Evolving Societies of Learning Autonomous Systems (ESLAS)

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ESLAS Project - Background

Main goal: Self-organizing of heterogeneous societies of autonomous robots

How to model dynamically changing goals of a robot?

biological principles: motivation system in terms of drives

How to individually achieve a specified goal?

self-exploration, self-awareness, individual learning

How to converge to group behaviour?

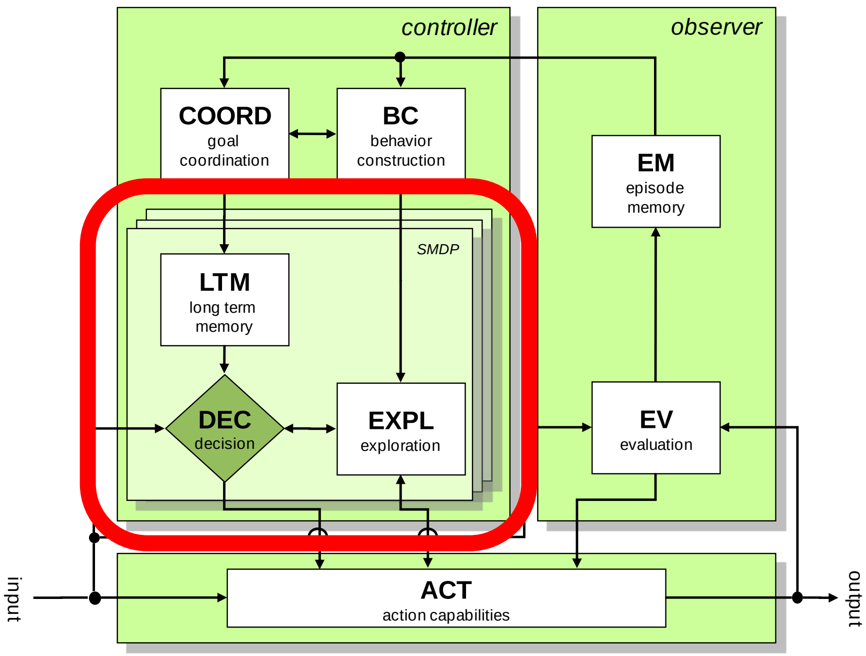
imitation: observing, understanding and incorporating additional knowledge

How to coordinate multiple possibly contradicting goals?

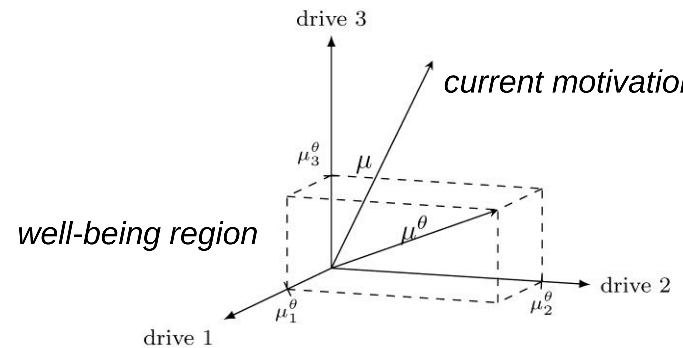
ESLAS Project Phase III – Brief Recap

Coordinating multiple goals of a single robot, e.g.:

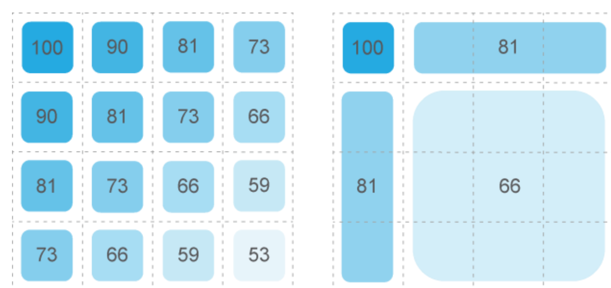
1. *battery loading*
2. *collecting items*
3. *transporting items to base*



Motivation system in terms of occasionally contradicting **drives**



Each drive is represented by a dynamically abstracted and adjusted **Semi-Markov Decision Process**



original *abstracted*

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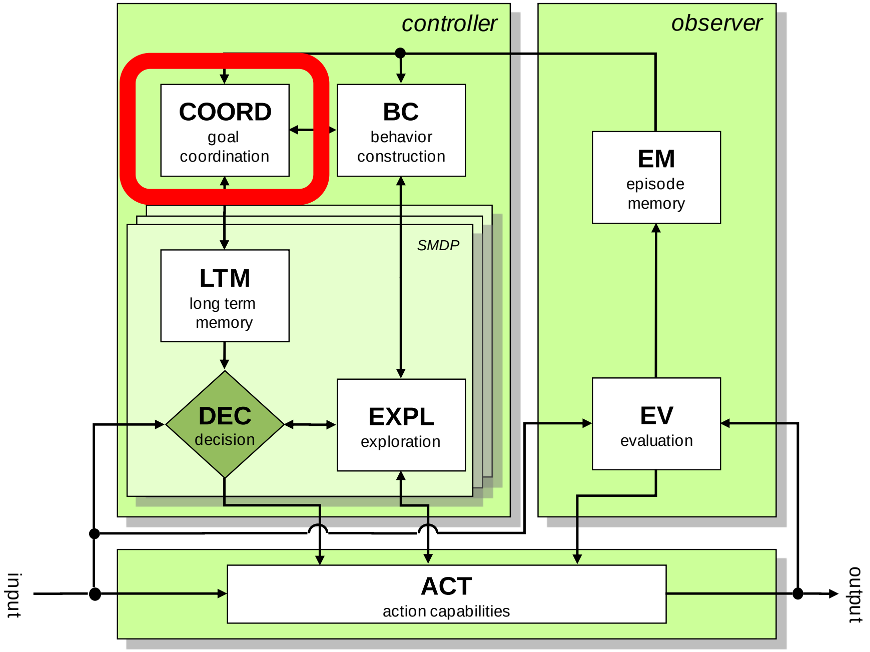
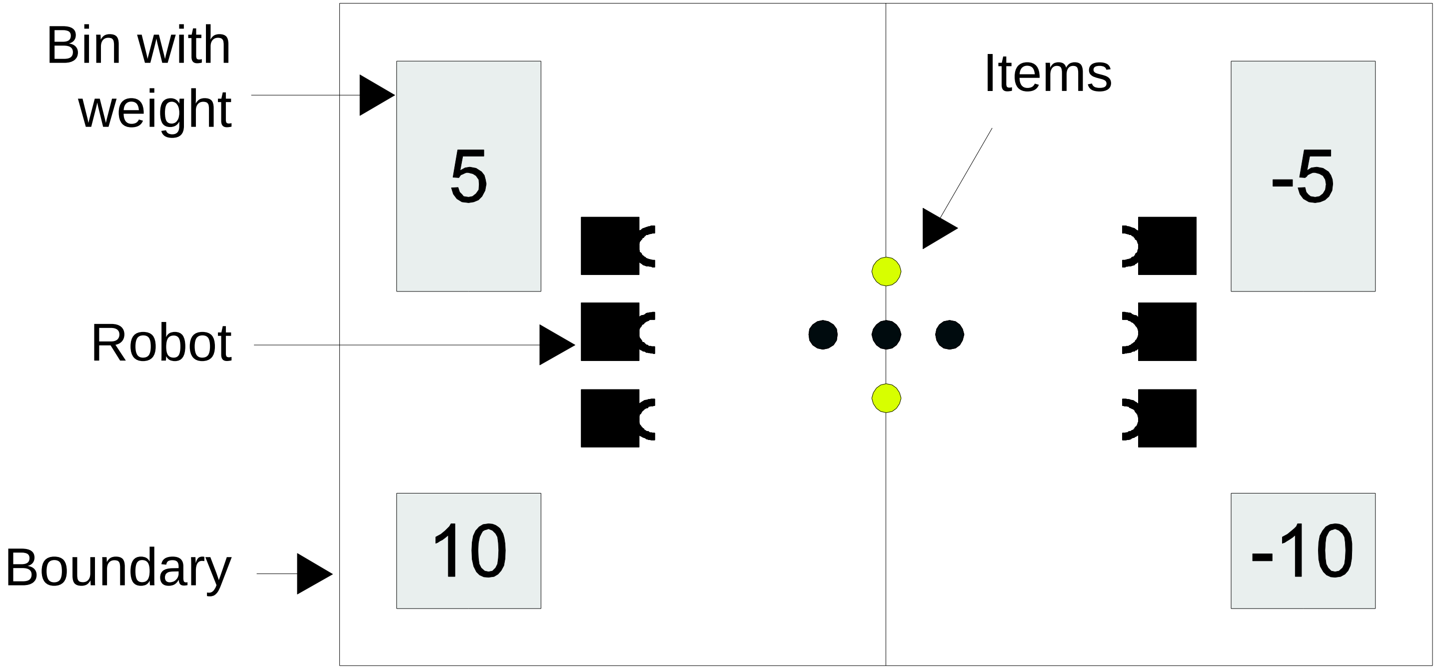


Goal coordination (COORD)
- keeps track of states spaces
- efficiently selects a robot's actions based on SMDP in the presence of dynamically prioritized goals

Goal selection mechanism:
- cumulative weighted reward of two drives
- detects a worthwhile detour in the state space for one additional goal
- acceptable runtime compared to considering all possible sequences

Real World Evaluation

- shift investigations from simulation to the real physical world with all its dynamics
- provide a demonstrative scenario
  1. sophisticated investigations
  2. appealing for audience



Real World Evaluation

Integrating the ESLAS approach

Learning: each robot has to **individually learn proper strategies** to maximize its score

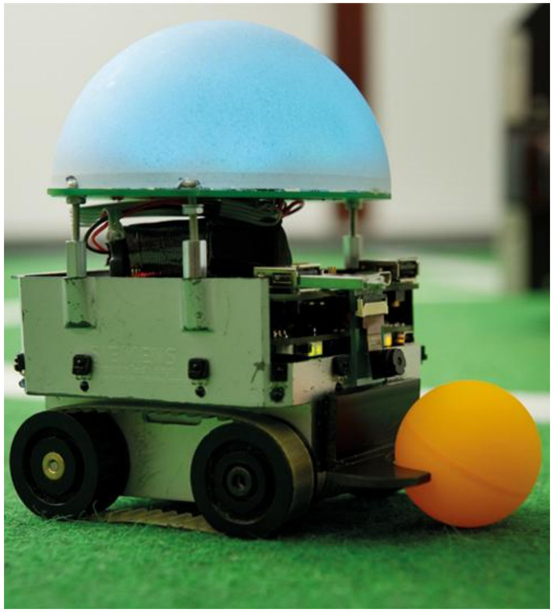
Imitation: each robot gathers **additional learning samples** by **observing**, **understanding** and **incorporating** the behaviour of other robots

Coordination: **dynamically changing goals**, such as *defending the own items*, *gathering new items* or *loading the battery,* have to be coordinated by each robot

Cooperation: team cooperation in a non-obtrusive manner, based on **observing** and **understanding**

Real World Evaluation

Different types of robots with different capabilities for heterogeneity



BeBot
(developed @ HNI)

Rovio
(commercial)

Spykee
(commercial)

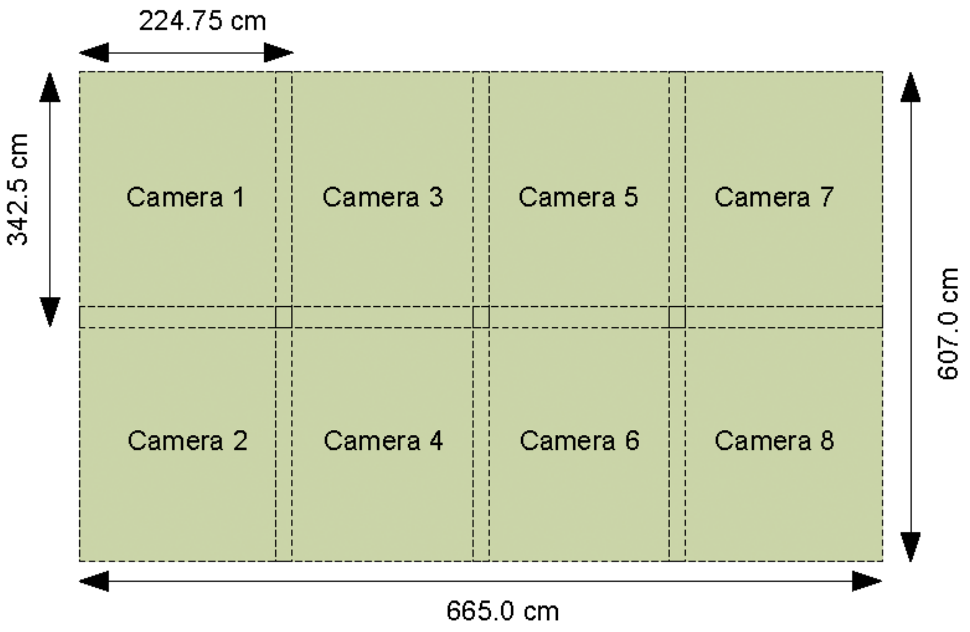
Real World Evaluation

Requirements:

- **overall view** of the entire environment for debugging and localization
- robust **localization** of the robots, independent of the robots' capabilities (sensors)
- **scalability** with respect to the scenario area as well as computational power
- **scalability** with respect to the degree of heterogeneity of the applied robots

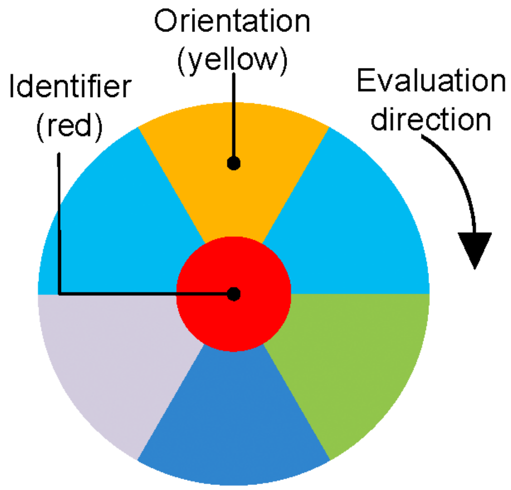
Global View of the Entire Environment

- eight cameras, supervising an area with a total size of **665 cm x 607 cm**
- all eight areas **overlap by 39 cm** to guarantee a continuous tracking of robots
- **coherent picture** is constructed by a stitching mechanism
- the stitching mechanism also merges robots that were detected in more than one frame

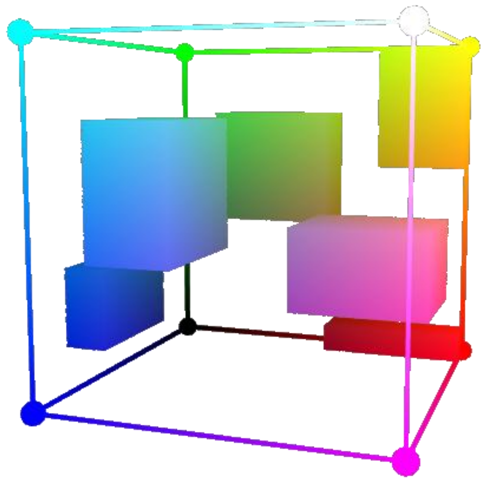


Marker-based Robot Localization

Realized by **artificial landmarks** that are attached to the top of the robots and detected by the external cameras

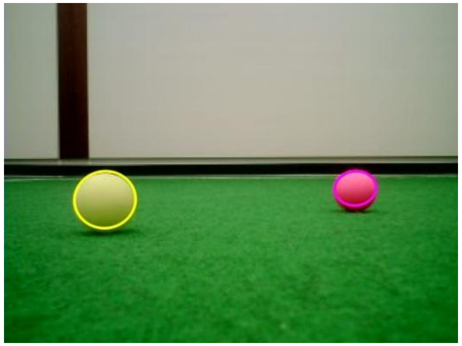


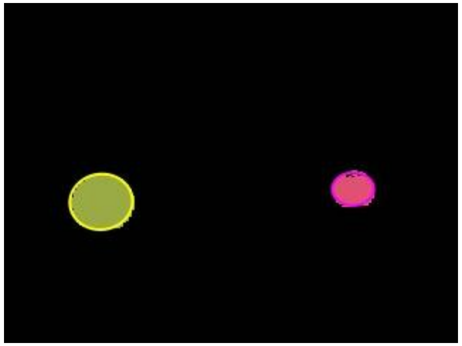
1. **color segmentation** for extracting regions of similar colors
2. assign regions to **pre-defined color classes**
3. marker detection algorithm based on **heuristics**
4. translation into field coordination system



Subjective Perspective of a Robot

- each robot has to individually perceive its actual environment
- focus on **vision based data**
- computational power not sufficient to do image processing on every robot
- a **proxy node** provides the camera image of an applied robot
- by providing it to all interested clients, the **network load is minimized**



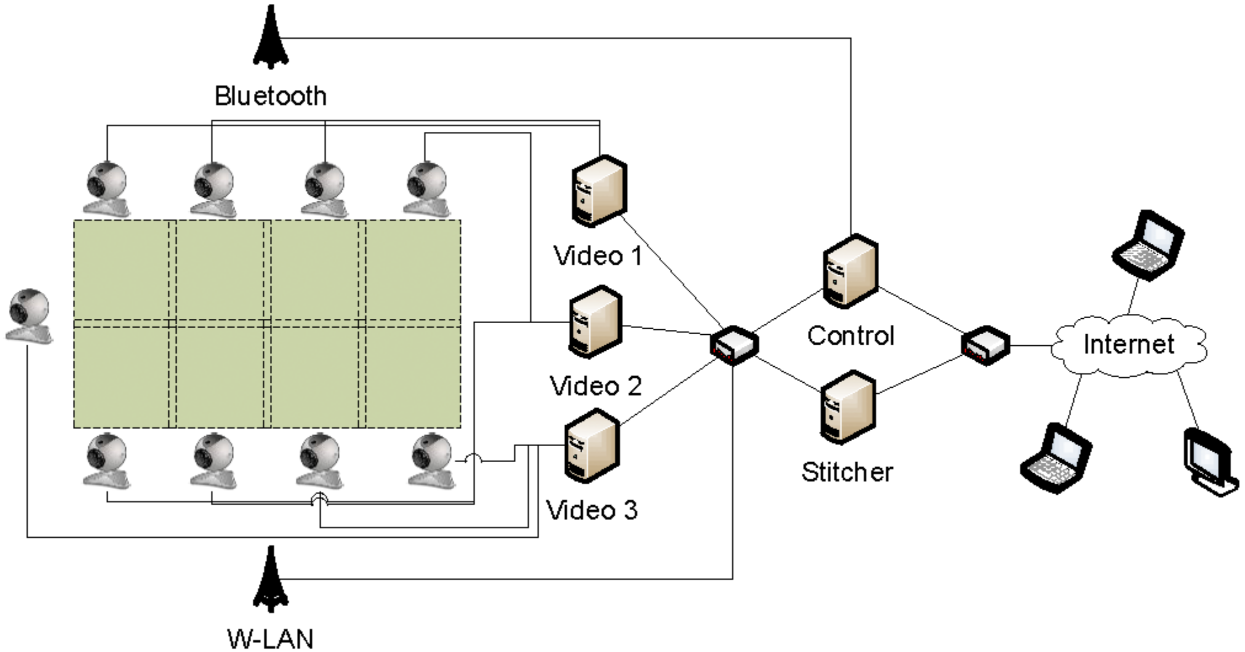


Scalable Structure

Software

- distributed software architecture in terms of **loosely coupled nodes**
- communication via TCP/IP (across processes)

Hardware



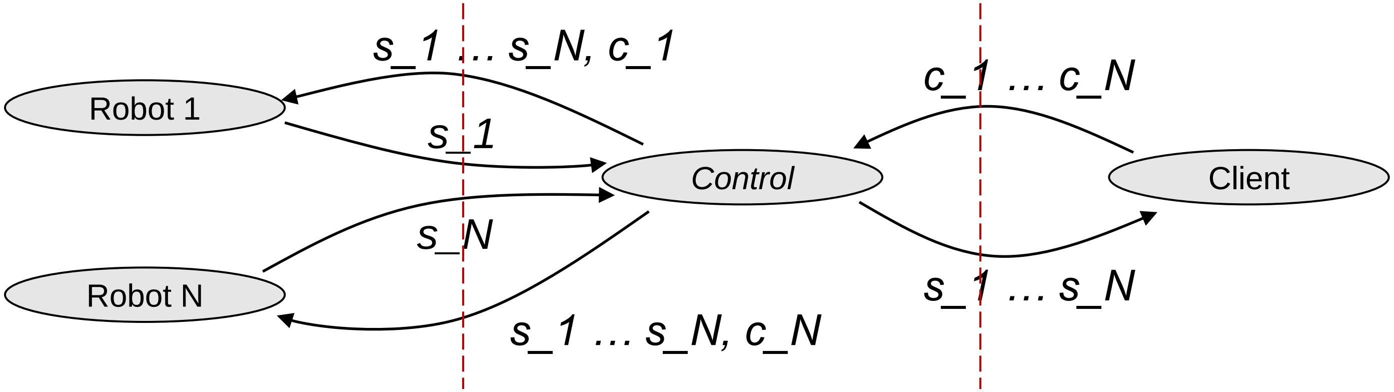
Deploying the system

Access and Usage

Decentralized user management:

1. *passive access level* (monitor experiments)
2. *active access level* (conduct experiments)

A **control node** realizes the connection between robots, node architecture and user clients

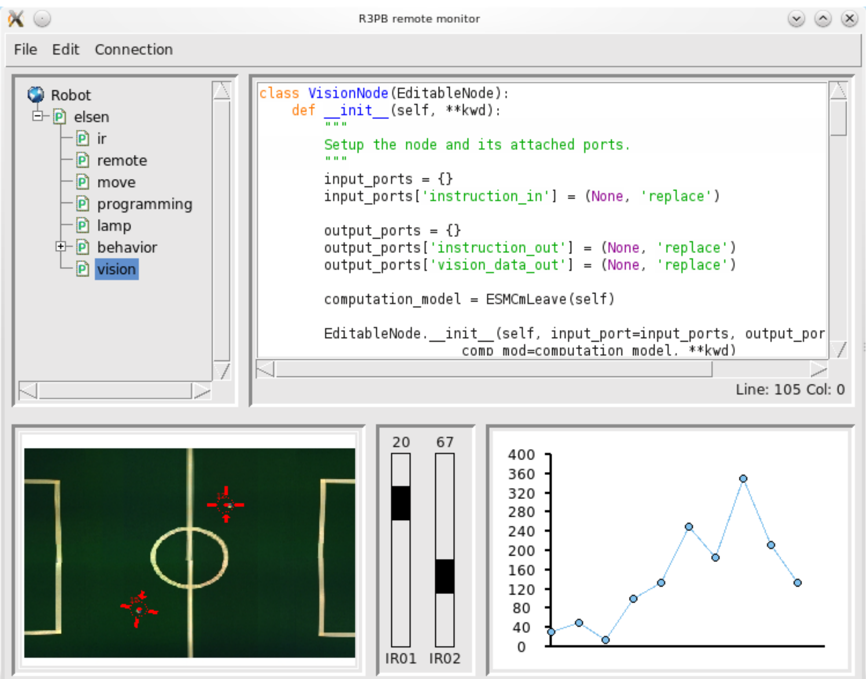


s_x: state of robot x
c_x: control command for robot x

Deploying the system

Clients

passive access (webpage)



active access (standalone)

R3PB Test Bed

<u>R</u>emote <u>R</u>eal <u>R</u>obots at the University of <u>P</u>ader<u>b</u>orn

- test bed for **conducting experiments** with mobile robots
- enables students and researchers to **control, program and monitor** groups of mobile robots
- **camera based tracking system** for locating robots and supervising the entire area
- software system consists of **loosely coupled, distributed nodes**
- **scalable infrastructure**, which can be easily extended

Summary

- realized a **controlled real-world environment** for conducting experiments under realistic conditions
- the scenario is **highly descriptive** and easy to understand on the one hand, and allows for **sophisticated investigations** on the other hand
- *ongoing:* **investigation and demonstration** of the Organic Computing principles provided by ESLAS in a real world scenario

Thank you

for your attention!