EUCognition Meeting 8-9.12.2016, Vienna
"Cognitive Robot Architectures"

Markus Vincze (local chair)

Vincent C. Müller (general chair)

Ron Chrisley (academic chair)

Yulia Sandamirskaya (academic chair)

What Do Industrial Developers and End-Users Expect from a Cognitive Robot?

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EUCog – European Association for Cognitive Systems
8-9 December 2016

What developers and their customers want

Questionnaire of AICoR Topic Group, euRobotics

Interviews with selected key persons in industry
- Tim Guhl, KUKA Systems GmbH (*) 2/8/2016
- Patrick Courtney, Tec-Communication (*) 2/8/2016
- Rich Walker, Shadow Robot Company (*) 23/8/2016
- Maja Rudinac, Robot Care Systems (*) 30/8/2016
- Slawomir Sander, KUKA Systems GmbH (**) 30/8/2016
- David Ball, Bosch () 30/8/2016
- Andrew Graham, OC Robotics () 7/9/2016
- Mauricio Calva, Chevron (*) 12/9/2016
- Amit Kumar Pandey, Softbank Robotics (*) 12/9/2016
- Ugo Cupcic, Shodaw Robot (*) 12/9/2016
- Daniel Wäppling, ABB (*) 19/9/2016
- Ekkehard Zwicker, GE Inspection Robotics (*) 19/9/2016
- Thilo Steckel, CLAAS E-Systems KGaA mbH & Co KG (*) 28/9/2016

What developers and their customers want

- Cognitive Abilities Cx

- Autonomy Ax

- Goals Gx

- Instruction Ix

Cognitive Abilities

C1 Safety and reliability

Robots help people and prioritize their safety

Only reliable behavior will build trust in cognitive robots

Should be able to explain their actions

Cognitive Abilities

C2 Implicit, task-oriented programming

Use high-level instructions that will exploit the robot's contextual knowledge of the task

Cognitive Abilities

C3 Task knowledge

C3.1 Contextual task knowledge

- Pre-select information that is important to effectively carry out the task.
- E.g., vase: leave or empty table

Cognitive Abilities

C3 Task knowledge

C3.2 Continuous knowledge acquisition

- Build and exploit experience
- Robot decisions incorporate present and long term data
- E.g., route planning in factory/hospital: use previous paths, take another look to overcome uncertainty
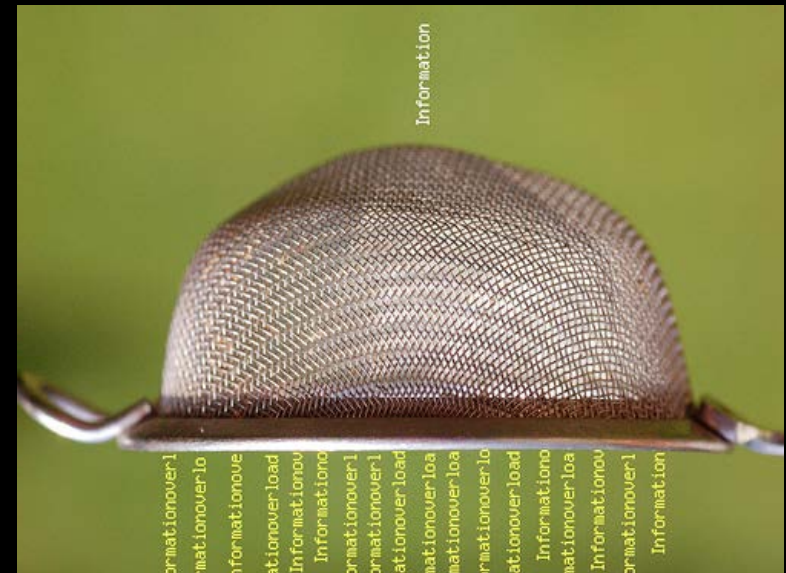
Cognitive Abilities

C3 Task knowledge

C3.3 Knowledge generalization

- Generalise knowledge to new task extrapolating from previous experience
- E.g., reuse knowledge of rehabilitation exercise to another person; welding a new instance of a family of parts

Cognitive Abilities

C4 Cope with unforeseen situations, error handling

- Recognise errors

- Recover from errors

- Anticipate and compensate
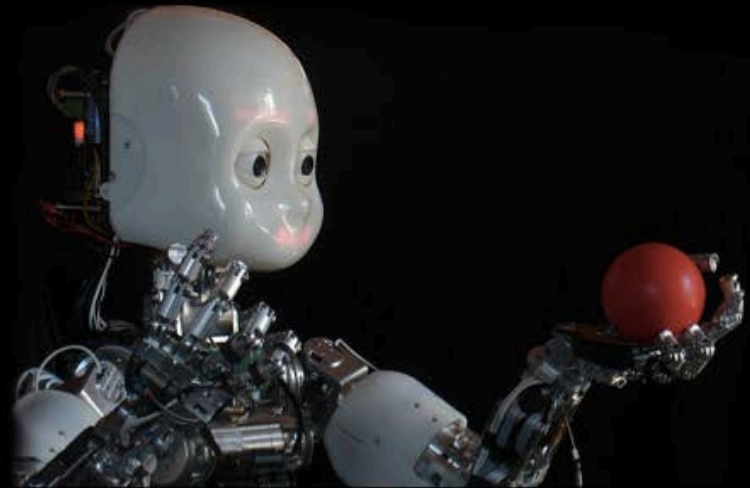
Cognitive Abilities

C5 Individualized operation

Adapt behavior and interaction policy to the user's preferences, needs, and emotional state

Cognitive Abilities
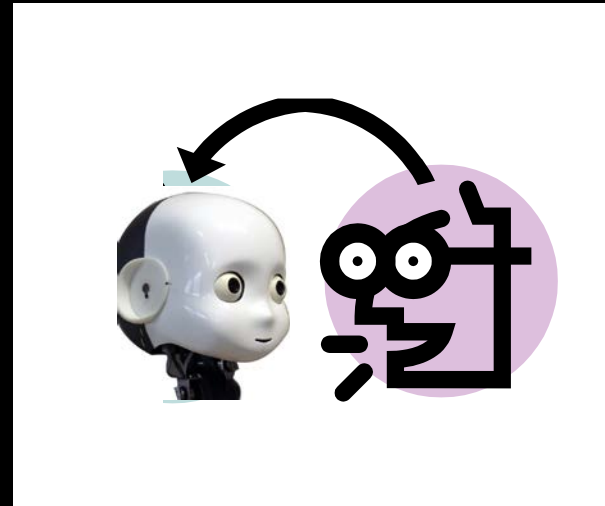
C6 Reason about own capabilities

Given a task,
robot is able to say
whether it can do it or not

Cognitive Abilities

C7 Task learning

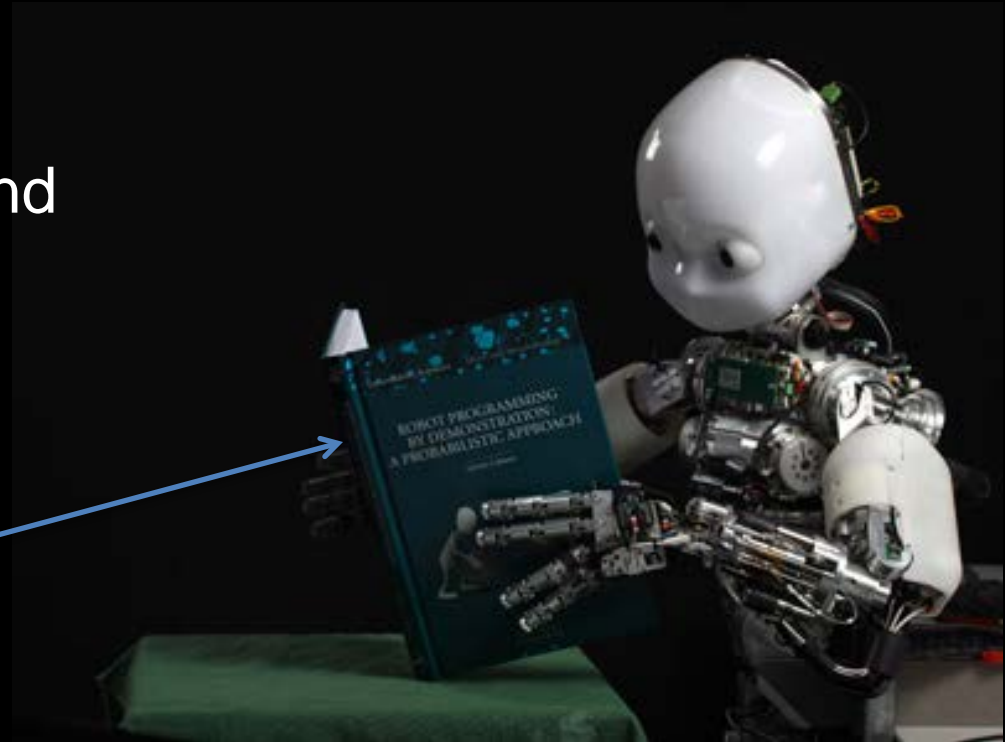From high level input,
e.g., speech, gestures

Cognitive Abilities

C8 Action learning, e.g., from demonstration

The entities involved and their usage

Robot Programming By Demonstration: A Probabilistic Approach

Sylvain Calinon
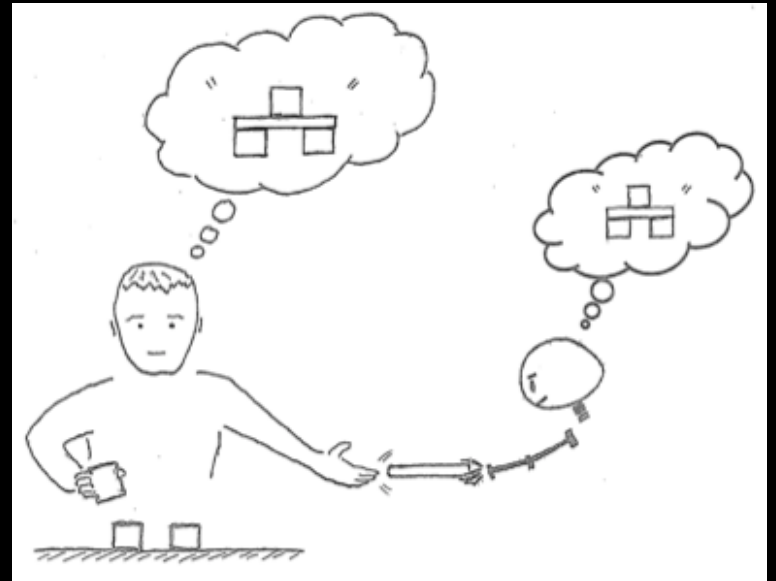
Cognitive Abilities

C9 Self-optimization

Continuous improvement
based on its own actions
and those of others
(people or other robots)

Cognitive Abilities
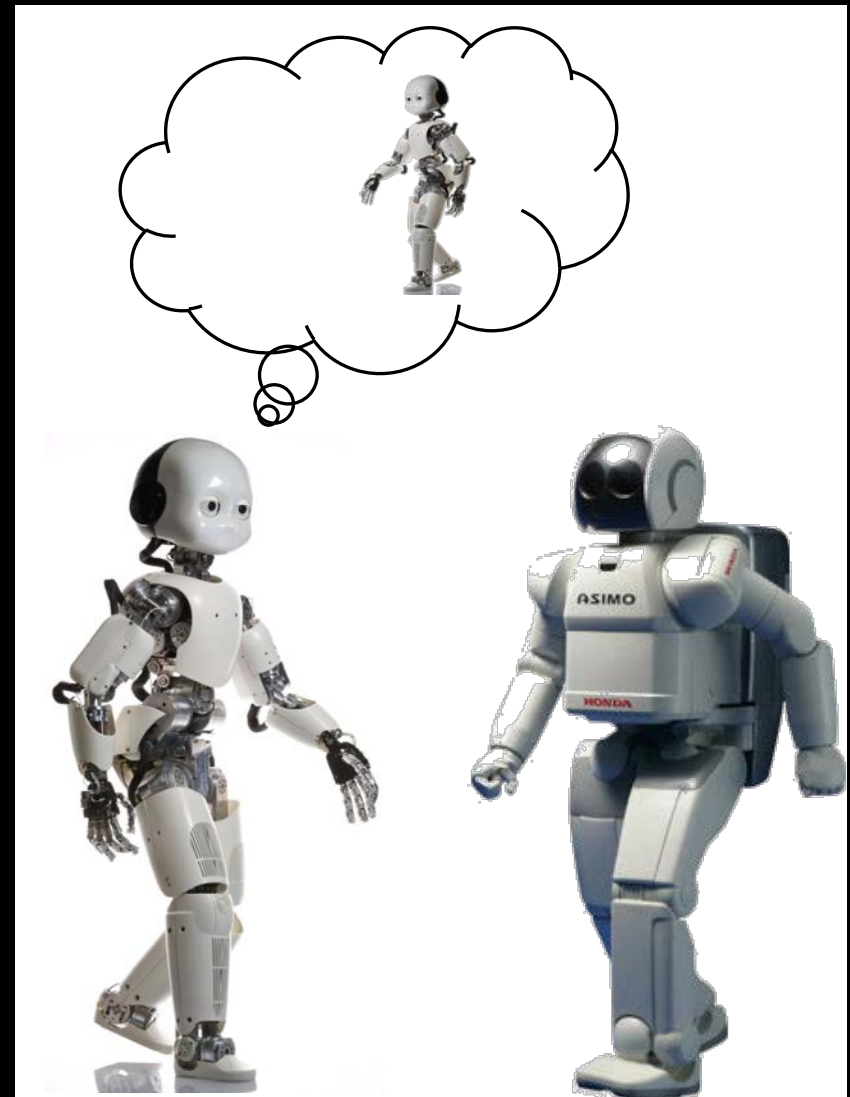
C10 Communicate robot intentions

To people around it so that they can anticipate the robot's actions and intentions

Cognitive Abilities

C11 Knowledge transfer

From one robot to another robot with a different physical, kinematic, and dynamic configurations

Autonomy

A1 Goal set by user

The robot should not have freedom to set its goal.

Autonomy

A2 Setting intermediate goals

Those that support the overall goal set by a user may be allowable within limits

Autonomy

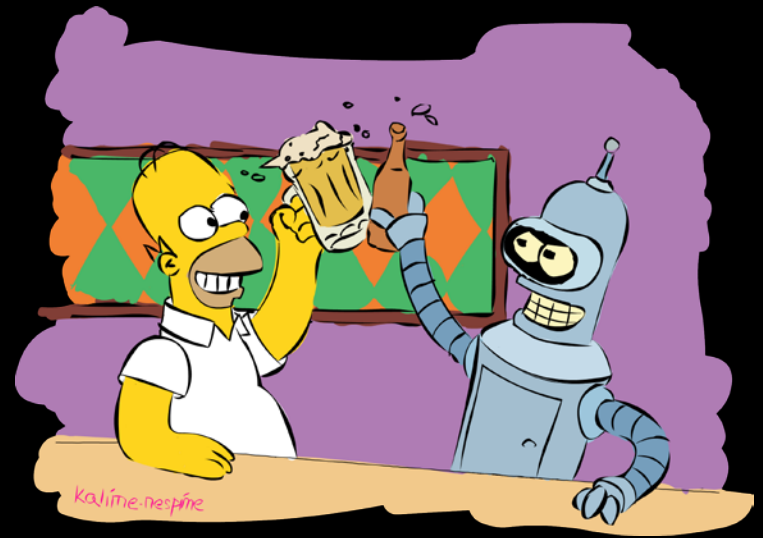## A3 Formal limits of autonomy

To assure any new action, task must be carried out in a safe manner

Autonomy

A4 Knowledge and reasoning about the limits

The robot needs to know what is normal, i.e. expected, behaviour (perhaps based on documented rules or practices)
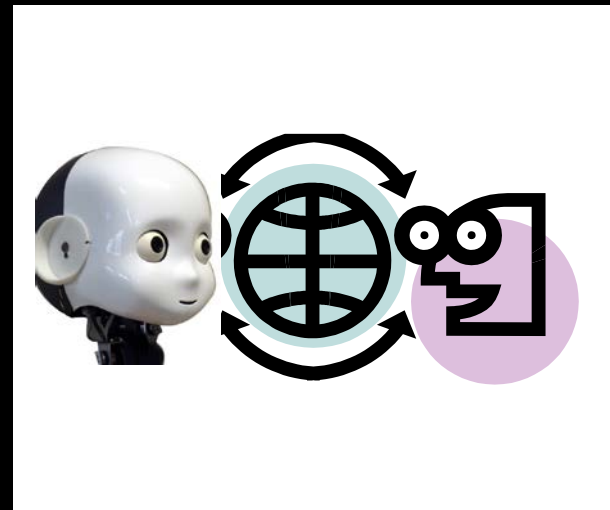
Goals

G1 High-level goal specification

That reflects the user's perspective

Specified in a formalised and structured way

Designer defines goals and can verify them

Goals

G2 Knowledge about the robot purpose

Used as contextual knowledge to enable the goal specification

Pre-load knowledge about the robot's purpose

Assist user by proposing goals from what it understood → user makes the final selection

Instruction

I1 Teaching by demonstration of robot actions

Instructions should be communicated by demonstration

Or high level commands

Instruction

I2 Teaching the application context

To simplify goal specification

Step by step teaching:
robot knows more and more

IF A PICTURE IS WORTH A THOUSAND WORDS, THEN CONTEXT IS WORTH A MILLION.

What developers and their customers want

- Cognitive Abilities
  - Safety, error detection & handling, individualise
  - Task & action learning, knowledge, optimise
  - Reasoning/communicate about own capabilities

- Autonomy
  - User sets goal, robot intermediate steps
  - Reasoning about limits, new but safe actions

- Goals
  - Specified at high level, robot knows about purpose

- Instructions
  - Teaching by demonstration, learn application context

"Exponential Technologies"

Industry 4.0 requires automation solutions to be **highly cognitive and highly autonomous**

It requires **enhanced collaboration between humans and machines**,

including **next generation robots that work hand-in-hand and safely with humans** [Deloitte 2014]

> consulting

What developers and their customers **REALLY** want

"Training a robot like an intern or an apprentice"

- Trainer: "Has someone shown you how to do this?

- "No? Okay, I'll show you how to do three, then you do 100 to practice (and to throw away afterwards)."

- "If you get stuck on one, call me, and I'll show you how to solve that problem."
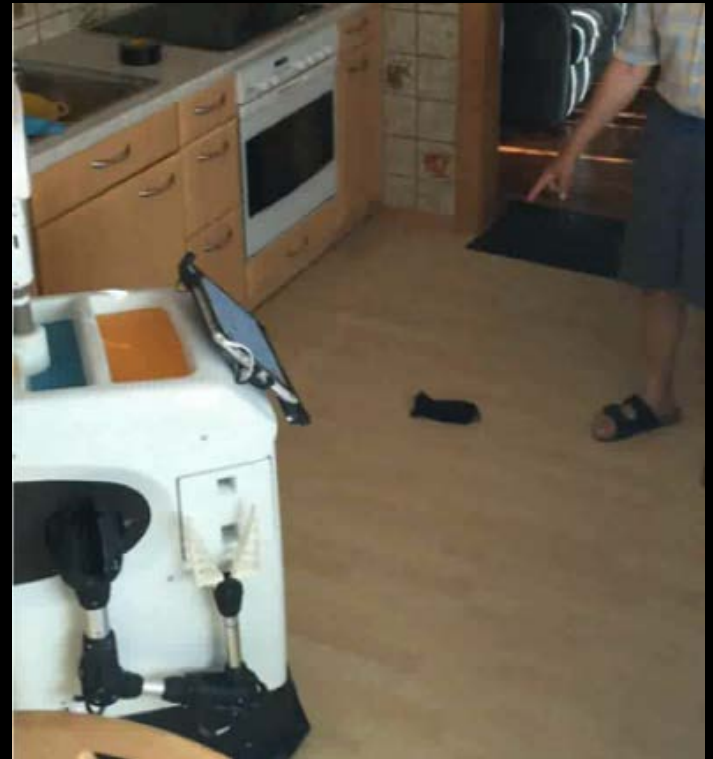
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Industry 4.0
Fourth Industrial Revolution

Enabled by networking among
an internet of things, services, data, and people

Cyber-Physical Systems CPS

Online networks of social machines

Industry 4.0 - Challenges and solutions for the digital transformation and use of exponential technologies, Deloitte, 2014.