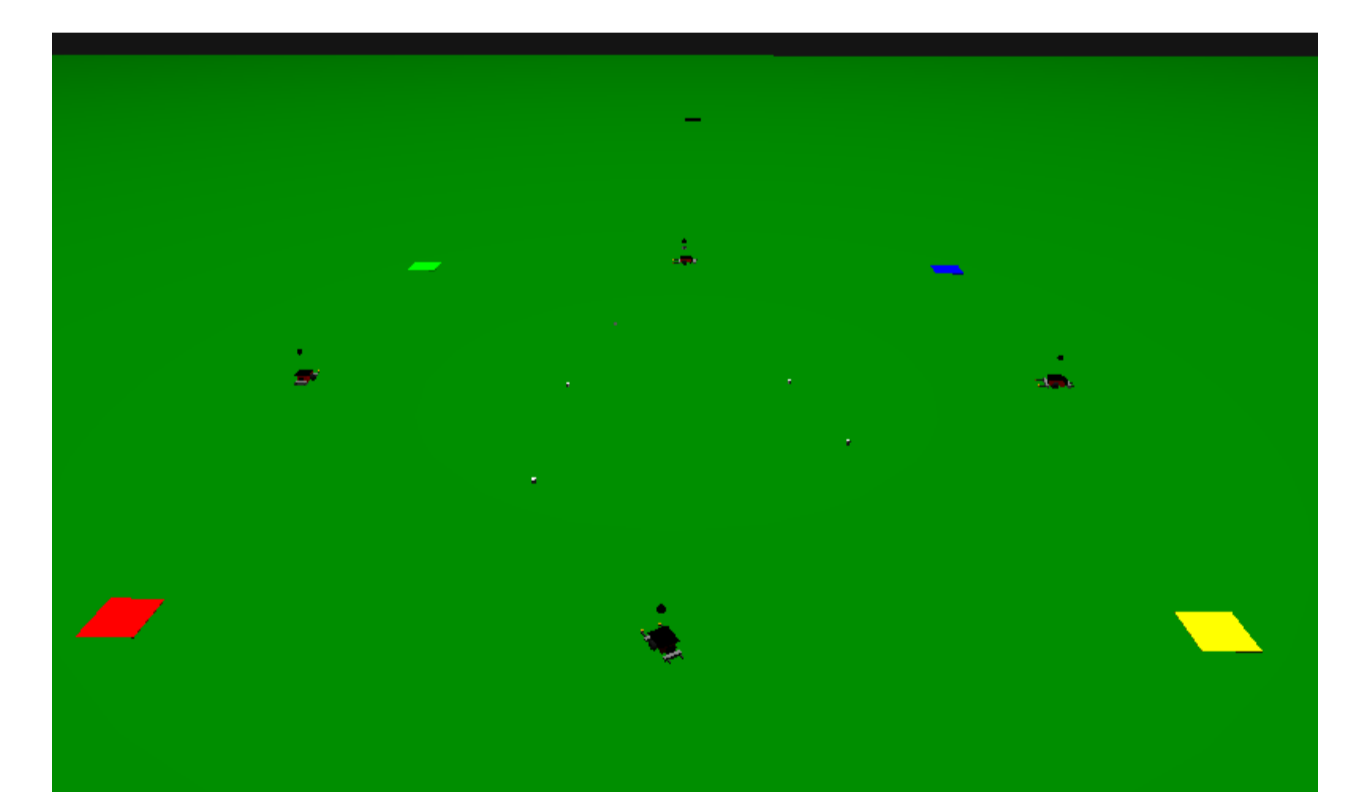
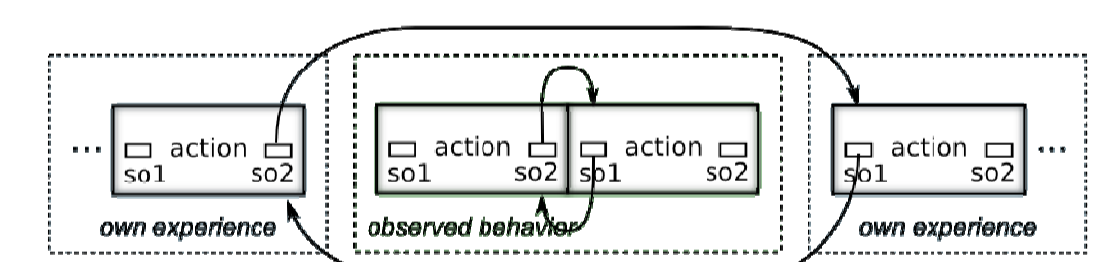
## Combining Imitation and Individual Learning

**Problem:** Integrating observed behavior into already existing knowledge

**Solution:** Treat “understood” behavior sequences as own observations

### Experimental Results

Scenario: Pucks have to be pushed to the bases. Black base is farther away but gives more reward  
Goal: Increase learning speed by imitation



## Institute

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