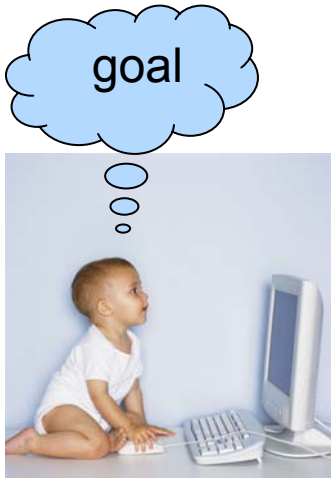
c-lab

Organic Computing Colloquium / Lübeck / Sept 2007



Evolving **S**ocieties of **L**earning **A**utonomous **S**ystems
(ESLAS)

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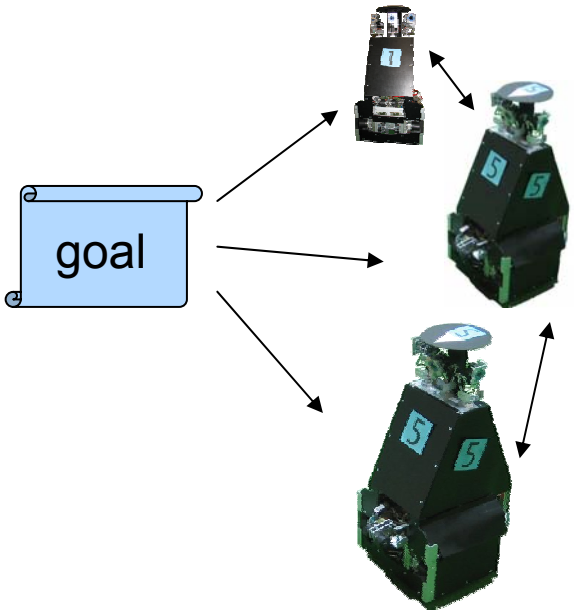
The ESLAS project

- **Goal:** Self-organization of individual learning robots in groups



- **How to achieve a specified goal?**
  → self-exploration, individual learning
- **How to control emergent behavior?**
  → decentralized evaluation functions inspired by socio-biologically principles
- **How to converge to group behavior?**
  → imitation

ESLAS within the SPP-OC

- **Our approach:**
  - Robot's individual adaptation guided by society's needs
    1. Selfish adaptation → sociologically based evaluation
    2. "Selfishness" dependent on the society's current needs
    3. Society's current needs dependent on entropy measurements
  - Robots having their own world model
  - |Society| << |Group| in typical ant algorithm applications

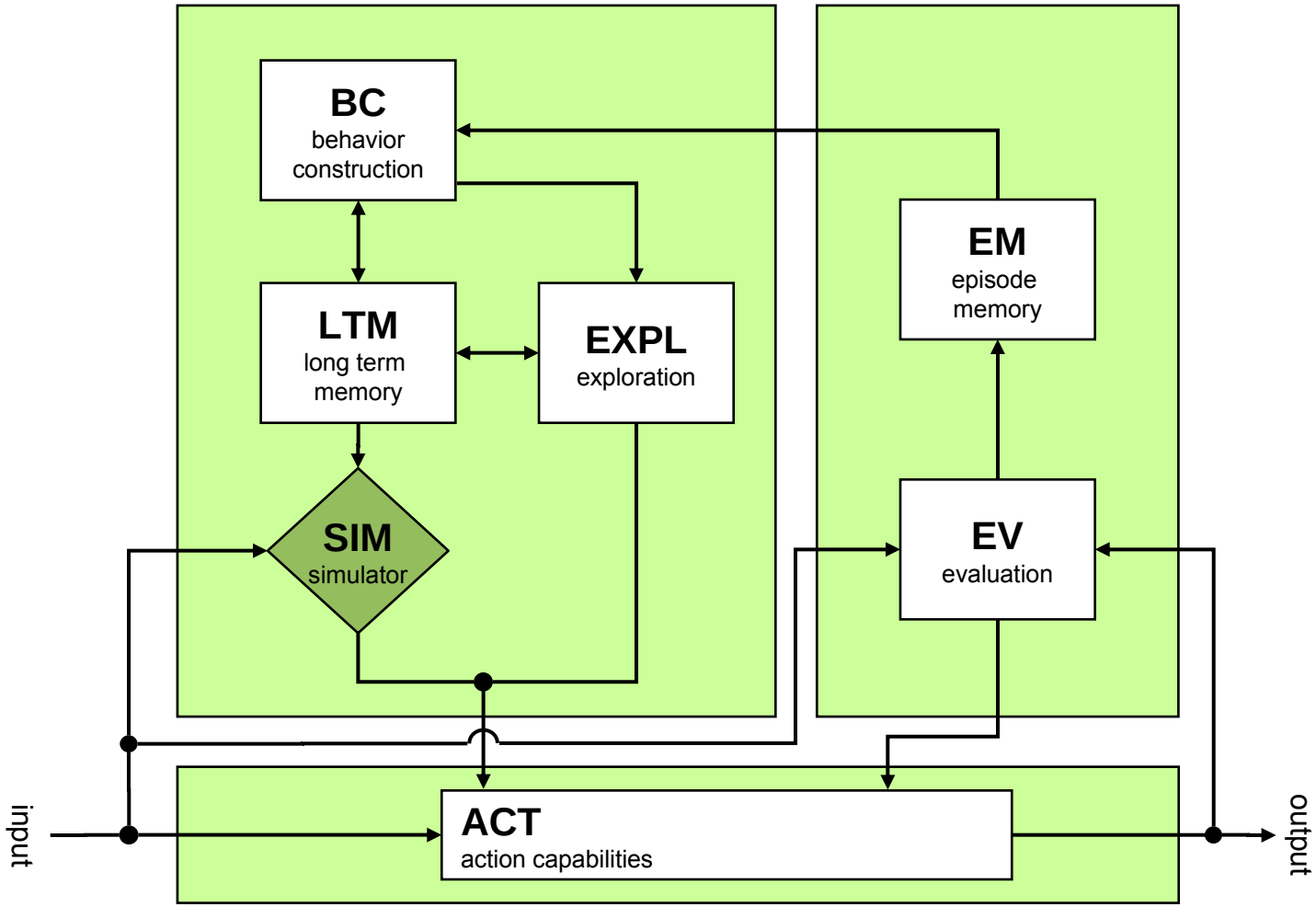
- **Related work within the SPP**
  - ***ORCA***
    Individual selfish adaptation without group aspect
  - ***SmartTeams***
    Strategies for exploration in groups without individual adaptation

Outline

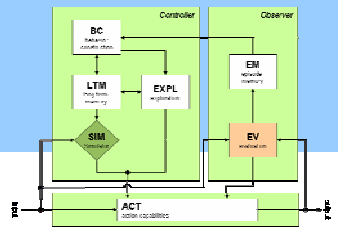
Topics in the ESLAS project

1. Design and implementation of the modular system
2. Evaluation system
3. Emergent behavior and imitation
4. Emergence measurement and design methodology
5. Evaluation by simulation and real world application

Design and implementation of ESLAS

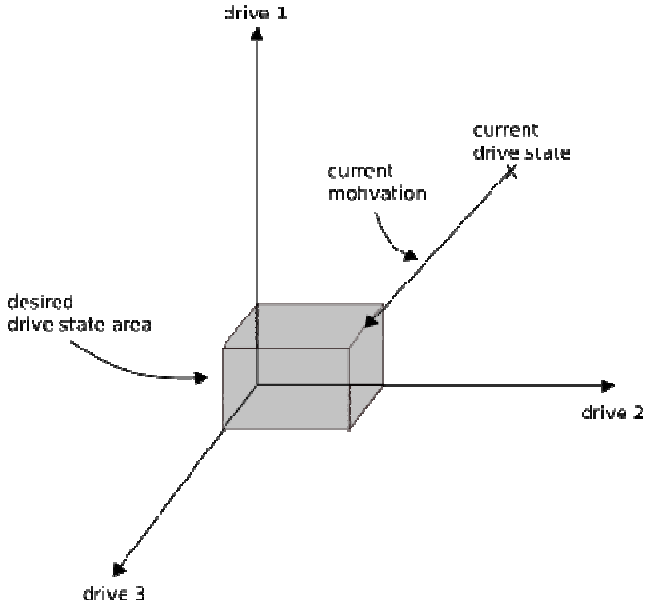


Evaluation system



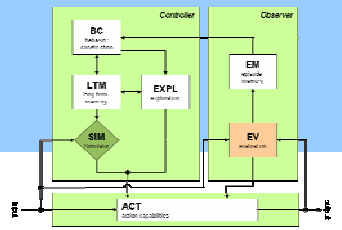
- **Intrinsic high-level state of the robot**
  - Robot's goals defined by means of drives
  - Dependent on perception and time-dependent functions
  - Threshold defines state of "well-being" or satisfaction

- **Drive examples**
  - Imitation
  - Task achievement
  - Survival

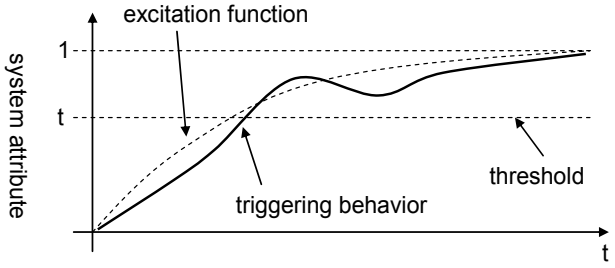


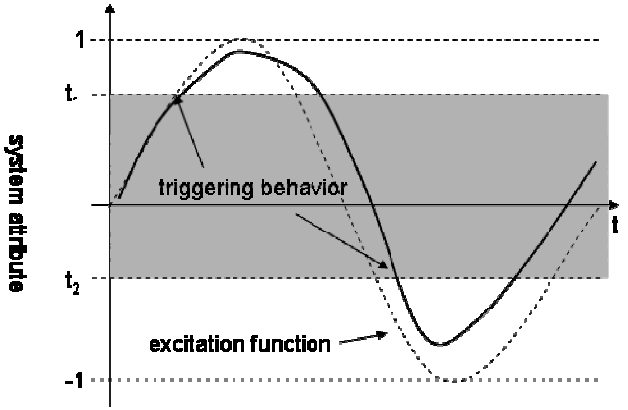
- **Generation of motivation**
  - Vector to "well-being region"
  - Dynamic drive state → dynamic motivation
    (useful e.g. for recurrent exploration)

Evaluation system



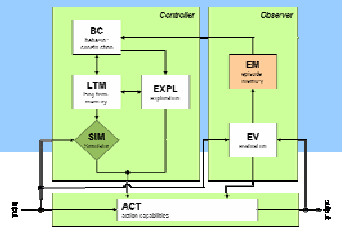
- **Two classes of excitation functions**
  - Excitation towards min/max with stimulus
  - Desired region min/max



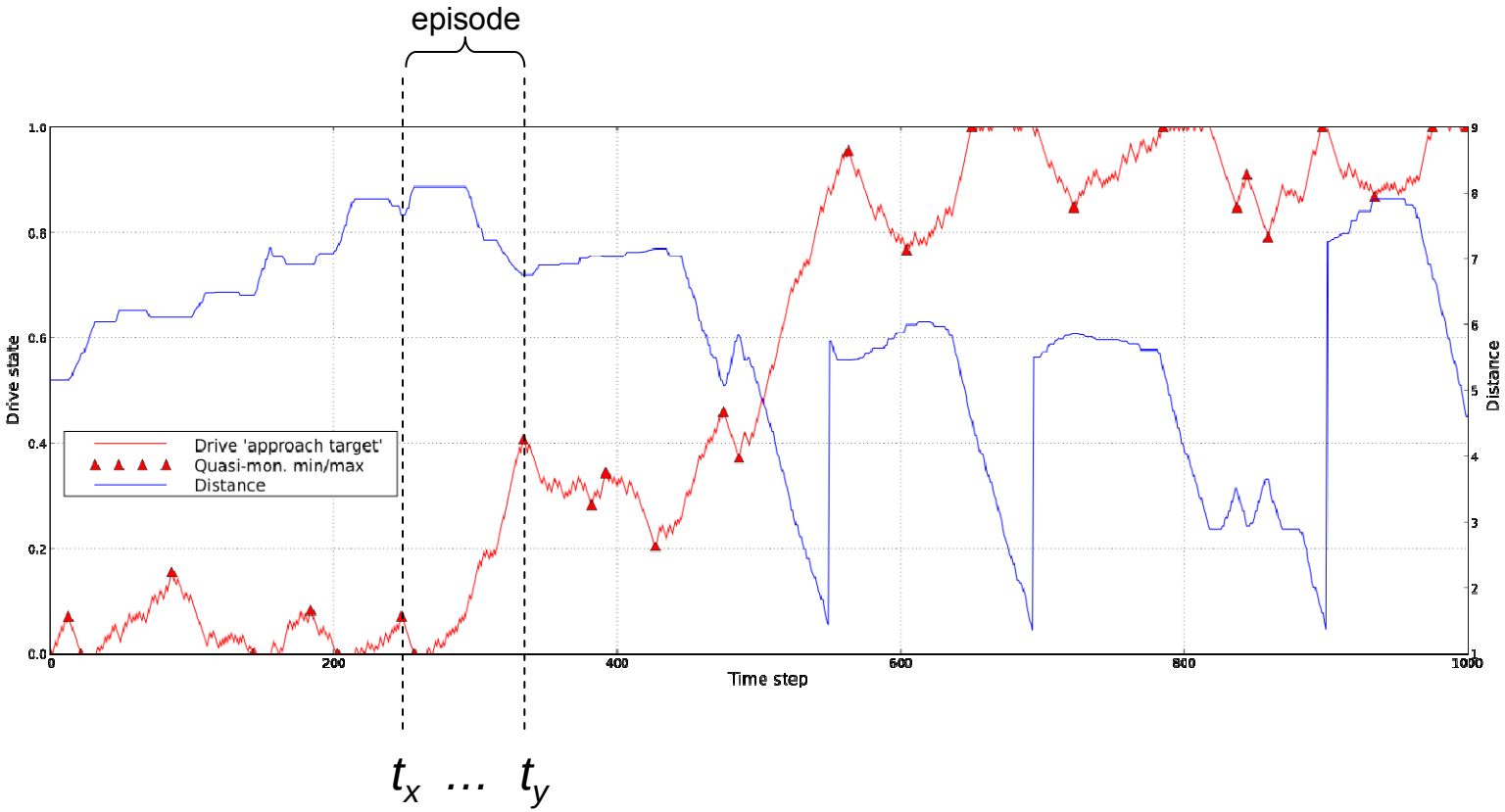


- **Thresholds**
  - triggers behavior to enforce / prevent according drive reaction
  - can be adapted

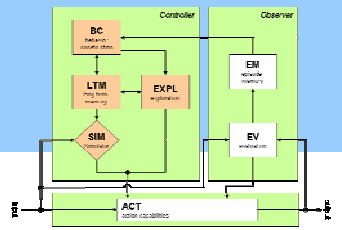
Episode Memory



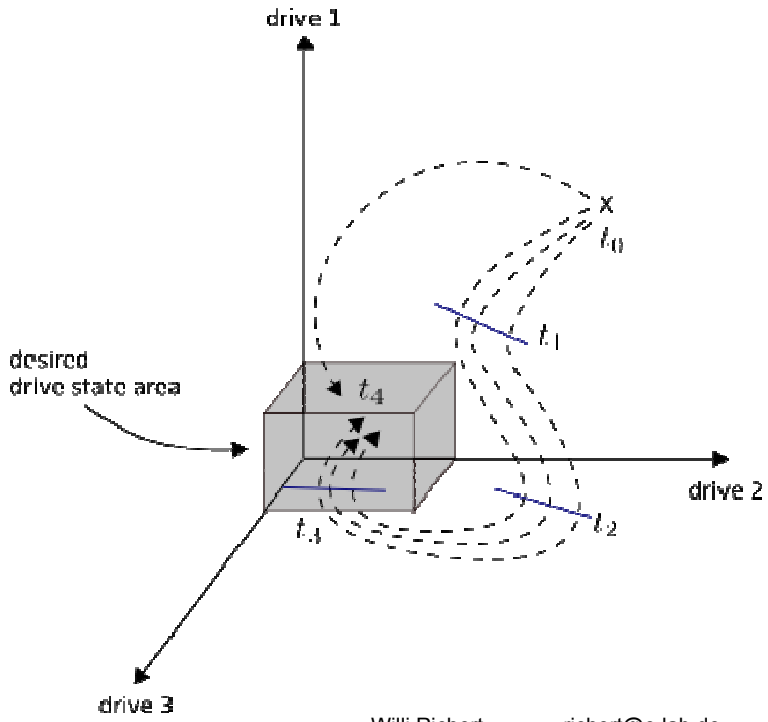
- Segmentation of the evaluation stream
- E.g. into quasi-monotonic intervals:



Learning from past experiences

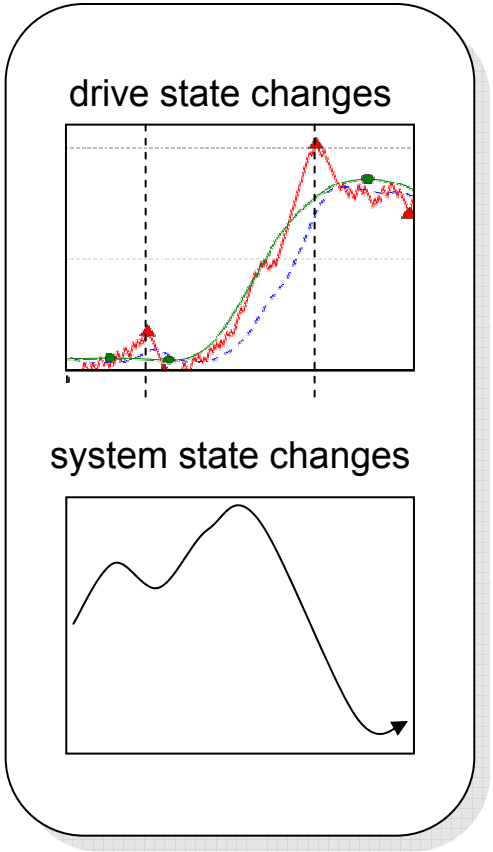


- Cluster starting and ending conditions of episodes
- Find environmental state transitions in the episodes
- Construct behavior from abstracted state transitions and use drive state changes as reinforcement signal for the according policy
- LTM builds a model of environment and itself
- SIM uses LTM to „dream“



Emergent behavior and imitation

Observed episode



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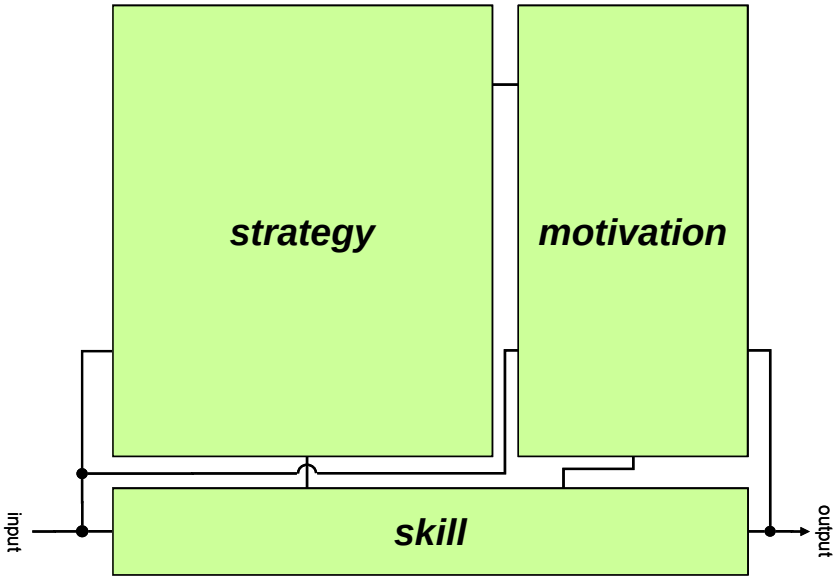
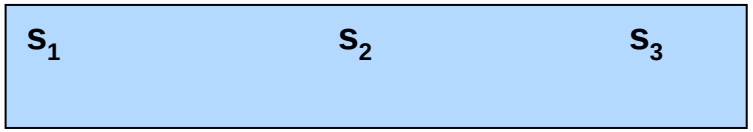


Emergent behavior and imitation

motivation
drive system

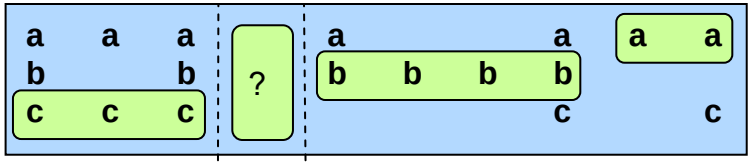
threshold adaptations

strategy
state transitions



alternative strategies

skill
recognized capabilities



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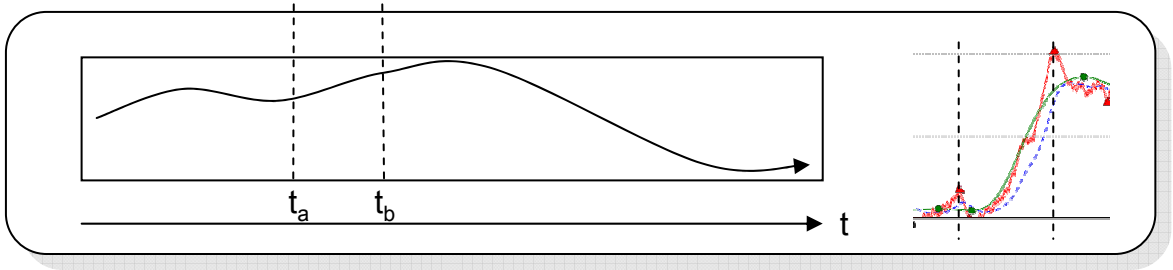
Observed episode



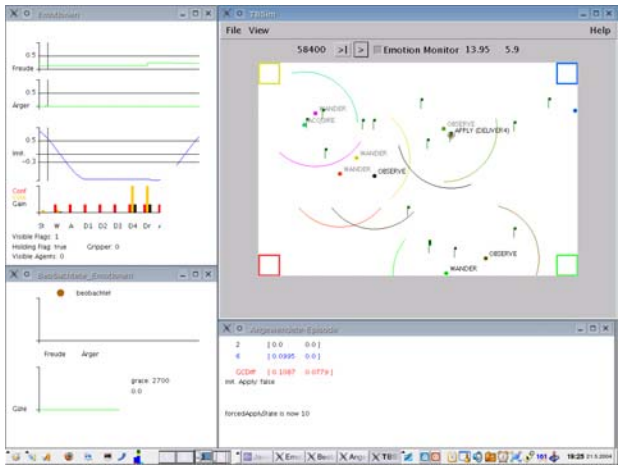
Emergent behavior and imitation

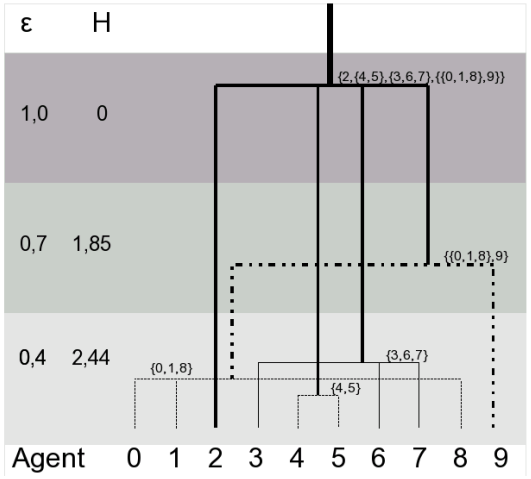
- Emergence and its control
  - New behavior emerges because of noisy imitation process
  - Controlled by the robot‘s own drive system
  - Adaptation of the drive system is controlled by the robot’s direct neighborhood → emergence measurement

- Interesting points
  - Learning when to imitate and when not to
  - Investigate imitation routes through a robot society

Emergence meas. and design methodology

- Shannon's Information Entropy on
  - robot group's attributes (Mnif)
  - robot's individual skill base (Richert)

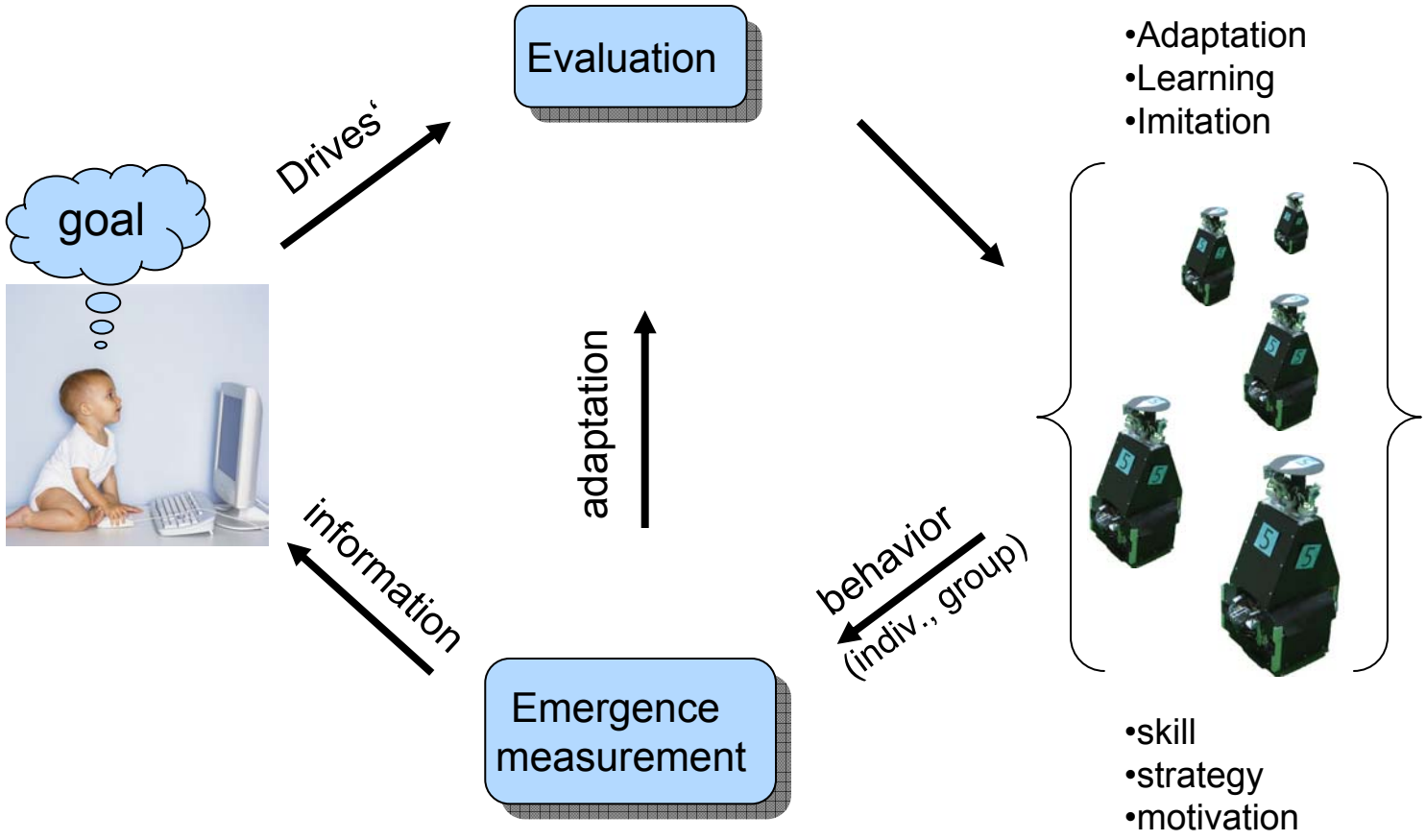




- Interesting points
  - How can the dependence between drive system design and society's desired emergence be integrated into the design process?
  - To what a degree has imitation led to a more heterogeneous or homogeneous society?

Emergence meas. and design methodology

- The vision of our design methodology:



Evaluation: simulation and real world application

- Soccer robot fleet
  - Mainly educational purpose
  - Seven 1-year-project groups
  - Participated in several tournaments

- Planned hardware adaptations
  - Drive state signal

Conclusion

- ESLAS – a modular approach for realizing self-organizing and self-optimizing autonomous systems
  - Emergent behavior in societies of such systems
  - Learning to adapt own capabilities to dynamic environments while paying attention to the overall group behavior
- Decentralized evaluation functions for assessing own behavior based on socio-biologically paradigms
- Learning combines individual adaptation with imitation to converge to desired group behavior

Thank you for your attention!

- Questions? Hints? Suggestions? Answers?