Introduction to Cognitive Robotics

Module 1: Overview of Cognitive Robotics

Lecture 3: Industrial requirements; resources

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www.vernon.eu

Industrial requirements for cognitive robots

- Based on survey of 13 industrial developers to determine what they and their customers want (Vernon and Vincze 2016)

- Cast as a series of 11 functional abilities

#1
Safe, reliable, and transparent operation

Industrial requirements for cognitive robots

Safe, reliable, and transparent operation

- A cognitive robot should operate reliably and safely around humans
- It should explain the decisions is makes, the actions it has taken, and the actions it is about to take
- It should have limited autonomy to set intermediate goals to when carrying out tasks set by users
- It should defer to the user's preferences apart from some exceptional circumstances, e.g. people with dementia can interact in unpredictable ways and the robot will be able to recognize these situations and adapt in some appropriate manner

Industrial requirements for cognitive robots

Safe, reliable, and transparent operation

- A cognitive robot's should ask for assistance when necessary
- In emergency situations, it should stop all tasks to follow some emergency procedure
- If the user is deliberately trying to misuse the robot, e.g. programming it to assist with some unethical task, a cognitive robot should cease operation

#2
High-level instruction and context-aware task execution

Industrial requirements for cognitive robots

High-level instruction and context-aware task execution

- Goals and tasks for a cognitive robot can be expressed using high-level instructions using natural language and gestures

- A cognitive robot should factor in contextual constraints that are specific to the application scenario when carrying out these tasks

  - Instructions can be grounded in the codified organizational rules, regulations, and behavioral guidelines that apply to a given application environment.

  - This grounding provide constraints which should make it easier for the robot to understand and perform the task effectively

Industrial requirements for cognitive robots

High-level instruction and context-aware task execution

- A goal can be given in non-specific terms; the robot should identify the sub-goals that are needed to achieve the goal
- A cognitive robot should learn ways of measuring the success of outcomes for the goals that have been set
- It should be possible to pre-load knowledge about the robot's purpose and its operating environment, including any rules or constraints that apply to behavior in that environment

Industrial requirements for cognitive robots

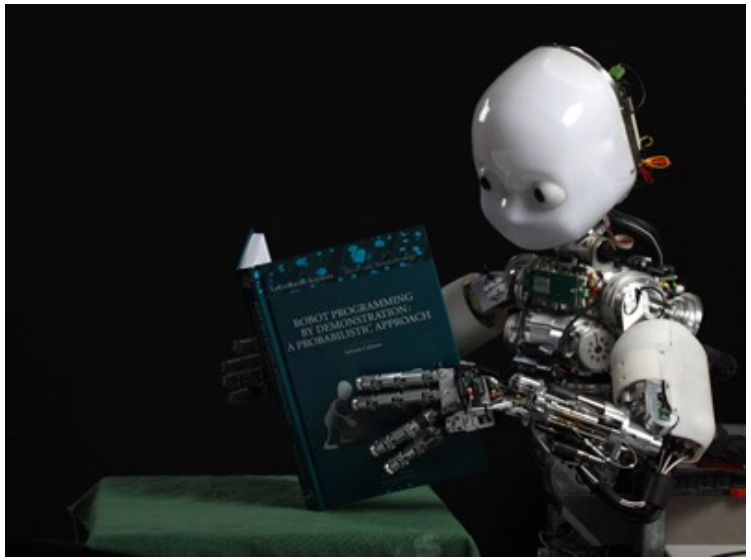
High-level instruction and context-aware task execution

- It should be possible to utilize domain-specific skill pools (e.g. from shared databases) so that the robot is pre-configured to accomplish basic tasks without having to resort to learning or development

- The level of detail in the goal description can decrease over time as the robot gains experience,

- It should be possible to instruct the robot off-line if there is no access to the physical site; e.g., using a simulation tool

#3
Knowledge Acquisition and Generalization



Industrial requirements for cognitive robots

Knowledge Acquisition and Generalization

- A cognitive robot should continuously acquire new knowledge and generalize that knowledge so that it can undertake new tasks by generating novel action policies based on its history of decisions
  - This will allow the rigor and level of detail with which a human expresses the task specification to be relaxed on future occasions
- In general, a cognitive robot should extract useful meaning from an interaction for a future and more general use, with the same or another user
  - This may extend to learn cultural preferences and social norms.

#4
Adaptive Planning

Industrial requirements for cognitive robots

Adaptive Planning

- A cognitive robot should be able to anticipate events, prepare for them in advance, and compensate for future conditions
  - For example, an automated combine harvester should be able to apply a pre-emptive increase of power to compensate for the demands caused when an area of high yield is encountered
- It will be able to cope with unforeseen situations, recognizing and handling errors, gracefully and effectively
  - This may include retrying with a slightly different strategy
  - The learning process will be fast, ideally learning from each error

Industrial requirements for cognitive robots

Adaptive Planning

- A cognitive robot should be able to learn about the environment, adapt to changes in the environment, verifying that the environment matches with what is known, or there is a change and updates
  - This may require an update of the task but only after asking the user
- A cognitive robot should be able to manipulate flexible or live objects, e.g. living creatures such as laboratory mice
  - To do so means that the robot must be able to construct a model of their behaviour and adapt its actions as required, continually refining the model

#5
Personalized Interaction

Industrial requirements for cognitive robots

Personalized Interaction

- A cognitive robot will personalize their interactions with humans, adapting its behaviour and interaction policy to the user's preferences, needs, and emotional or psychological state

- It should learn the personal preferences of the person with whom it is interacting
  - For example, an autonomous car will learn the preferred driving style of the owner and adopt that style to engender trust

- A cognitive robot should understand nuances in tone to learn a person's voice, detecting signs of stress so that it can react to it and review what it is doing

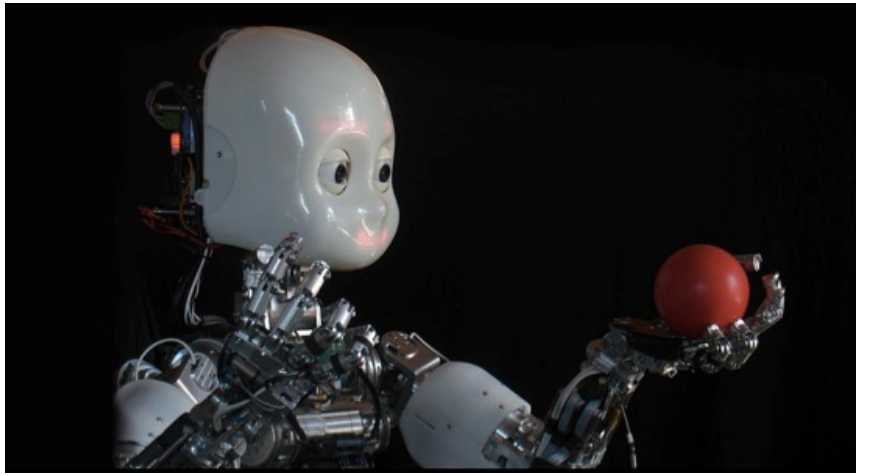
Industrial requirements for cognitive robots

Personalized Interaction

- In cases where showing the robot what to do involves physical contact between the user and the robot, the robot should be able to learn the dynamics of the user, i.e. his or her personal preferred use of forces when interacting with objects in the environment

- It should be able to monitor the psychological state of a user, e.g. based on the facial expressions, gestures, actions, movements. Based on this, it should be able to determine what they need by cross-referencing that with knowledge of the person's history

#6
Self-Assessment



Industrial requirements for cognitive robots

Self-Assessment

- Cognitive robots should be able to reason about their own capabilities, being able to determine whether they can accomplish a given task
- If it detects something is not working, it will be able to ask for help
- It should will be able to assess the quality of its decisions
- If a cognitive robot is asked to perform a certain task, it should be able to say whether it can do it or not
- It will detect when something is not working and will be able to ask for help.

#7
Learning from Demonstration

https://sketchucation.com/forums/viewtopic.php?f=15&t=58587

https://www.istockphoto.com/de/fotos/man-vacuuming?sort=mostpopular&mediatype=photography&phrase=man%20vacuuming

Industrial requirements for cognitive robots

Learning from Demonstration

- A cognitive robot should be able to learn new actions from demonstration by humans
- Instructions can be communicated through examples, including showing the robot the final results
  - The robot should be able to merge prior know-how and knowledge with learning by demonstration
  - Some of this prior knowledge should be extracted from codified organisational rules, regulations, and behavioural guidelines

Industrial requirements for cognitive robots

Learning from Demonstration

- A cognitive robot should learn and adapt the parameters to achieve the task
- Teaching will exploit natural language, gaze and pointing gestures, and by showing the robot what to do and helping it when necessary
- When being taught, the robot should be anticipating what you are trying to teach it so that it predicts what you want it to do and then tries to do it effectively
- It should be possible to provide direct support for the robot, switching fluidly between full autonomy, partial autonomy, or manual control

#8
Evaluating the Safety of Actions

LEA
http://www.robotikworld.com/lea/

Industrial requirements for cognitive robots

Evaluating the Safety of Actions

- When it learns a new action, a cognitive robot should take steps to verify the safety of carrying out the action

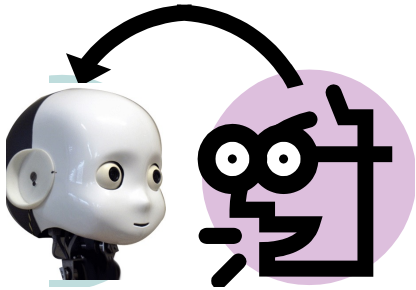
#9
Development and Self-Optimization

Industrial requirements for cognitive robots

Development and Self-Optimization

- A cognitive robots should develop and self-optimize
  - learning in an open-ended manner from its own actions and those of others (humans or other robots), continually improving its abilities
- It should be able to use what it has learned to determine possible ways to improve its performance, e.g. through internal simulation at times when the robot is not working on a given task
- It should also be able to learn from its mistakes

#10
Knowledge Transfer



Industrial requirements for cognitive robots

Knowledge Transfer

- A cognitive robot should be able to transfer knowledge to other robots, even those having a different physical, kinematic, and dynamic configurations
- It should be able to operate seamlessly in an environment that is configured as an internet of things
  - The robot can be used, for example, as a way of collecting data from large experiments

#11
Communicating Intentions and Collaborative Action

Industrial requirements for cognitive robots

Communicating Intentions and Collaborative Action

- A cognitive robot should be able to communicate their intentions to people around them
- Vice versa, it should be able to infer the intention of others, i.e. understanding what someone is doing and anticipating what they are about to do
- Ultimately, a cognitive robots should be able to collaborate with people on some joint task with a minimal amount of instruction

IEEE Robotics and Automation Society Technical Committee for Cognitive Robotics
www.ieee-coro.org

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Scope

There is growing need for robots that can interact safely with people in everyday situations. These robots have to be able to anticipate the effects of their own actions as well as the actions and needs of the people around them.

(Image courtesy of Fraunhofer IPA)

To achieve this, two streams of research need to merge, one concerned with physical systems specifically designed to interact with unconstrained environments and another focussing on control architectures that explicitly take into account the need to acquire and use experience.

The merging of these two areas has brought about the field of *Cognitive Robotics*. This is a multi-disciplinary science that draws on research in adaptive robotics as well as cognitive science and artificial intelligence, and often exploits models based on biological cognition.

Committee News

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Resources

Research
Research Challenges
Cognitive Architecture Surveys
Cognitive Architecture Design Principles
Robot Platforms
Research Networks
White Papers
Journals

Software Resources

Teaching Resources
Videos
Tutorials
Model Curricula
Courses

Degrees in Cognitive Systems

Robots

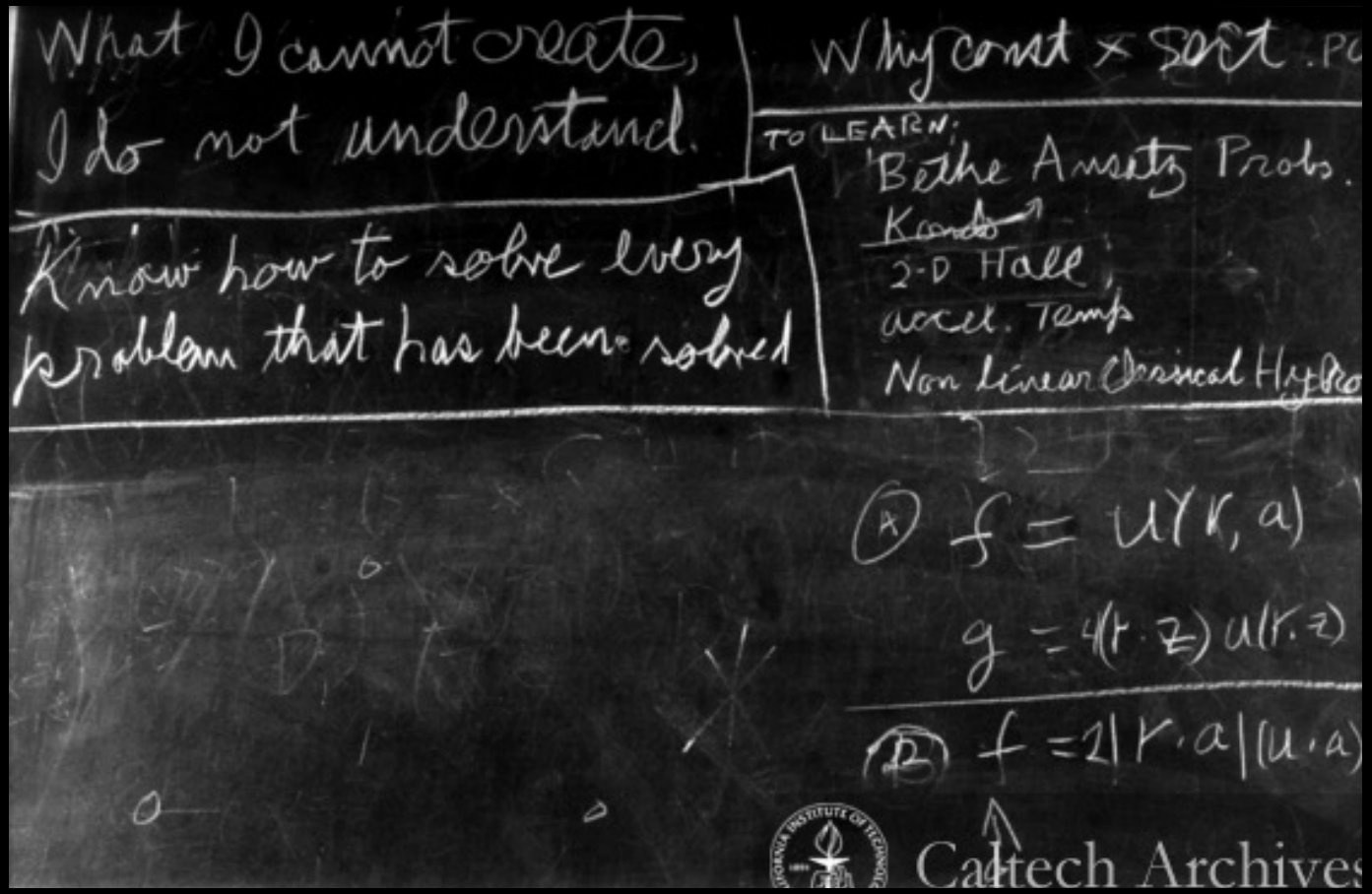
www.ieee-coro.org

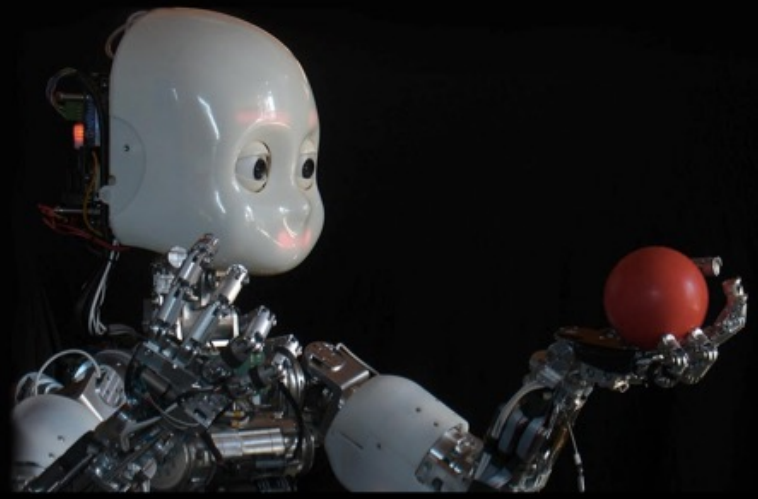
A Final Thought ...

There are two reasons people study cognitive robotics

1. They want to build smart robots
2. They want to understand cognition

Richard Feynman

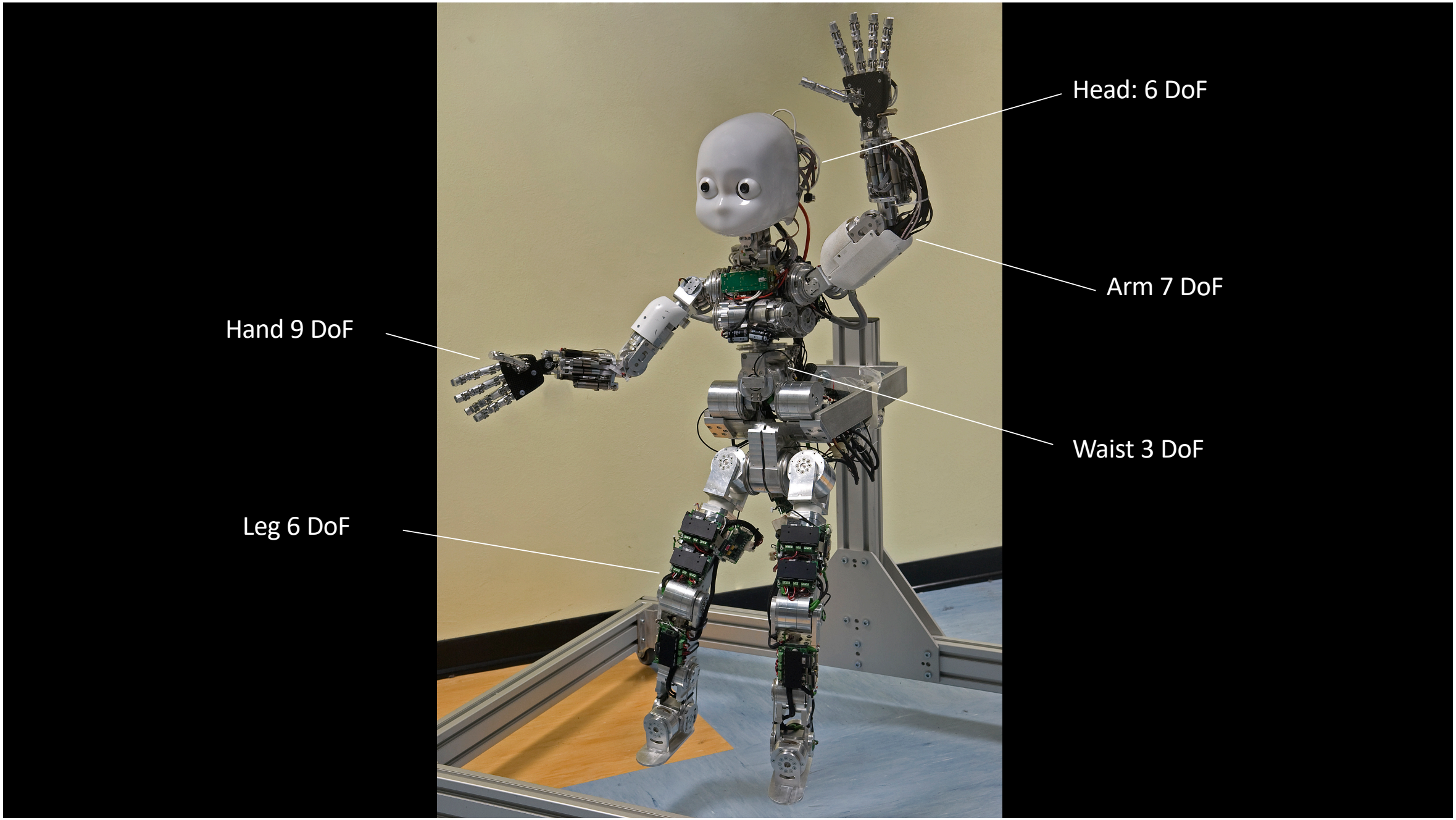




iCub.org

an open source cognitive humanoid robotic platform

Funded by The European Commission, Project IST-004370, RobotCub,
under Strategic Objective 2.3.2.4: Cognitive Systems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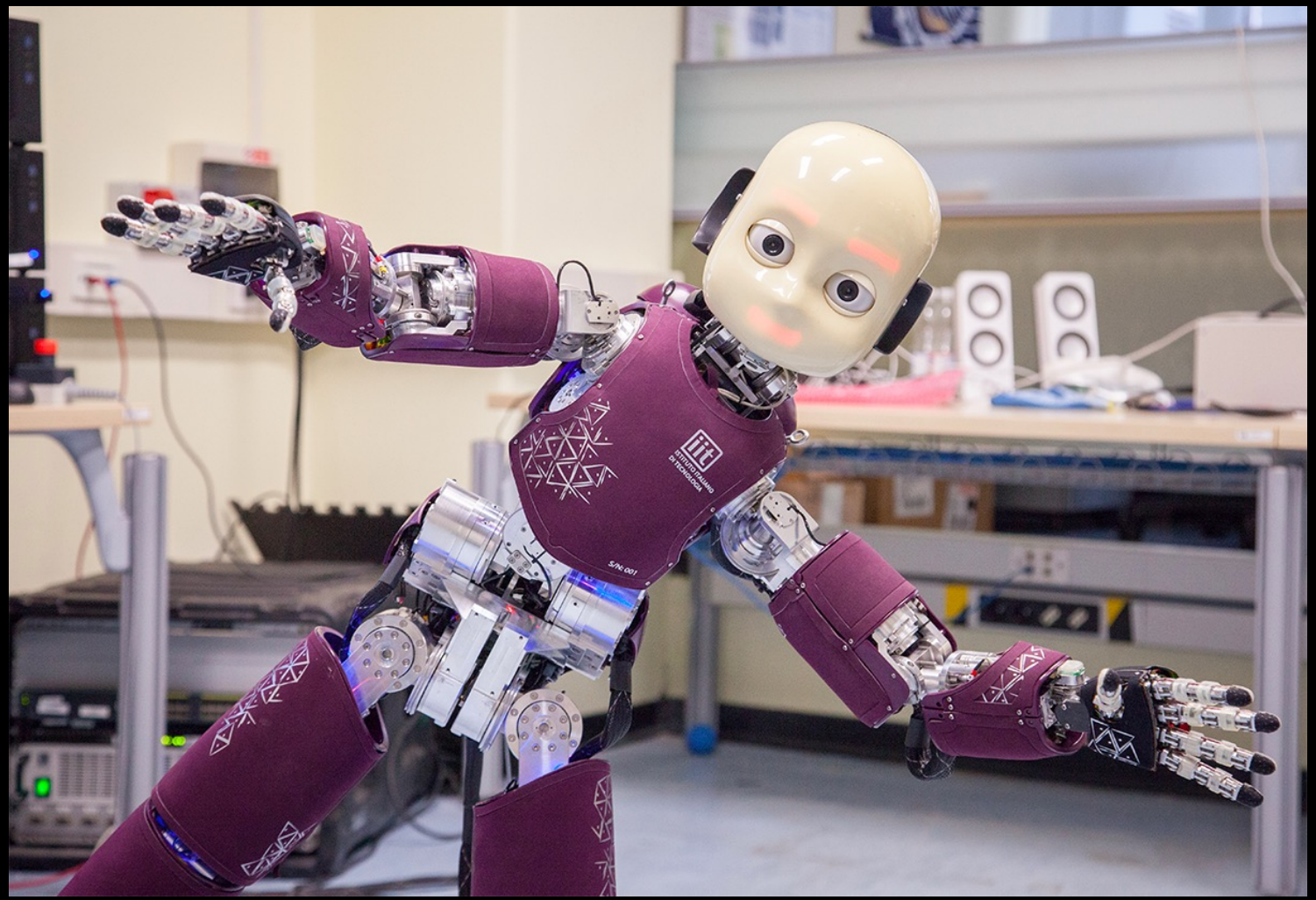
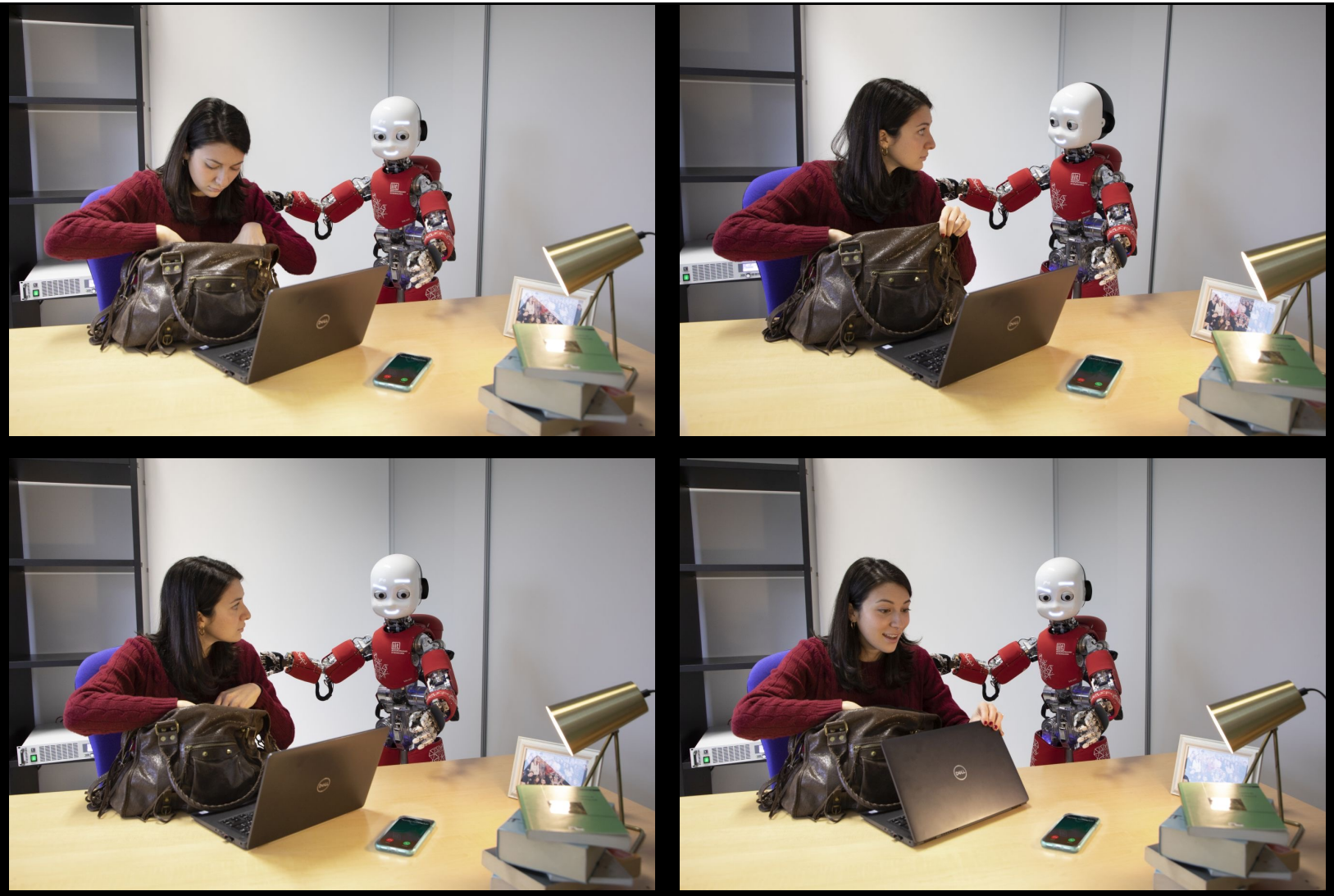
Arm 7 DoF
Hand 9 DoF
Waist 3 DoF
Leg 6 DoF



https://icub.iit.it/products/icub-robot



"This sequence of pictures depicts a situation in which the iCub humanoid robot (www.icub.org) is interacting with a human, reading her intention to get her phone from her bag, and alerting her to the fact that it is on the desk, hidden from her by the laptop.
Note that this sequence has been staged to illustrate the desired capabilities of a cognitive robot and has not yet been implemented."

Sandini, G., A. Sciutti, and D. Vernon. Cognitive Robotics. In M. Ang, O. Khatib, and B. Siciliano (Eds.), Encyclopedia of Robotics. Springer, 2021.
Images courtesy of Istituto Italiano di Tecnologia

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Cognitive Robotics Resources

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Definitions of Cognition [edit]

42 definitions of cognition ... it has proved difficult to define cognition: read Aaron Sloman's argument that it isn't worth trying (go to the end of the article)
A definition of a cognitive system from the Springer Reference Guide to Computer Vision
What is Cognition? in Current Biology 29, R603-R622, 2019

Robots [edit]

IEEE Guide to the World of Robots

http://www.vernon.eu/wiki/Cognitive_Robotics_Resources

Recommended Reading

D. Vernon and M. Vincze. "Industrial Priorities for Cognitive Robotics", Proceedings of the European Society for Cognitive Systems Meeting, EUCognition 2016, Vienna, 8-9 December, R. Chrisley. V. C. Müller, Y. Sandamirskaya. M. Vincze (eds.), CEUR-WS Vol-1855, ISSN 1613-0073, pp. 42-43, 2017.