Innovative Industrial Applications of Robots: The RoboCup@Work and RoCKIn@Work Competitions

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RoboCup

From RoboCup to …

Gerhard Kraetzschmar
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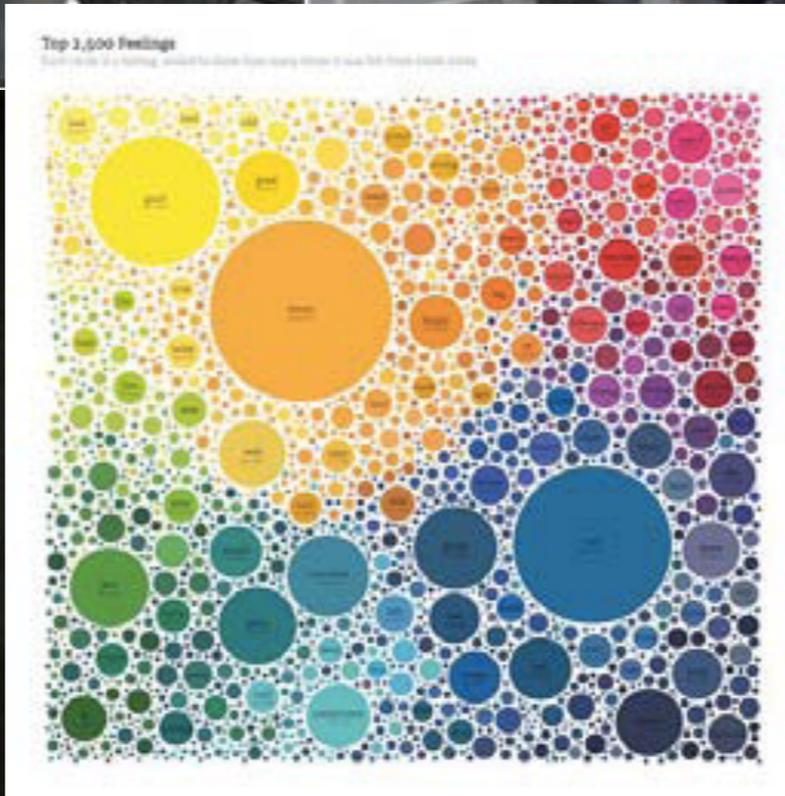**Sankt Augustin, Germany**

Challenges in Manufacturing and Logistics

- feeding parts from a palette onto a machine

- loading parts from machines onto a palette

- feeding a set of parts from several containers into a tray for a subsequent assembly process

- performing pre-assembly tasks

- packing parts and boxes into containers

- unloading boxes from containers

- sorting objects from unstructured heaps

- wrapping objects (e.g. before packing and shipping them)

- assembling complex objects from parts based on an example

- painting objects according to an example given as image

- moving parts and objects around

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Some more examples …

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- Extend RoboCup with a league attractive to industry

- Target new challenge problems for industrial applications

- Combine ideas that work from

    - RoboCup Soccer (fascination of competitions)

    - RoboCup Rescue (rigid evaluation by well-defined measures)

    - RoboCup@Home (staged sequence of increasingly complex tests)

    - into a new RoboCup challenge

- Drive the use of simulation in the software development process for real robots
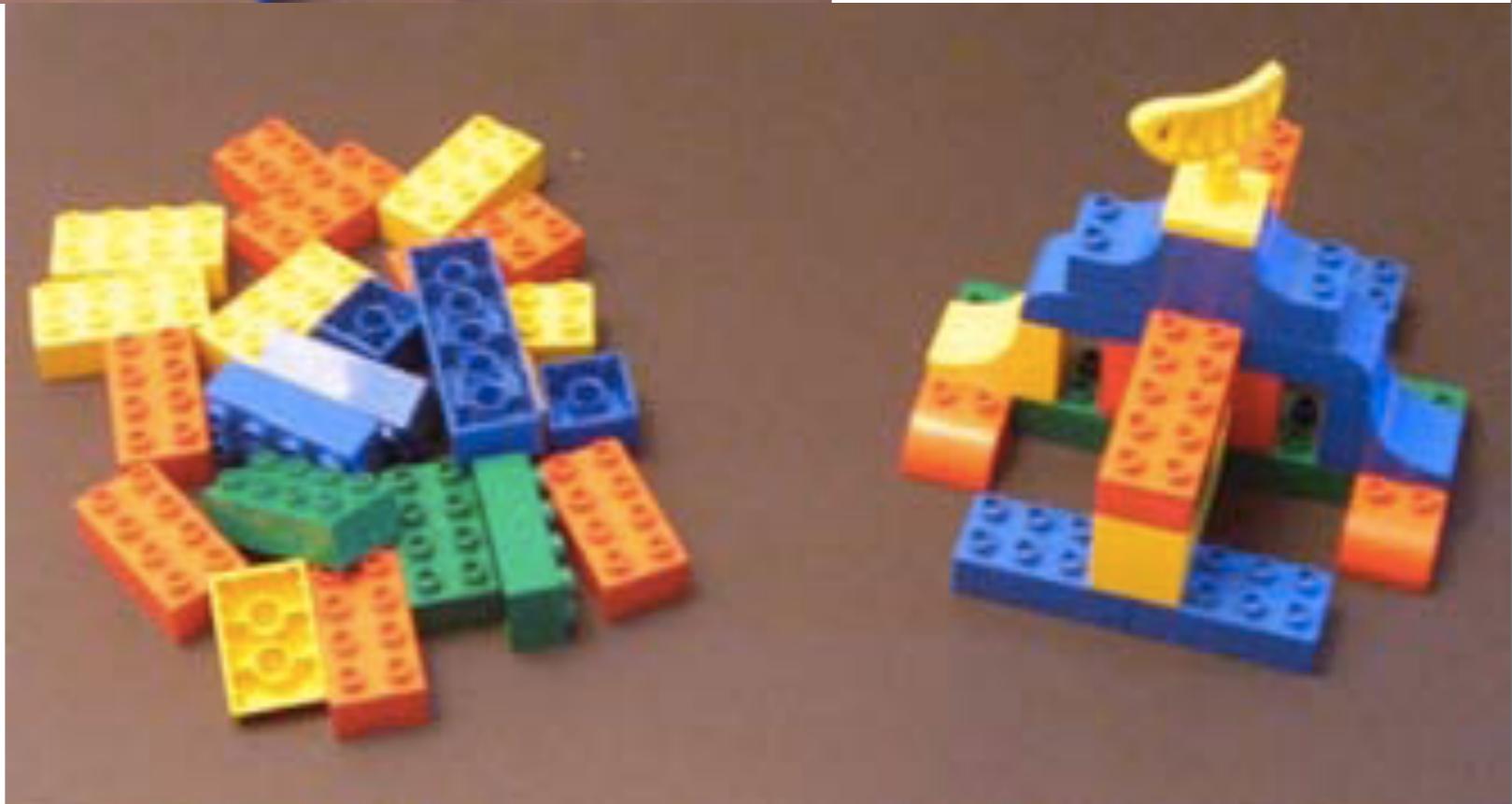
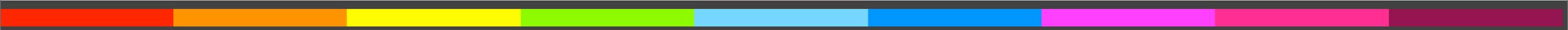# Motivation for RoboCup@Work

- Industry needs it and wants it

- Funding agencies welcome it

- RoboCup teams gain opportunities for cooperation

- RoboCup Federation complements its competition range
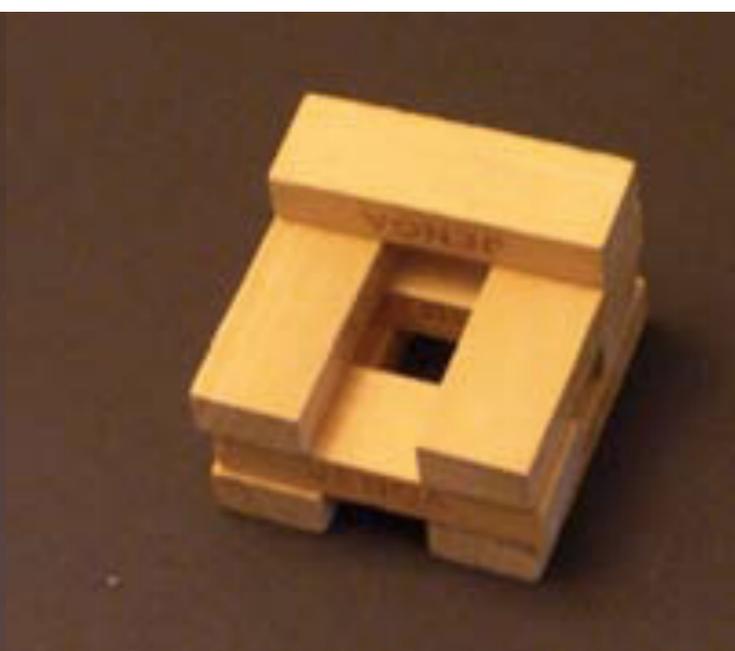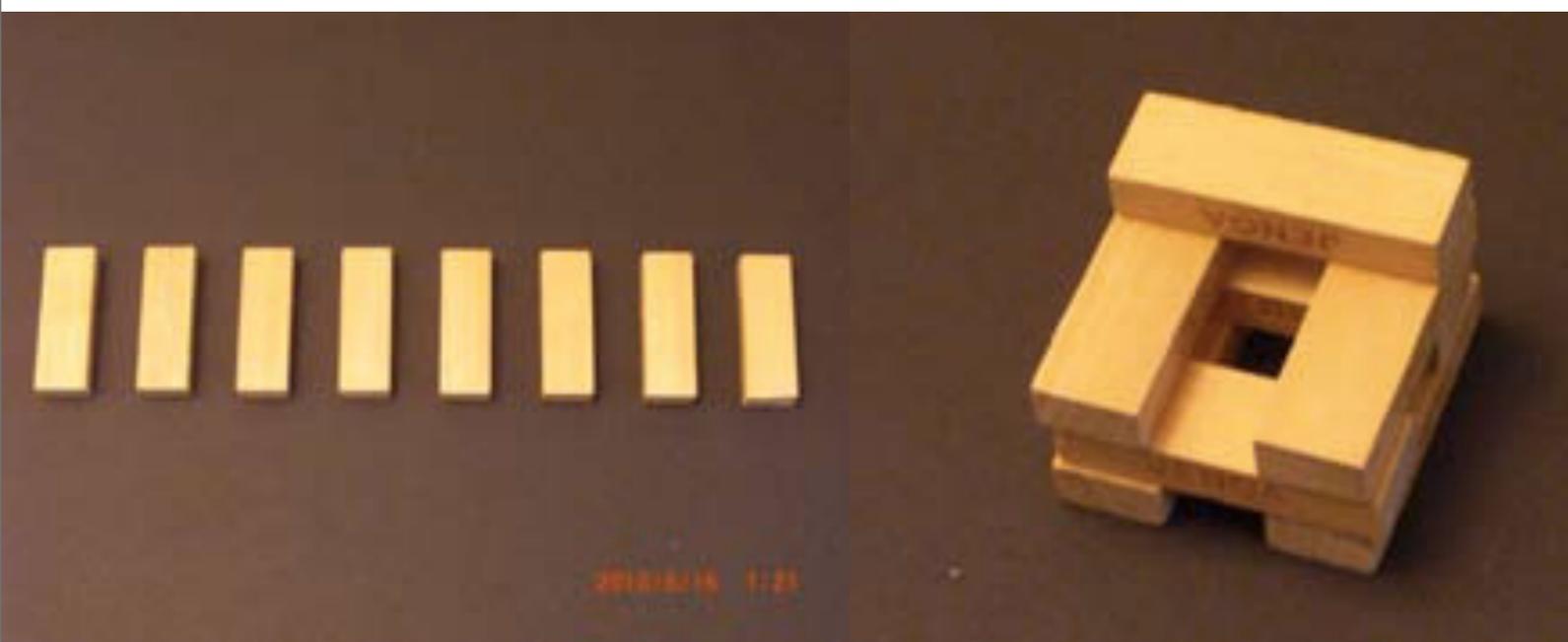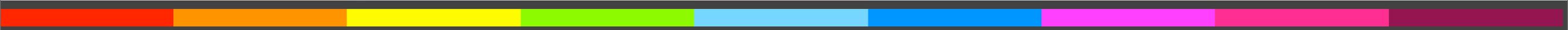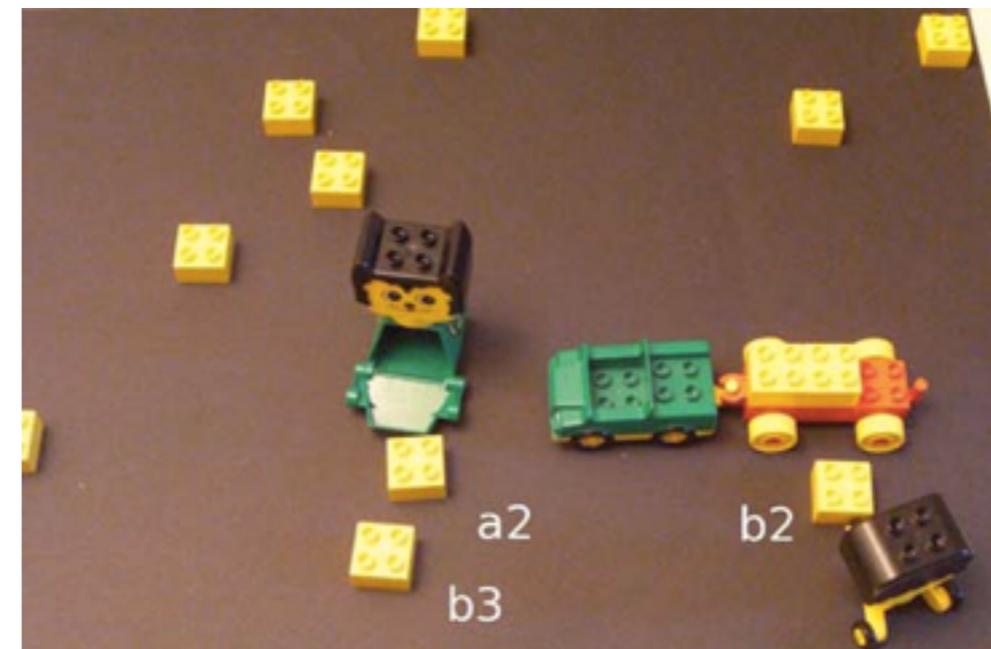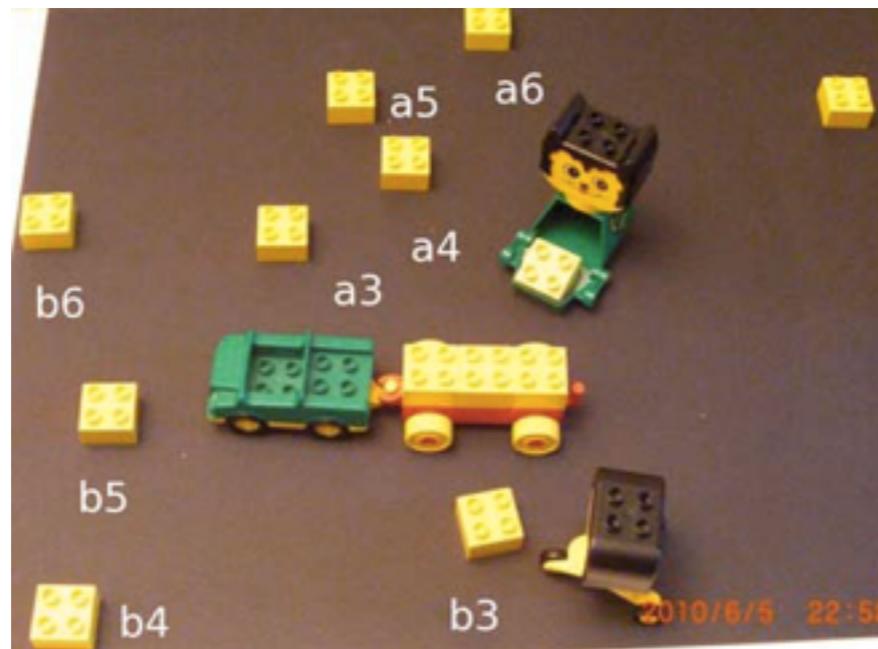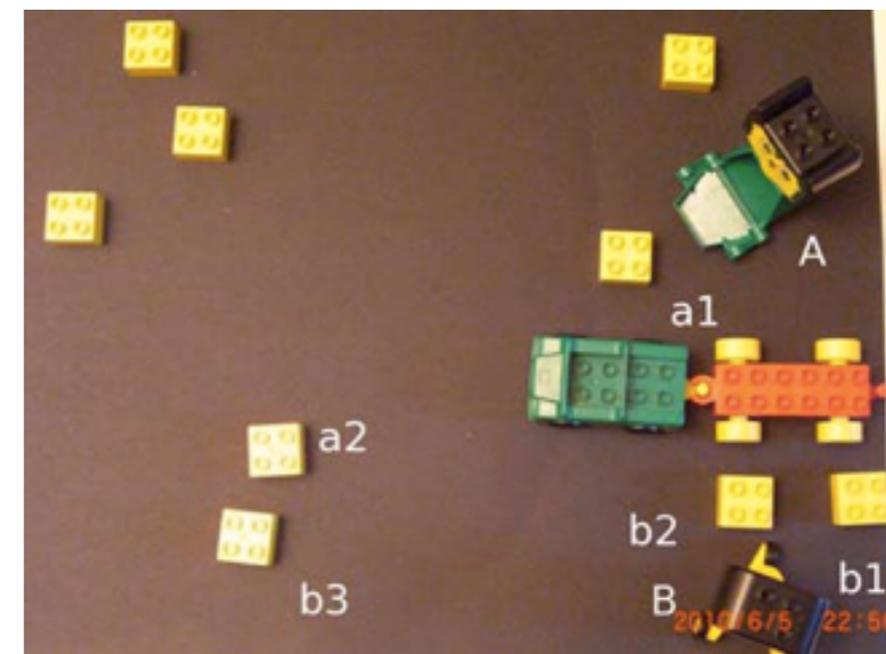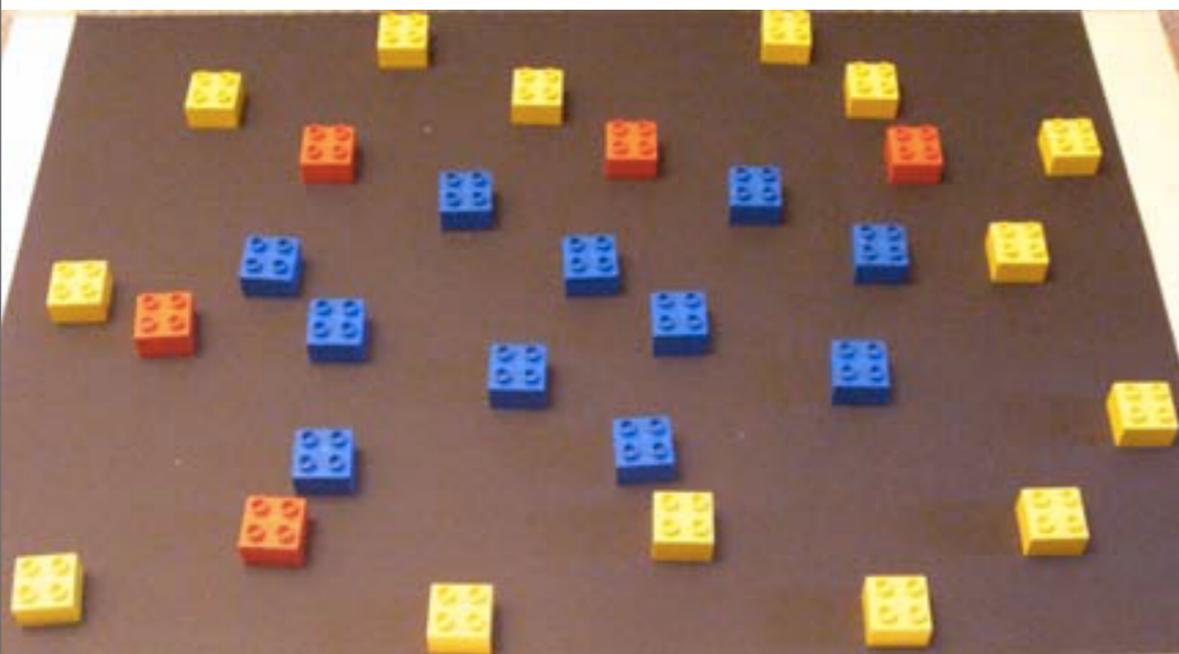
- A nice version of this for RoboCupJunior would be possible
- Alternative? post-reception table cleaning

- Competition design is not trivial!

- How to design successful competitions?

- How to design competitions to drive scientific progress?

- How to design competitions to allow for benchmarking?

Expectations

- Competitions:
  - interesting to watch
  - fair
  - safe
  - maintaining public order
  - rewarding participating people
- Scientific competitions:
  - giving feedback on scientific ideas
  - fostering research
  - attracting students
- Benchmarking through competitions:
  - evaluating, measuring, comparing approaches
  - allowing for analysis

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Competition Design

- Identify a challenge:
    - Address an open research problem
    - Address an open engineering problem
    - Address an open integration problem
- But be feasible: solutions must be within reach
    - Scenario and task simplifications
    - DARPA Grand Challenge
- Consider entry barriers:
    - investment cost
    - personnel effort
    - existing performance levels

RoboCup@Work Competition Design

- **Current**
  - BNT Basic Navigation Test (show me that you can navigate and not get lost)
  - BMT Basic Manipulation Test (show me that you can perceive objects, grasp them, and do pick and place)
  - BTT Basic Transportation Test (combine the first two tests)
  - CTT Competitive Transportation Test (two teams compete at same time; resource conflicts)
- **Future**

  CBT Conveyor Belt Test

  - Advanced Manipulation Test (constrained grasping, articulated objects, variability, precision, obstacles)
  - Assembly Test (putting things together, HRCoop, bimanual manipulation)
  - Feeding Test (dynamics; taking and putting things on belts, feeders, carousels)
  - Logistics Test (picking, placing, packing, closing, transporting)
  - Cooperative Manipulation Test
  - Cooperative Transportation and Logistics Test
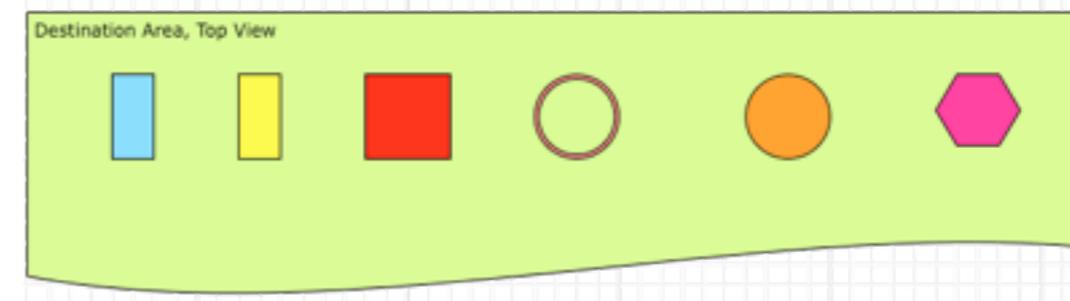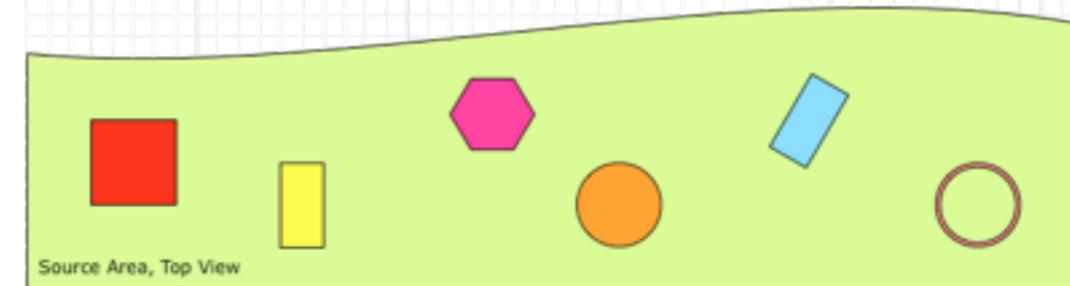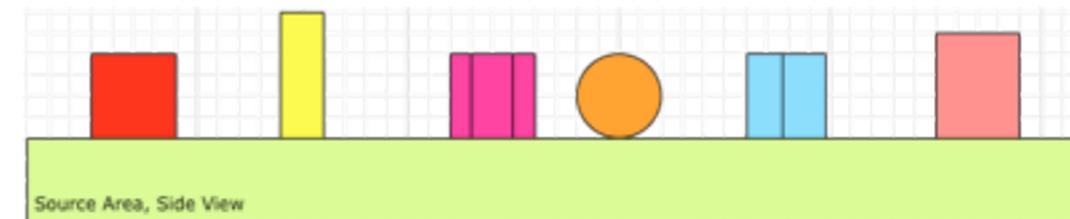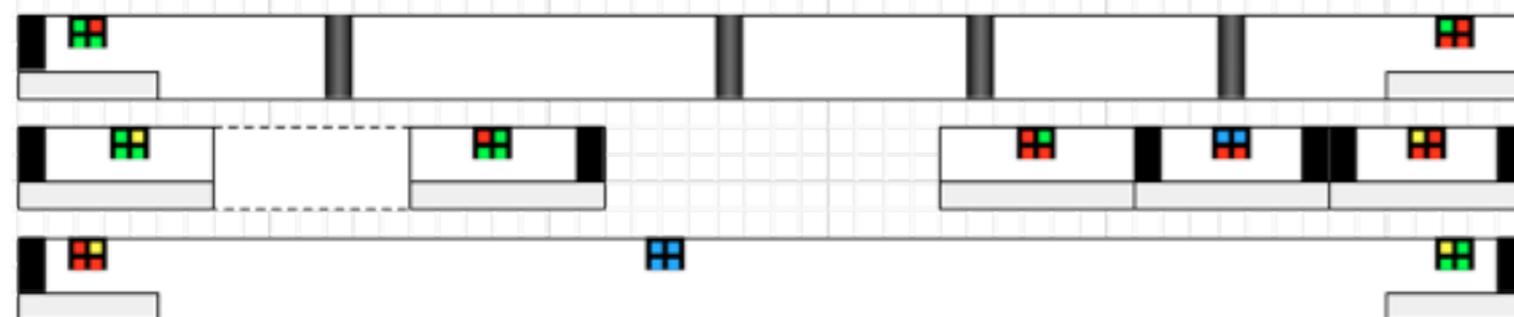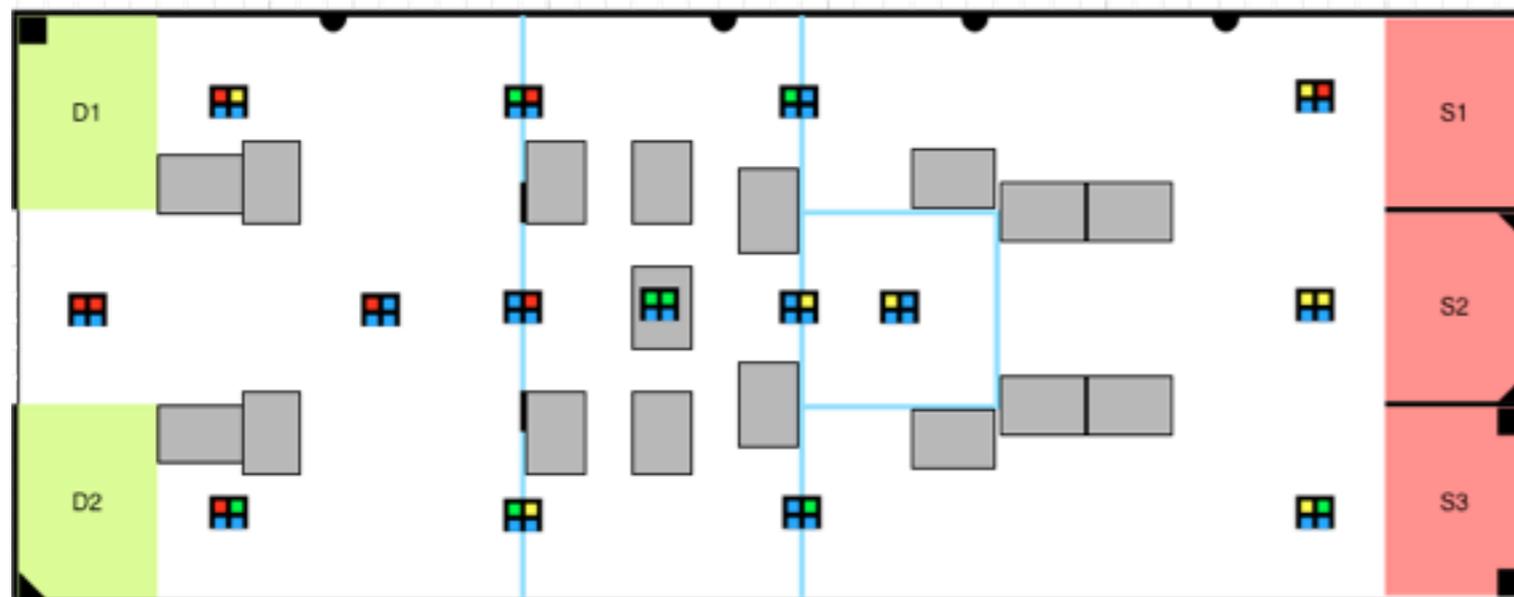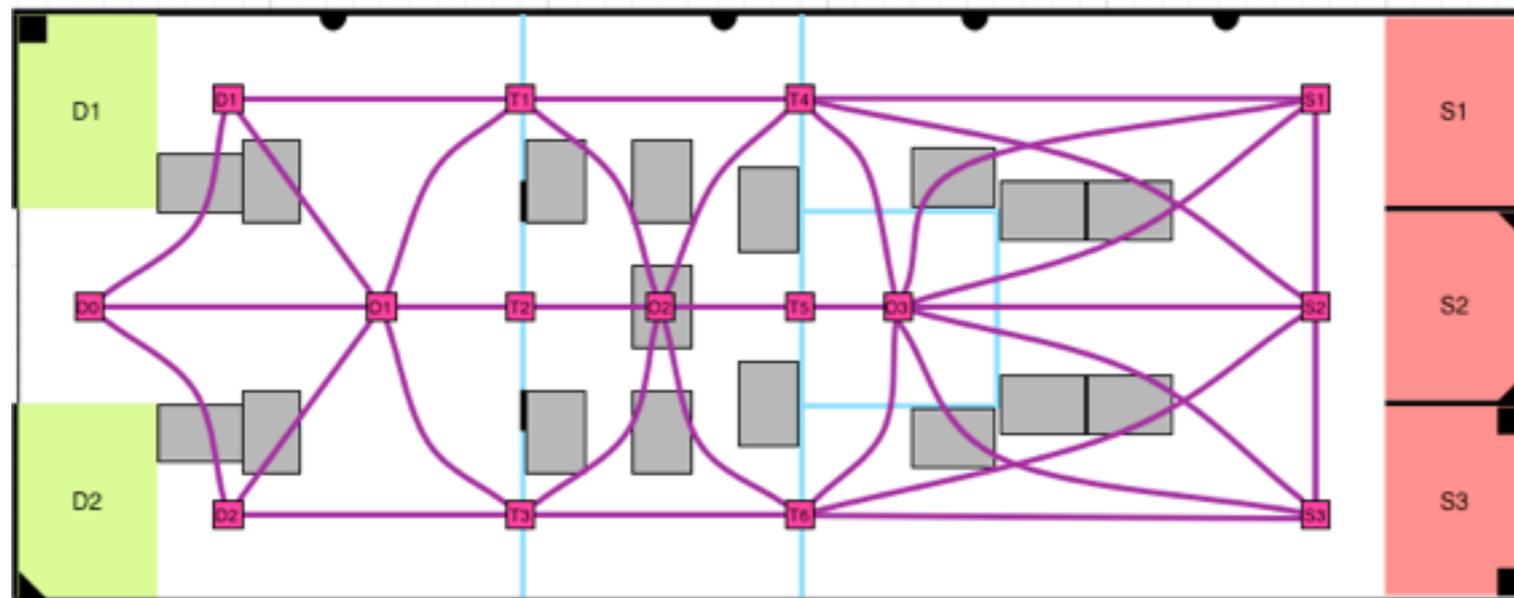
symbolic task descriptions!

Scientific Challenges in RoboCup@Work

- perception in static and dynamic environments, varying environmental conditions

- path planning and motion control of mobile bases in dynamic environments

- grasp planning, trajectory planning, and motion control of mobile manipulators

- planning and decision making

- representation of plans, knowledge, strategy and tactics

- adaptivity and learning

- cooperation in both cooperative and competitive environments

- human-robot and robot-robot interaction

- design, construction, and operation of robust robots at affordable cost

- **multiagent planning and scheduling, multi-criteria optimization**

- **logistics**

- **mobile manipulation**

- **cooperative mobile manipulation**

- **benchmarking**

- perception in static and dynamic environments, varying environmental conditions
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Special tribute to Matteo: ---> functionalities!!!!

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RoCKIn@Work

Innovative robot applications in industry that:

- – Work interactively with humans

- – Have reduced initial programming requirements

- – Have enhanced physics simulation capabilities

•**Contribute to the continued commercial competitiveness of European industry**

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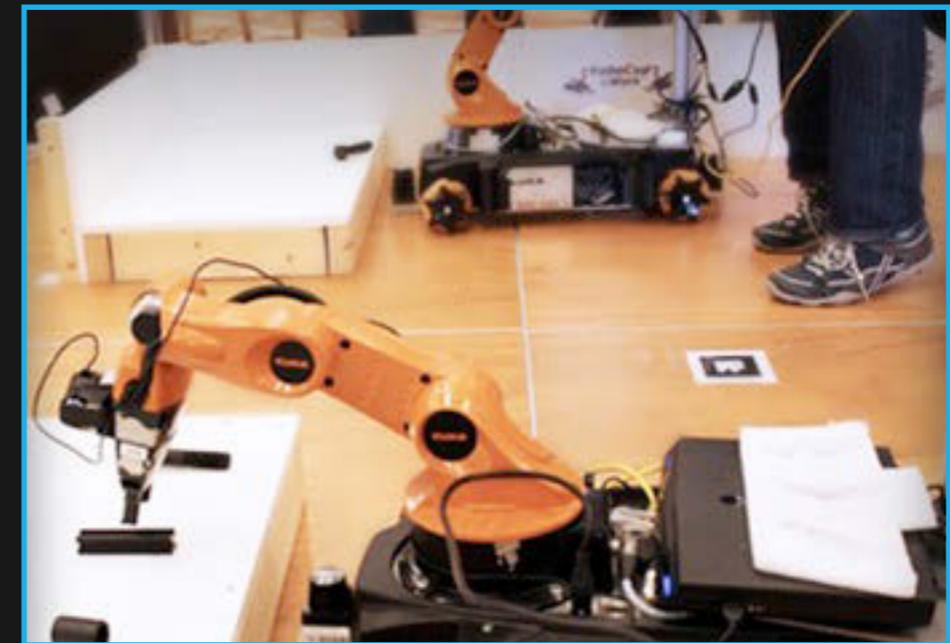
- Continuation of current RoboCup@Work competition

- Long-term objective:

  - improving manufacturing in tasks currently not doable for (classical) industrial robotics

  - new innovative applications, new markets

- Setup ideas ...

- Variations and variability ...

- **Motivation:**
  - Supposedly, about 50% of all shipments by Amazon are returned
  - Many reasons: wrong part, item not fitting, wrong size, faulty part, etc.
  - Return shipments must be opened, checked, and processed
    - Parts in original packaging **->** return to storage shelves
    - Parts opened, not in original packaging **->** check and repackage
    - Faulty parts **->** dispose or deliver to repair
- Idea: Have robot open parcels using a cutter
  - requires 2 arms or combination of arm and fixation device
- Setup ideas ...
- Variations and variability ...

- Motivation: restaurant experience in Rome
- Idea: Have a robot assisting a restaurant chef in pasta cooking
  - robot cooks pasta
  - chef prepares sauce and readies dish for delivery
- Setup ideas ....
- Variations and variability ...

- Note: This IS an industrial application, although the robotics industry currently does not yet believe so!

- Motivation:
  - Do something requiring bimanual manipulation and compliant motion
- Guiding ideas:
  - cleaning, polishing, finishing surfaces
  - painting or glueing surfaces
  - spreading mortar
  - tiling
  - decorative painting of cups

- Rule definition process: rulebook addressing the following aspects:
    - Vision; challenge addressed
    - Organization
        - pre-competition: (league organization)
            - Technical Committee (TC), Organizational Committee (OC)
            - Web site, mailing lists
        - competition: (tournament organization)
            - Schedule, team meetings, practice schedule, competition schedule
            - Scoring and ranking
            - Referees, referee instructions, roles of TC and OC
            - Code of conduct; disqualification
    - Participation (Qualification Process)
    - Test description
        - Design and implementation of the environment, objects, subjects
        - Design and behavior of robots
        - Task
        - Rules for task execution (time available, team order, …)

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- Definitely fix rules BEFORE the competition!

- Latest rule fixes can be made at team meeting before competition starts!

- NEVER change rules during the competition!

- Rule clarifications can be done by TC!

- In case of problems the TC+OC decides!

- OC should take care of organization!

- TC should ensure rule implementation!

- Keeping clear role assignment supports smooth competitions!

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Other considerations

- Attracting an audience
    - Allowing for good views; bleachers
    - Light! Light! Light!
    - Noise! Noise! Noise!
- Ensuring safety
    - Separation of audience and arena
    - Emergency stop?? Robot specs
- Maintaining public order
    - Security precautions (fire, riots, epidemics)
    - Controlling fan behavior
- Rewarding people
    - Make the award ceremony a real show!
    - EVERY participant is a winner!
    - Give visibility to sponsors and organizers!
    - Remember to mention not only big shots!

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- Keep rules stable while most teams cannot yet perform really well
- When more than half the teams can solve the challenge, it is time to push the border
- Design competitions with controlled variability and scalability

- Attract students by being at the brink of the state of the art
  - Create opportunities for student research projects
  - Combine with coursework; give credit

- What are the evaluation criteria?
  - Of interest: coverage of problem space, robustness, performance
  - In practice: often performance criteria dominate
  - Ranking: how to do it if evaluation is based on multiple criteria
- How to measure the evaluation criteria?
  - (seemingly) easy: time, space, #right solutions, anything countable, measurable
    - still possible to make a lot of mistakes
  - difficult: portability, robustness, openness, extensibility, interoperability, coverage
    - quantitative assessment prohibitive; maybe only expert judgement possible
- How are the evaluation criteria influenced?
  - … by the environment
  - … by problem parameters
  - … by randomness and other circumstances

- What is the goal of doing benchmarking?

  - Assessing a single system in different environments / under different conditions
    wrt. coverage, robustness, performance

  - Comparing different systems for making a choice

- What do you want to benchmark?

  - an algorithm

    - algorithms themselves are not benchmarkable, only implementations

  - the implementation of a function or an algorithm

    - may be easy; at least some experience available for most cases

  - a more complex system consisting of several modules

    - problem of how to attribute system performance to its components

Impact

- Prerequisites for Impact:
  - Formulate the challenge clearly and simple
  - Implement knowledge sharing activities
  - Raise attention in the community
  - Create public awareness
- Some scientific results from RoboCup
  - omnidirectional vision in MSL
  - omnidirectional drive systems in MSL, SSL, Junior
  - fast, robust vision in all leagues
  - reliable communication
  - fast, robust walking for Sony Aibo
  - speech commanding robots in @Home

The consortium

- Find out more:
  - http://rockinrobotchallenge.eu
  - Twitter: @RoCKInchallenge
  - Facebook: search 'RoCKiN'