(Impressions from) AI applications in Robotics

Applied artificial intelligence (EDAF70)
Lecture 14
2018-03-08
Elin A. Topp

Course book (chapters 15 and 25), images & movies from various sources, and original material
(Some images and all movies will be removed for the uploaded PDF)

Outline

AI in Robotics - integrating the "brain" into the "body"

- Probabilistic methods for Mapping & Localisation (recap Kalman filter)
- SJPDAFs for person tracking
- Identifying interaction patterns in
  Human Augmented Mapping with BNs
- Knowledge representation, reasoning, and NLP to support HRI and high-level robot programming
- (Reinforcement) Learning in robotics
- Deliberation & High level decision making and planning

HRI - going beyond pressing buttons

HRI - going beyond pressing buttons

Human-Robot Interaction is quite new as a research field of its own

HRI - going beyond pressing buttons

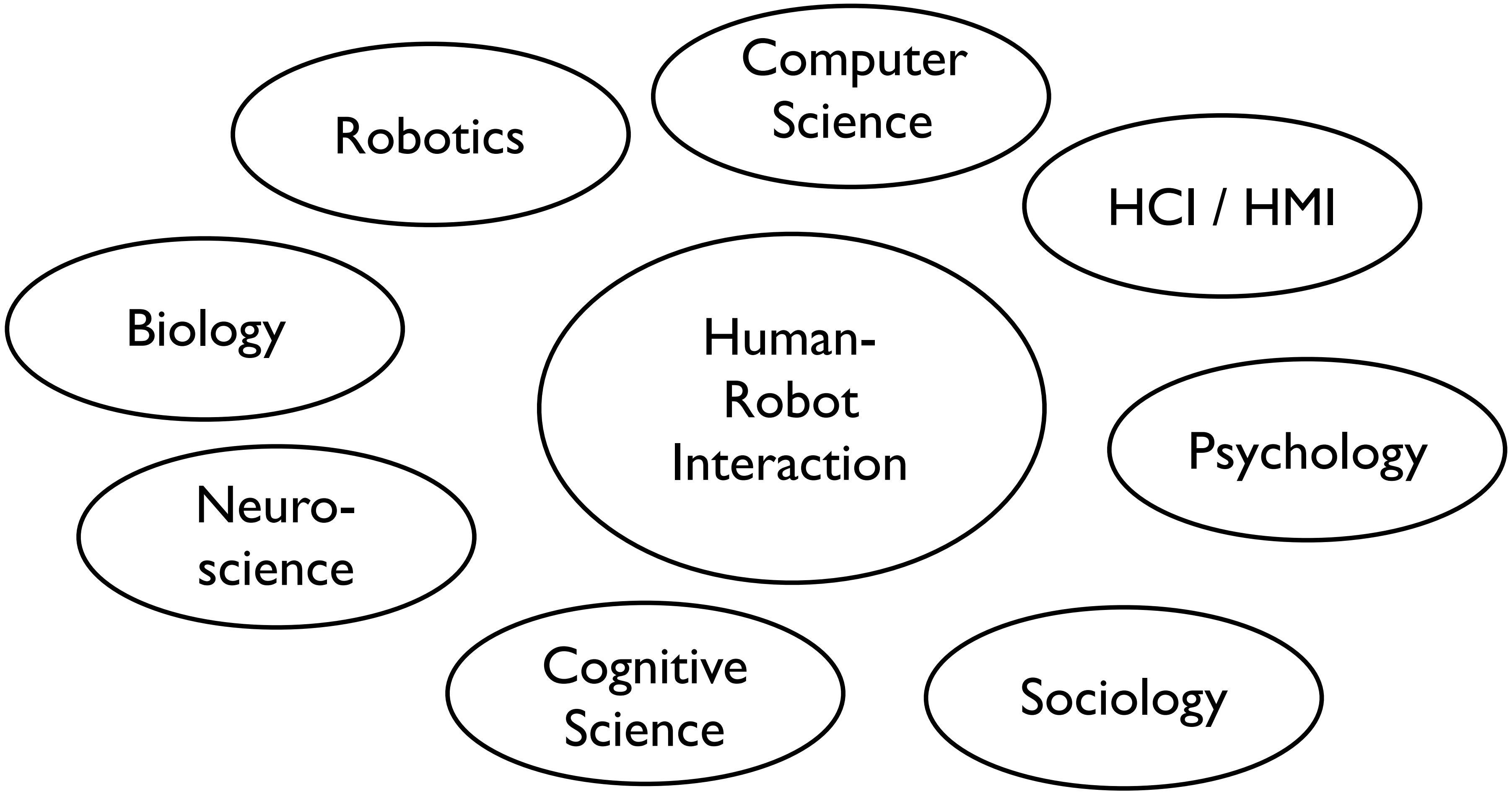
Human-Robot Interaction is quite new as a research field of its own

Like AI and Robotics themselves it is quite multidisciplinary

HRI - going beyond pressing buttons

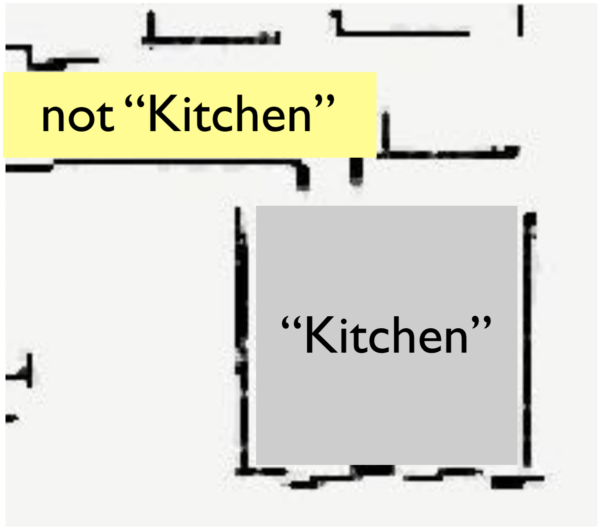
Human-Robot Interaction is quite new as a research field of its own

Like AI and Robotics themselves it is quite multidisciplinary



Human augmented mapping - an example for work in HRI

- Integrate robotic and human environment representations



- Home tour / guided tour as initial scenario

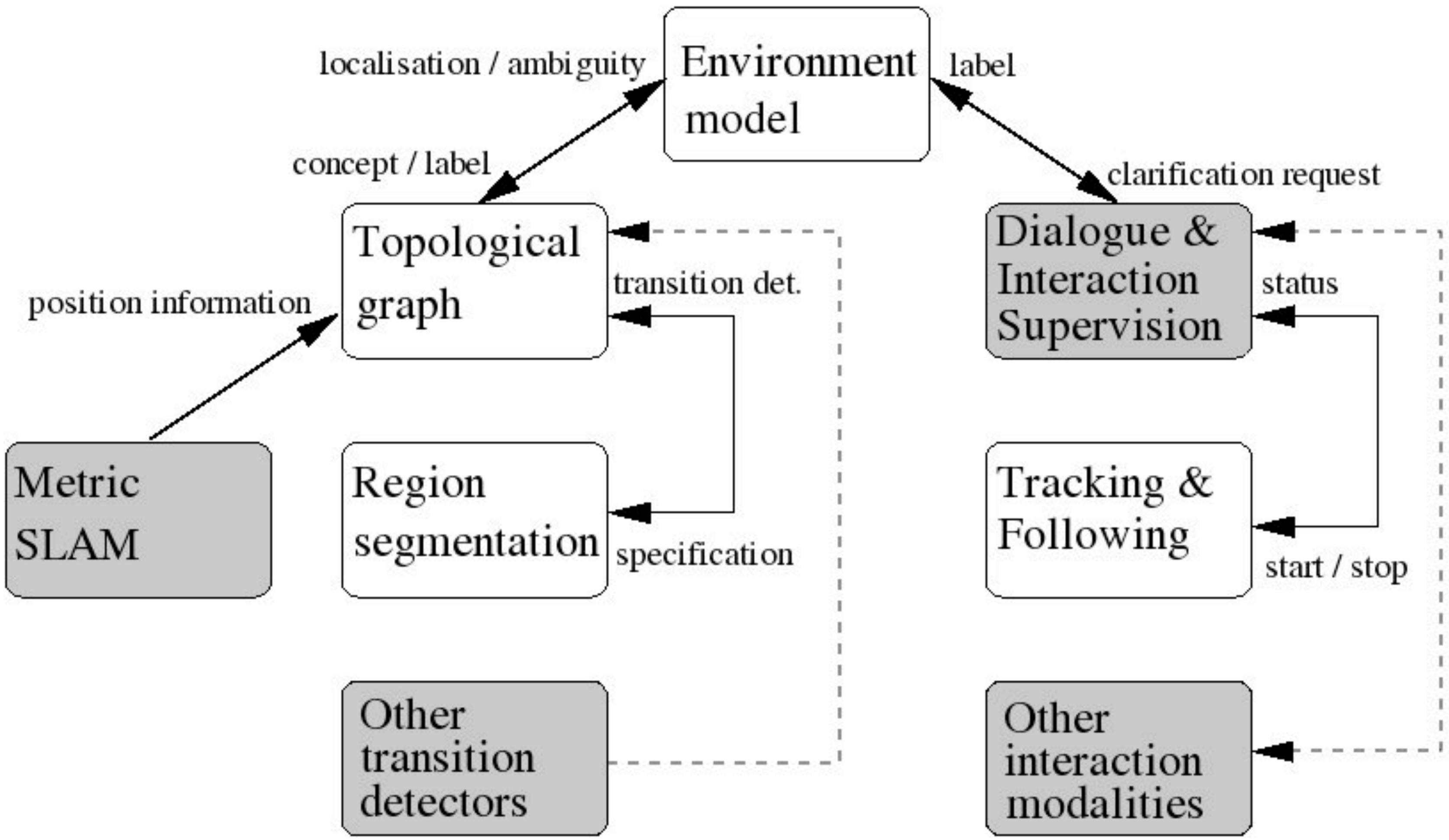
Outline

AI in Robotics - integrating the “brain” into the “body”

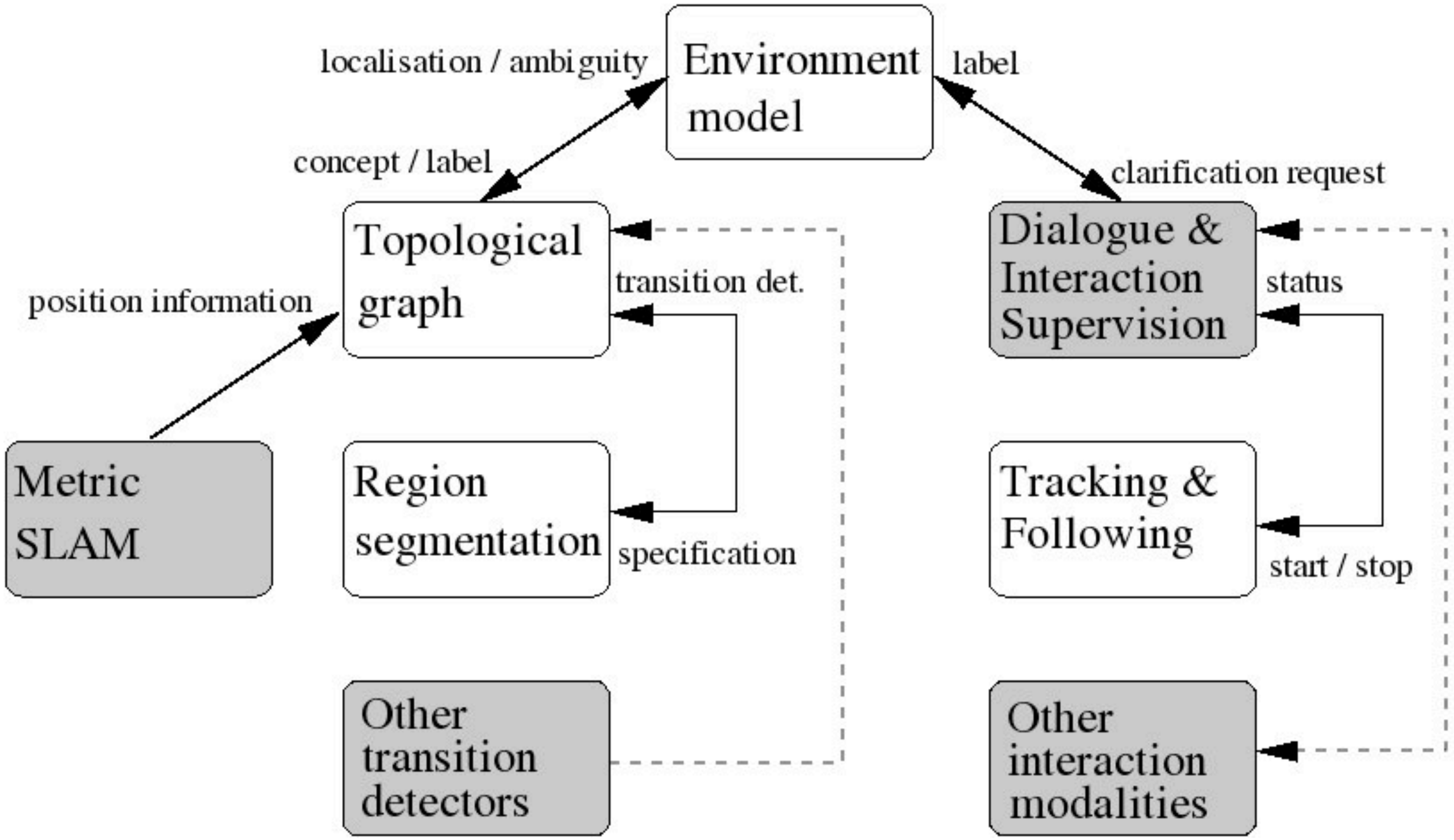
- Probabilistic methods for Mapping & Localisation (recap)
- SJPDAFs for person tracking
- Identifying interaction patterns in
  Human Augmented Mapping with BNs
- Knowledge representation, reasoning, and NLP to support HRI and high-level robot programming

- (Reinforcement) Learning in robotics
- Deliberation & High level decision making and planning

Human augmented mapping - overview

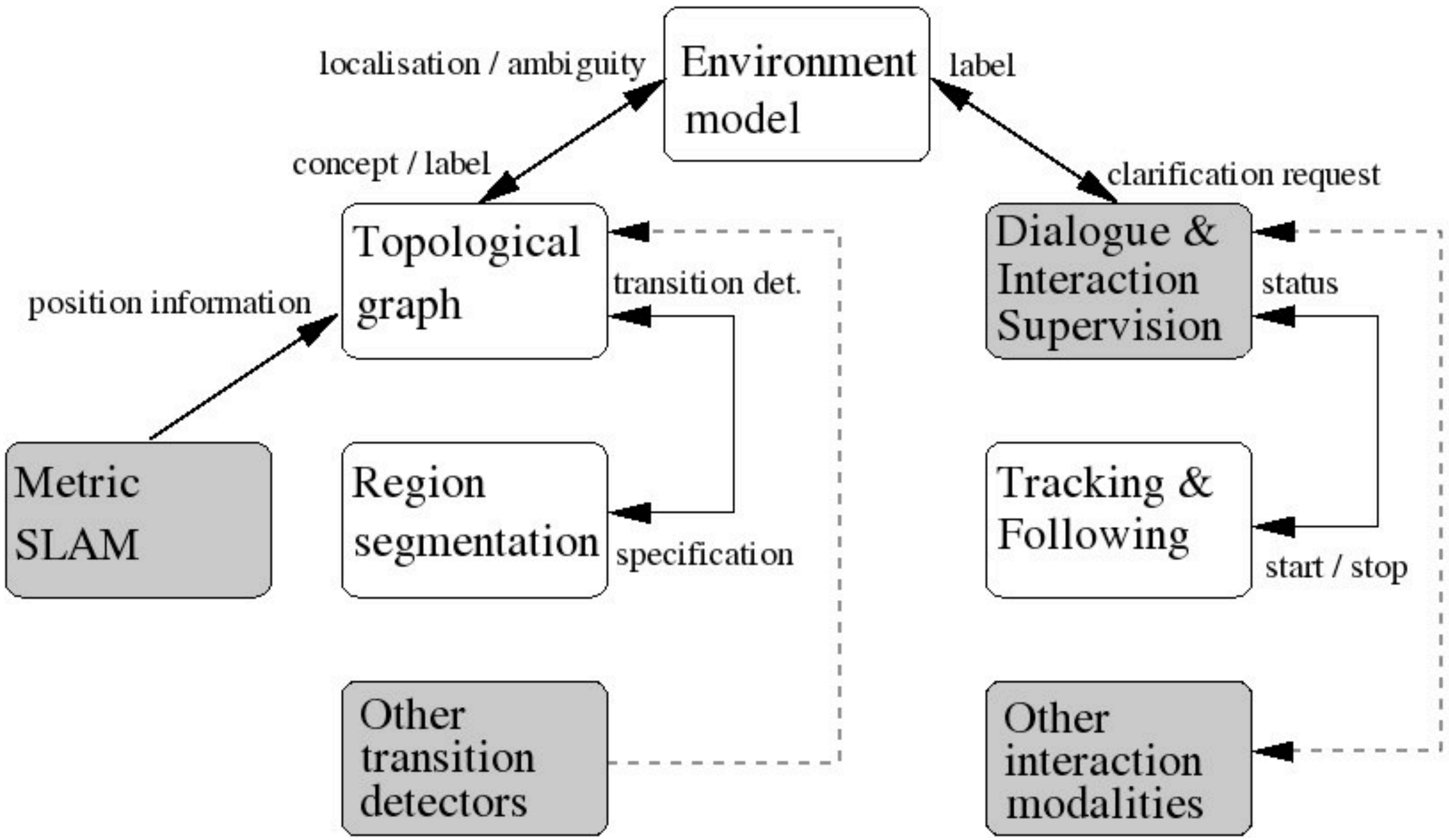


Human augmented mapping - overview



Tracker "live" demo

Human augmented mapping - overview

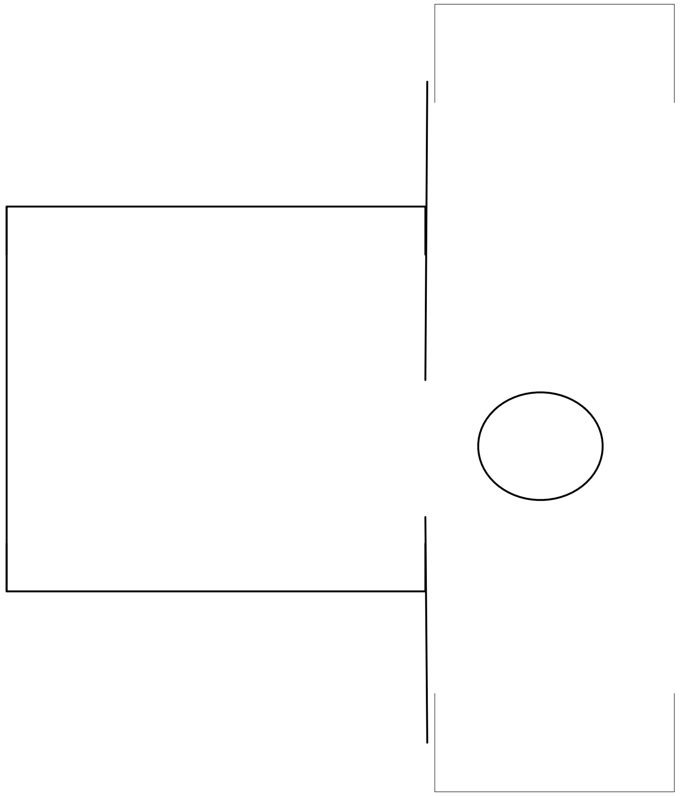


Outline

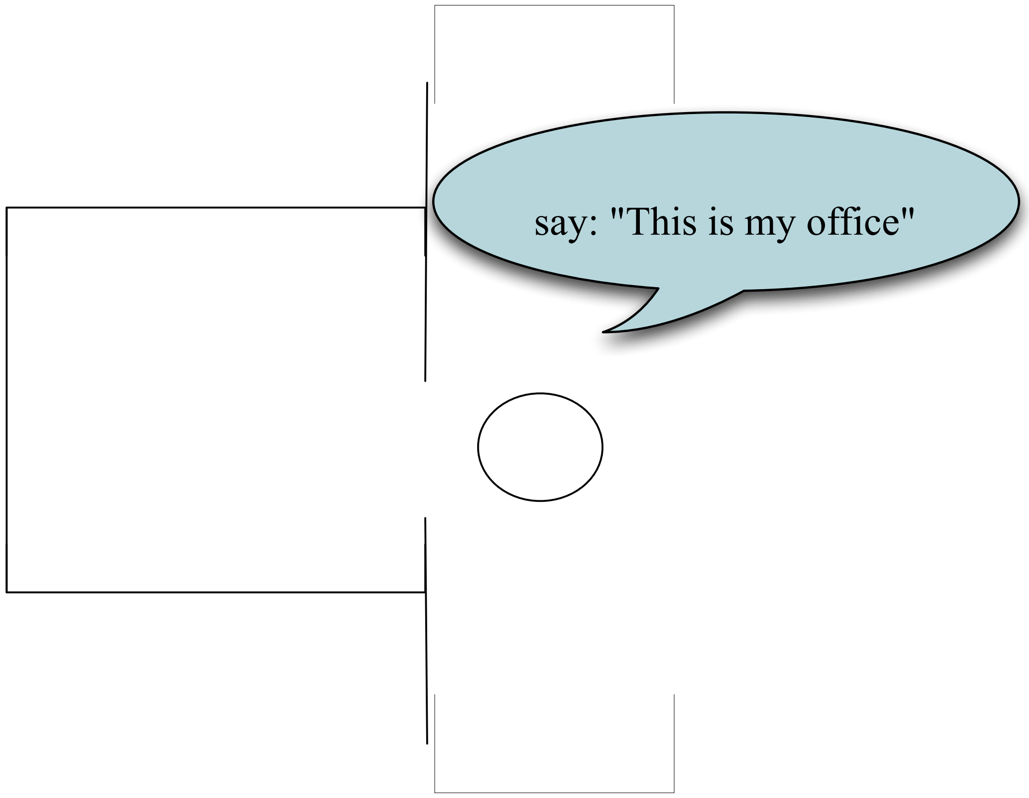
AI in Robotics - integrating the "brain" into the "body"

- Probabilistic methods for Mapping & Localisation (recap)
- SJPDAFs for person tracking
- Identifying interaction patterns in
  Human Augmented Mapping with BNs
- Knowledge representation, reasoning, and NLP to support HRI and high-level robot programming
- (Reinforcement) Learning in robotics
- Deliberation & High level decision making and planning

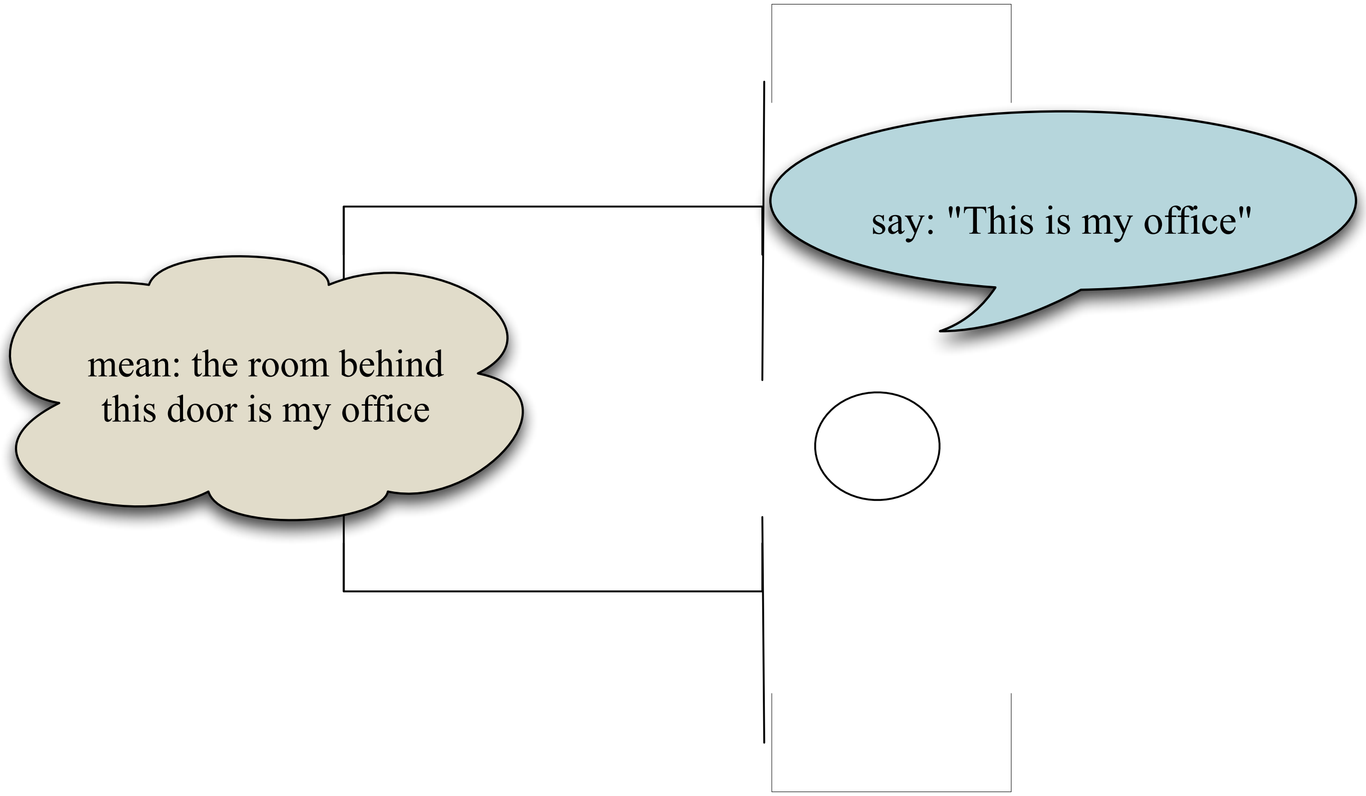
What if…



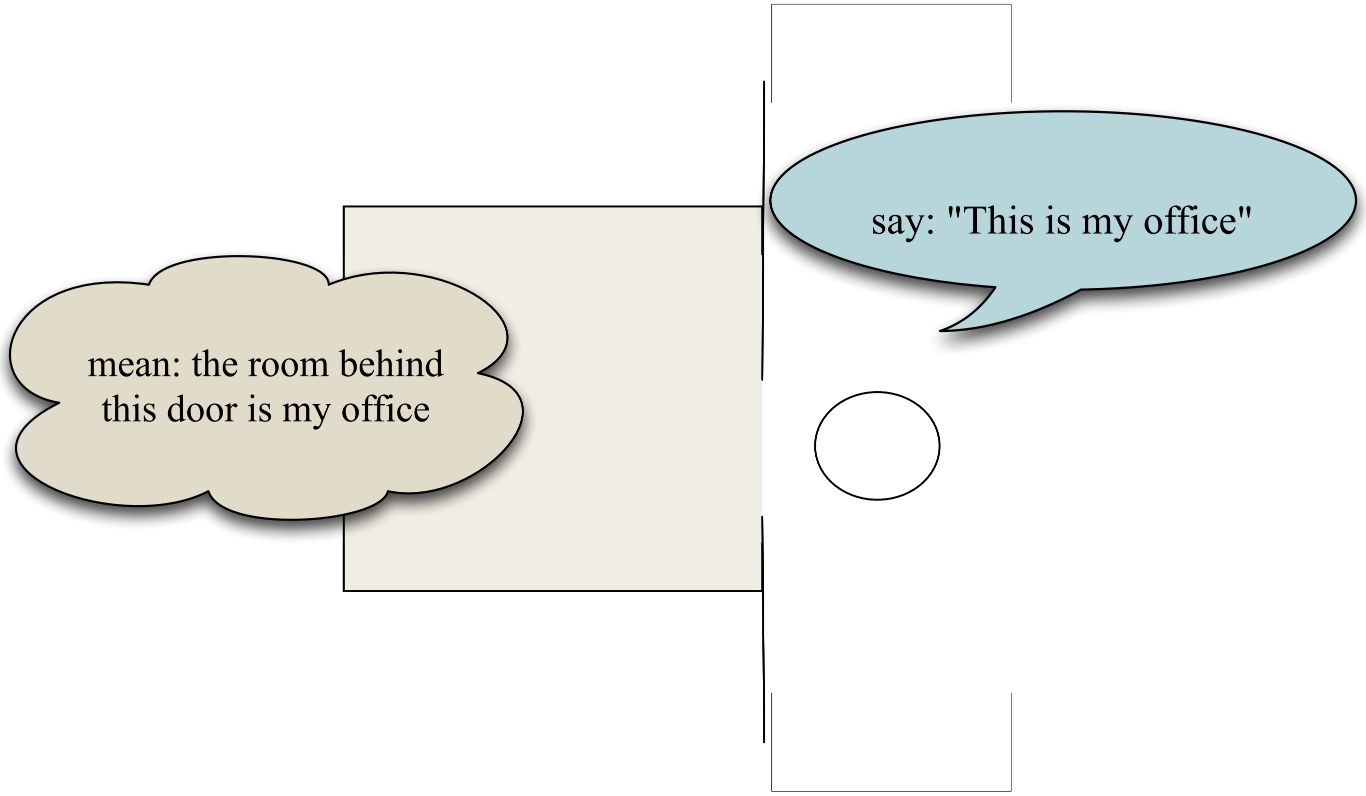
What if…



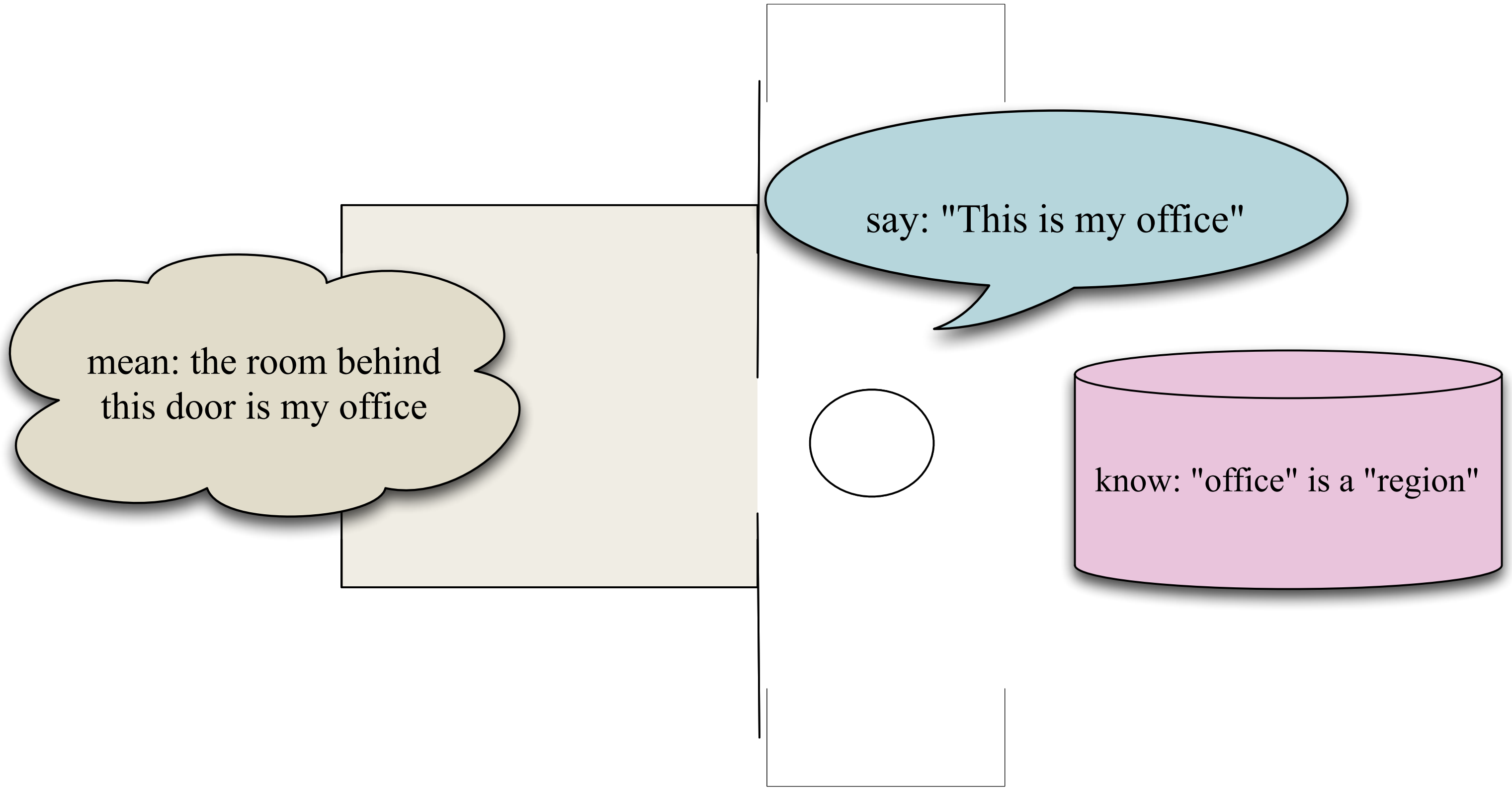
What if…


mean: the room behind this door is my office
say: "This is my office"

What if…


say: "This is my office"
mean: the room behind this door is my office

What if…

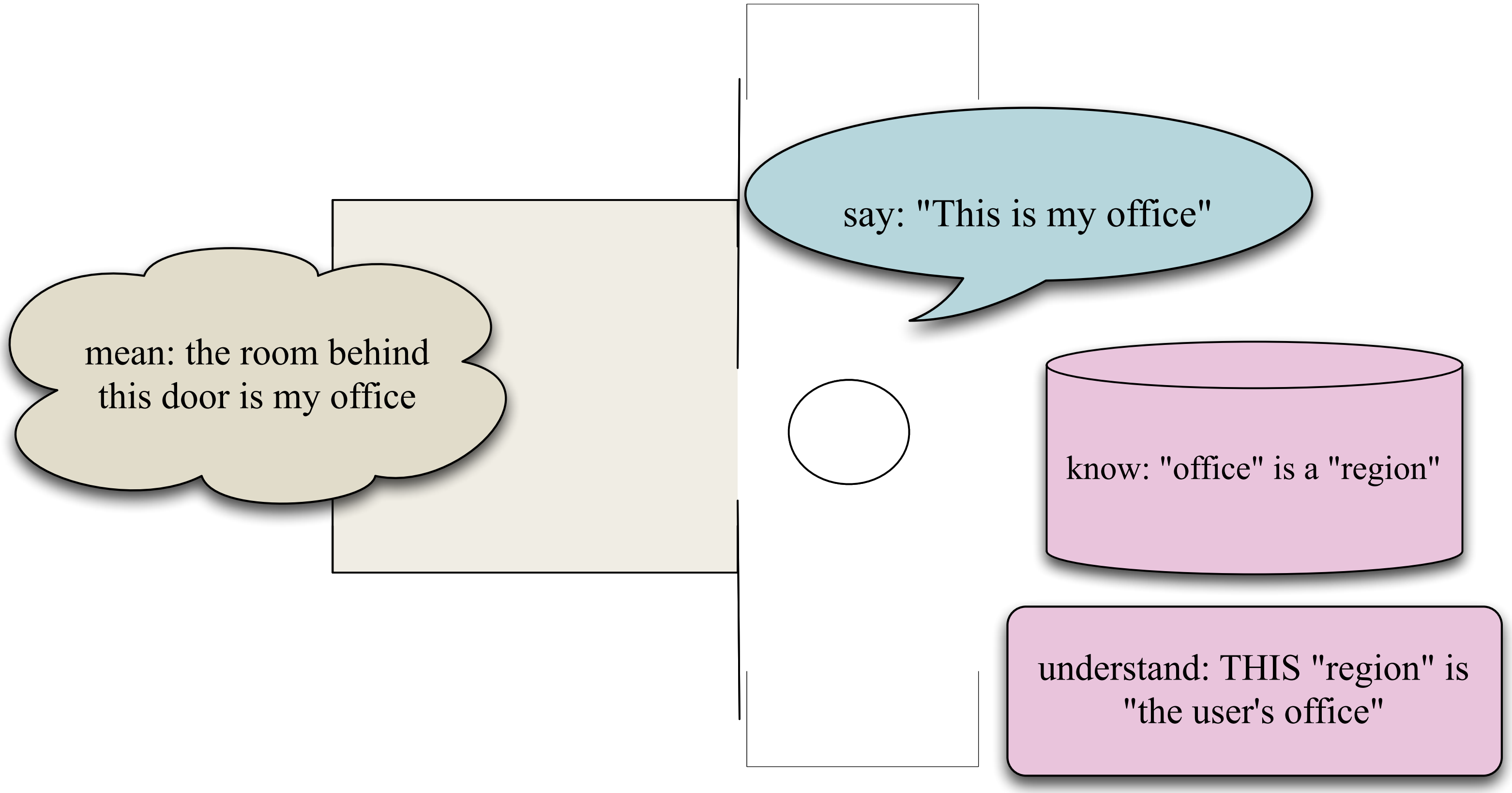


mean: the room behind this door is my office

say: "This is my office"

know: "office" is a "region"

What if…



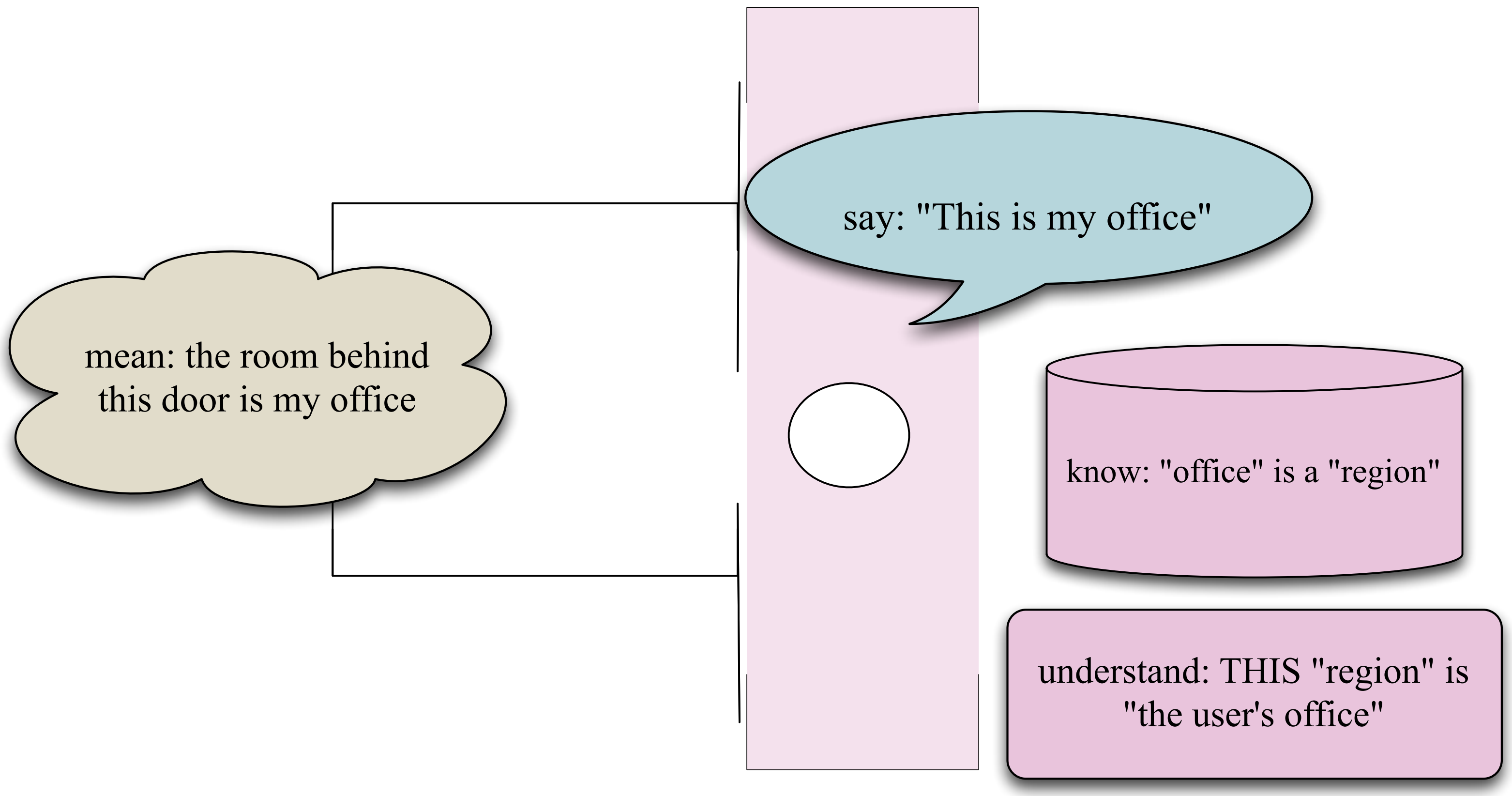
mean: the room behind this door is my office

say: "This is my office"

know: "office" is a "region"

understand: THIS "region" is "the user's office"

What if…



mean: the room behind this door is my office

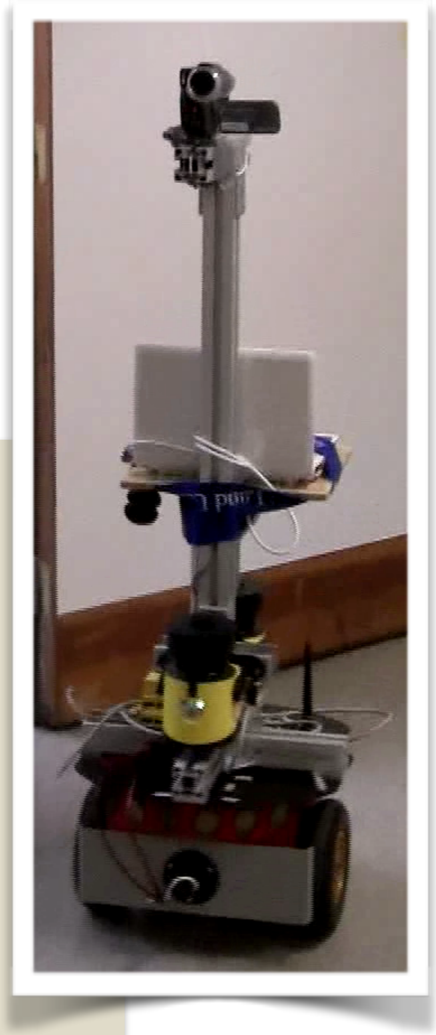
say: "This is my office"

know: "office" is a "region"

understand: THIS "region" is "the user's office"

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?

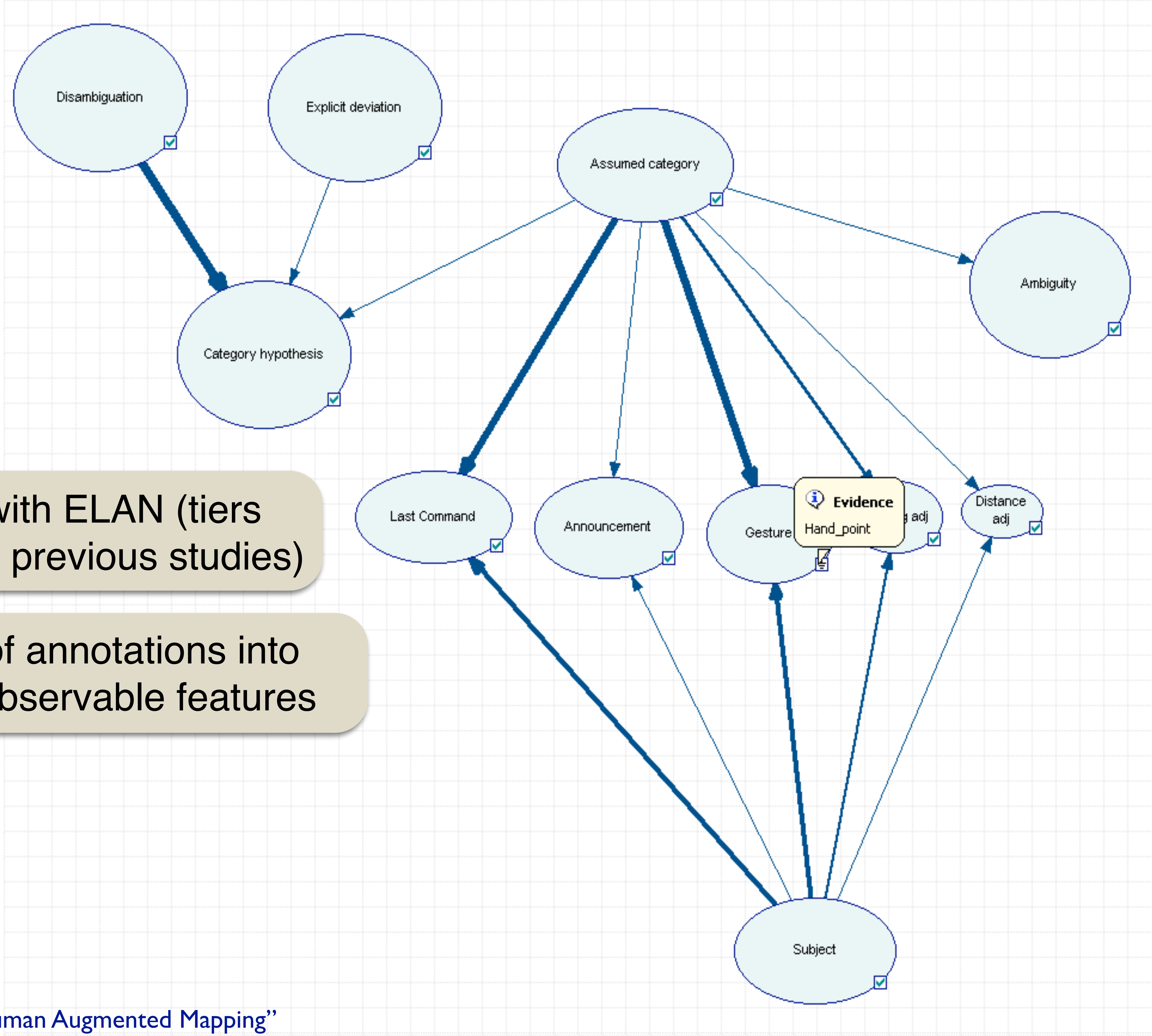


37 Participants

Guide the robot
(three rooms/regions, at least three small objects and three locations/workspaces according to suggestion list)

Video (one external camera and one on the robot) and robot sensor data were stored for later analysis.

Interaction patterns!

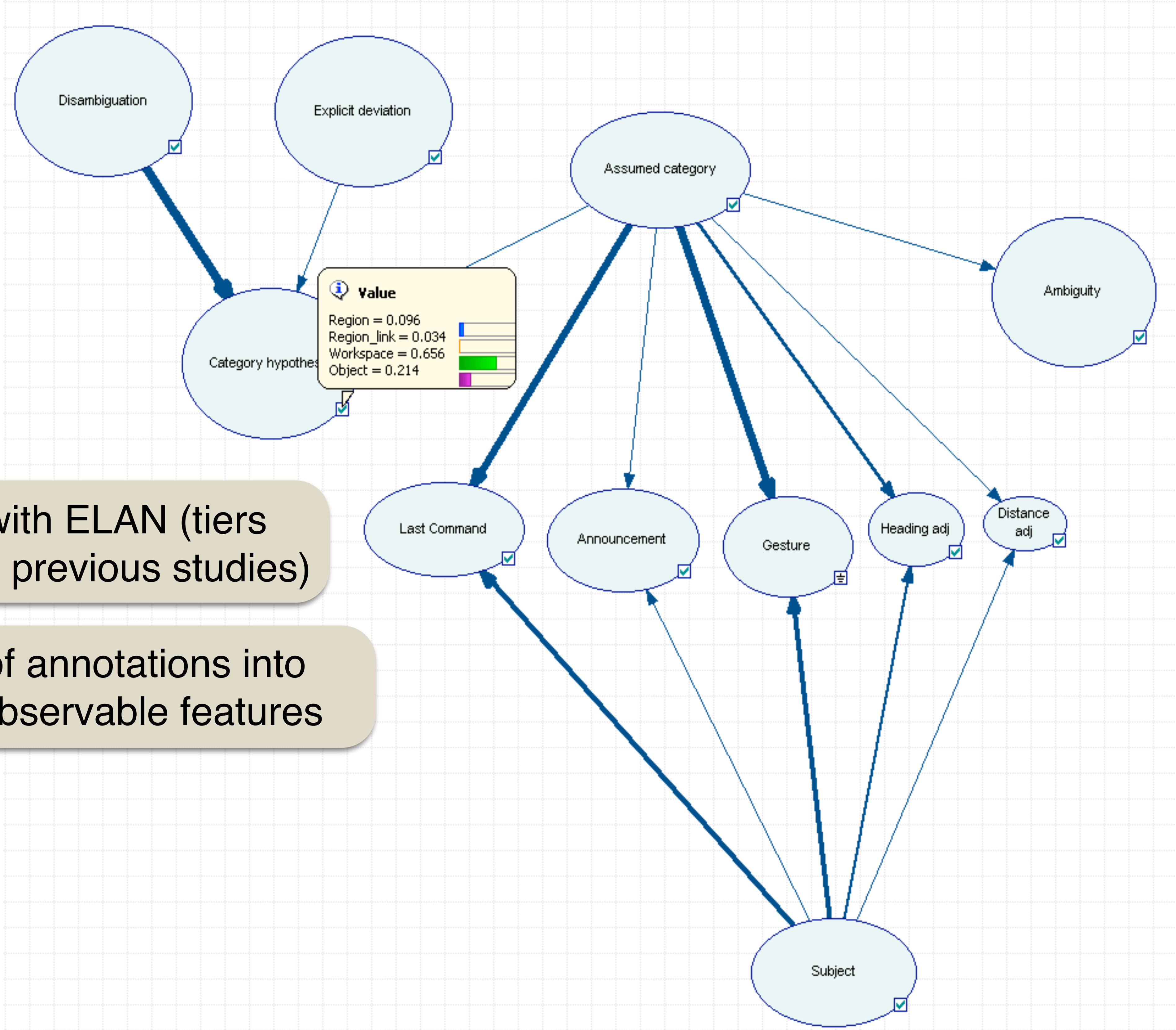


Annotation of videos with ELAN (tiers according to results from previous studies)

Manual summary of annotations into potentially system observable features

Elin A. Topp, "Interaction Patterns in Human Augmented Mapping"
Special Issue on Spatial Interaction and Reasoning for Real-World Robotics, RSJ Advanced Robotics, vol 5, issue 31, March 2017

Interaction patterns!



Value

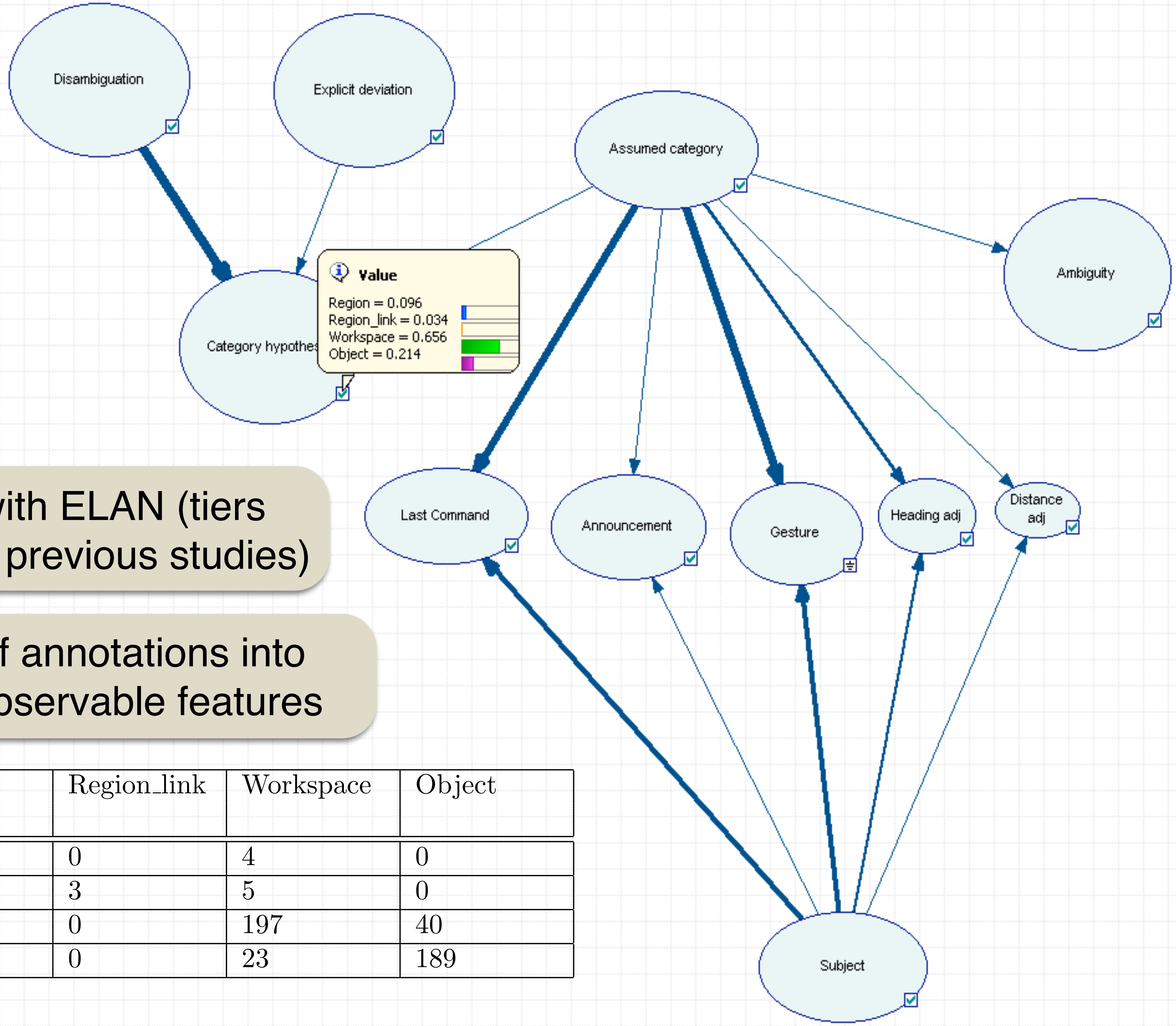
Region = 0.096
Region_link = 0.034
Workspace = 0.656
Object = 0.214

Annotation of videos with ELAN (tiers according to results from previous studies)

Manual summary of annotations into potentially system observable features

Elin A. Topp, “Interaction Patterns in Human Augmented Mapping”
Special Issue on Spatial Interaction and Reasoning for Real-World Robotics, RSJ Advanced Robotics, vol 5, issue 31, March 2017

Interaction patterns!



Value
Region = 0.096
Region_link = 0.034
Workspace = 0.656
Object = 0.214

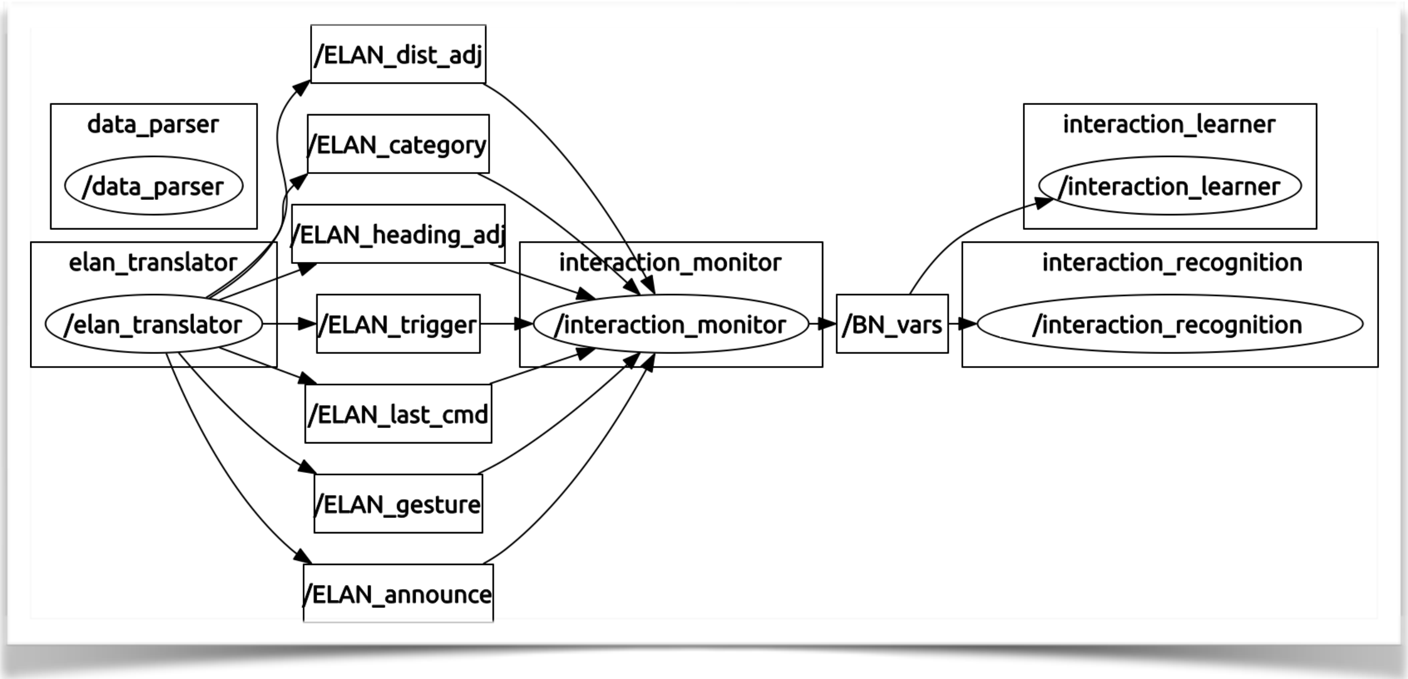
Annotation of videos with ELAN (tiers according to results from previous studies)

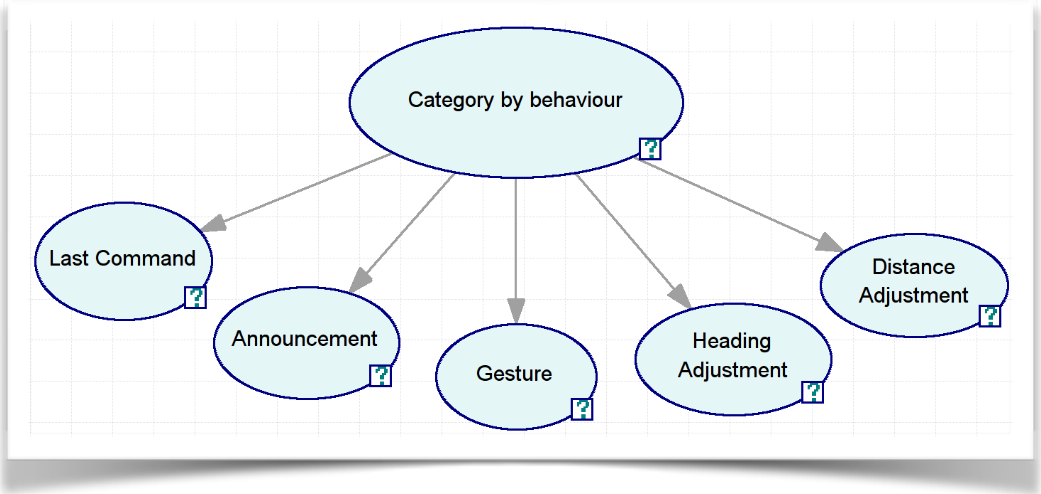
Manual summary of annotations into potentially system observable features

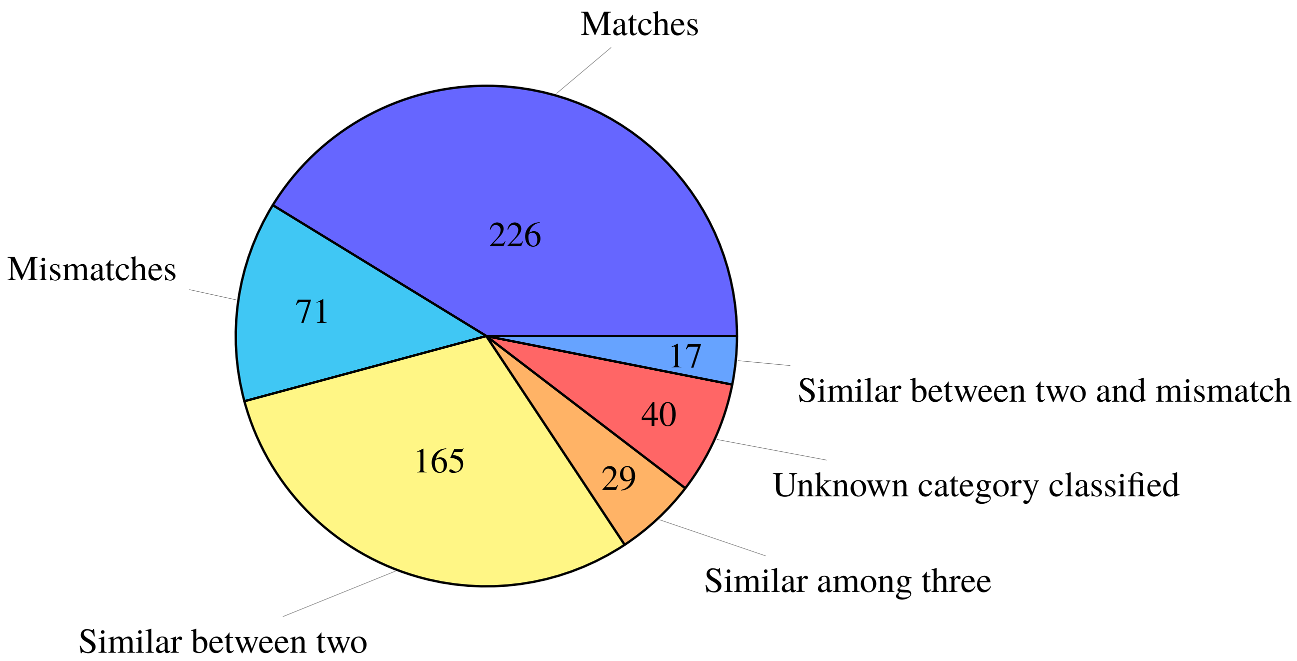
Prediction Definition	Region	Region_link	Workspace	Object
Region	62	0	4	0
Region_link	16	3	5	0
Workspace	5	0	197	40
Object	0	0	23	189

Elin A. Topp, "Interaction Patterns in Human Augmented Mapping"
Special Issue on Spatial Interaction and Reasoning for Real-World Robotics, RSJ Advanced Robotics, vol 5, issue 31, March 2017

Interaction patterns with probabilistic methods







71 clear mismatches:

40 *objects -> workspace* (mostly chairs)

17 *workspaces -> region*

6 *regions -> workspace*

(Felip Martí Carillo and Elin A. Topp,
"Interaction and Task Patterns in Symbiotic, Mixed-Initiative Human-Robot Interaction",
AAAI-WS on Symbiotic Cognitive Systems, February 2017, Phoenix, AZ, USA)

Outline

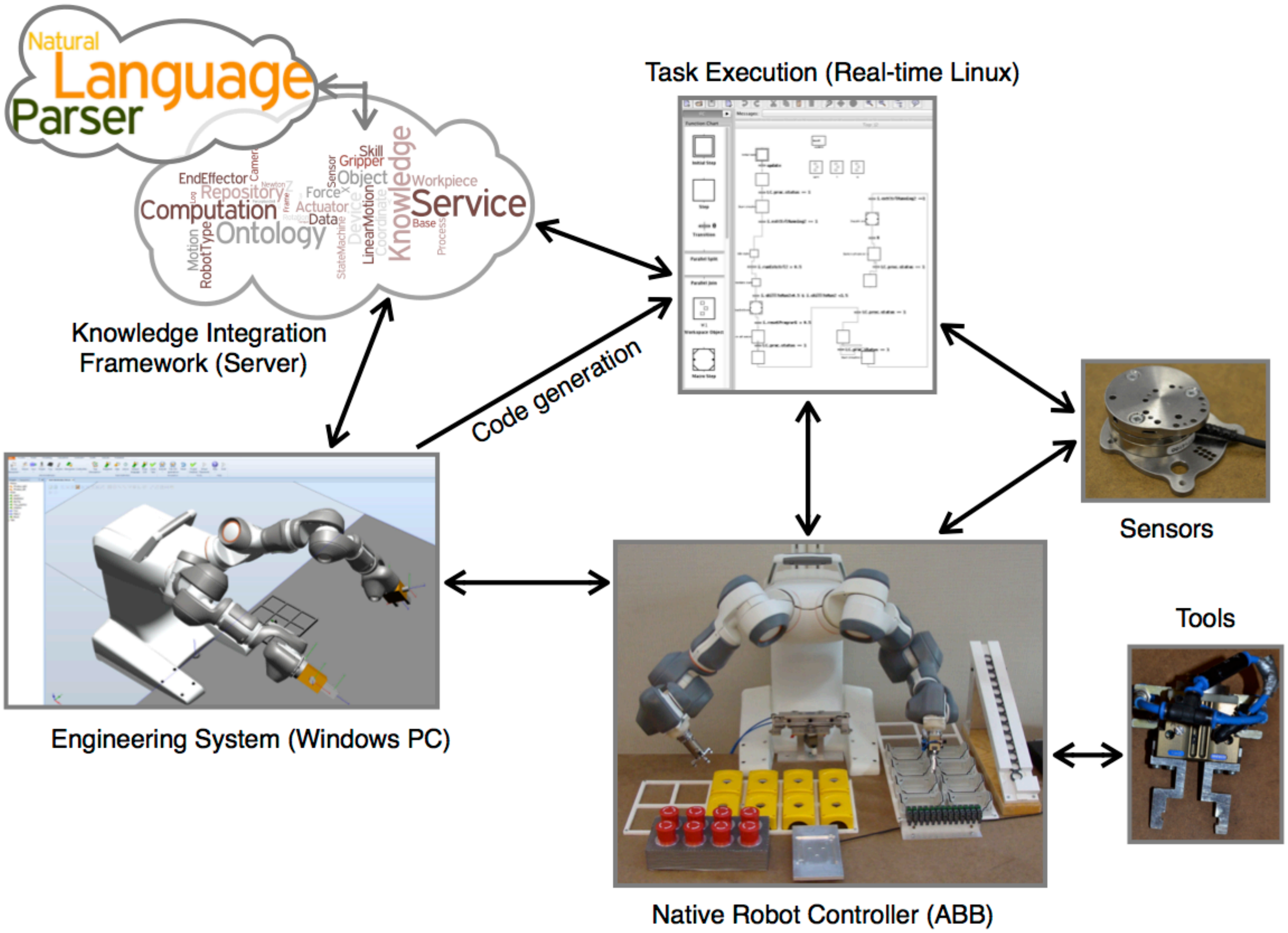
AI in Robotics - integrating the "brain" into the "body"

- Probabilistic methods for Mapping & Localisation (recap)
- SJPDAFs for person tracking
- Identifying interaction patterns in
  Human Augmented Mapping with BNs
- Knowledge representation, reasoning, and NLP to support HRI and high-level robot programming
- (Reinforcement) Learning in robotics
- Deliberation & High level decision making and planning

NLP-based programming

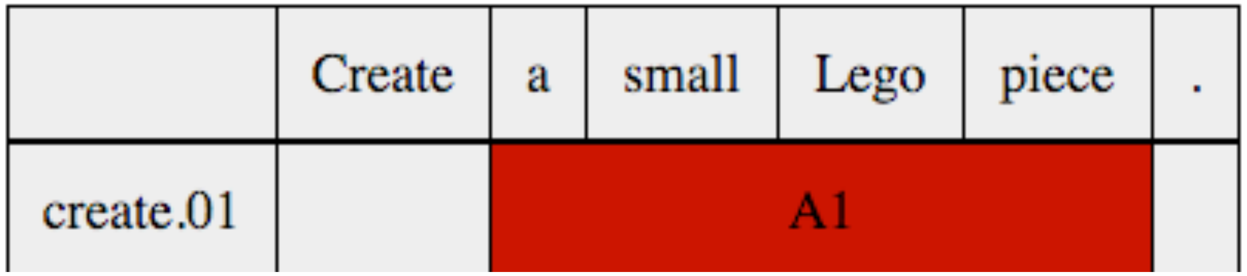
(Maj Stenmark, 2013)

The AI-bits behind…



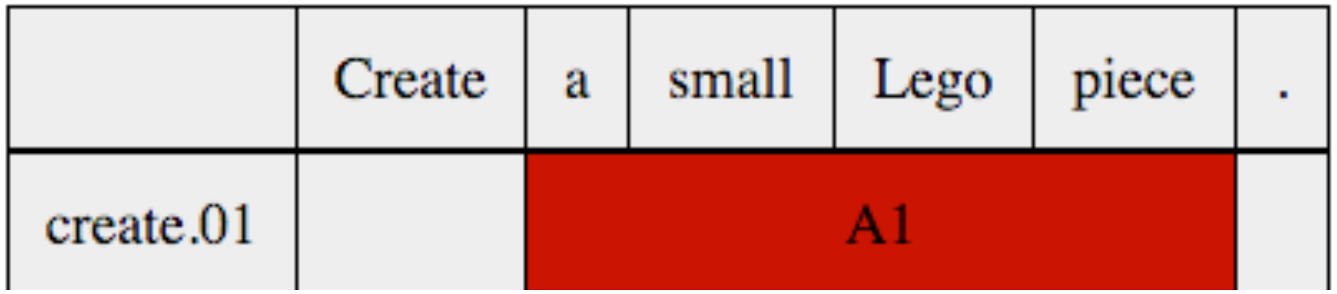
(Maj Stenmark, 2014)

NLP-based programming



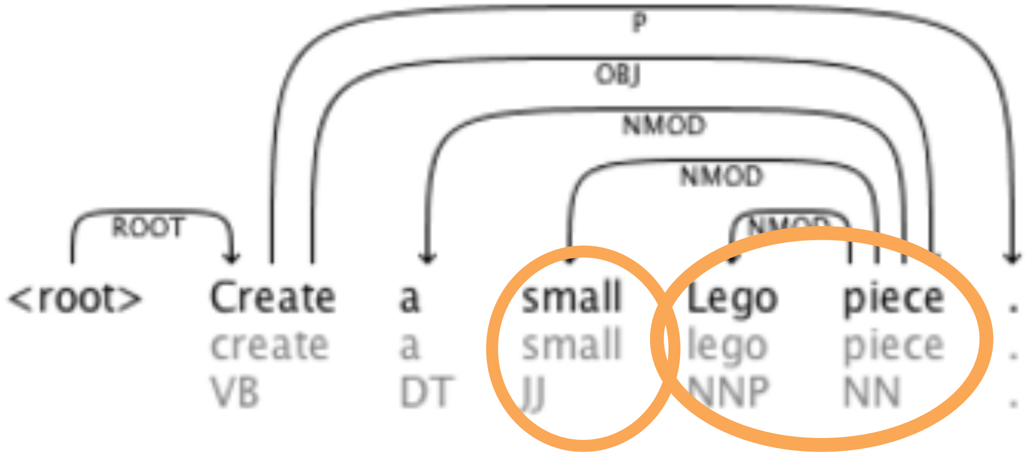
<table>
<tr><th></th><th>Create</th><th>a</th><th>small</th><th>Lego</th><th>piece</th><th>.</th></tr>
<tr><td>create.01</td><td></td><td colspan="4">A1</td><td></td></tr>
</table>

Predicate-argument structures



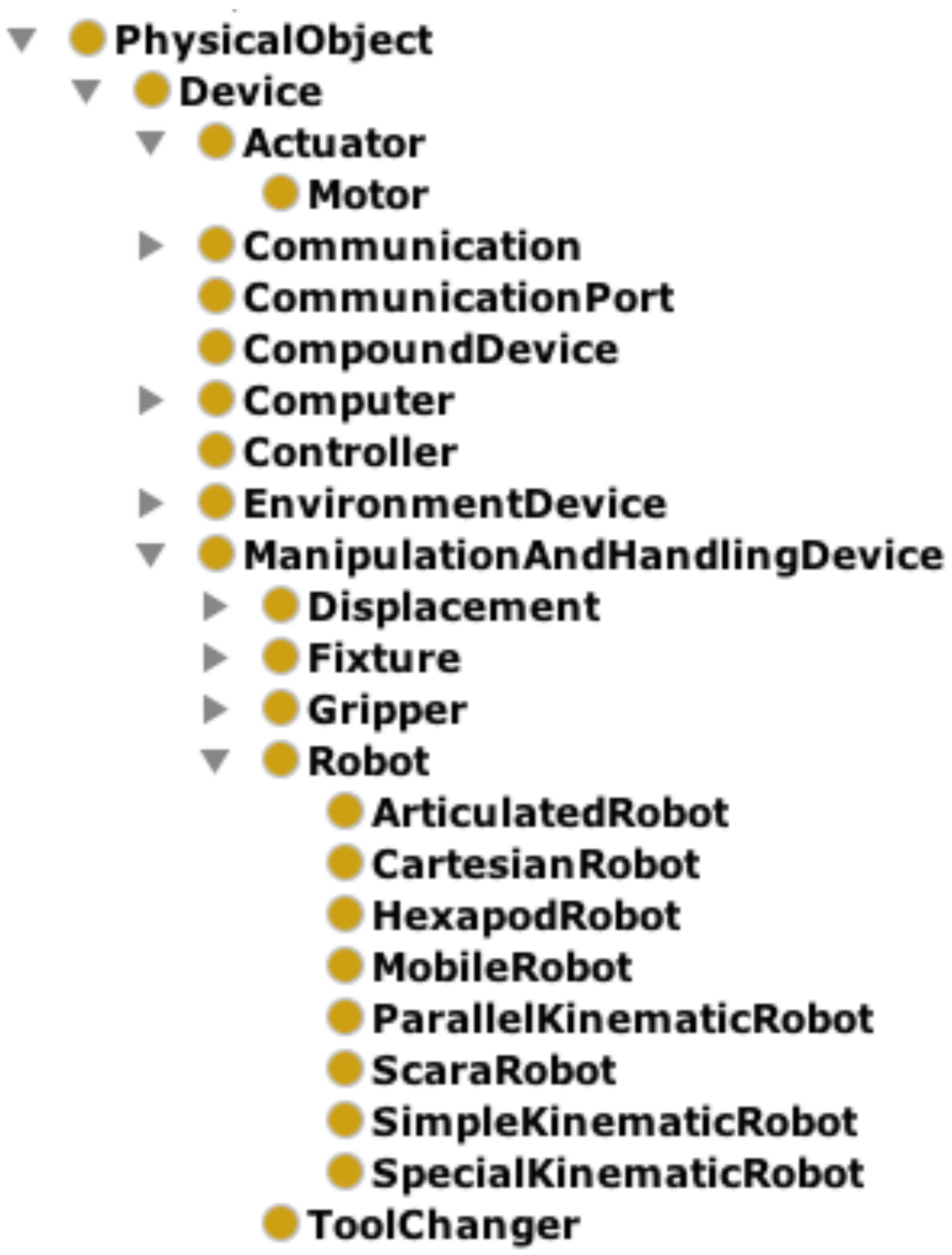
<table>
<tr><th></th><th>Create</th><th>a</th><th>small</th><th>Lego</th><th>piece</th><th>.</th></tr>
<tr><td>create.01</td><td></td><td colspan="4">A1</td><td></td></tr>
</table>

Map to existing commands or programs



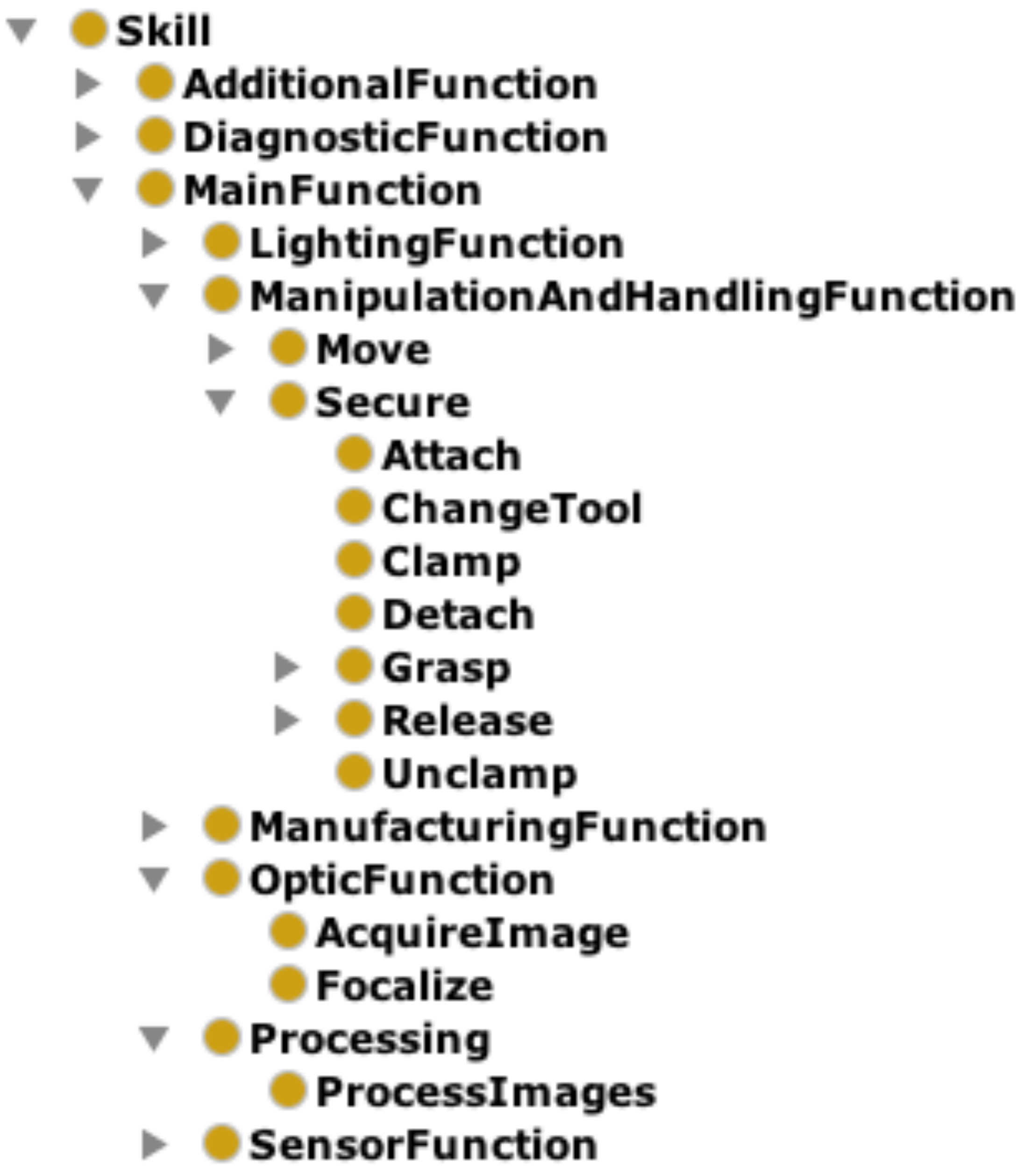
Skills and knowledge

Devices



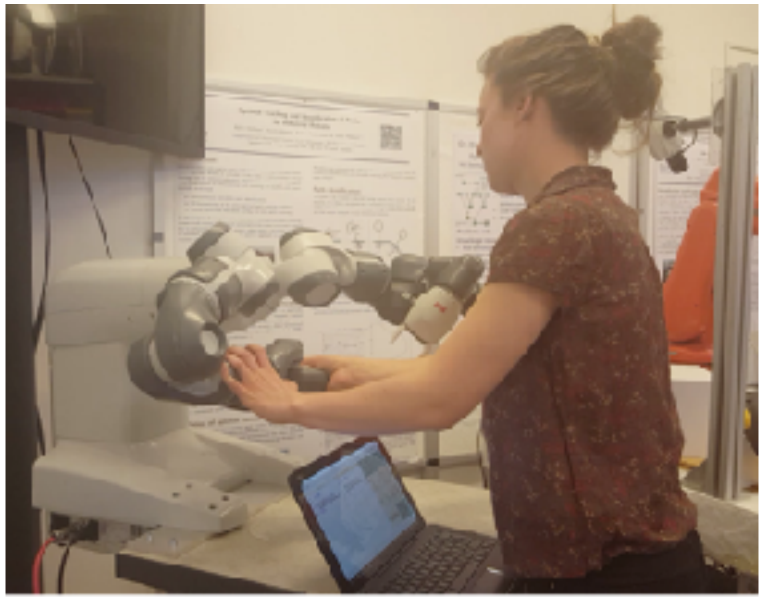
- PhysicalObject
  - Device
    - Actuator
      - Motor
    - Communication
    - CommunicationPort
    - CompoundDevice
    - Computer
    - Controller
    - EnvironmentDevice
    - ManipulationAndHandlingDevice
      - Displacement
      - Fixture
      - Gripper
      - Robot
        - ArticulatedRobot
        - CartesianRobot
        - HexapodRobot
        - MobileRobot
        - ParallelKinematicRobot
        - ScaraRobot
        - SimpleKinematicRobot
        - SpecialKinematicRobot
      - ToolChanger

Skill types



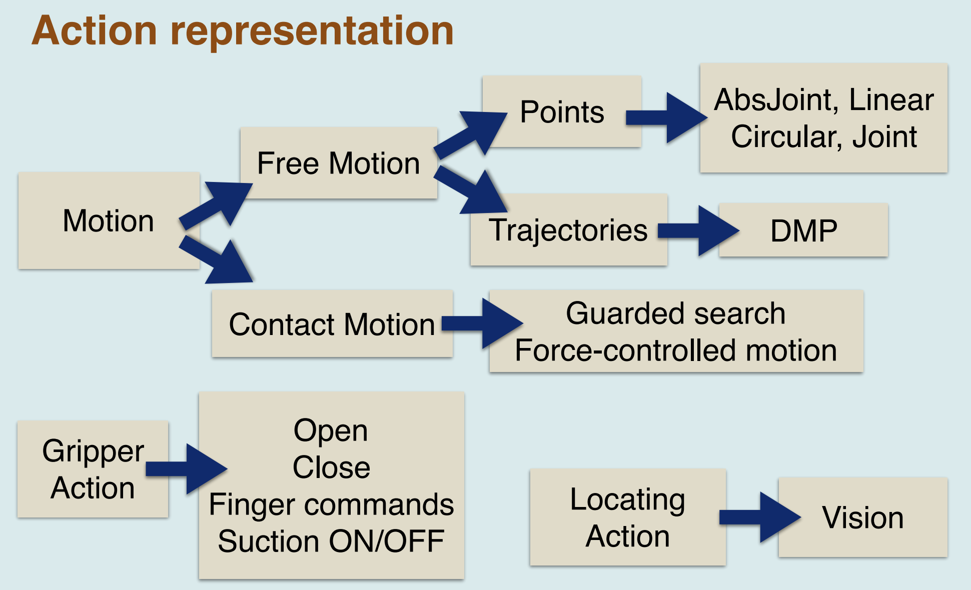
- Skill
  - AdditionalFunction
  - DiagnosticFunction
  - MainFunction
    - LightingFunction
    - ManipulationAndHandlingFunction
      - Move
      - Secure
        - Attach
        - ChangeTool
        - Clamp
        - Detach
        - Grasp
        - Release
        - Unclamp
    - ManufacturingFunction
    - OpticFunction
      - AcquireImage
      - Focalize
    - Processing
      - ProcessImages
    - SensorFunction

However …



Even though the robot has lead-through built in, and
even though we could use NLP and high-level instructions to
make use of our skill representation -

… we must get the skills into the system!



Action representation

Motion

Free Motion

Points

AbsJoint, Linear Circular, Joint

Trajectories

DMP

Contact Motion

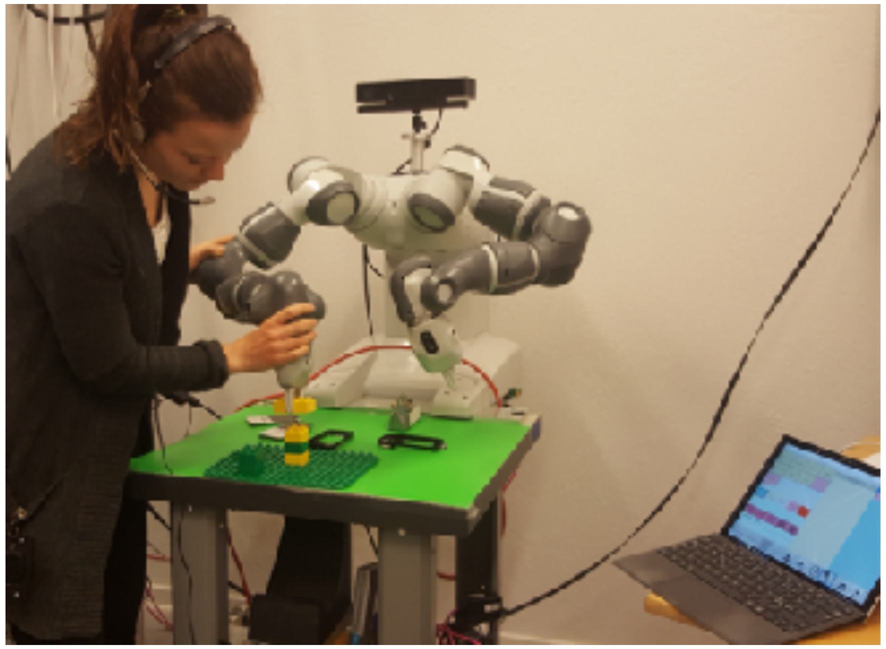
Guarded search Force-controlled motion

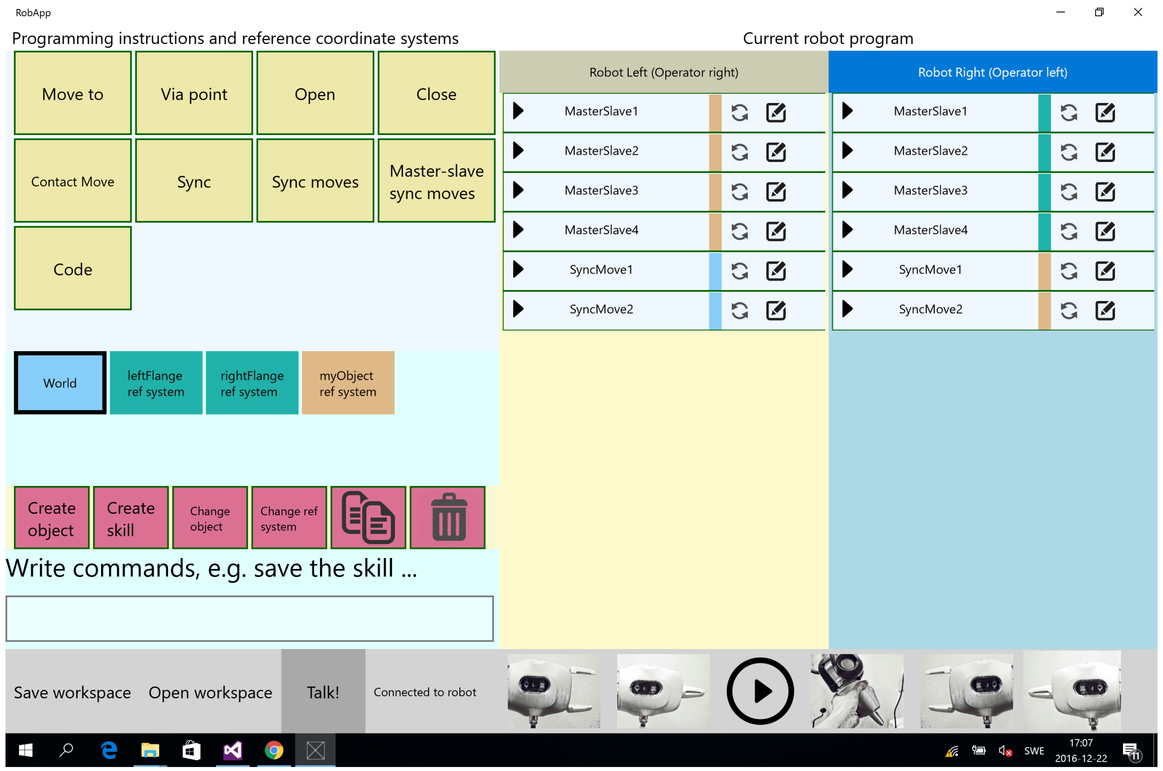
Gripper Action

Open Close Finger commands Suction ON/OFF

Locating Action

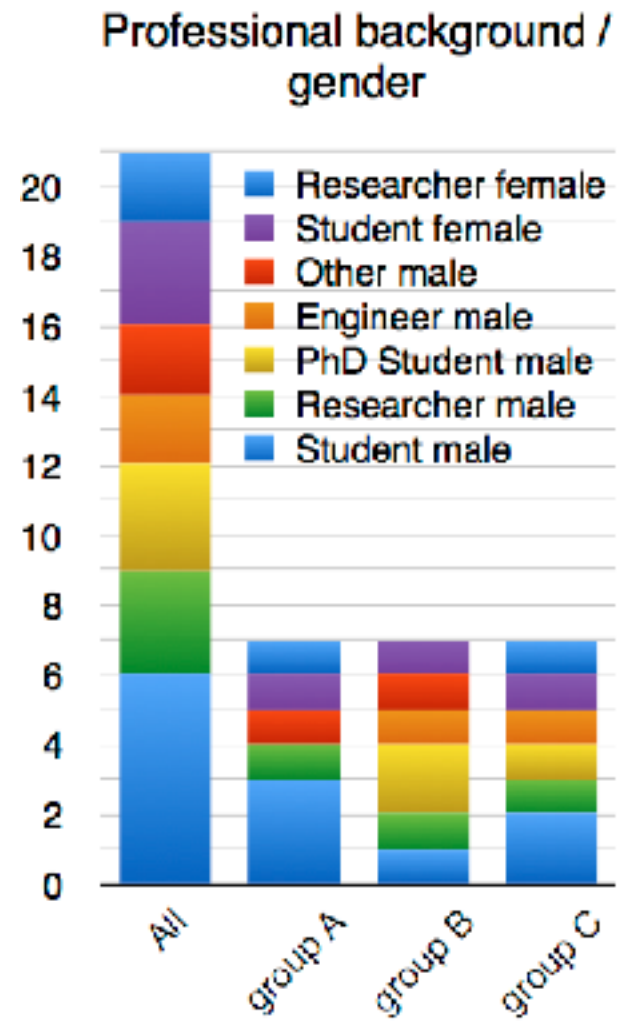
Vision

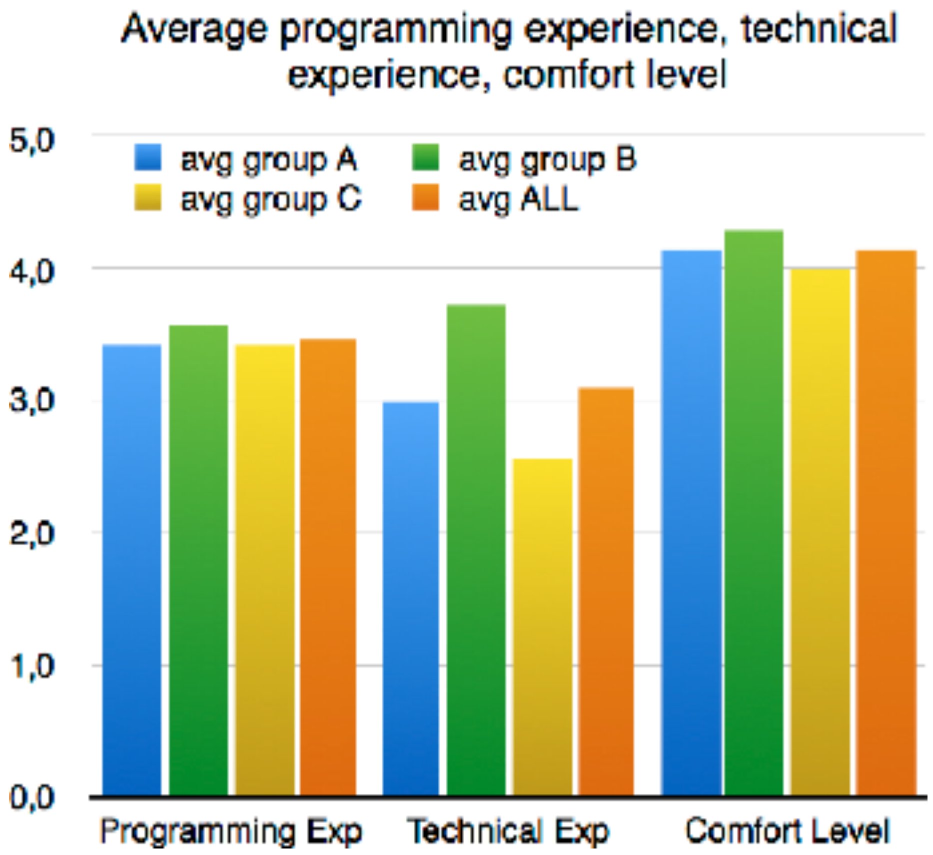


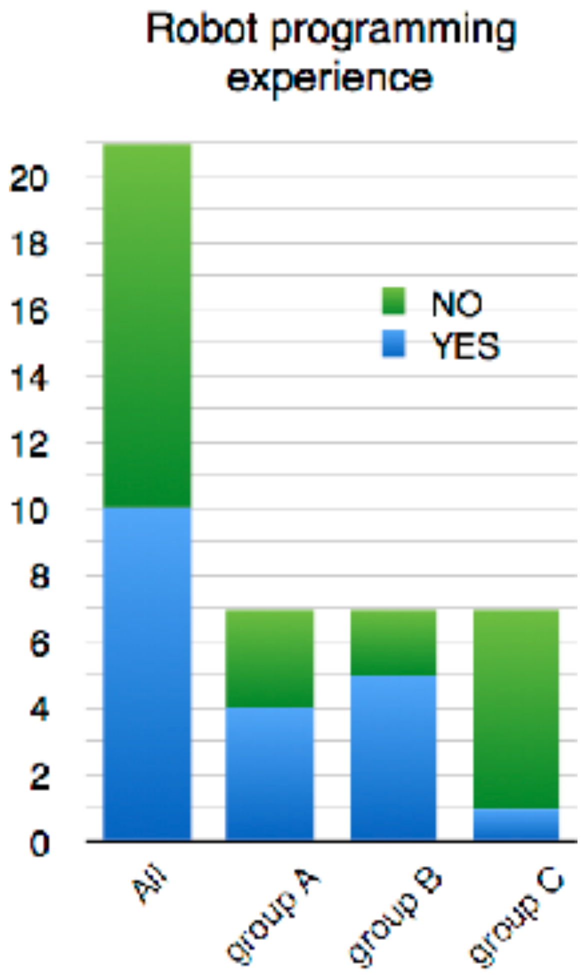


(Maj Stenmark, Mathias Haage, Elin A. Topp, and Jacek Malec,
"Supporting Semantic Capture during Kinesthetic Teaching of Collaborative Industrial Robots",
ICSC-IW on Semantics in Engineering and Robotics, January 2017, San Diego, CA, USA)
(Maj Stenmark, Mathias Haage, Elin A. Topp, and Jacek Malec,
"Making Robotic Sense of Incomplete Human Instructions in High-Level Programming for Industrial Robotic Assembly",
AAAI-WS on Human-Machine Collaborative Learning, February 2017, San Francisco, CA, USA)

Does skill re-use help?
Can non-experts program the robot?


Professional background / gender


Average programming experience, technical experience, comfort level


Robot programming experience

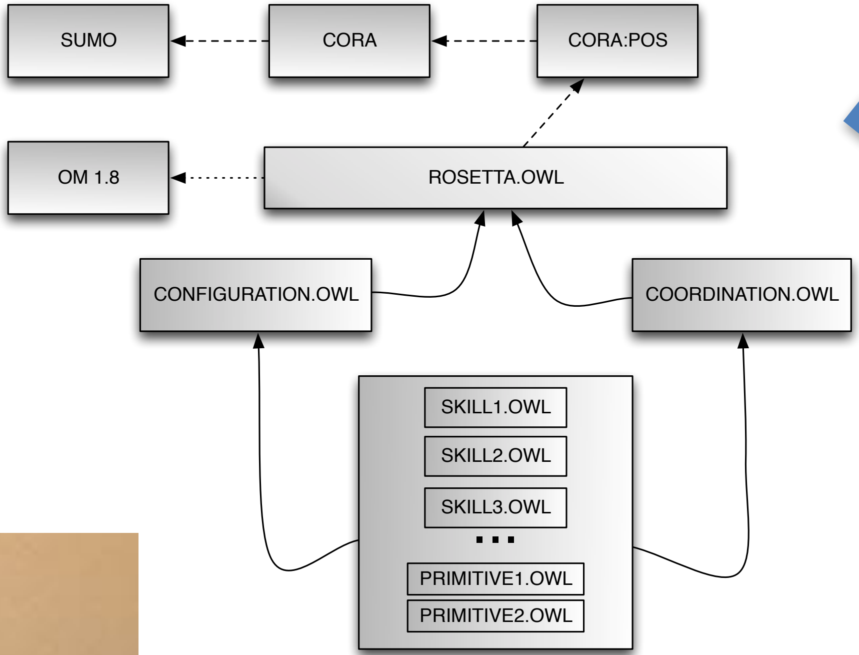
Two phases: I: Step 1 (create "pick up and insert a 2x2 Duplo on another one" - skill) and
II: Steps 2-4 "repeat" Step 1 (different conditions) with a 2x4 Duplo

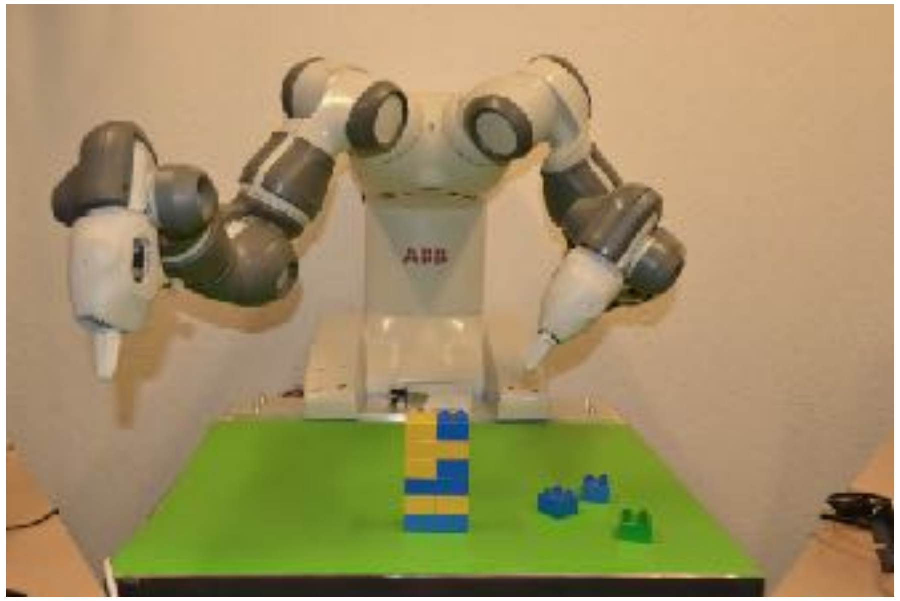
Three Conditions: A: re-use your step 1 skill
B: re-use a provided, expert-made skill
C: build everything from scratch

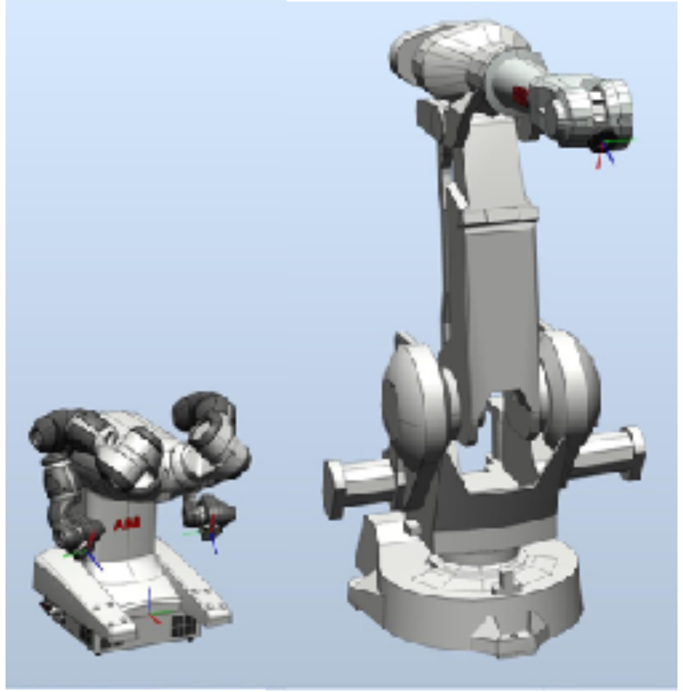
Yes! and Yes!

Maj Stenmark, Mathias Haage, and Elin A. Topp,
"Simplified Programming of Re-usable Skills on a Safe Industrial Robot - Prototype and Evaluation",
ACM / IEEE Conference on Human-Robot Interaction, March 2017, Vienna, Austria

Program here - run there…

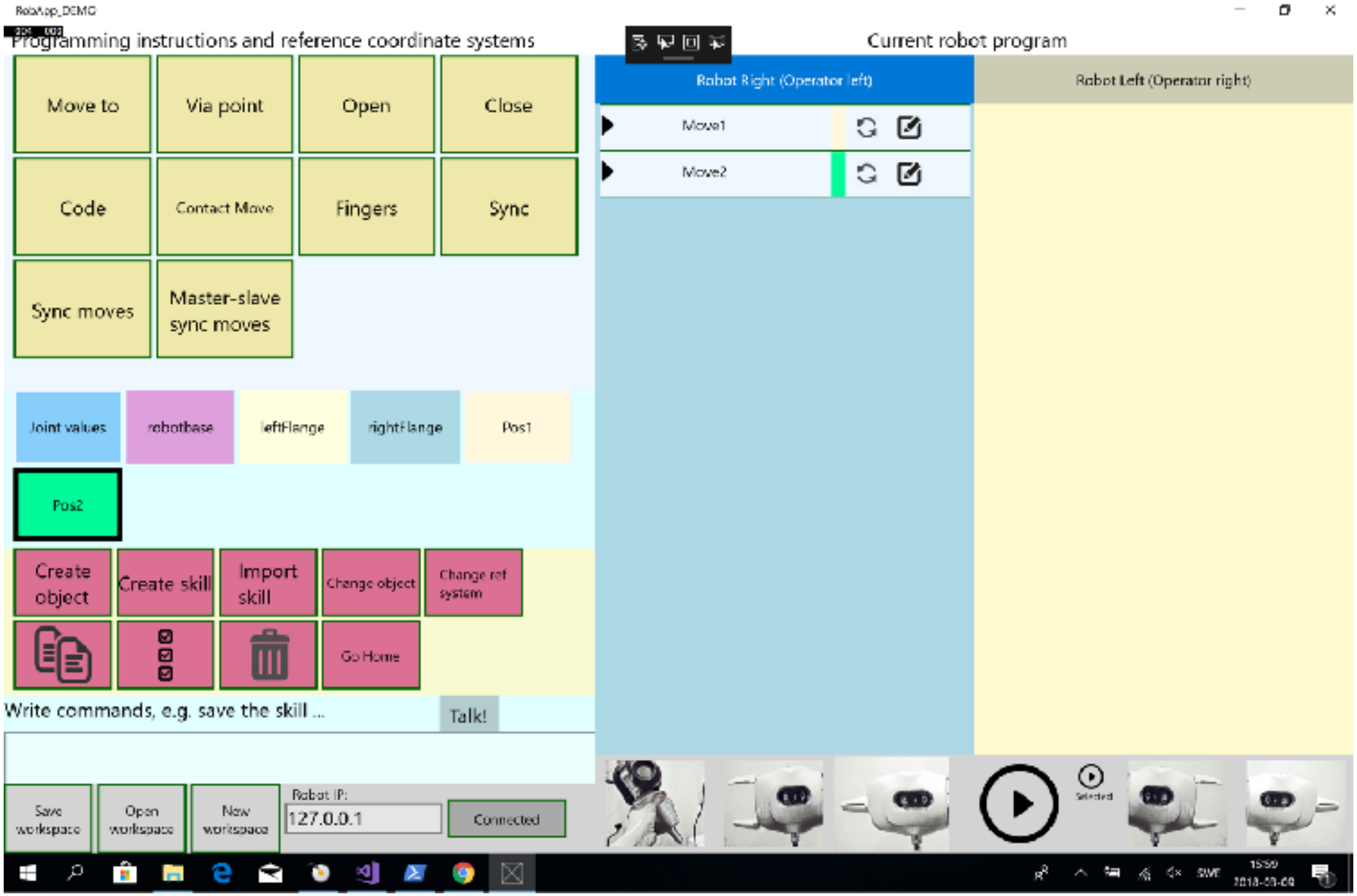




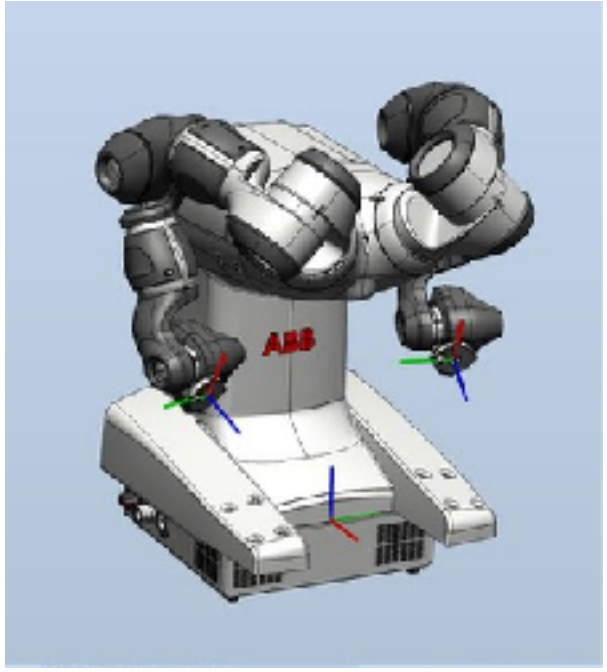


[Topp, Stenmark, Ganslandt, Svensson, Haage, Malec, IROS 2018]

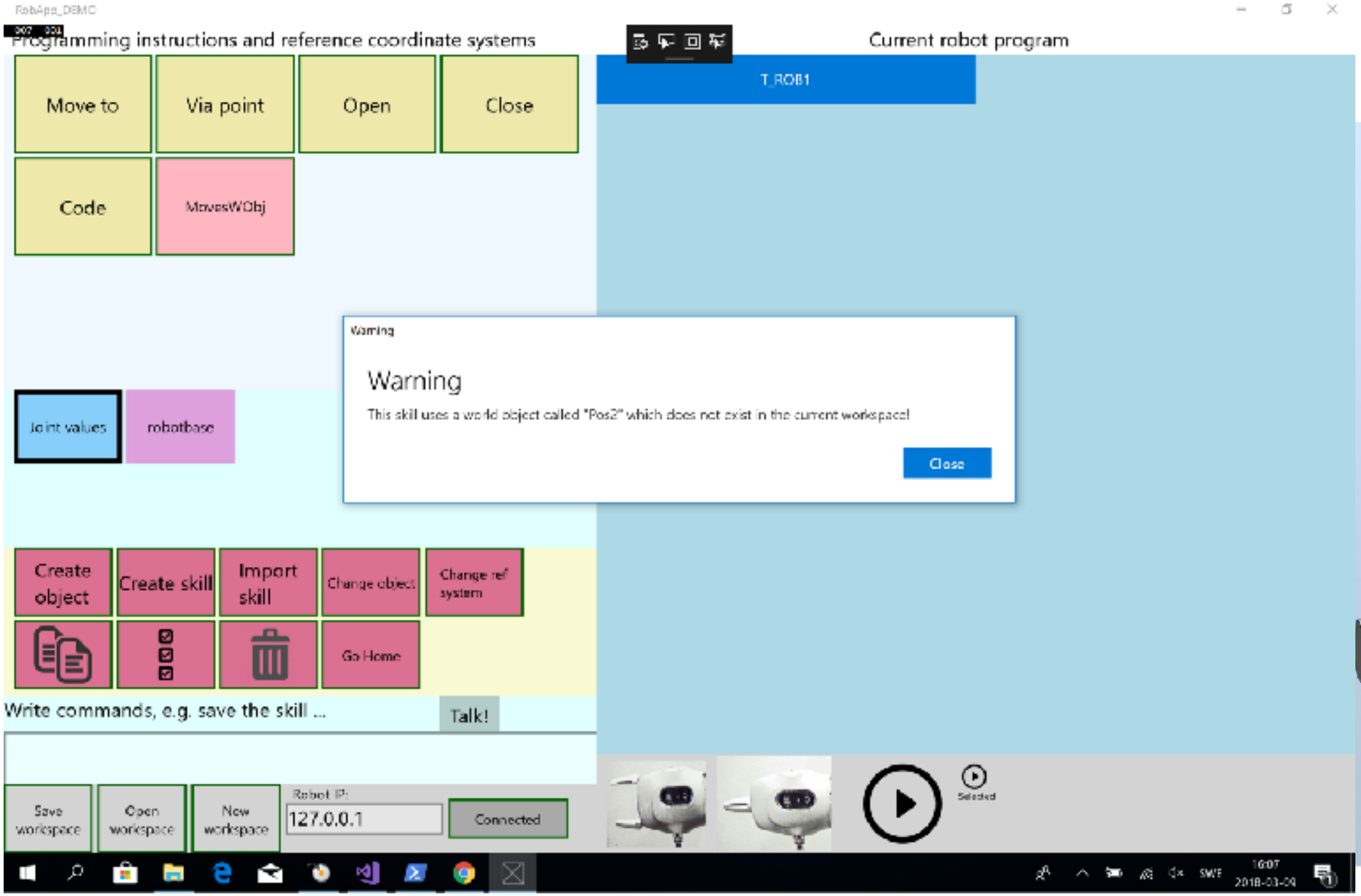
Programming on YuMi



Robot IP: 127.0.0.1



Re-using the skill on IRB2400

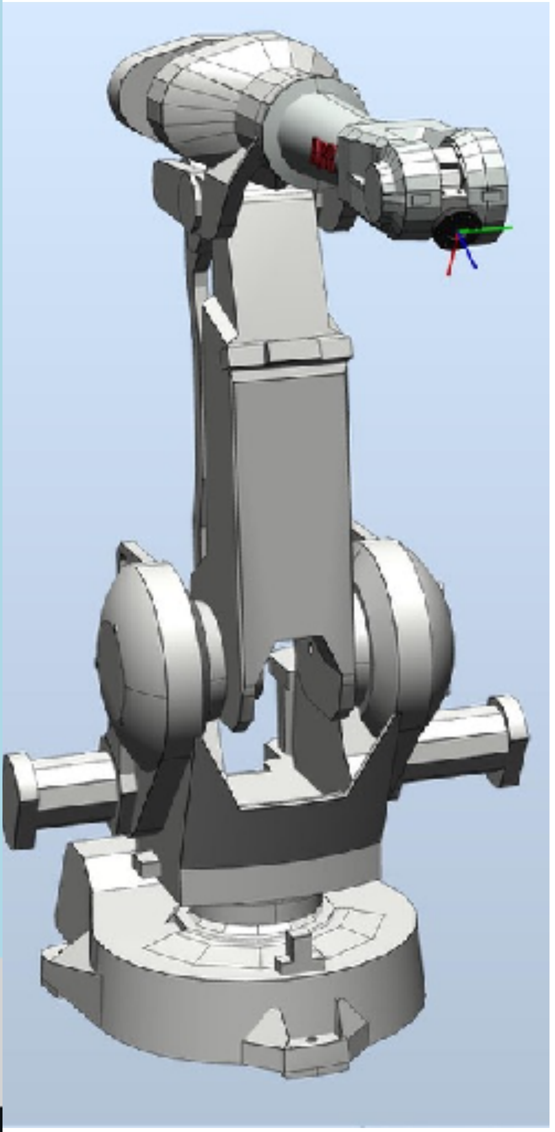


Warning

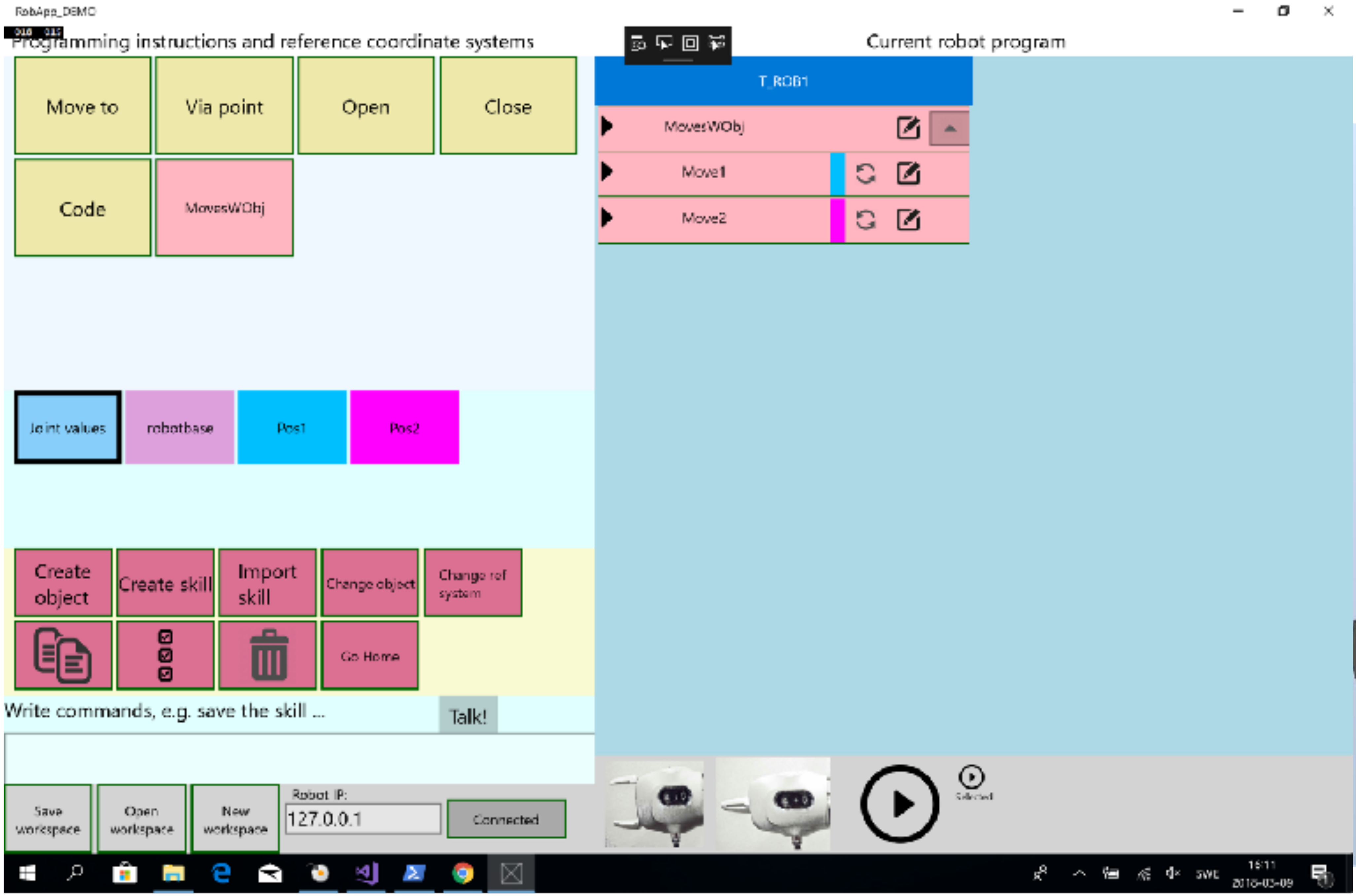
Warning

This skill uses a world object called "Pos2" which does not exist in the current workspace!

Close



Re-using the skill on IRB2400

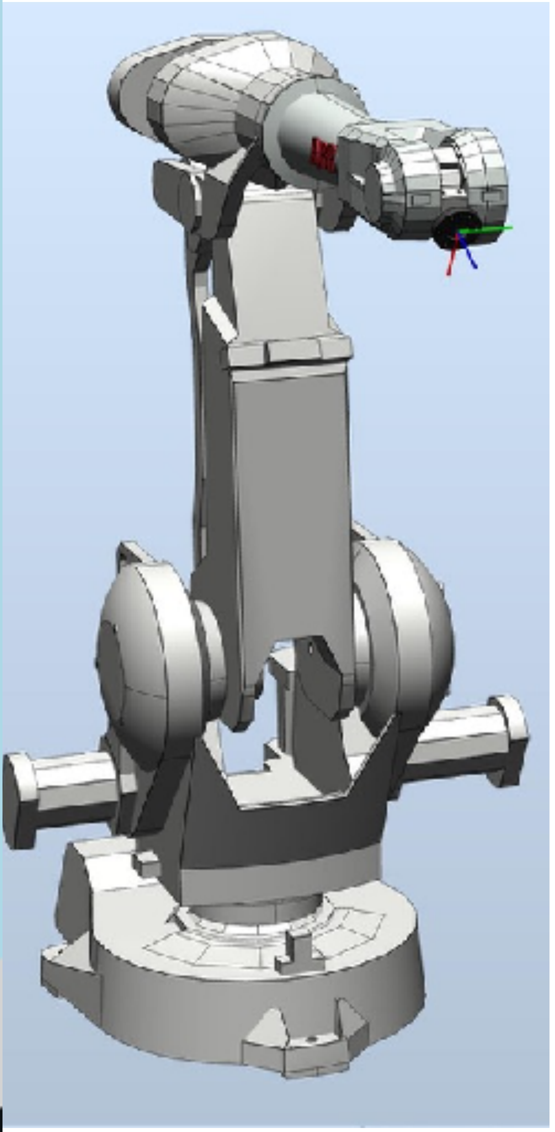


Programming instructions and reference coordinate systems

Current robot program

Write commands, e.g. save the skill ...

Robot IP: 127.0.0.1



Outline

AI in Robotics - integrating the "brain" into the "body"

- Probabilistic methods for Mapping & Localisation (recap)
- SJPDAFs for person tracking
- Identifying interaction patterns in
  Human Augmented Mapping with BNs
- Knowledge representation, reasoning, and NLP to support HRI and high-level robot programming

- (Reinforcement) Learning in robotics
- Deliberation & High level decision making and planning

Sensorimotor policies (RL)

“Image in - action sequence out”

Sensorimotor robot policy training using Reinforcement Learning

Ali Ghadirzadeh, KTH, PhD Thesis 2018.

Outline

AI in Robotics - integrating the “brain” into the “body”

- Probabilistic methods for Mapping & Localisation (recap)
- SJPDAFs for person tracking
- Identifying interaction patterns in
  Human Augmented Mapping with BNs
- Knowledge representation, reasoning, and NLP to support HRI and high-level robot programming
- (Reinforcement) Learning in robotics
- Deliberation & High level decision making and planning

More complex decisions / plans

More complex decisions / plans

If the system does not only involve one robot with several "competencies", but several robots with partly overlapping, partly complementary abilities, the decisions are to be taken to another dimension:

More complex decisions / plans

If the system does not only involve one robot with several "competencies", but several robots with partly overlapping, partly complementary abilities, the decisions are to be taken to another dimension:

- Given a task, what do I need to know to fulfill it?

More complex decisions / plans

If the system does not only involve one robot with several “competencies”, but several robots with partly overlapping, partly complementary abilities, the decisions are to be taken to another dimension:

- Given a task, what do I need to know to fulfill it?
- Do I know these things?

More complex decisions / plans

If the system does not only involve one robot with several "competencies", but several robots with partly overlapping, partly complementary abilities, the decisions are to be taken to another dimension:

- Given a task, what do I need to know to fulfill it?
- Do I know these things?
- Given I know what to do, do I have the means (robot) to do it?

More complex decisions / plans

If the system does not only involve one robot with several "competencies", but several robots with partly overlapping, partly complementary abilities, the decisions are to be taken to another dimension:

- Given a task, what do I need to know to fulfill it?
- Do I know these things?
- Given I know what to do, do I have the means (robot) to do it?
- If yes, which one?

More complex decisions / plans

If the system does not only involve one robot with several "competencies", but several robots with partly overlapping, partly complementary abilities, the decisions are to be taken to another dimension:

- Given a task, what do I need to know to fulfill it?
- Do I know these things?
- Given I know what to do, do I have the means (robot) to do it?
- If yes, which one?
- Given different steps and parts of a task, can things be done in parallel?

More complex decisions / plans

If the system does not only involve one robot with several "competencies", but several robots with partly overlapping, partly complementary abilities, the decisions are to be taken to another dimension:

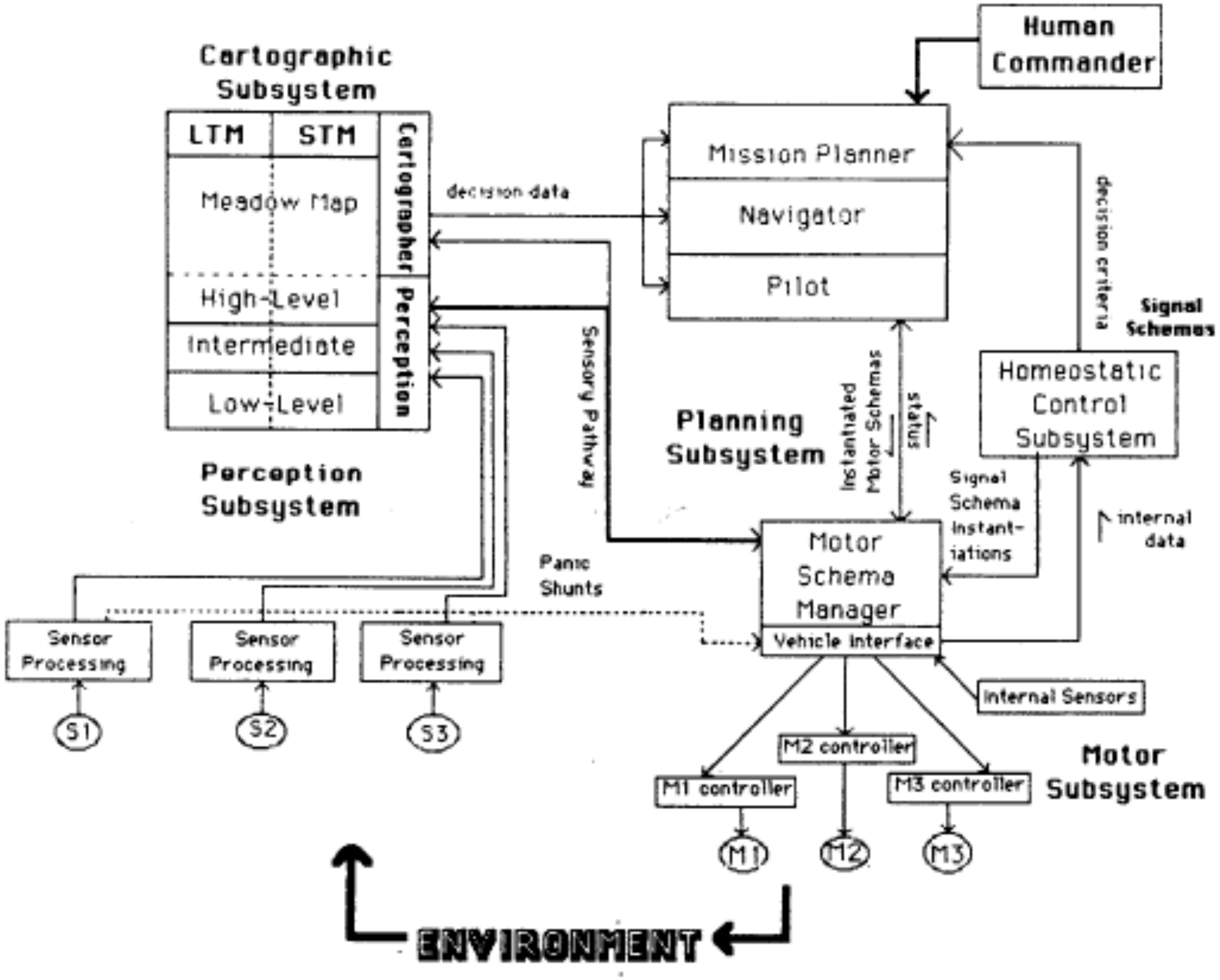
- Given a task, what do I need to know to fulfill it?
- Do I know these things?
- Given I know what to do, do I have the means (robot) to do it?
- If yes, which one?
- Given different steps and parts of a task, can things be done in parallel?
- By which robot?

More complex decisions / plans

If the system does not only involve one robot with several "competencies", but several robots with partly overlapping, partly complementary abilities, the decisions are to be taken to another dimension:

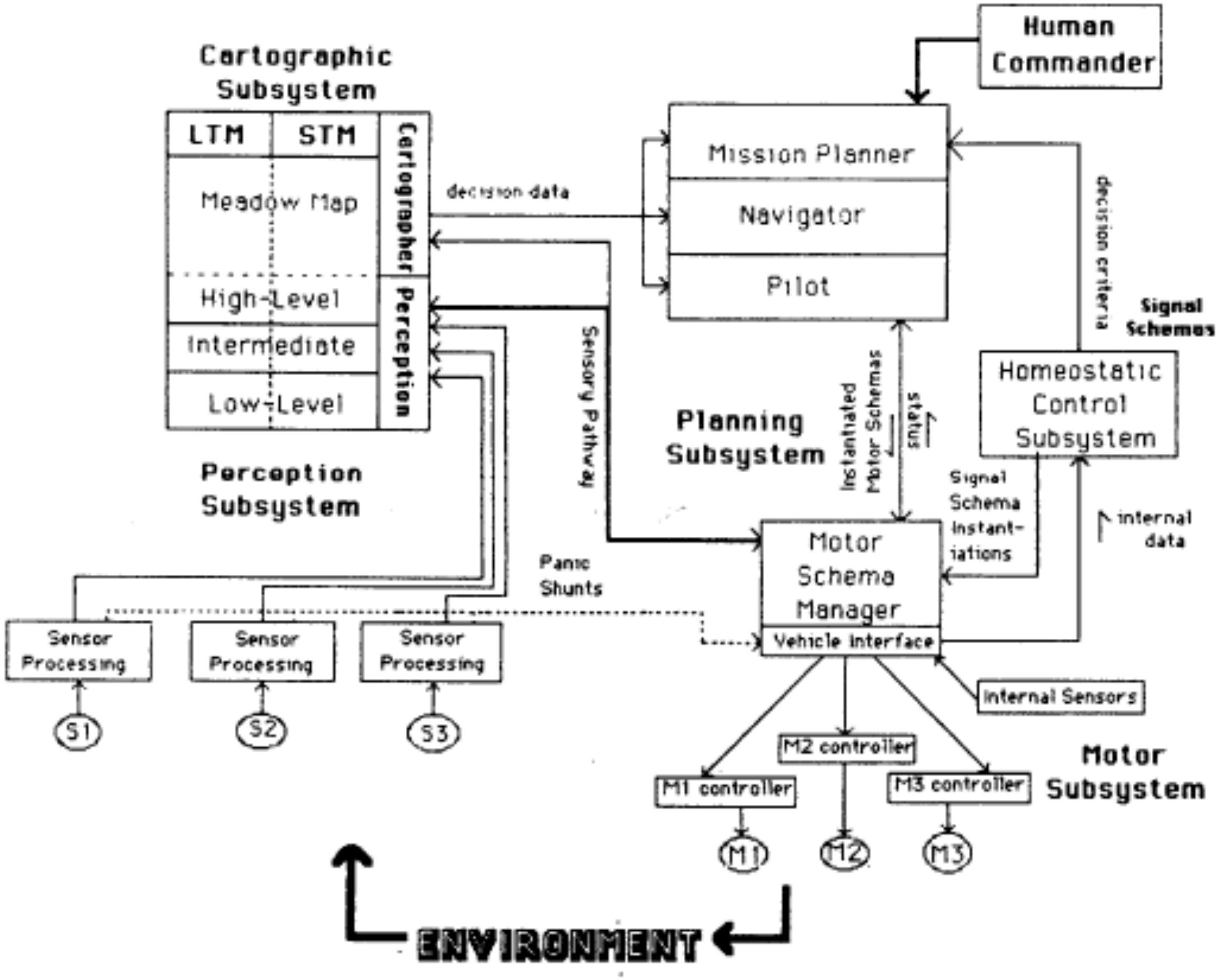
- Given a task, what do I need to know to fulfill it?
- Do I know these things?
- Given I know what to do, do I have the means (robot) to do it?
- If yes, which one?
- Given different steps and parts of a task, can things be done in parallel?
- By which robot?
- What if something goes wrong with one part of the plan? Does this affect the whole task execution, or only one of the robots?

Deliberation in, e.g. a navigation system



Deliberation in, e.g. a navigation system

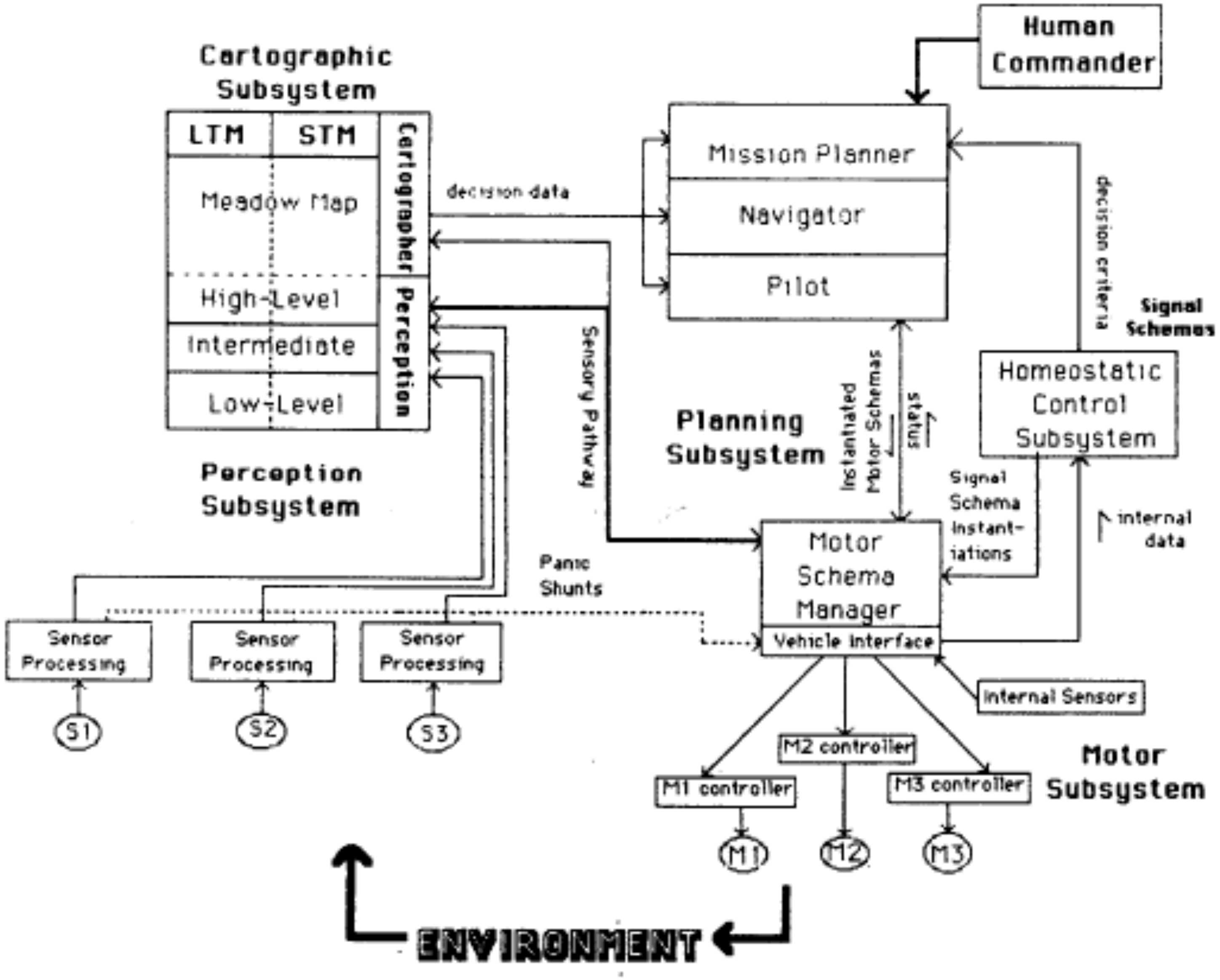
A robotic system might have several goals to pursue, e.g.



Deliberation in, e.g. a navigation system

A robotic system might have several goals to pursue, e.g.

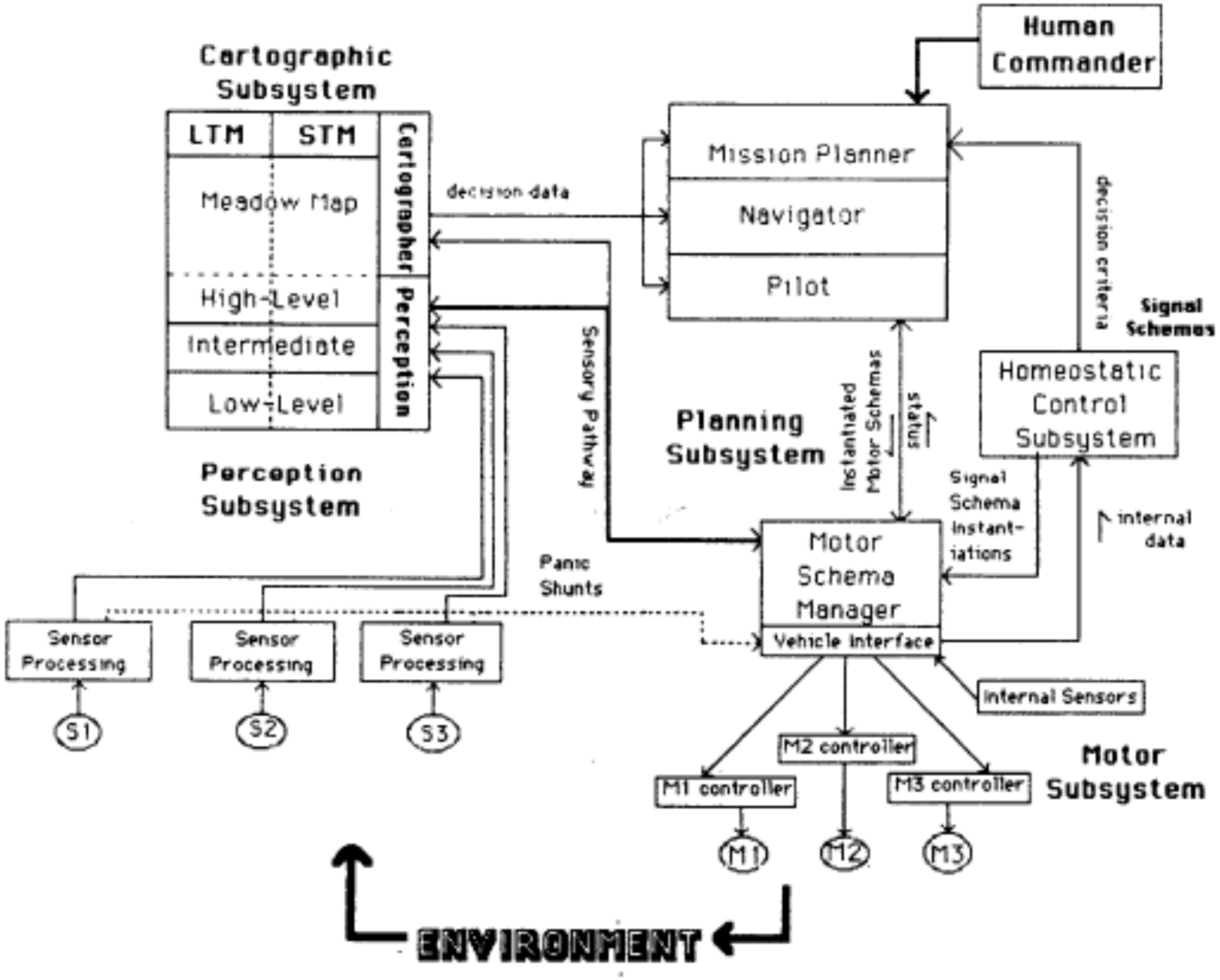
- Explore the environment



Deliberation in, e.g. a navigation system

A robotic system might have several goals to pursue, e.g.

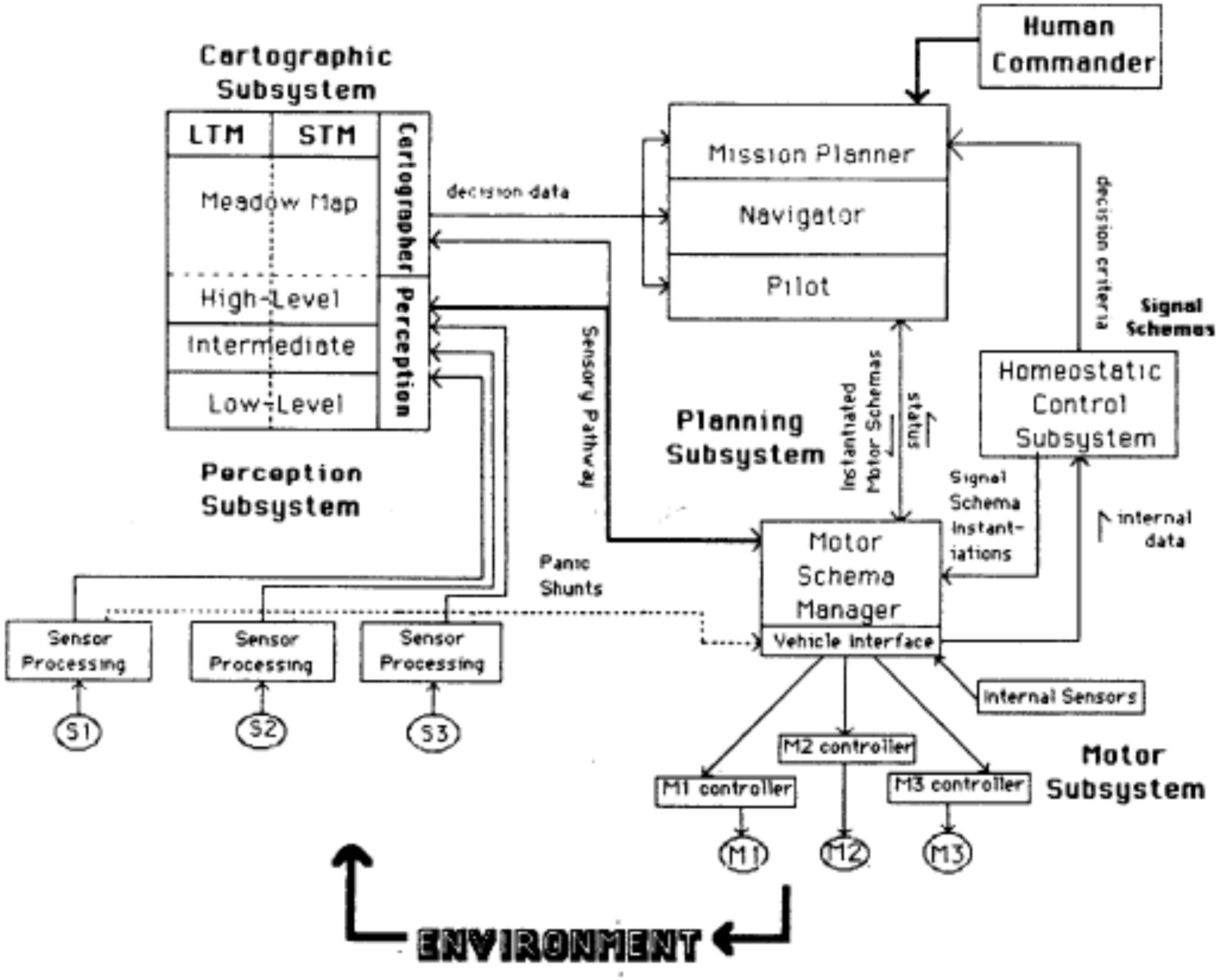
- Explore the environment
- Use a certain strategy
  (e.g. follow the wall to the right)



Deliberation in, e.g. a navigation system

A robotic system might have several goals to pursue, e.g.

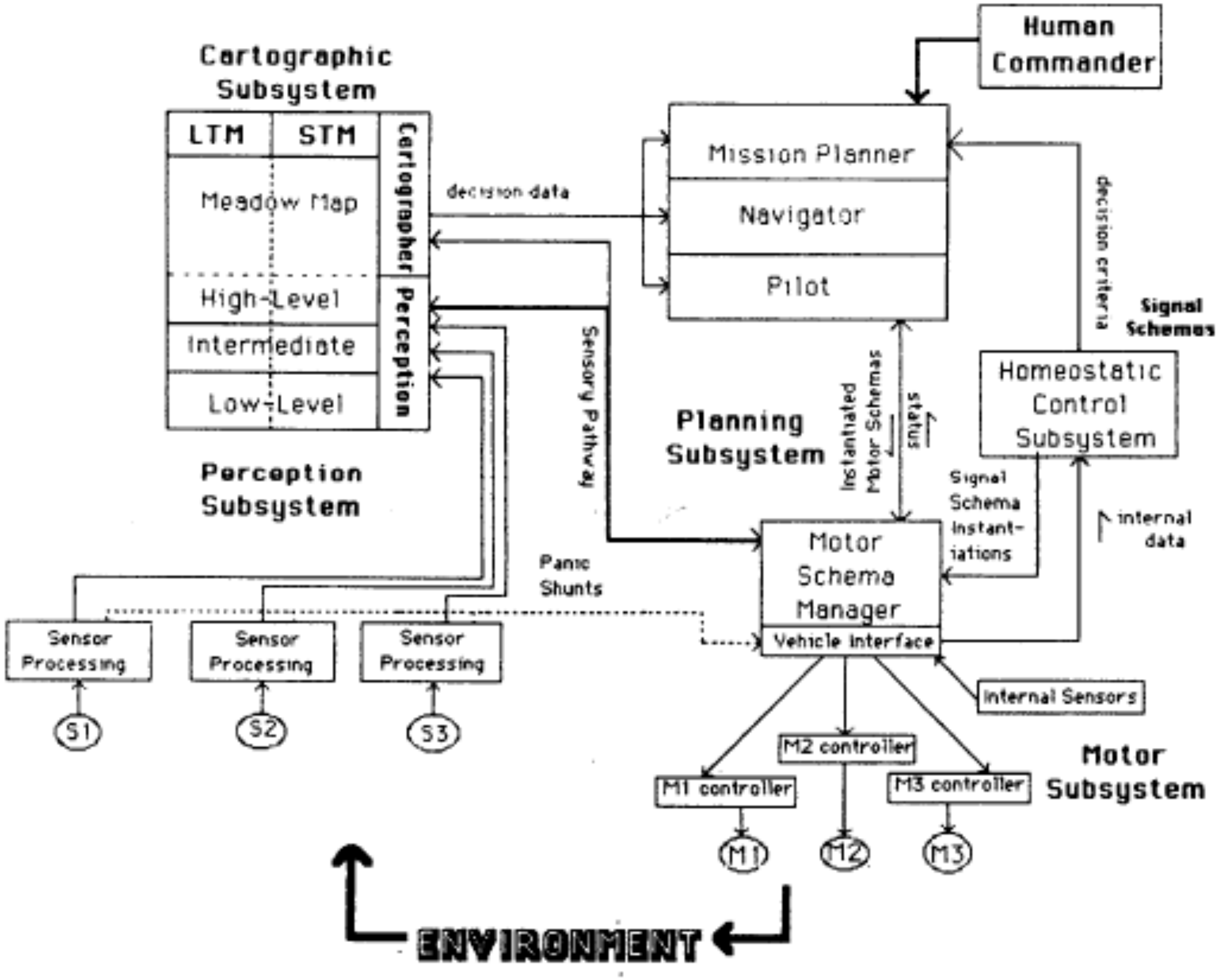
- Explore the environment
- Use a certain strategy
(e.g. follow the wall to the right)
- Do not bump into things or people



Deliberation in, e.g. a navigation system

A robotic system might have several goals to pursue, e.g.

- Explore the environment
- Use a certain strategy
  (e.g. follow the wall to the right)
- Do not bump into things or people
- Go "home" for recharging in time

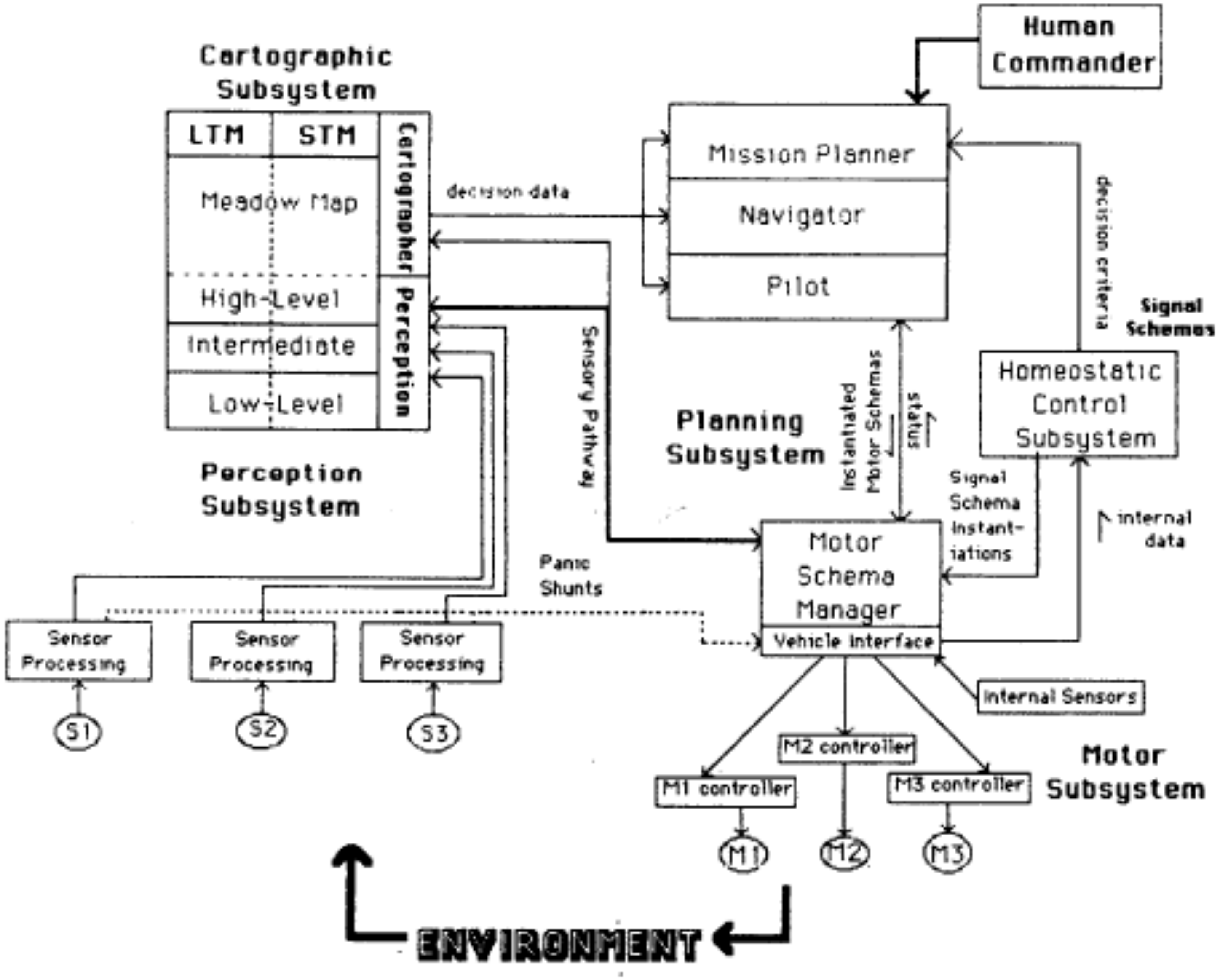


Deliberation in, e.g. a navigation system

A robotic system might have several goals to pursue, e.g.

- Explore the environment
- Use a certain strategy
  (e.g. follow the wall to the right)
- Do not bump into things or people
- Go “home” for recharging in time

Behaviours (e.g., as used by Arkin) can take care of each of the goals separately



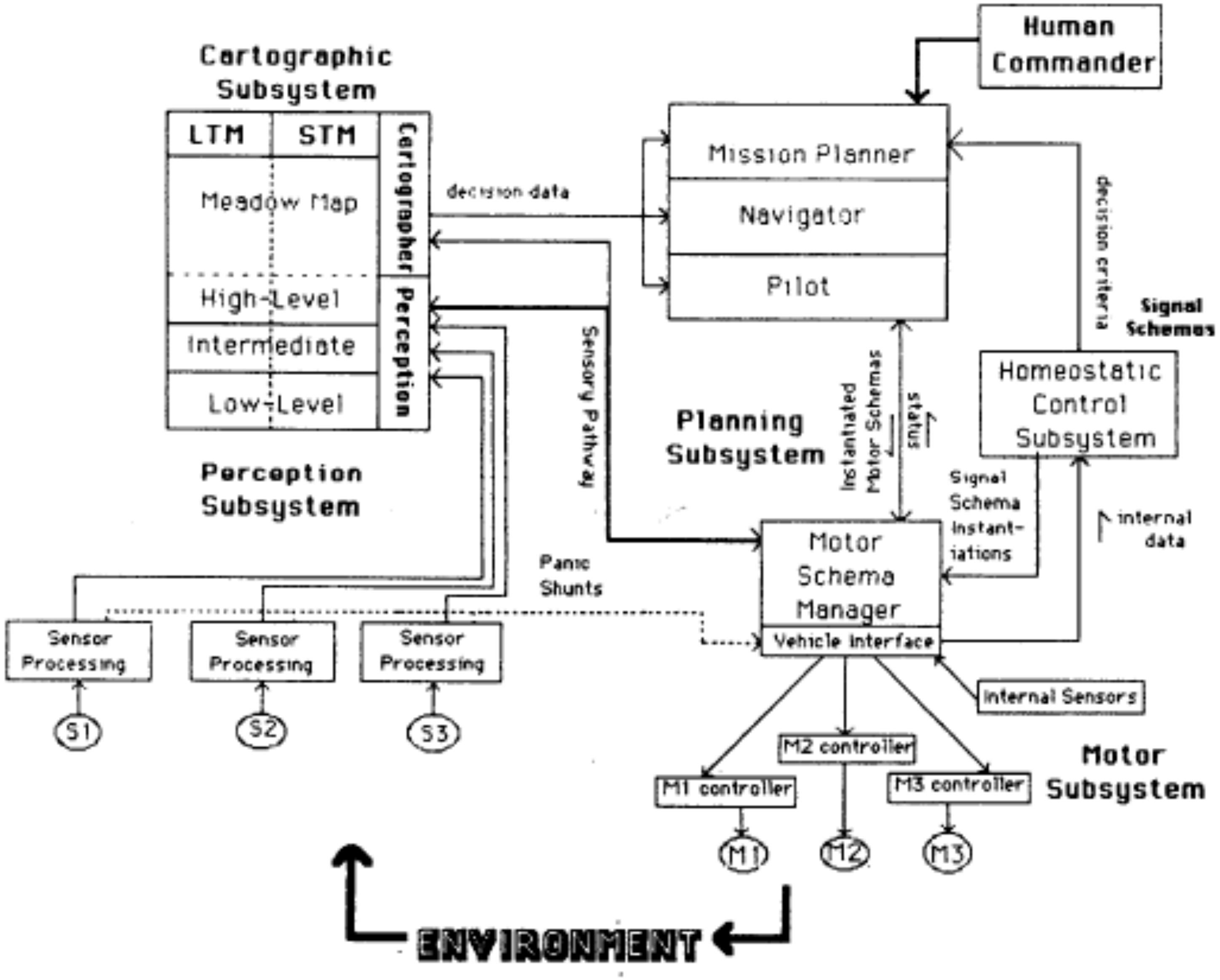
Deliberation in, e.g. a navigation system

A robotic system might have several goals to pursue, e.g.

- Explore the environment
- Use a certain strategy
  (e.g. follow the wall to the right)
- Do not bump into things or people
- Go “home” for recharging in time

Behaviours (e.g., as used by Arkin) can take care of each of the goals separately

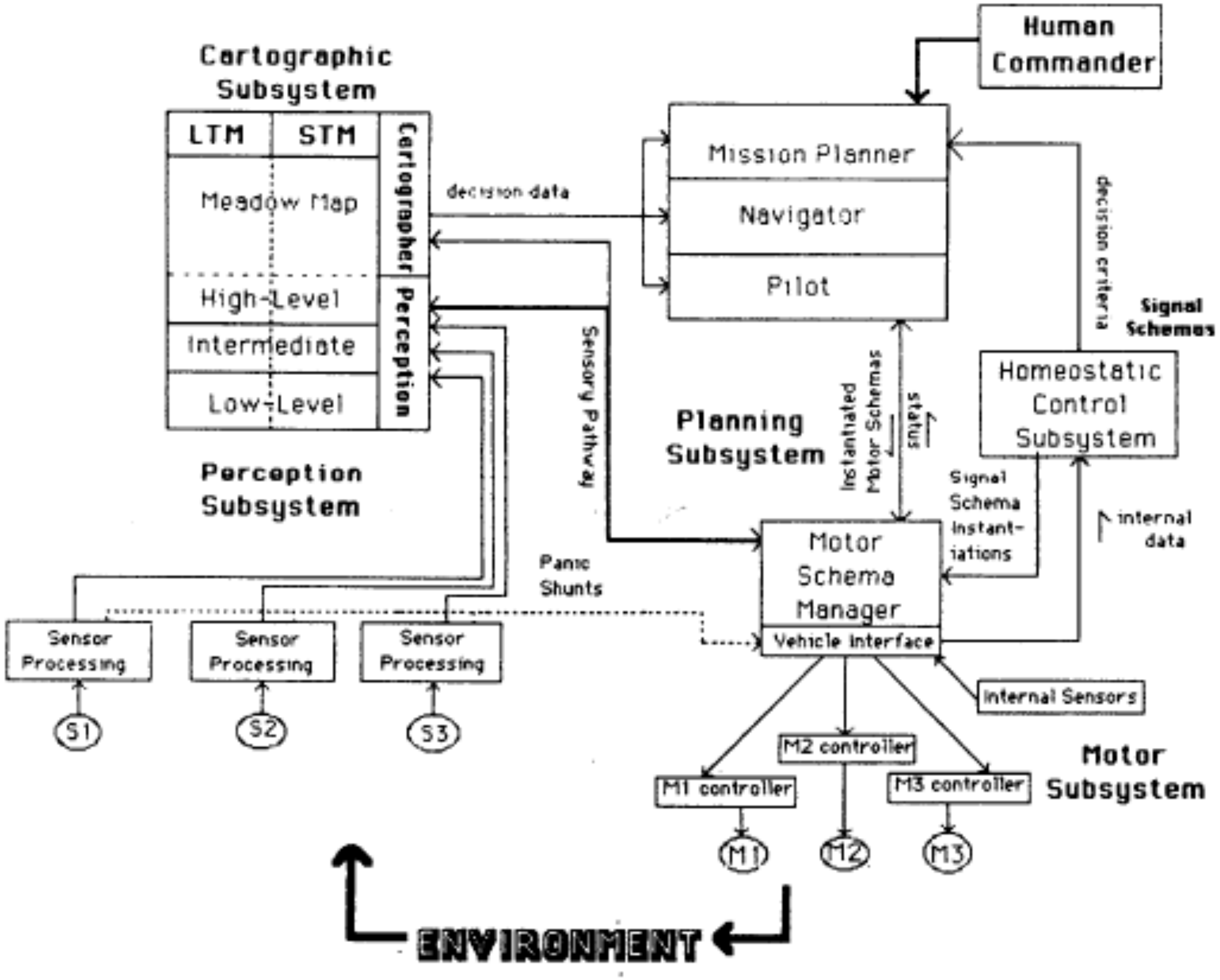
This decision making unit (deliberation process) can assign weights (priorities) to the behaviours depending on the sensor data.



Deliberation in, e.g. a navigation system

A robotic system might have several goals to pursue, e.g.

- Explore the environment
- Use a certain strategy
  (e.g. follow the wall to the right)
- Do not bump into things or people
- Go “home” for recharging in time



Behaviours (e.g., as used by Arkin) can take care of each of the goals separately

This decision making unit (deliberation process) can assign weights (priorities) to the behaviours depending on the sensor data.

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.

Robotics and Semantic Systems @CS

- Lab visit to the Robotlab in M-huset
- Master's projects (Ex-jobb)
  - Internal (research oriented) or external (industry related)
- Contact us: Jacek, Pierre, Elin or other members of the group: Volker Krueger, Mathias Haage, Matthias Mayr, Alexander Duerr, Hampus Åström
- Robotics related courses:
  - EDAN70, Project in Computer Science, VT2
  - EDAN95, Applied Machine Learning, HT2
  - MMKF15, Applied Robotics (Automatic Control / Design)
  - MMKN30, Service Robotics (through IKDC)