# Robotics


Applied artificial intelligence (EDA132)
Lecture 10
2015-02-20
Elin A. Topp

Course book (chapter 25), images & movies from various sources, and original material

Images are film characters found on the web, from “Star Wars” and “WALL-E”

# What is a "Robot"?

b)

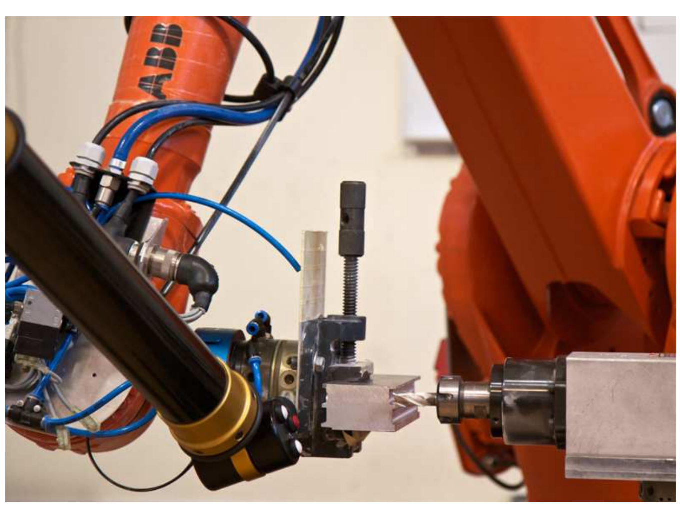
c)

Honda Asimov

a)

Keepon ?

i)




e)

Leonardo / MIT ?

iCub

Images a, c, e, i from RobotLab@LTH, image b from CVAP/CAS@KTH, all others removed due to IPR • • •

# Types of robots

Industrial robots vs. service robots vs. personal robots / robot toys

Static manipulators vs. mobile platforms (vs. mobile manipulators)

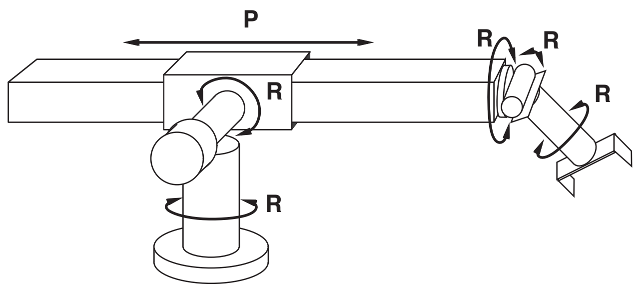
Mechanistic vs. humanoid / bio-inspired / creature-like

For all in common:

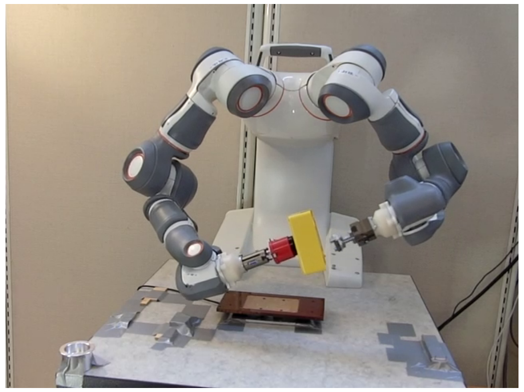
A robot is a physical agent in the physical world
(with all the consequences that might have... ;-)

# Robot actuators - joints and wheels

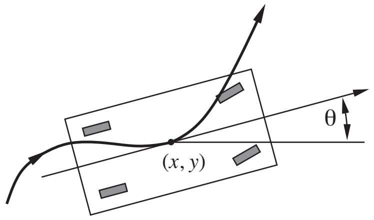
6 DOF (6 "joint") arm:




2x7 DOF ("humanoid" torso "Yumi" / Frida):



2 (3 effective) DOF synchro drive (car):




2 (3 effective) DOF differential drive (Pioneer p3dx):

3 DOF holonomic drive ("shopping cart", DLR's Justin):

# Kinematics - controlling the DOFs

Direct (forward) kinematics (relatively simple):

Where do I get with a certain configuration of parts / wheel movement?

Inverse kinematics (less simple, but more interesting):

How do I have to control joints and wheels to reach a certain point?

# Dynamics - controlling consequences of movement

Dynamics:

Make the robot move (and move stuff) without falling apart, or crashing into things

How much payload is possible?

How fast can I move without tipping over?

What is my braking distance?

How do I move smoothly? (ask the automatic control people ;-)

Weight: ca 1300 kg

Payload: ca 150 kg

Movie removed for privacy reasons

Image from KUKA website

# Dynamics in practice

Dynamics also gets you into two problems: direct and inverse dynamics.

Direct dynamics:

Given masses, external forces, position, velocities and acceleration in the joints / wheels, what forces / moments are put to the depending joints and the tool centre point (TCP)? “Rather” simply solvable, at least more or less straight forward.

Inverse dynamics (again, more interesting than direct dynamics):

While solving the *inverse kinematics* problem is nasty, but still “only” a bunch of linear equations, solving the *inverse dynamics* problem leaves you with a bunch of more or less complex differential equations.

# Supporting parts: Sensors

In a predictable world, we do not need perception, but good planning and programming

As the world is somewhat unpredictable, some perception is useful, i.e., robots / robot installations need sensors.

Passive / active sensors.

Range / colour / intensity / force / direction ...

Optical / sound / radar / smell / touch ...

Most common for mobile robots: position (encoders / GPS), range (ultrasound or laser range finder), image (colour/intensity), sound

Most common for manipulators: position (encoders), force / torque, images, (range - infrared, laser RF)

# Sensors on a mobile robot


Microphones (sound)

Ultrasound (24 emitters / receivers) (range)

Camera (image - colour / intensity)

Laser range finder (SICK LMS 200) (range)

Infrared (range / interruption)

Bumpers (touch)

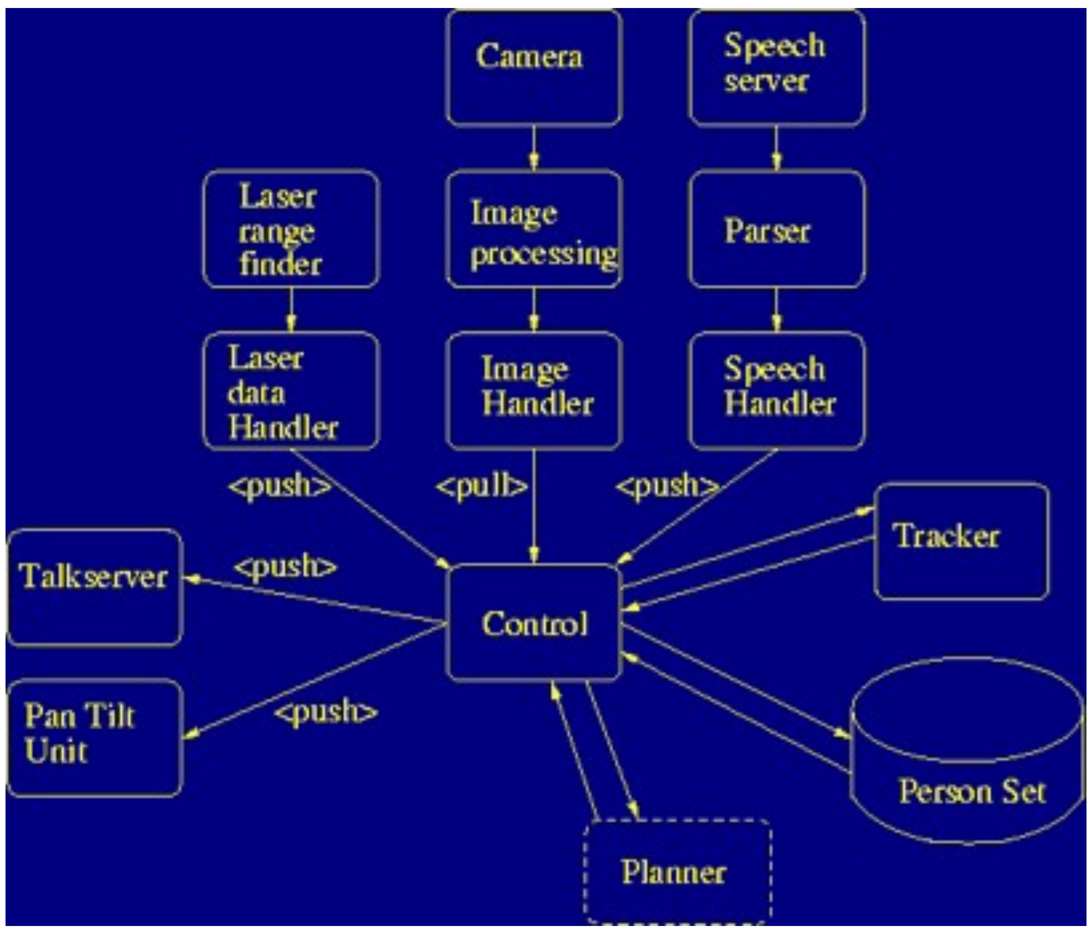
Wheel encoders (position / pose)

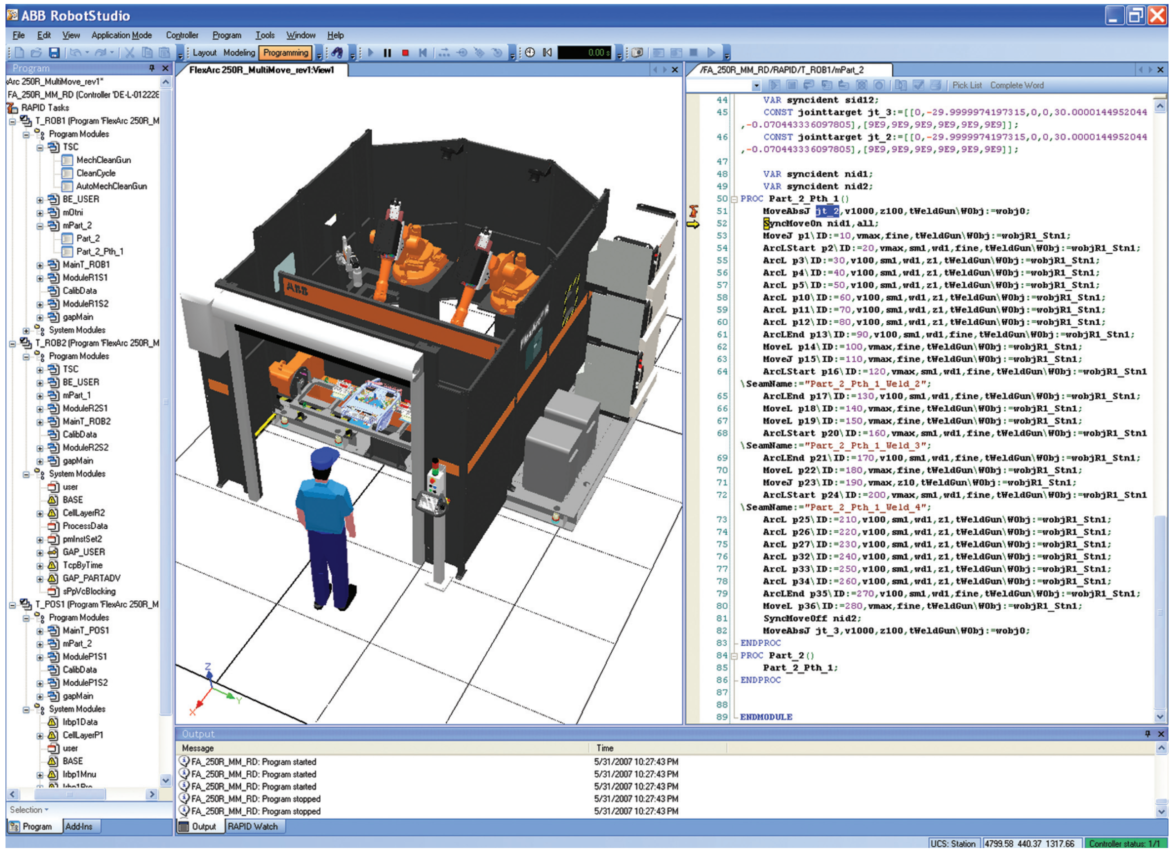
Image is original material (Elin A. Topp), CVAP/CAS@KTH

# System integration

Make all those components work together

Architectures, “operating systems”, controllers, programming tools ...




Images are original material (Elin A. Topp) / ABB RobotStudio from ABB website

# Behaviour based system architectures

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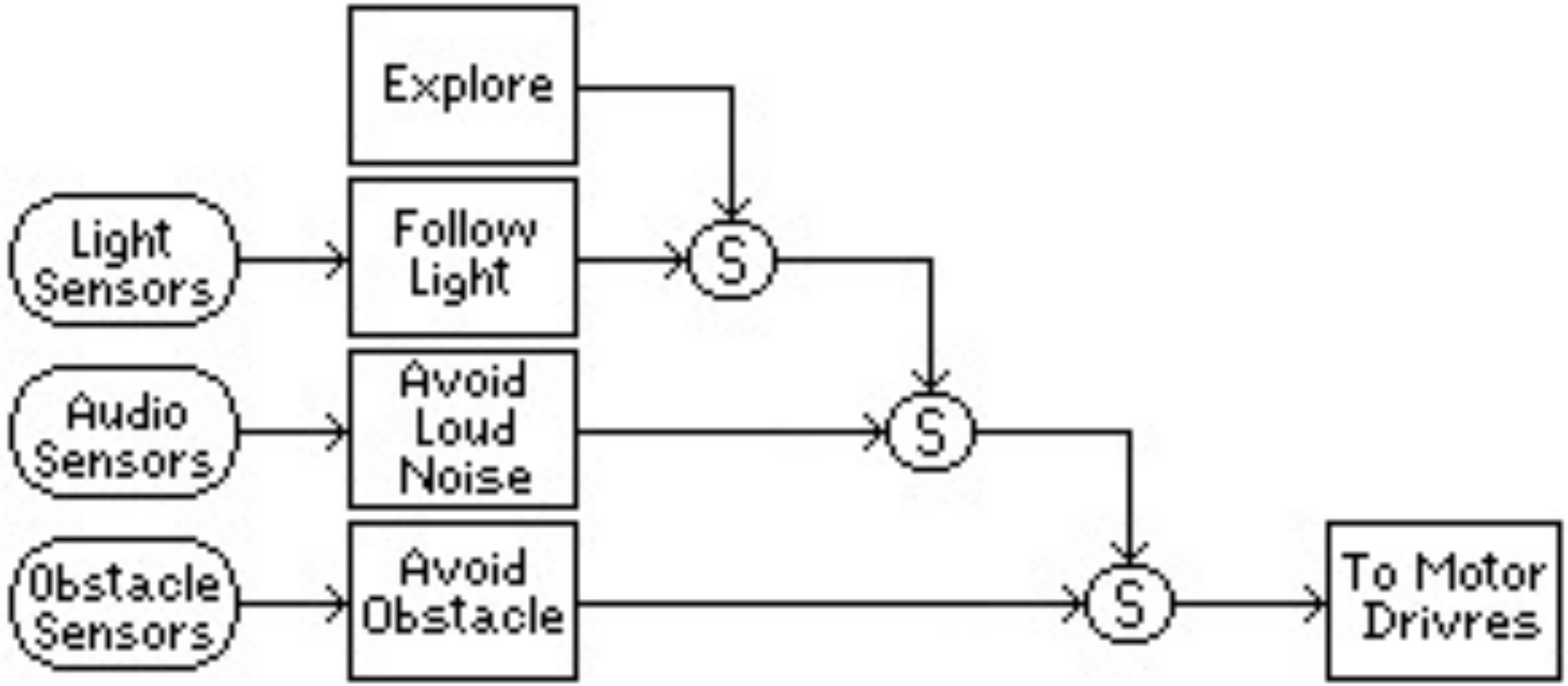
from sense-react (Brooks: "Planning is just a way of avoiding figuring out what to do next", 1987)



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from sense-react (Brooks: "Planning is just a way of avoiding figuring out what to do next", 1987)

via hybrid-deliberative (e.g., Arkin's "AuRA", 1990) and event-based systems

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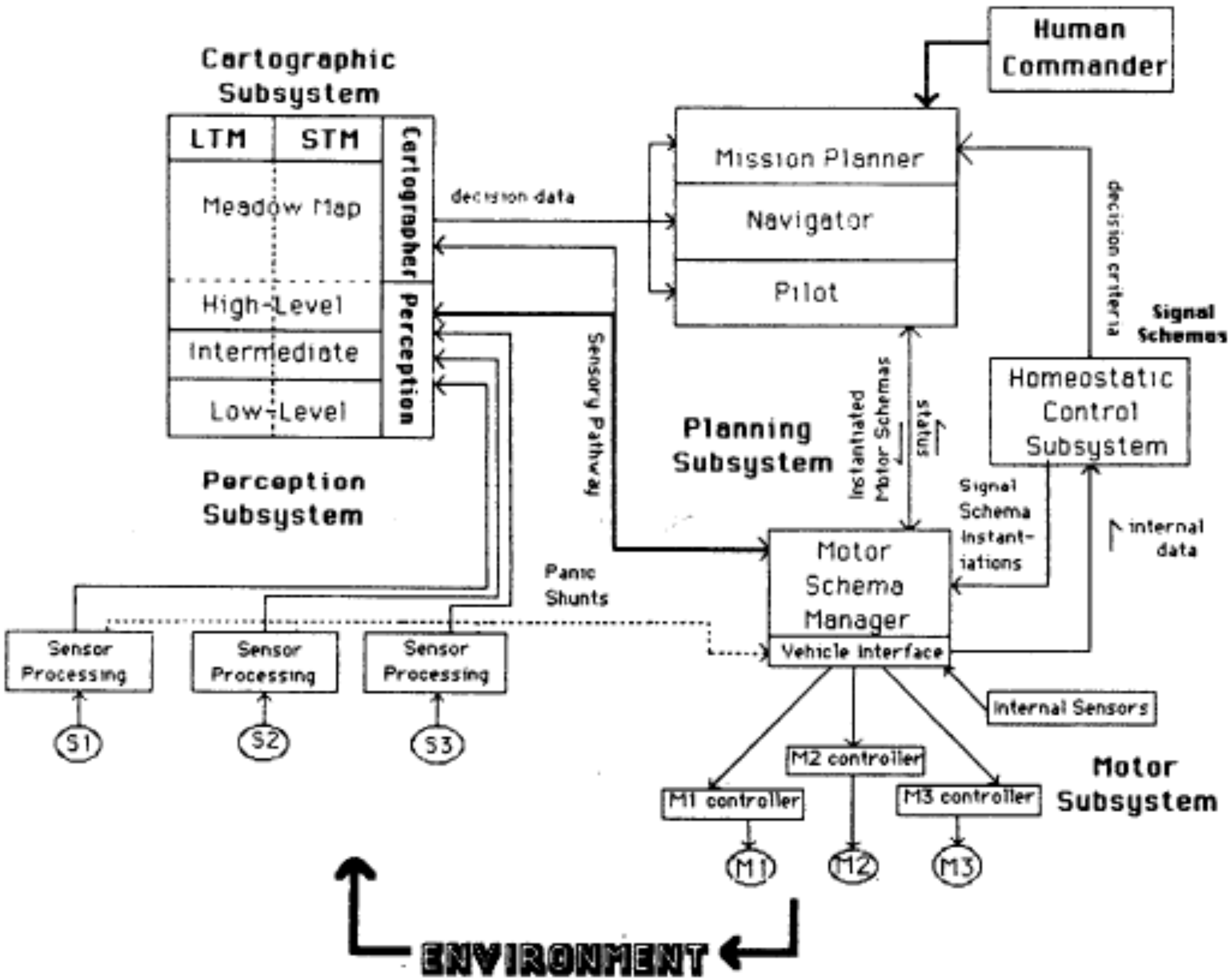
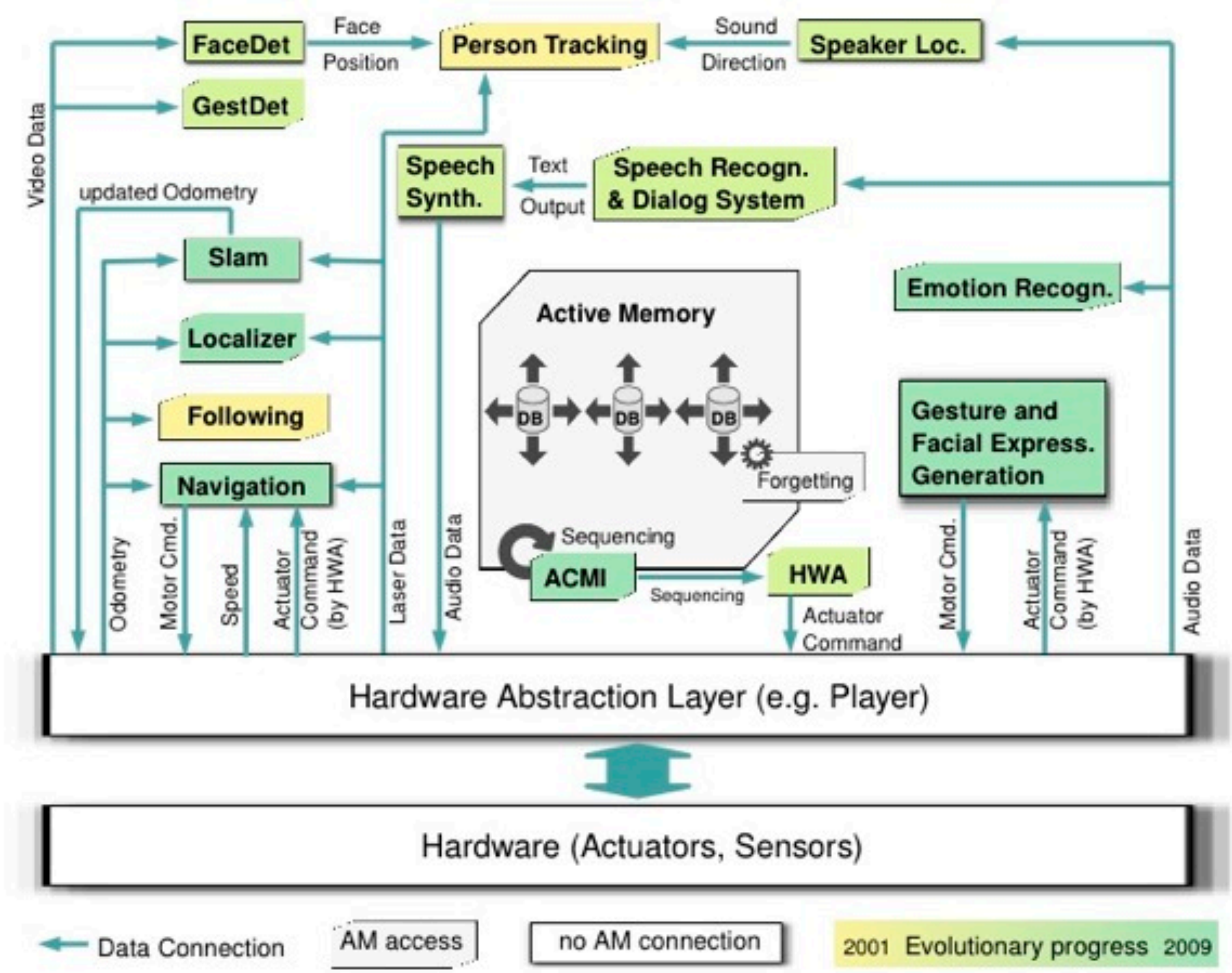



Material from research papers by the respective authors

# Behaviour based system architectures




to “cognitive” architectures (memory & event based, e.g., T.P. Spexard, 2009)

Material from research papers by the respective authors

# Do the right thing at the right time...

Make industrial robots more flexible, interactive, easy to program (get some of the "behaviour"- and cognition idea into them)

Make mobile service robots more precise, go from research code to applications!

How far have we come?

Quite a bit, actually!

Movies removed (available through YouTube / author's website, look for "Fanta Cans ABB" and "Magnus Linderoth, LTH"

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ABB robots and their precision... 2009

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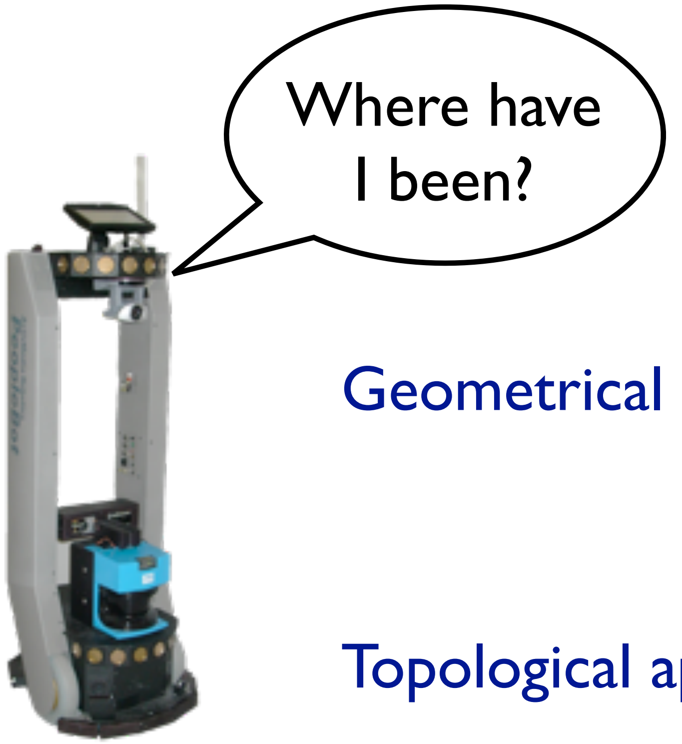
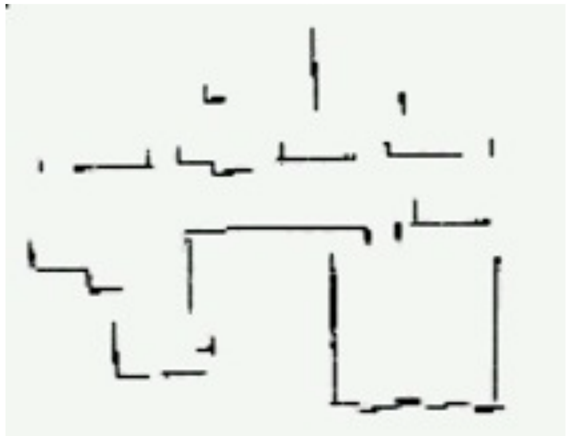
# Outline

- Robots and Robotics
  - Types of robots
  - Robotics
    - Kinematics and dynamics
    - Systems (hard- and software, components)
    - Challenges (and results)
- AI in robotics
  - Mapping & Localisation
  - (Path) Planning
  - Deliberation & High level decision making and planning
  - Human-Robot Interaction

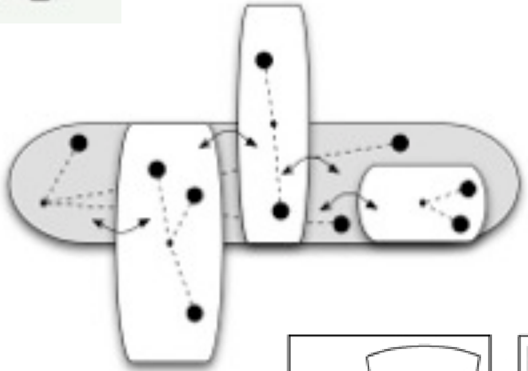
# Mapping



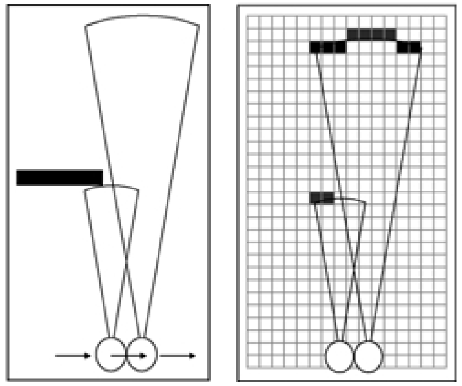

Geometrical approaches



Topological approaches

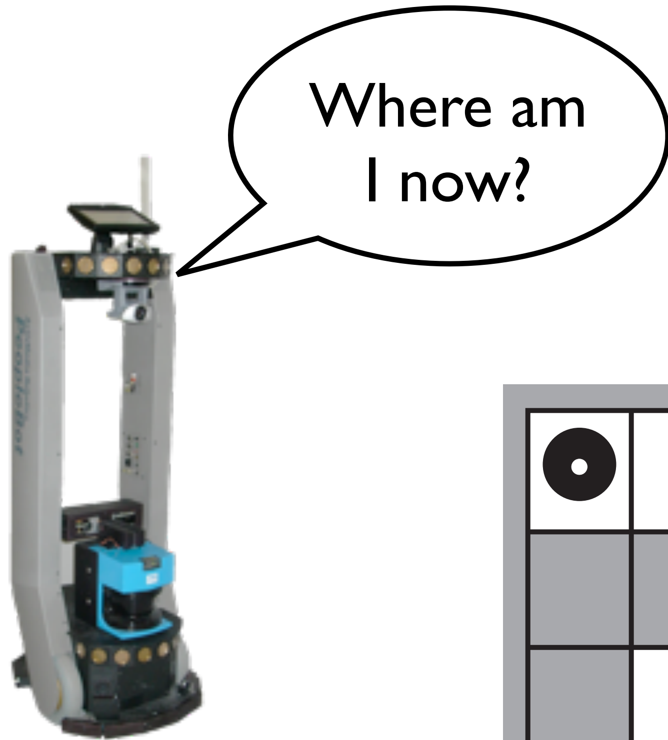


Occupancy grid approaches (e.g., Sebastian Thrun)

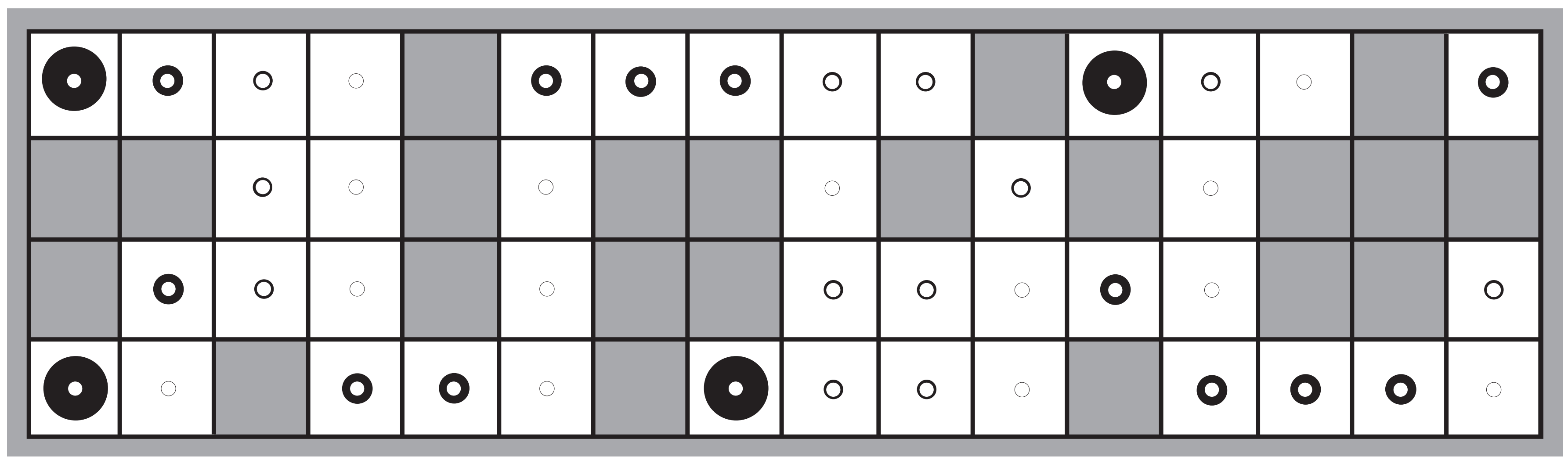


(Hybrid approaches)

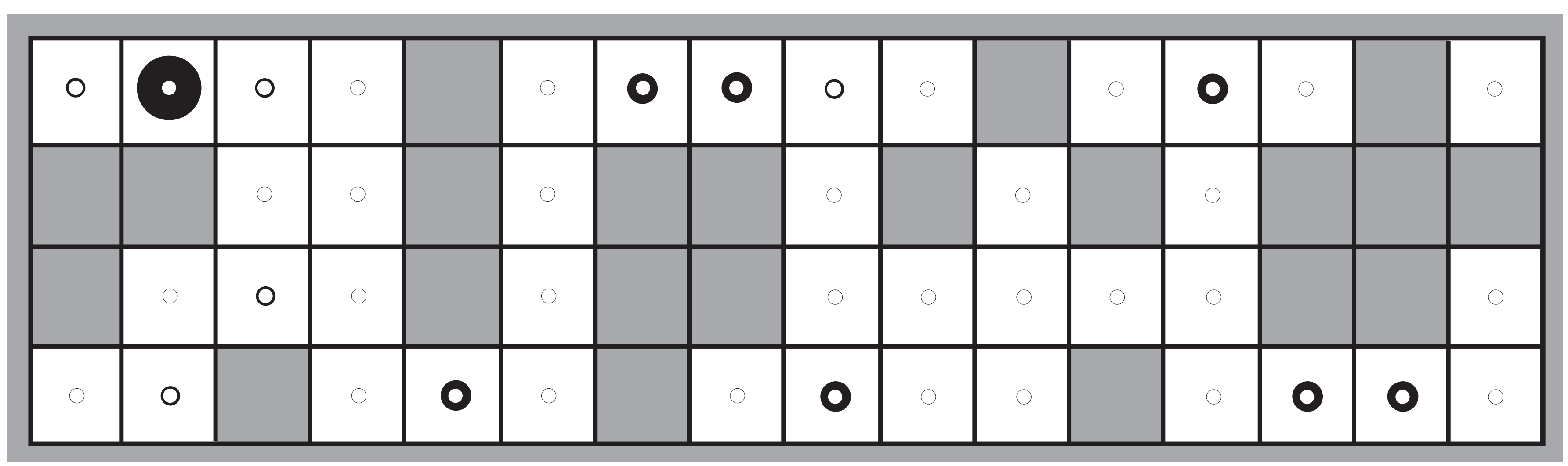
# Localisation




HMM in a grid world



(a) Posterior distribution over robot location after $E_1 = NSW$



(b) Posterior distribution over robot location after $E_1 = NSW, E_2 = NS$

Images from AIMA resources, fig 15.7

# Localisation


E.g., Monte Carlo Localisation (S. Thrun)

Movie / snapshot-show from author's website, look for "Sebastian Thrun, Monte Carlo Localization"

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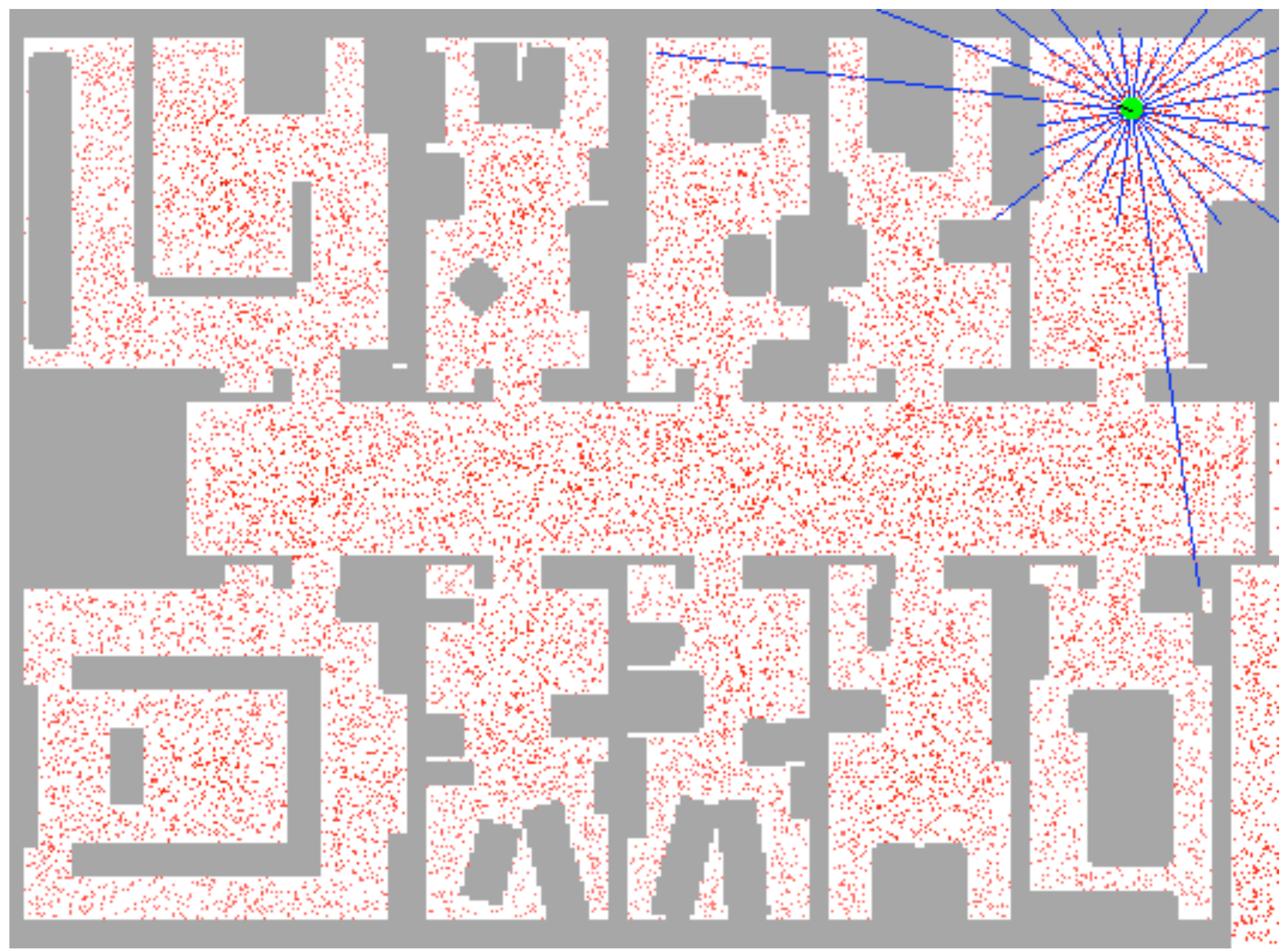

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# Mapping & Localisation: Chicken & Egg?

Simultaneous localisation and mapping (SLAM)

While building the map, stay localised!

Use filters to “sort” landmarks:

- Known? Update your pose estimation!
- Unknown? Extend the map!

# SLAM example

FastSLAM (D. Haehnel)

Movie from author's website, look for "Dirk Haehnel, FastSLAM"

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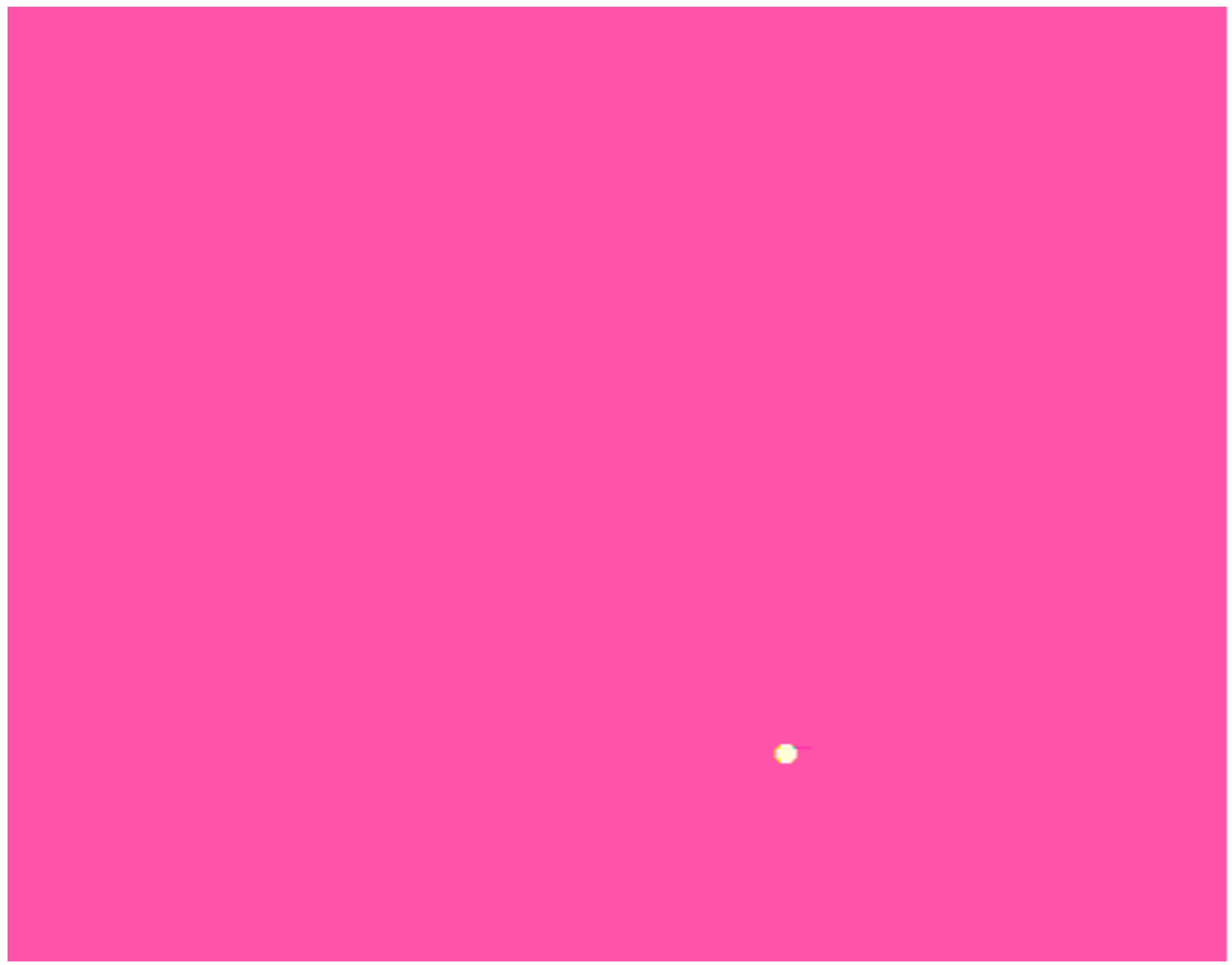

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# Path / trajectory planning


Assumption: we have a map!

Workspace vs configuration space

Cell decomposition - how many cells, granularity?

Potential fields - repelling forces around obstacles

Voronoi graph - keep always the same distance to all obstacle points

# Planning movement under uncertainty?

Not knowing anything about the surroundings and simply following instructions might "hurt"

Apply "careful" exploration strategies and consider "emergency braking" (obstacle avoidance)

"Decide" on the fly, based on gathered information!


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E.g., when battery level sensor reports a certain level, only the "going home" behaviour and immediate obstacle avoidance are allowed to produce control output, exploring and wall following are ignored.

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- What if something goes wrong with one part of the plan? Does this affect the whole task execution, or only one of the robots?

# HRI - going beyond pressing buttons

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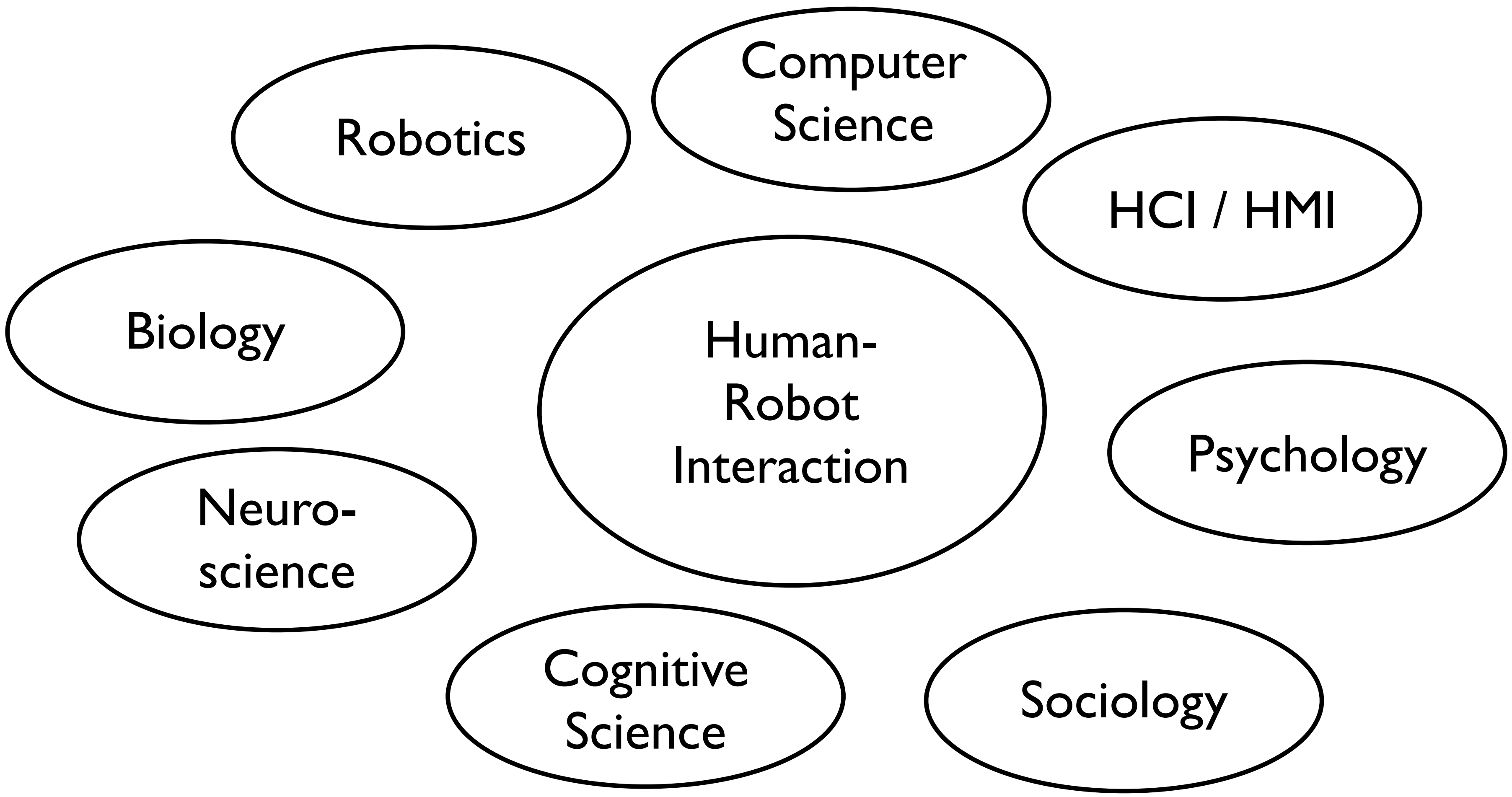
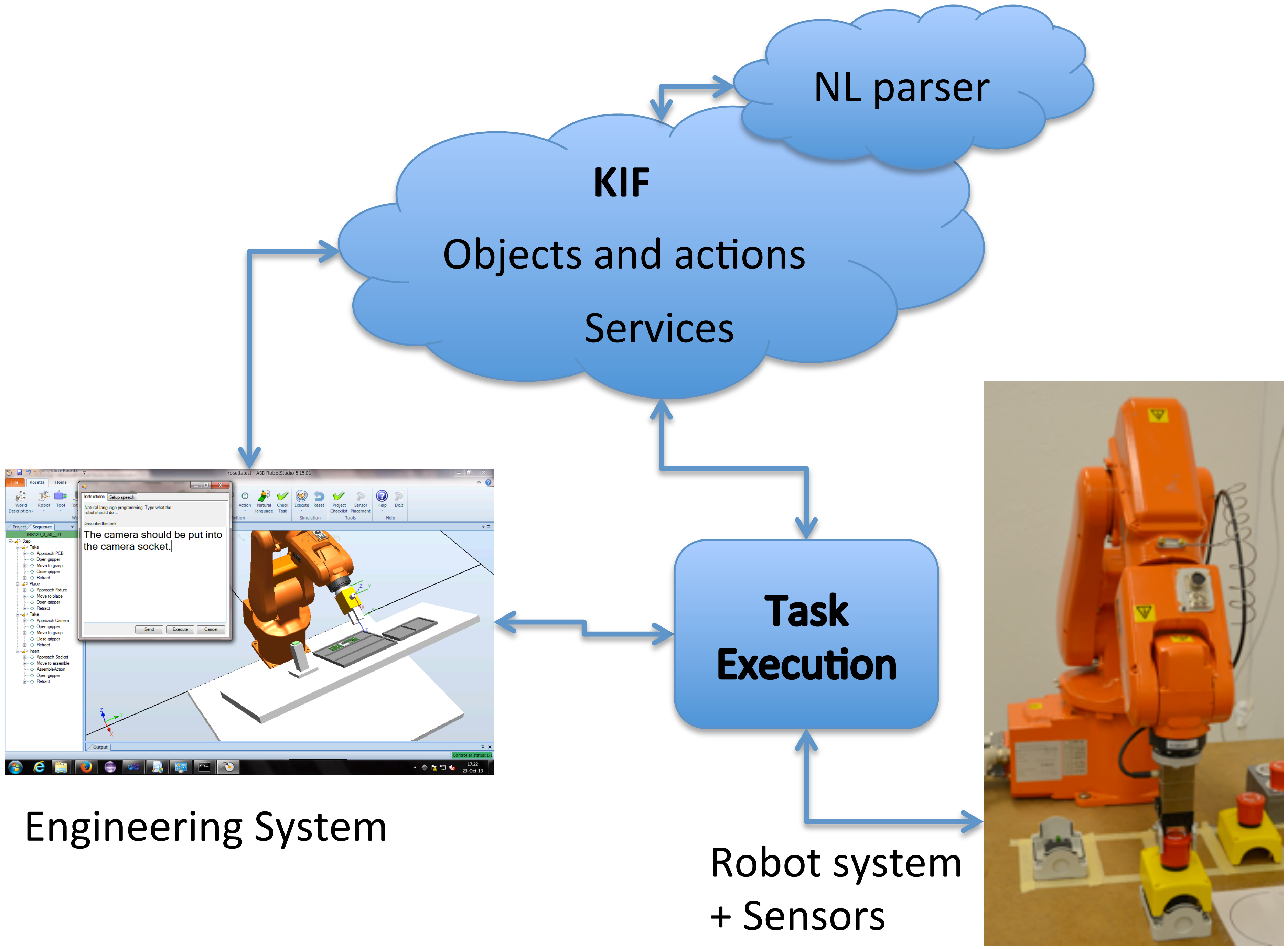


# Learning useful stuff from humans

Movie removed (iCub learning how to grab balls, cans and trays) for IPR reasons

# Tell your robot to do something ...




(Image courtesy of Maj Stenmark, 2013, RSS group@LTH)

# ... and it might even understand you!

(Image (movie) courtesy of Maj Stenmark, 2013, RSS group@LTH)

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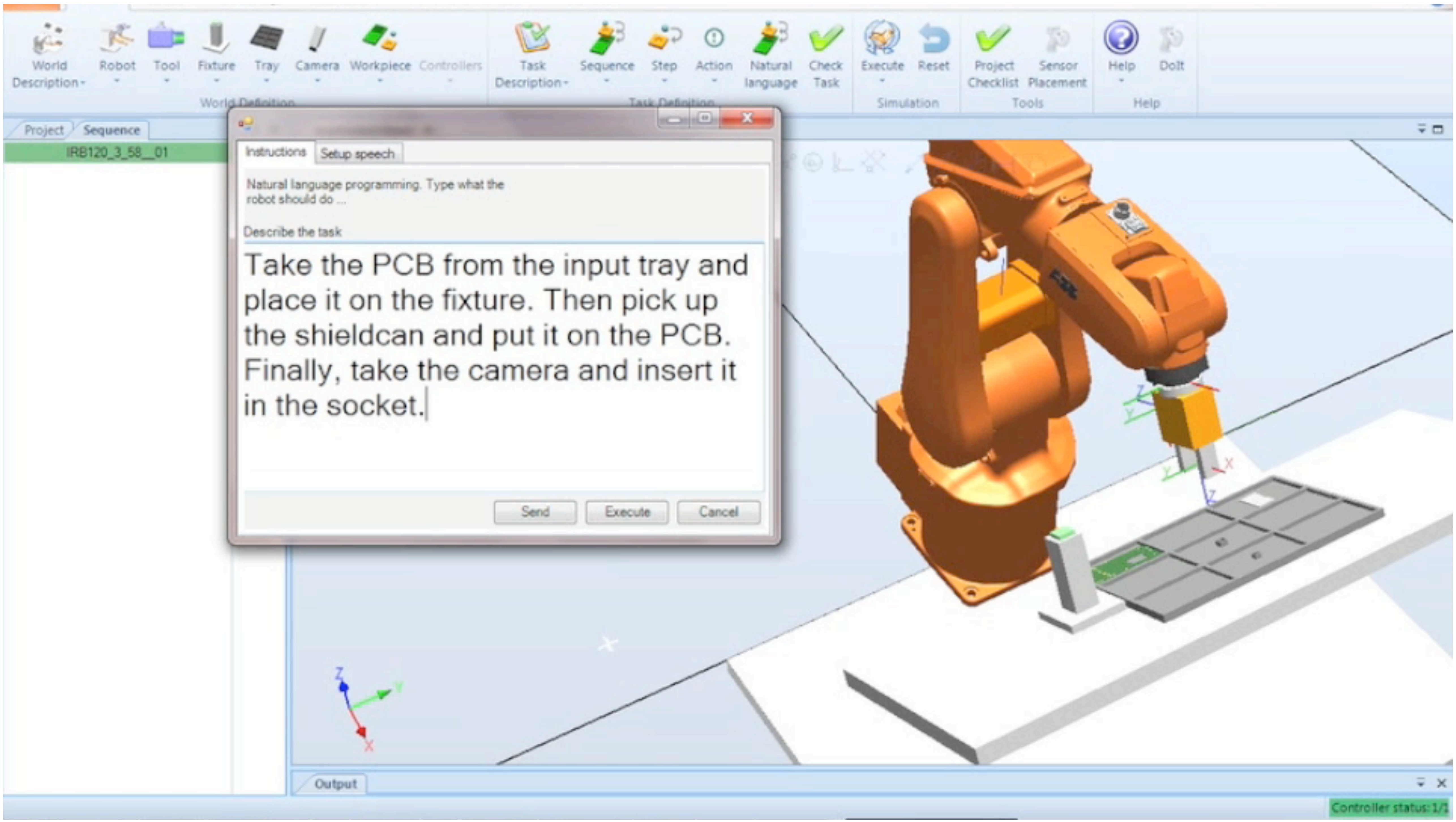


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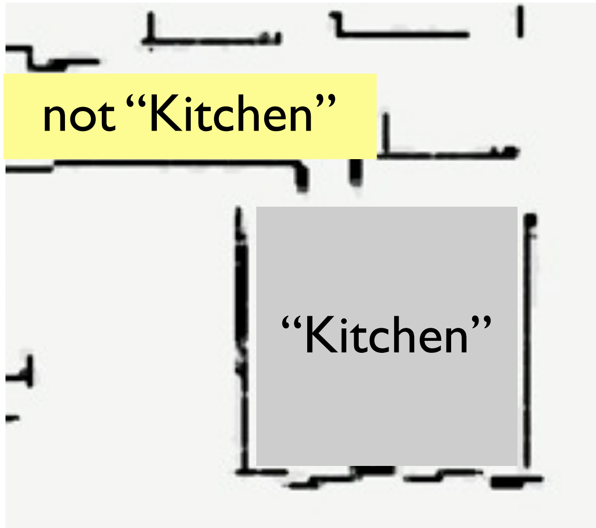
# Human augmented mapping - an example for work in HRI

- Integrate robotic and human environment representations




- Home tour / guided tour as initial scenario

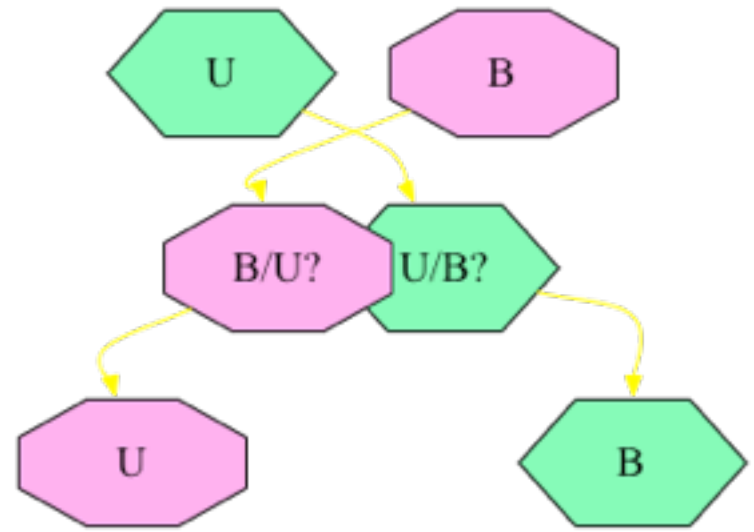
Images are original material (Elin A. Topp), from CVAP/CAS@KTH

# HRI techniques - tracking for following Issues

Confusion user - bystander:

Robot might follow a bystander

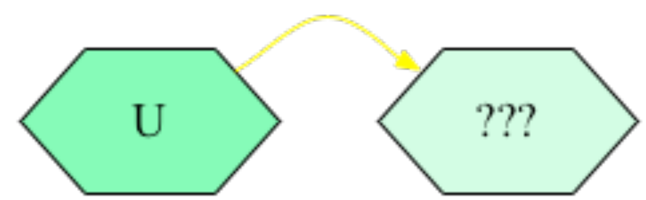
No error reported




Loss of the user

No person to follow

Error handling is possible - depending on the strategy of user choice

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# HRI techniques - tracking for following Approach

- Detect persons by filtering laser range data for respective patterns (legs, body sized shapes)
- Assign flags (walking, static, user ...) to targets
- Sample based Joined Probabilistic Data Association Filters (Schulz *et al.* 2001) for tracking (particle filters!)
  - Designed to keep track of multiple targets
  - Approach capable of handling the critical situations
  - Accept static targets for tracking

# HRI and cognition - environment model

- Finding an environment representation that fits
  1. a human
  2. a hierarchical robotic mapping system
- Evaluating model and methods both empirically and with user studies

# What we hope for ...

(A user explaining very thoroughly where she is and where the robot is during a guided tour)

Movie removed for privacy reasons

# ... is not always what we get!

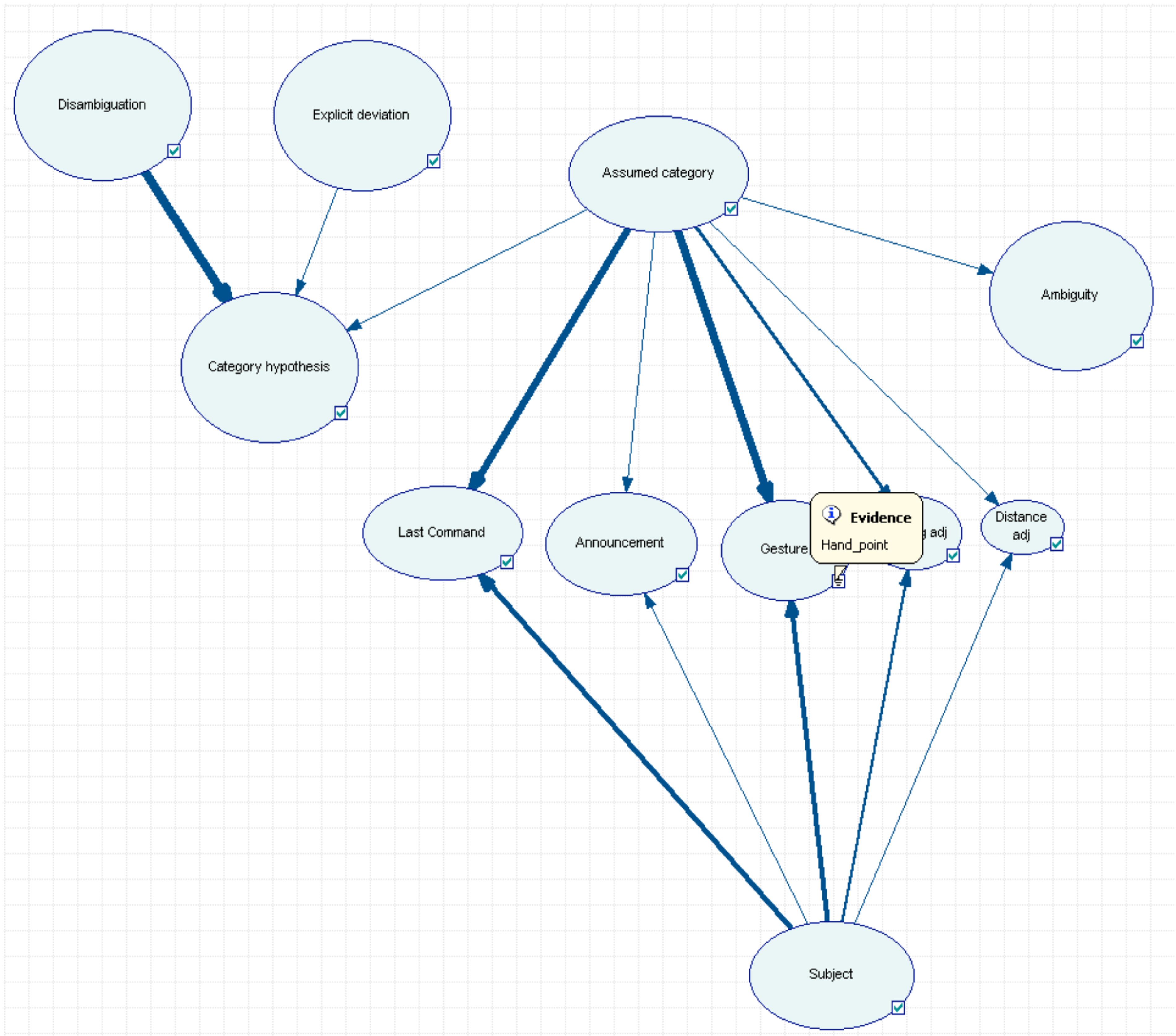
(A user not really explaining that the room that is presented is behind the door...)

Movie removed for privacy reasons

# Interaction patterns?

Can we repeatedly, with several subjects, in a clearly designed set-up, observe any structure, frequent strategies, "interaction patterns", that correspond to the spatial categories *Region*, *Workspace*, and *Object* when people present an indoor environment to a mobile robot?

# Interaction patterns!

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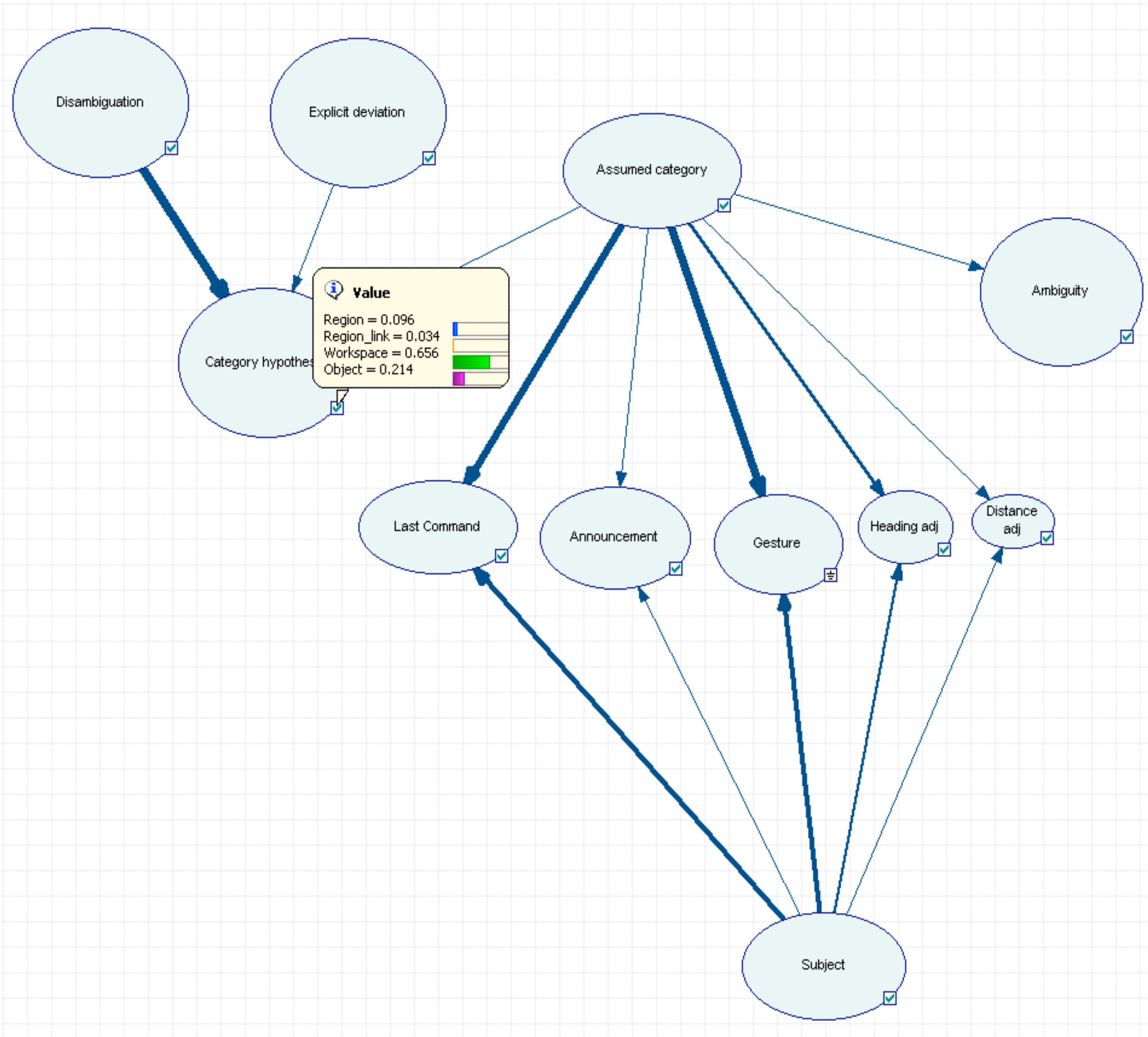


Original material (Elin A. Topp)

# Robotics and Semantic Systems @LTH

- Master's projects (Ex-jobb) in AI, NLP, Robotics (mapping, software, cognitive modeling...), HRI
  - Internal (research oriented) or external (industry related)
  - International through project partners (depends of course on formalities as well ;-)
- Lab visit to the Robotlab in M-huset
- Contact us: Jacek, Pierre, Elin or other members of the group: Klas Nilsson, Mathias Haage, Sven Gestegård Robertz