Workshop on Teaching & Training Students for Cognitive Robotics
IROS 2023
1st October

Experience in Teaching Cognitive Robotics

David Vernon

Carnegie Mellon University Africa
www.vernon.eu

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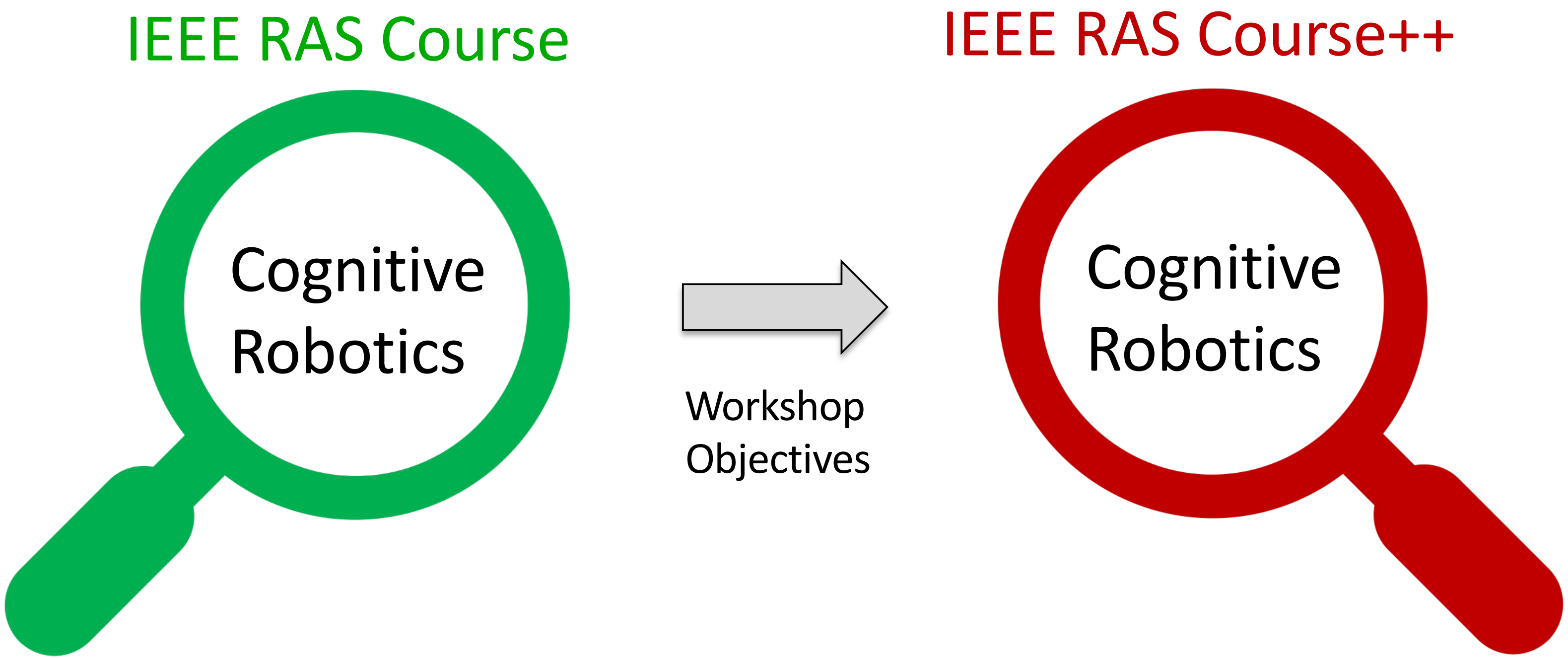
IEEE RAS Course
Cognitive Robotics
Workshop Objectives
IEEE RAS Course++
Cognitive Robotics

Cognitive Robotics

An introductory course for the IEEE Robotics and Automation Society Technical Committee for Cognitive Robotics

Instructors: send an email to request the complete set of PowerPoint slides. Example code is available on Github.
If you already have a copy, check the Version History to make sure you have the most recent version. If you don't, please send an email to request it.

A PR2 robot pours popcorn from a saucepan (left) and sets a table (right) during demonstrations of cognitively-enabled robot manipulation using CRAM.
Image courtesy of the Everyday Activity Science and Engineering (EASE) interdisciplinary research center at the University of Bremen, Germany.

Cognitive Robotics

"The word cognition derives from the Latin verb *cognosco*, a composition of *con* (meaning related to) and *gnosco* (to know). Cognitive robotics, then, is the branch of robotics where knowledge plays a central role in supporting action selection, execution, and understanding.

It focuses on designing and building robots that have the ability to learn from experience and from others, commit relevant knowledge and skills to memory, retrieve them as the context requires, and flexibly use this knowledge to select appropriate actions in the pursuit of their goals, while anticipating the outcome of those actions when doing so.

Cognitive robots can use their knowledge to reason about their actions and the actions of those with whom they are interacting, and thereby modify their behavior to improve their overall long-term effectiveness.

In short, cognitive robots are capable of flexible, context-sensitive action, knowing what they are doing and why they are doing it."

Sandini, G., Sciutti, A., and Vernon, D. (2021) "Cognitive Robotics", in Ang M., Khatib O., Siciliano B. (eds), *Encyclopedia of Robotics* . Springer, Berlin, Heidelberg.

www.CognitiveRobotics.net

Lecture Notes

Module 1: Overview of Cognitive Robotics

Lecture 1. Component disciplines; the nature of cognition; definition of cognitive robotics.
Lecture 2. Operation of a cognitive robot; reasons for studying cognitive robotics.
Lecture 3. Industrial requirements; resources.
Lecture 4. Installation of software development environments for exercises.

Module 2: The Robot Operating System (ROS)

Lecture 1. Introduction to ROS (Robot Operating System); the Turtlesim turtlebot simulator.
Lecture 2. Writing ROS software in C++: publishers.
Lecture 3. Writing ROS software in C++: subscribers,
Lecture 4. Writing ROS software in C++: services.

Module 3: Mobile Robots (optional)

Lecture 1. Types of mobile robots; the challenge of robot navigation; relative position estimation using inertial sensors.
Lecture 2. Relative position estimation using odometry; kinematics of a two-wheel differential drive robot.
Lecture 3. Absolute position estimation.
Lecture 4. Closed-loop control and PID control; the go-to-position problem; divide-and-conquer controller.
Lecture 5. The go-to-position and go-to-pose problems; MIMO controller.
Lecture 6. Finding a shortest path in a map; breadth-first search algorithm; other search approaches.

Module 4: Robot Manipulators

Lecture 1. Robot programming; coordinate frames of reference and homogenous transformations.
Lecture 2. Object pose specification with homogenous transformations and vectors & quaternions.
Lecture 3. Robot programming by frame-based task specification.
Lecture 4. Pick-and-place example of task-level robot programming.
Lecture 5. Implementation of the pick-and-place example for a Lynxmotion AL5D robot arm using the Frame class in C++.
Lecture 6. Kinematics; Denavit-Hartenberg representation; kinematics and inverse kinematics of the LynxMotion AL5D arm.

Module 5: Robot Vision (optional)

Lecture 1. Computer vision; optics and sensors; image acquisition; image representation; image processing.
Lecture 2. Introduction to OpenCV.
Lecture 3. Segmentation; region-based approaches; feature-based thresholding; graph cuts.
Lecture 4. Segmentation; boundary-based approaches; edge detection.
Lecture 5. Image analysis; feature extraction.
Lecture 6. K-nearest neighbour, minimum distance, linear, maximum likelihood and Bayes classifiers.
Lecture 7. Perspective transformation; camera model; camera calibration.
Lecture 8. Inverse perspective transformation; stereo vision; epipolar geometry.

Module 6: Artificial Cognitive Systems
Lecture 1. The paradigms of cognitive science: the cognitivist paradigm.
Lecture 2. The paradigms of cognitive science: the emergent and hybrid paradigms.
Lecture 3. Learning and development.
Lecture 4. Memory and prospection.
Lecture 5. Internal simulation; the symbol grounding problem.
Lecture 6. Interaction, social cognition; theory of mind; instrumental helping; collaboration.

Module 7: Cognitive Architectures
Lecture 1. Role and requirements; desirable characteristics; core cognitive abilities.
Lecture 2. Example cognitive architectures: Soar, ACT-R, CLARION, BBD.
Lecture 3. Example cognitive architectures: ISAC
Lecture 4. The CRAM cognitive architecture: design principles.
Lecture 5. The CRAM cognitive architecture: structure.
Lecture 6. The CRAM cognitive architecture: operation.

Module 8: An Introduction to Functional Programming with Lisp
Lecture 1. Common Lisp - REPL, lists, structures, equality, conditionals, CONS, CAR, CDR, dotted and assoc-lists.
Lecture 2. Common Lisp - functions, I/O, recursion, iteration, lambda and mapping functions, CLOS, inference.
Lecture 3. Emacs.

Module 9: The CRAM Plan Language
Lecture 1. Fluents, concurrency, reasoning, exception handling.
Lecture 2. Designators, process modules.

Module 10: Using Turtlesim with CRAM
Lecture 1. Pose specification in ROS; Transform Library (TF).
Lecture 2. Creating a CRAM package; controlling a turtle.
Lecture 3. Implementing plans to move a turtle.
Lecture 4. Using Prolog for reasoning.
Lecture 5. Creating motion designators for the TurtleSim.
Lecture 6. Creating process modules.
Lecture 7. Automatically choosing a process module for a motion.
Lecture 8. Using location designators with TurtleSim.
Lecture 9. Writing high-level plans for TurtleSim.
Lecture 10. Implementing failure handling for TurtleSim.

Module 11: Mobile Manipulation using the PR2 Robot with CRAM
Lecture 1. Fetch-and-place CRAM plan with the Bullet real-time physics simulator.
Lecture 2. Error handling and recovery looking in different places.
Lecture 3. Error handling and recovery using different arms.
Lecture 4. Defining a new grasp pose.

CRAM
Bullet Simulator
ROS Melodic
Ubuntu 18.04
Virtual Box Virtual Machine

(Thank you, University of Bremen)

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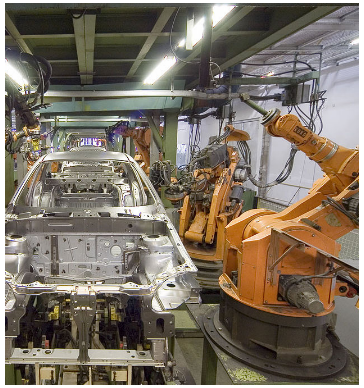
Motivation for Cognitive Robots

Controlled environment

We know what to expect,
and can program the robot
to do what we want

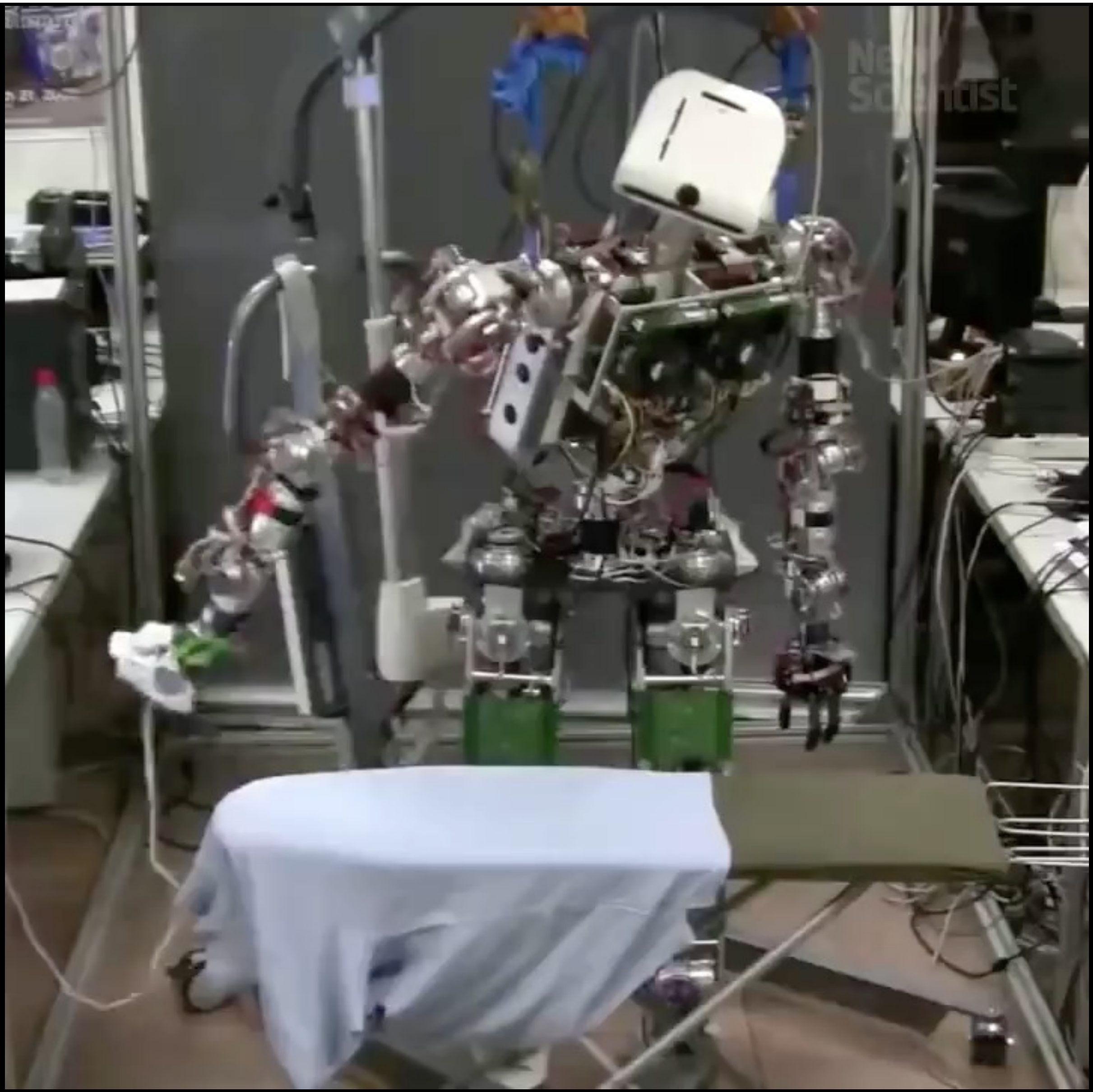


Complex environment

We don't know what to expect,
and the robot has to be flexible and adaptable

Uncertainty, incomplete knowledge, change

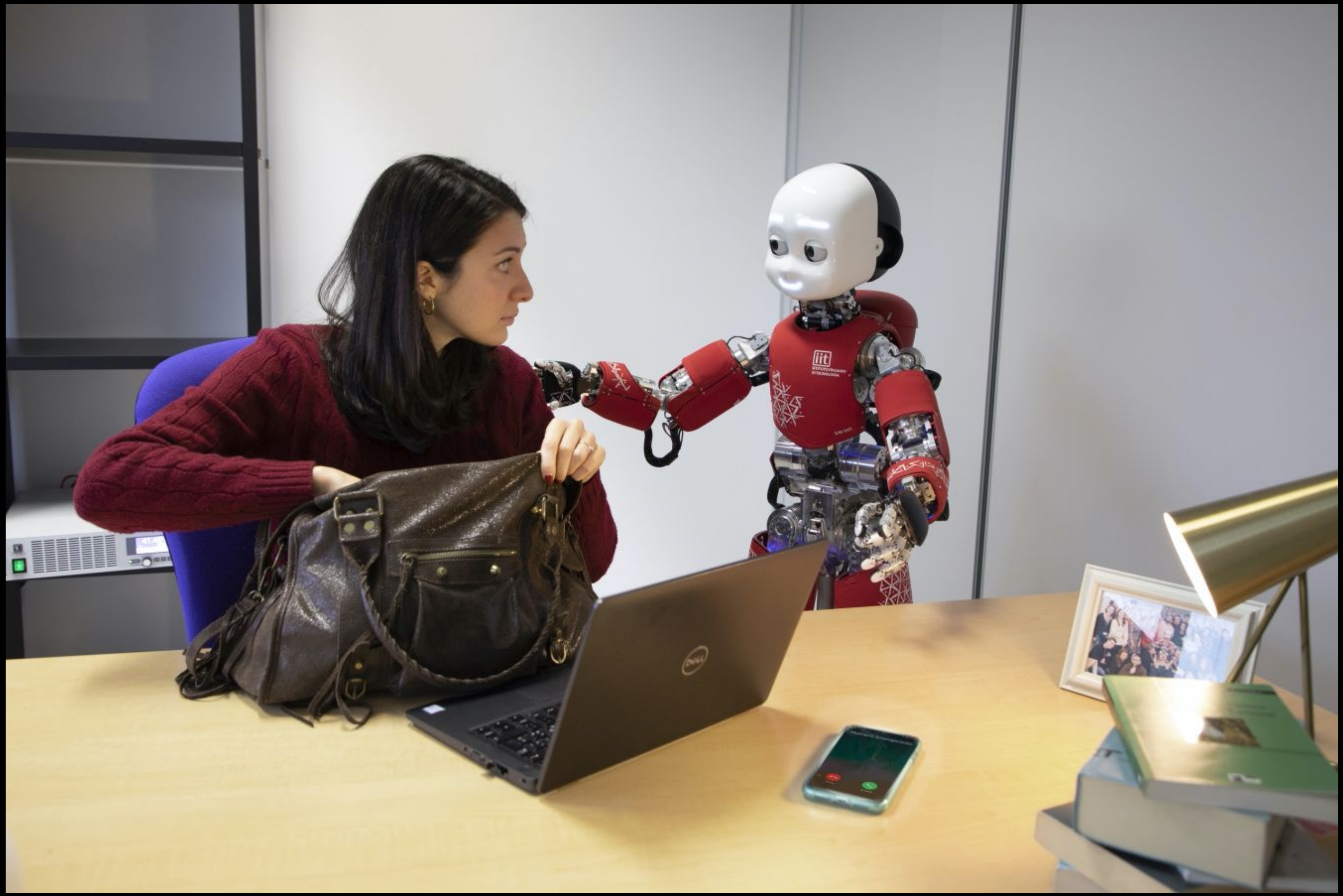
c.f. Maria Petrou's Ironing challenge
see http://www.commsp.ee.ic.ac.uk/~mcpetrou/iron.html



https://www.newscientist.com/article/2138264-this-handy-robot-will-iron-your-clothes-so-you-dont-have-to/

IEEE RAS Technical Committee for Cognitive Robotics
www.ieee-coro.org

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



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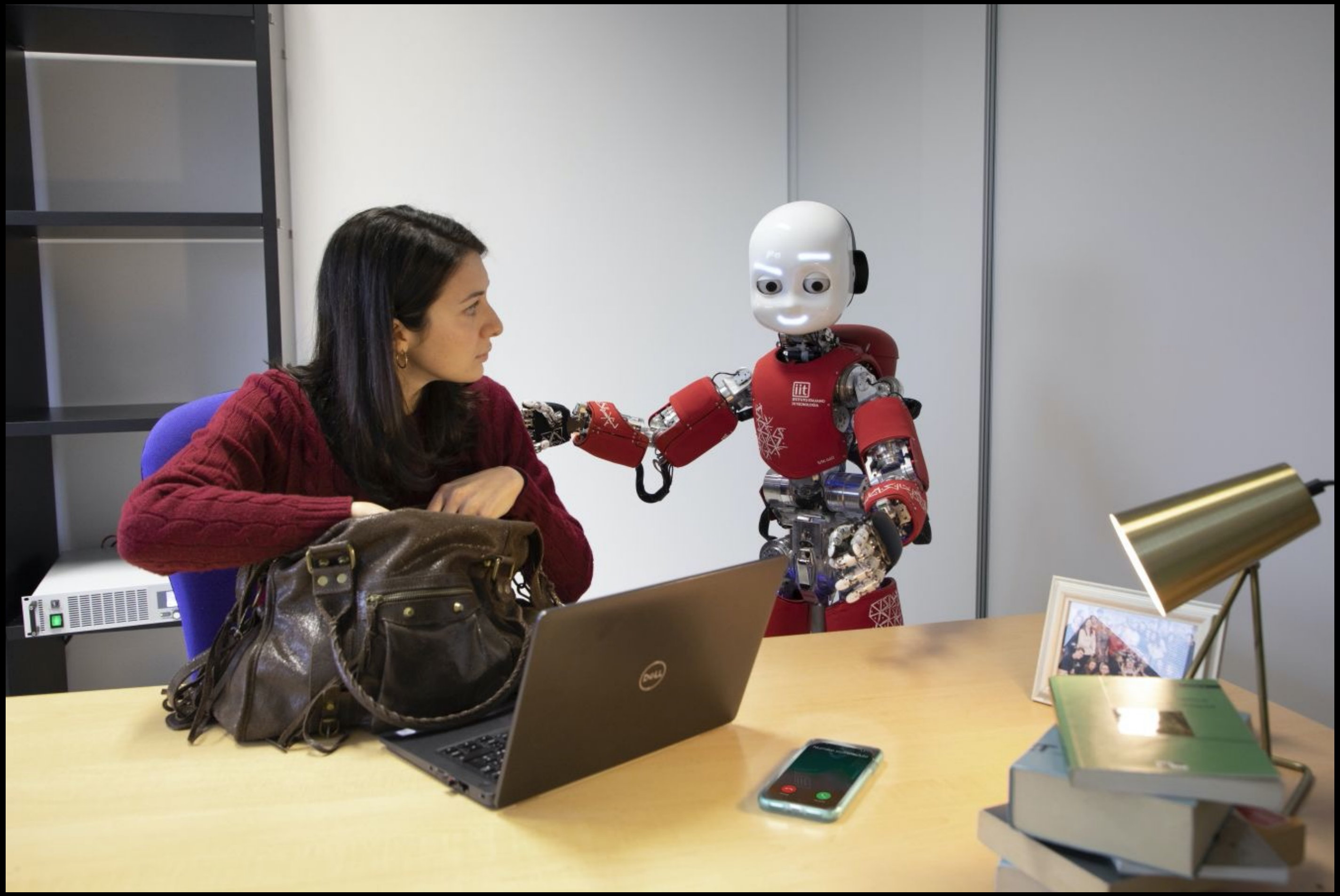

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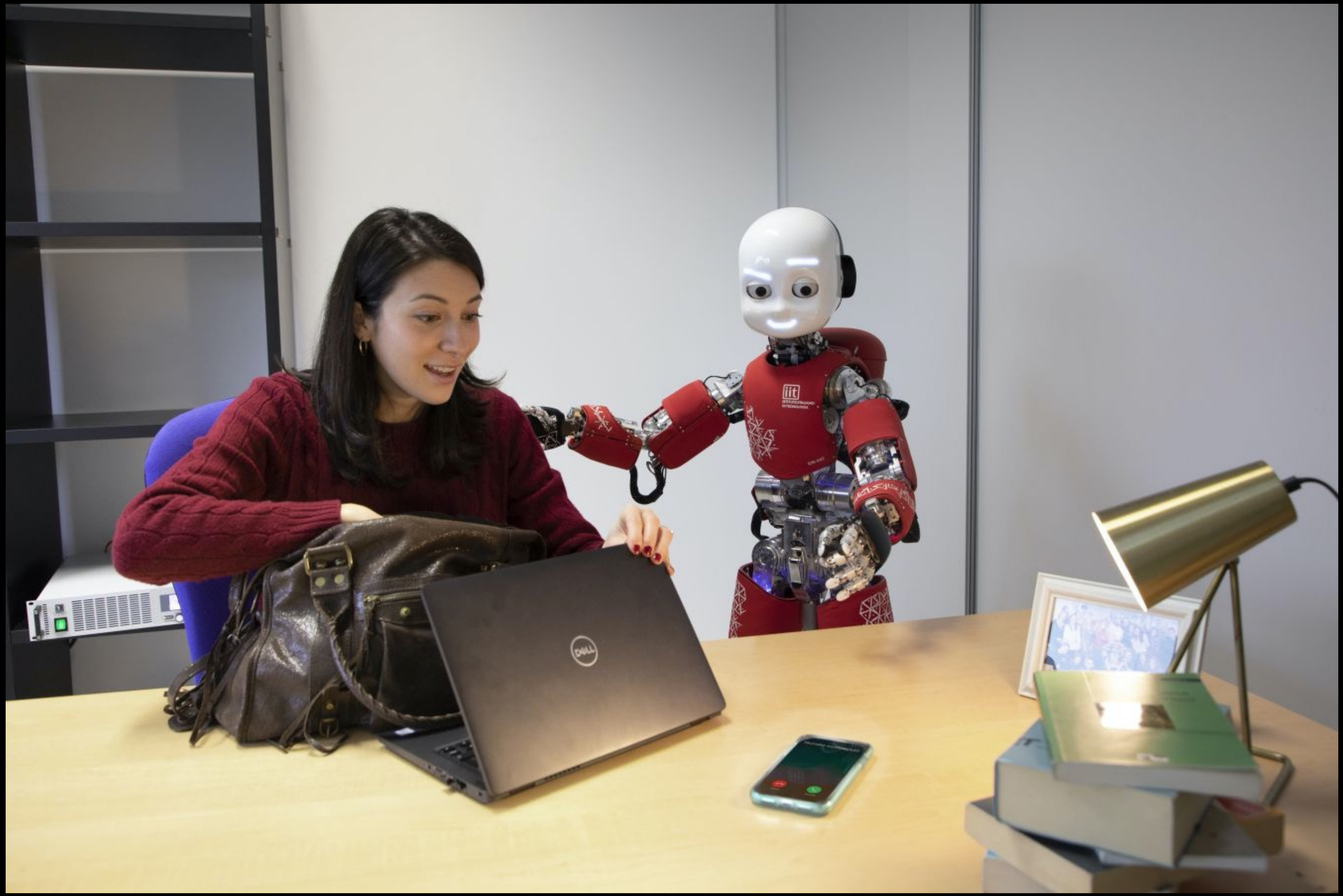

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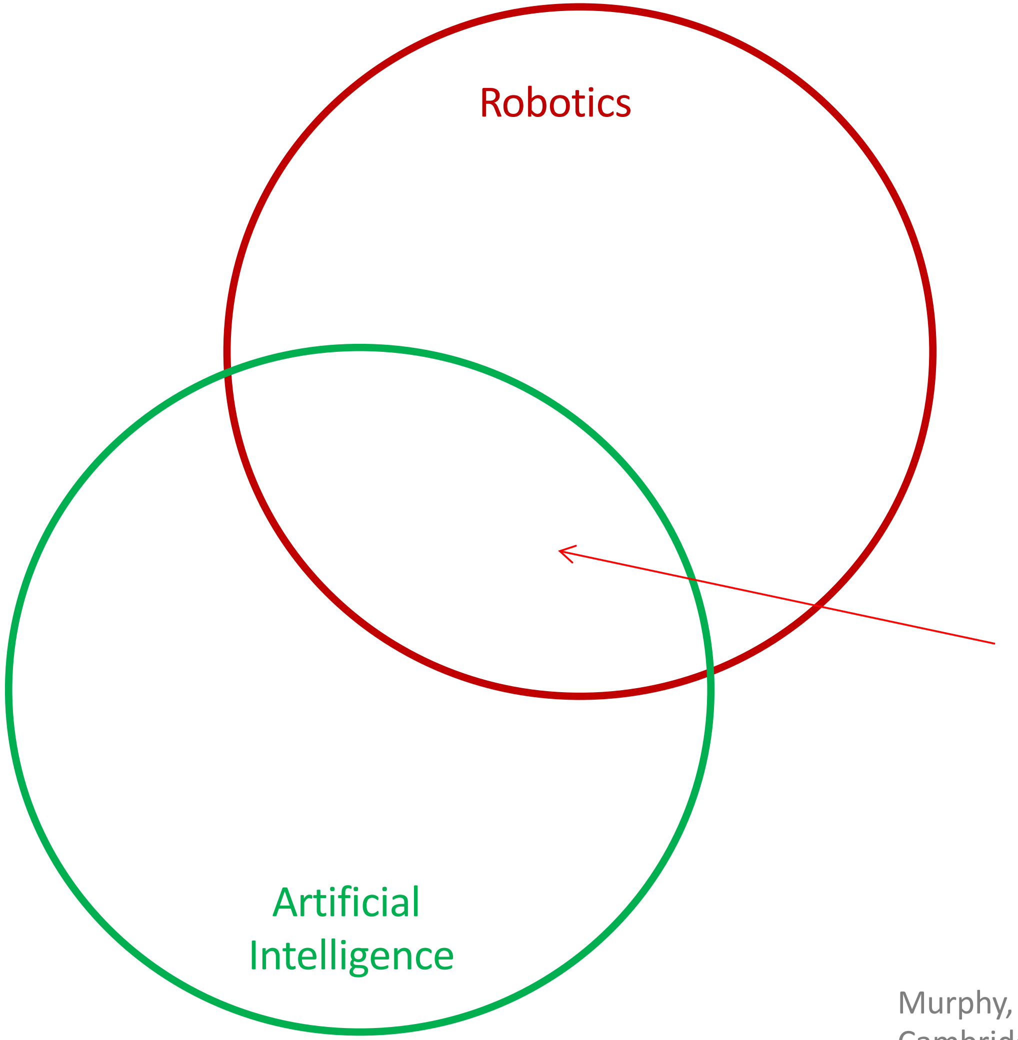
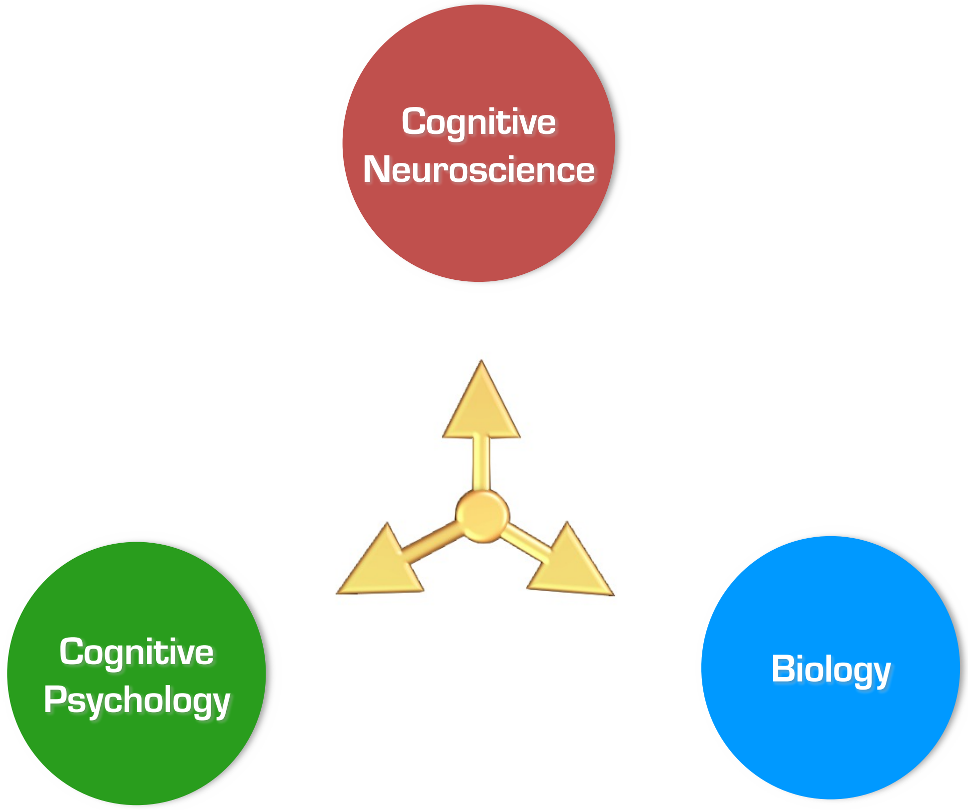
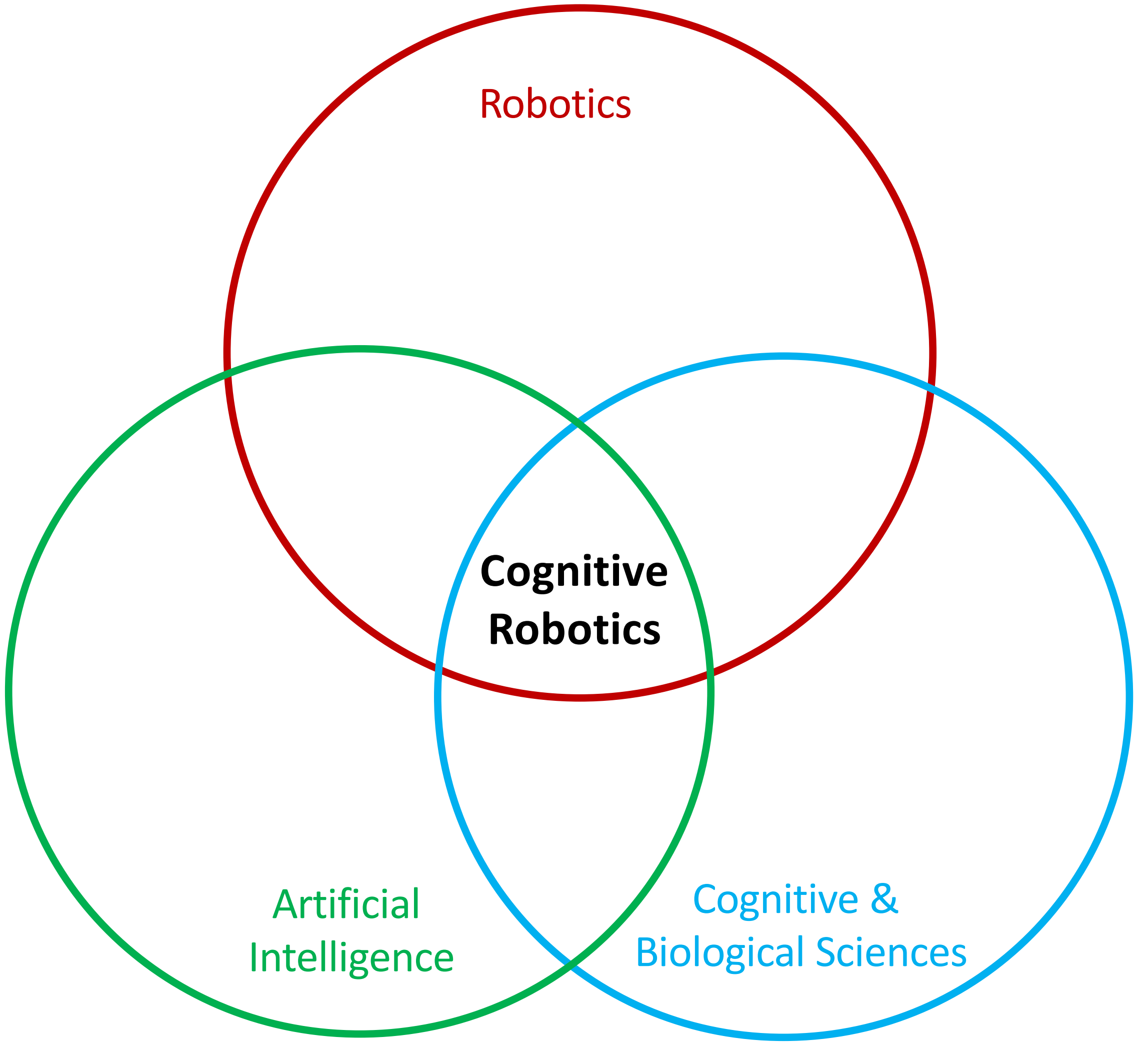


Intelligent Robotics
or
AI Robotics
(Murphy, 2017)

Murphy, Robin R. Introduction to AI Robotics.
Cambridge, MA: MIT press, 2019.

Cognitive & Biological Sciences




Robotics
Cognitive Robotics
Artificial Intelligence
Cognitive & Biological Sciences

A Definition of Cognitive Robotics

"Cognitive Robotics is the field that combines insights and methods from

robotics, AI and cognitive and biological sciences

to design an integrated cognitive system combining the

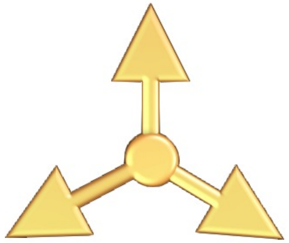
sensorimotor behavior and higher-level functions and social capabilities

of an intelligent robot"

A. Cangelosi and M. Asada, Cognitive Robotics, Chapter 1, MIT Press, in press.

Cognitive Robotics Emphasizes …

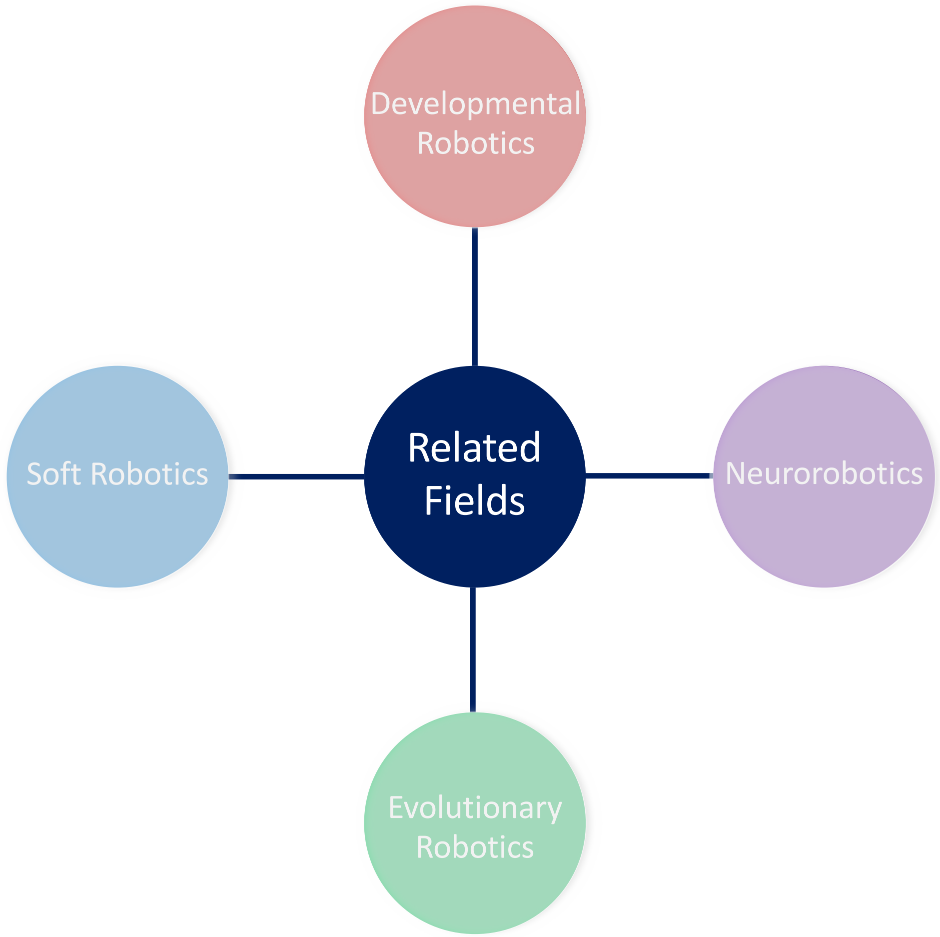
Bio-inspired
human-like and animal-like
behaviour and intelligence

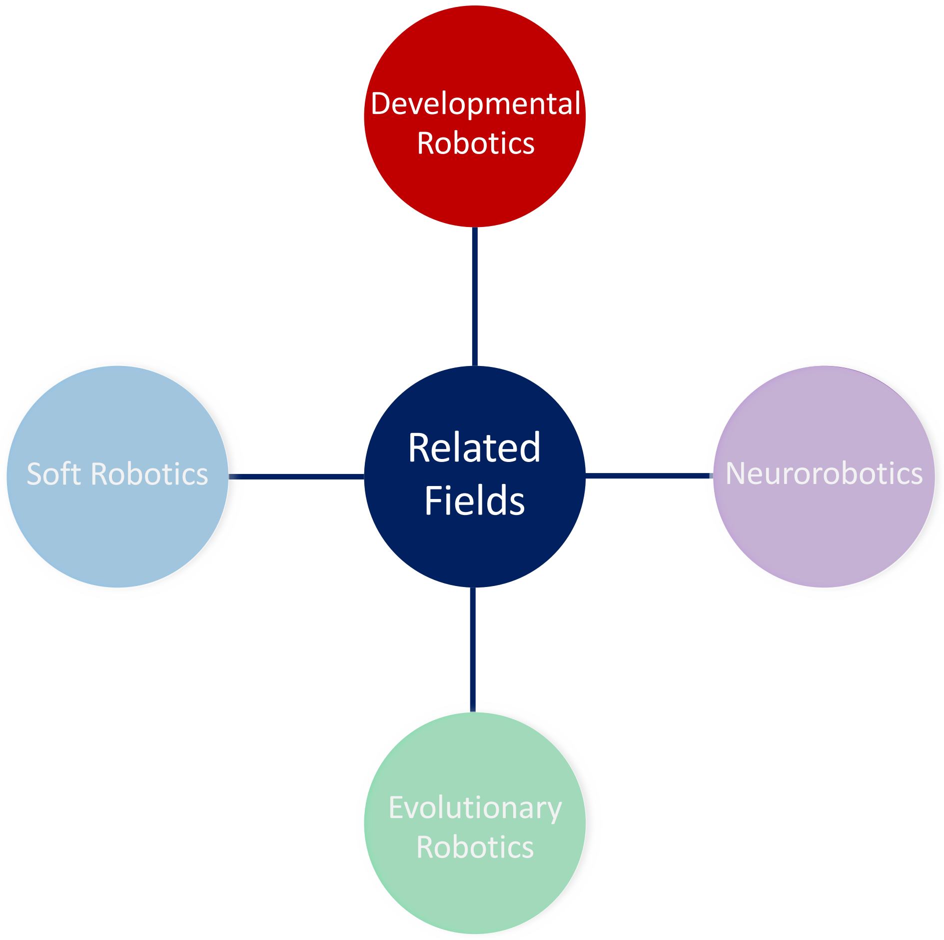


System-level integration
of a range of cognitive abilities:

- Sensorimotor skills
- Knowledge representation & reasoning
- Social interaction

Interdisciplinary approach,
including cognitive (neuro)science,
cognitive psychology, and biology


Developmental Robotics
Soft Robotics
Related Fields
Neurorobotics
Evolutionary Robotics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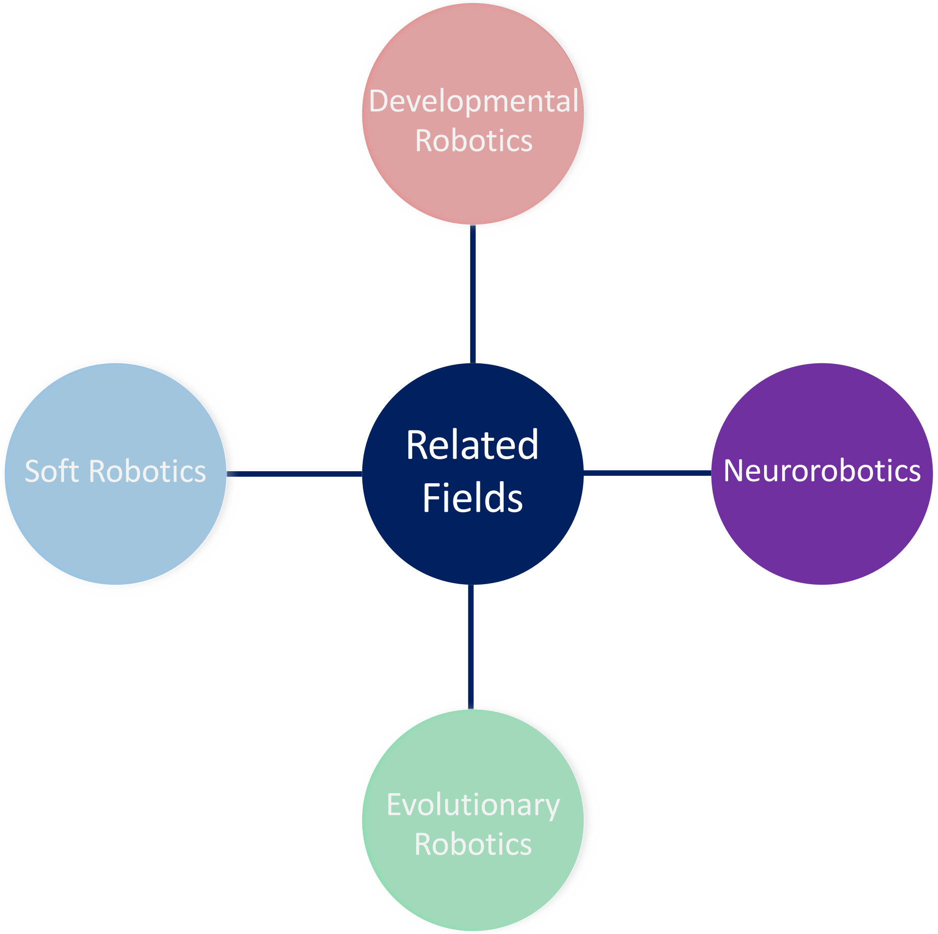
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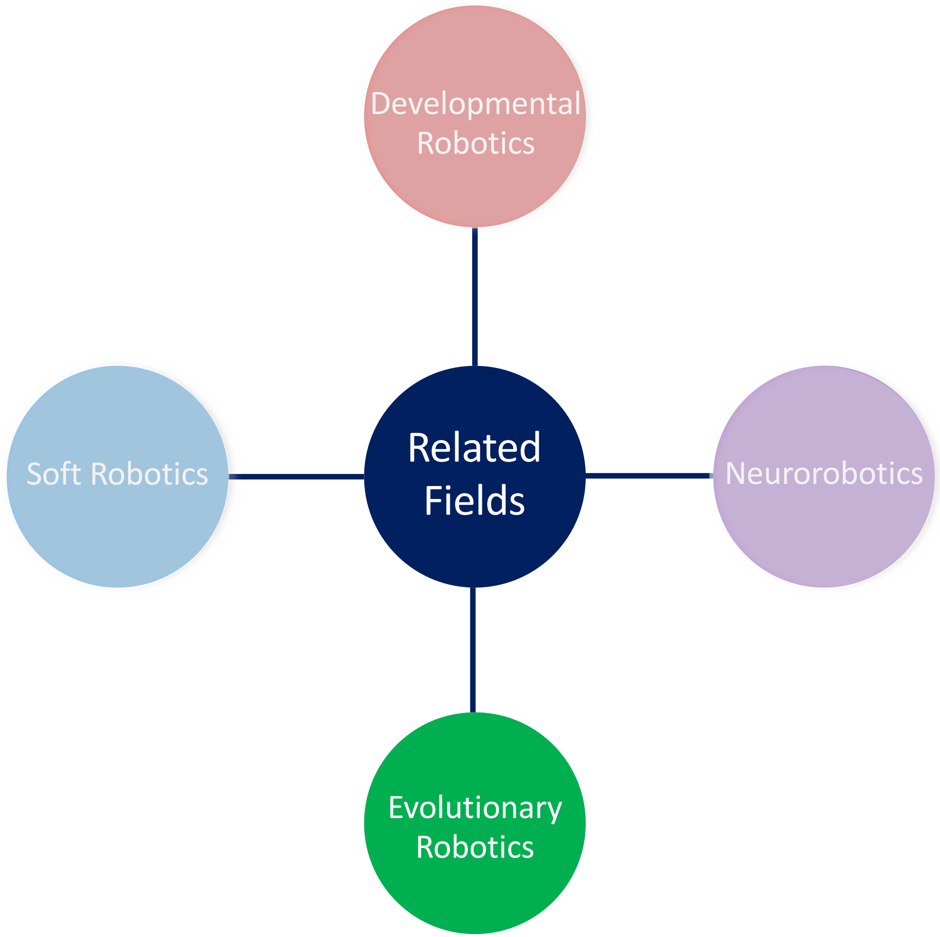
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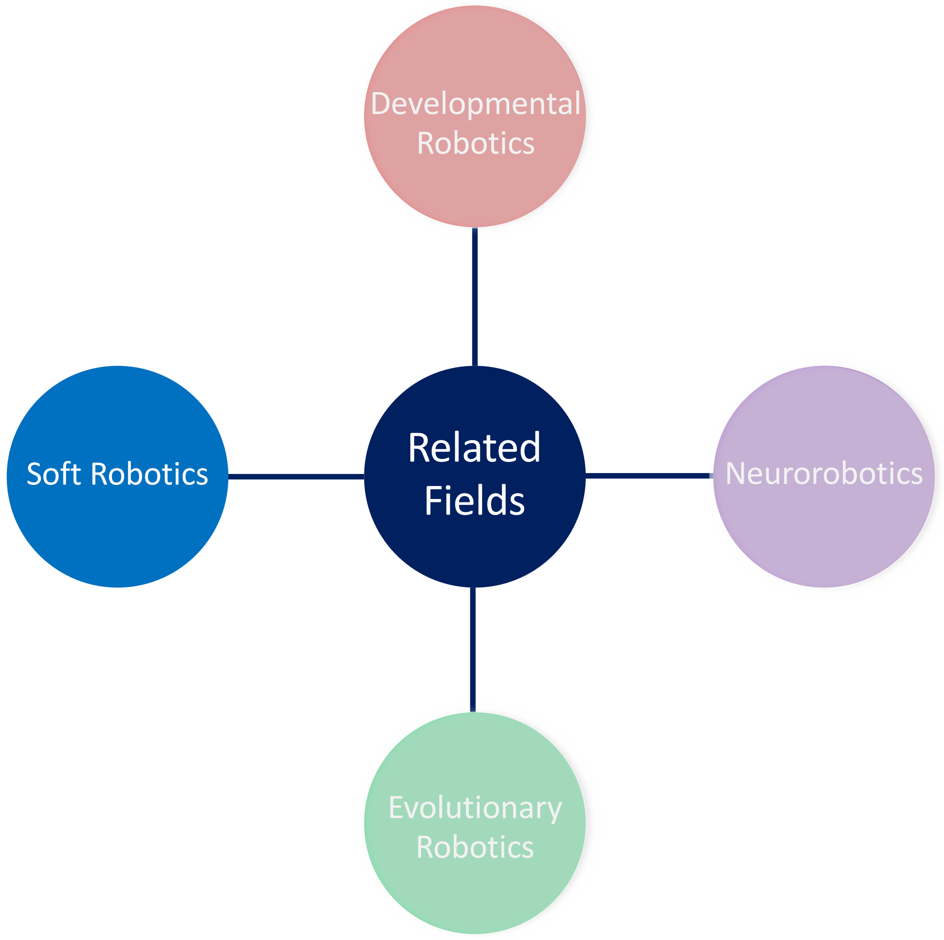
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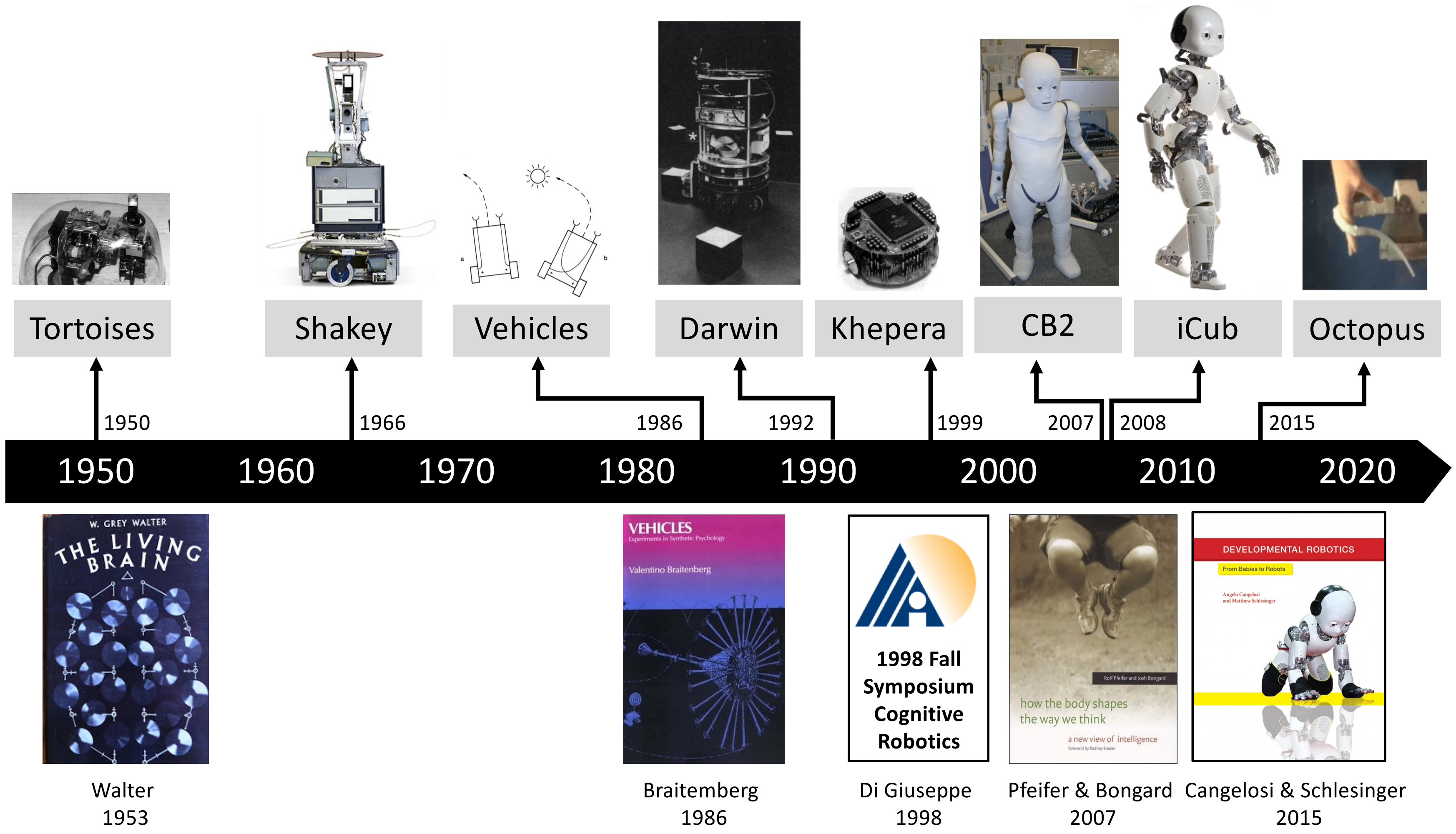
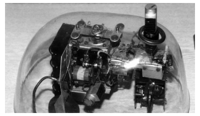
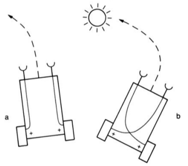
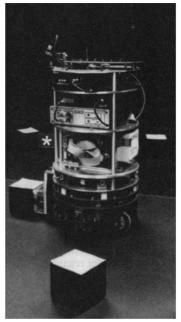


A. Cangelosi and M. Asada, Cognitive Robotics, Chapter 1, MIT Press, 2022







Tortoises

Shakey

Vehicles

Darwin

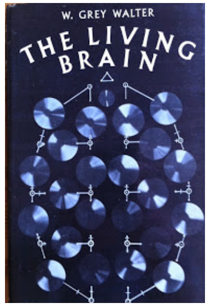
1950

1966

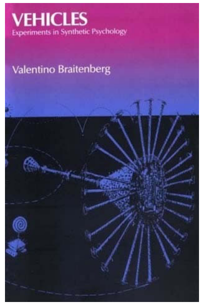
1986

1992

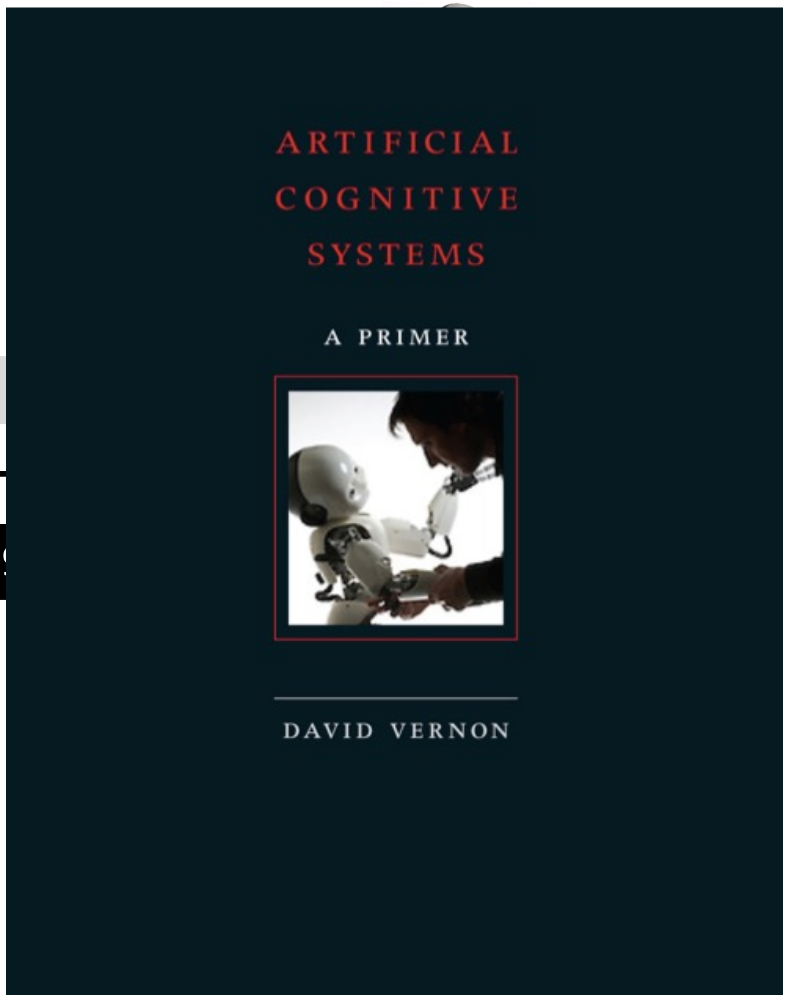
1950 1960 1970 1980 19



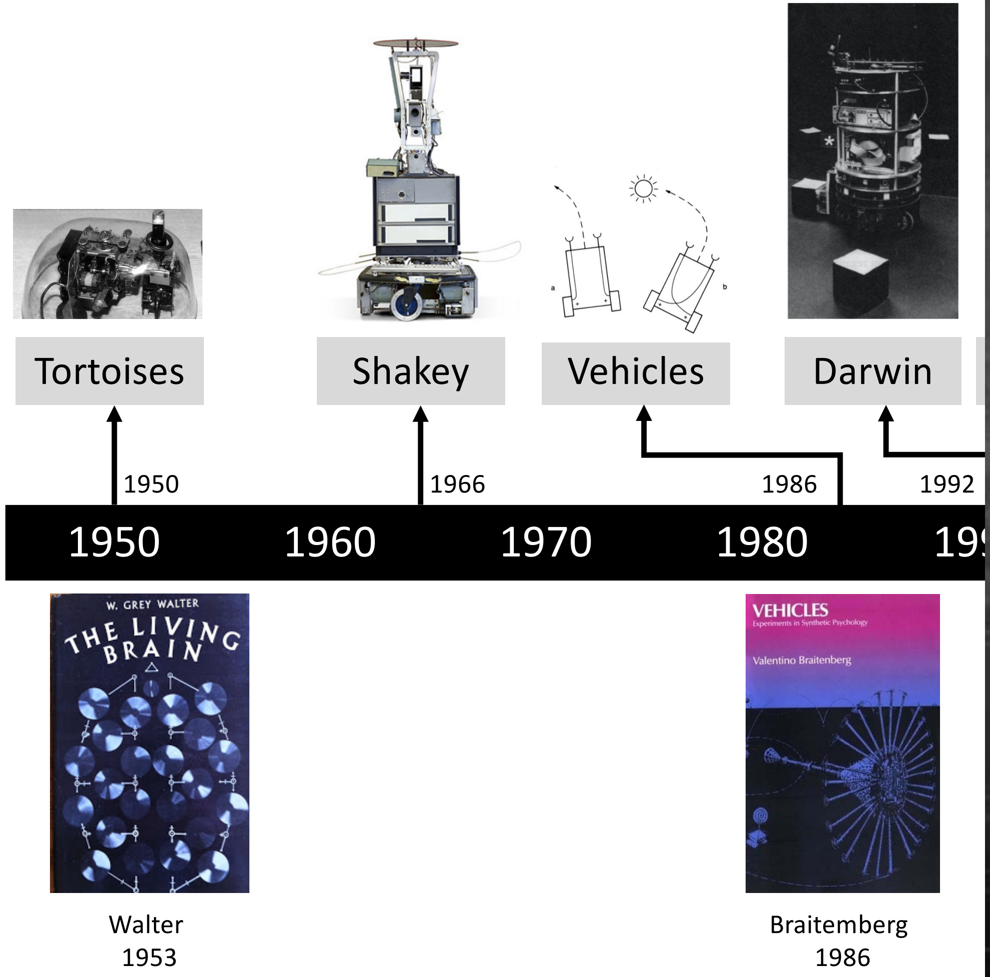
Walter
1953

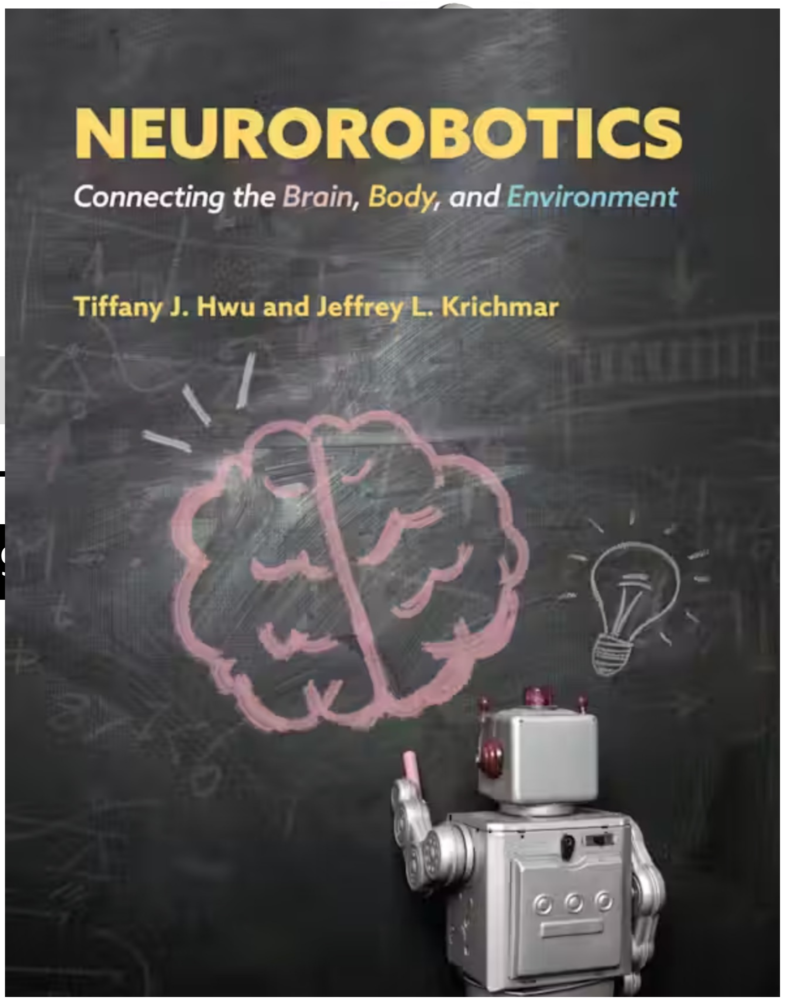


Braitemberg
1986

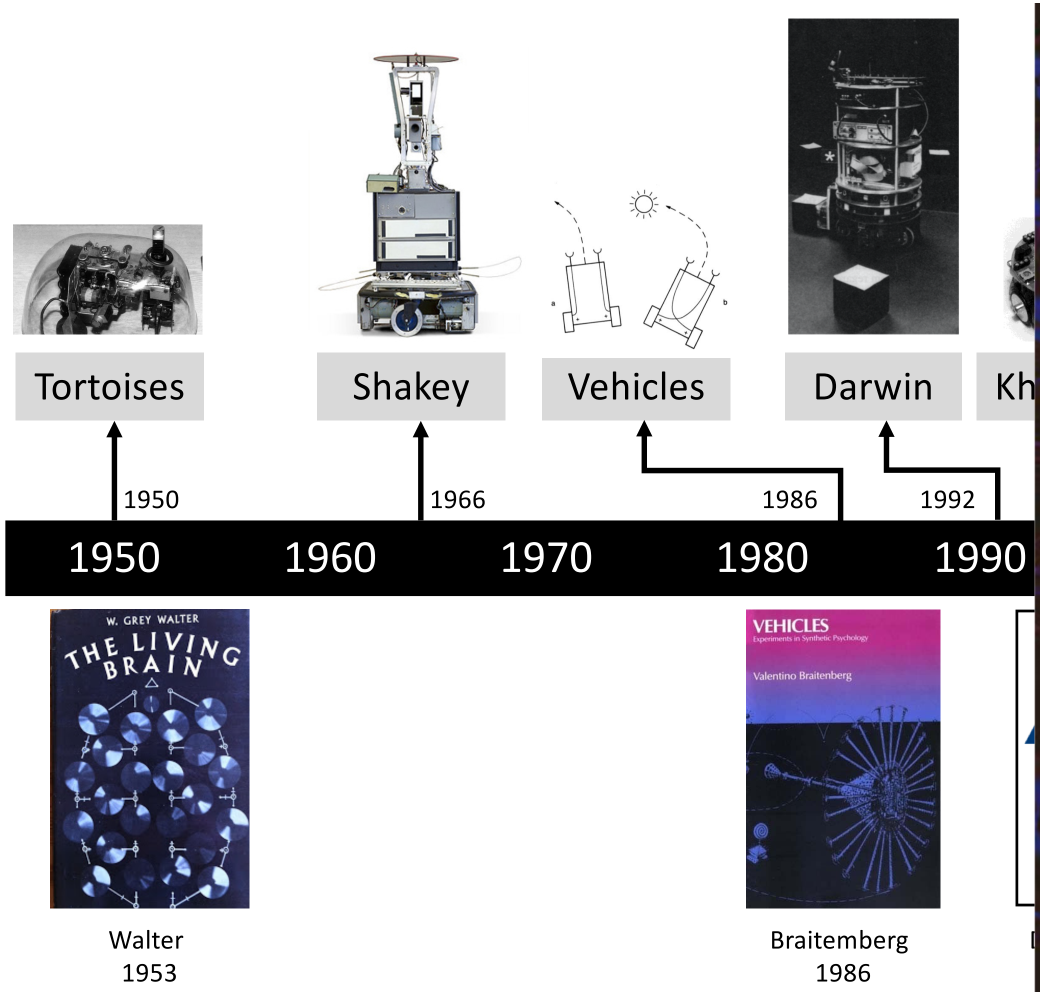


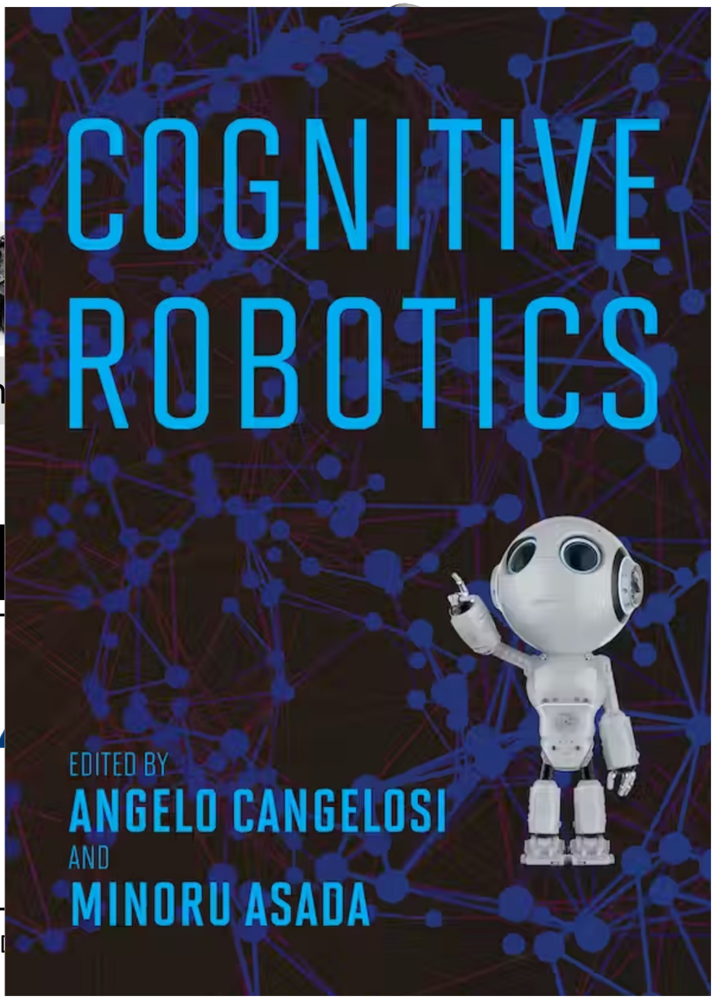
David Vernon, Artificial Cognitive Systems, MIT Press, 2014.





Tiffany J. Hwu and Jeffrey L. Krichmar. Neurorobotics Connecting the Brain, Body, and Environment. MIT Press 2022.





A. Cangelosi and M. Asada (Eds.), Cognitive Robotics. MIT Press 2022.

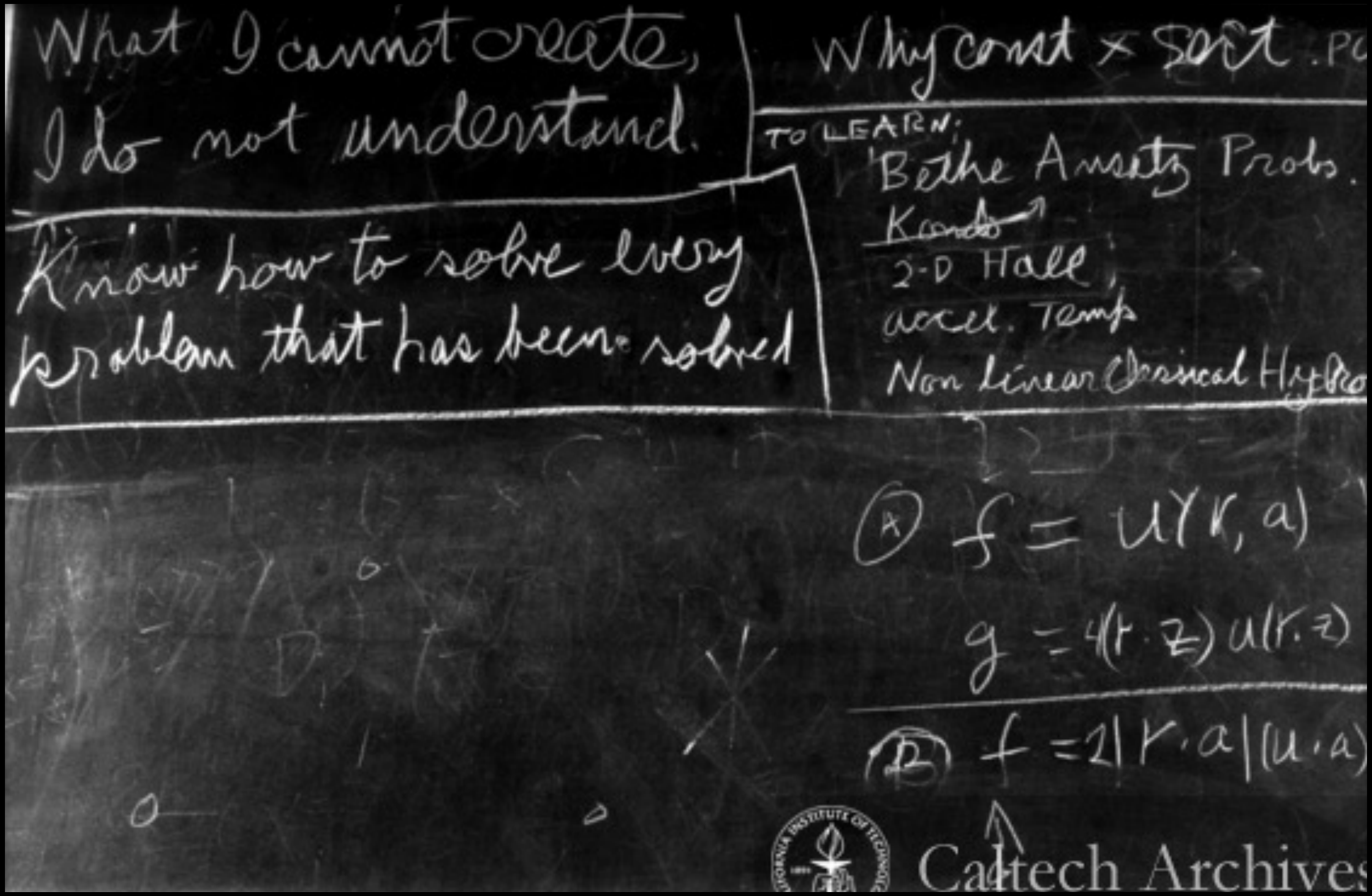
There are two reasons people study cognitive robotics

Build smart robots

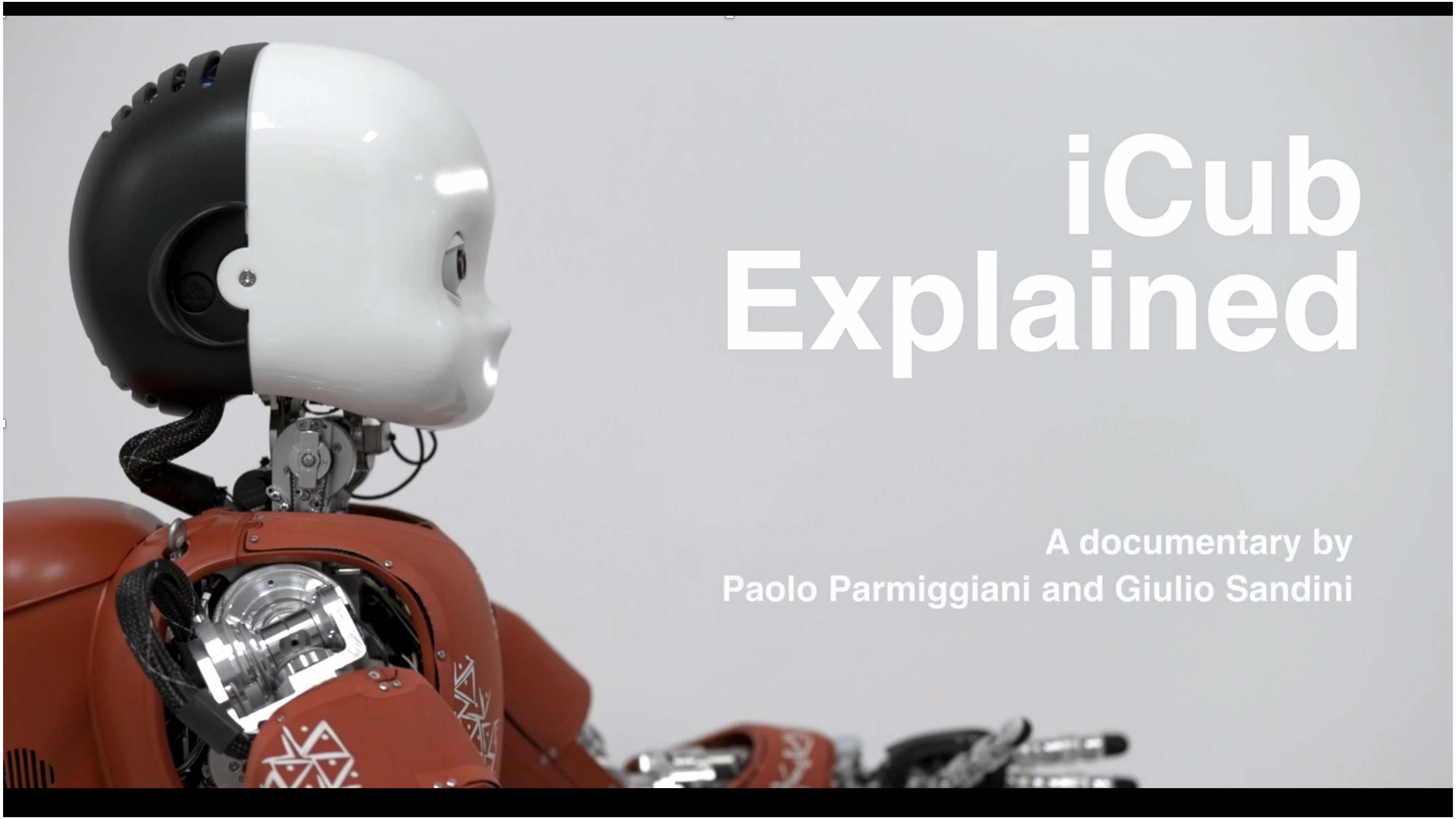
There are two reasons people study cognitive robotics

Build smart robots

Understand cognition



Richard Feynman

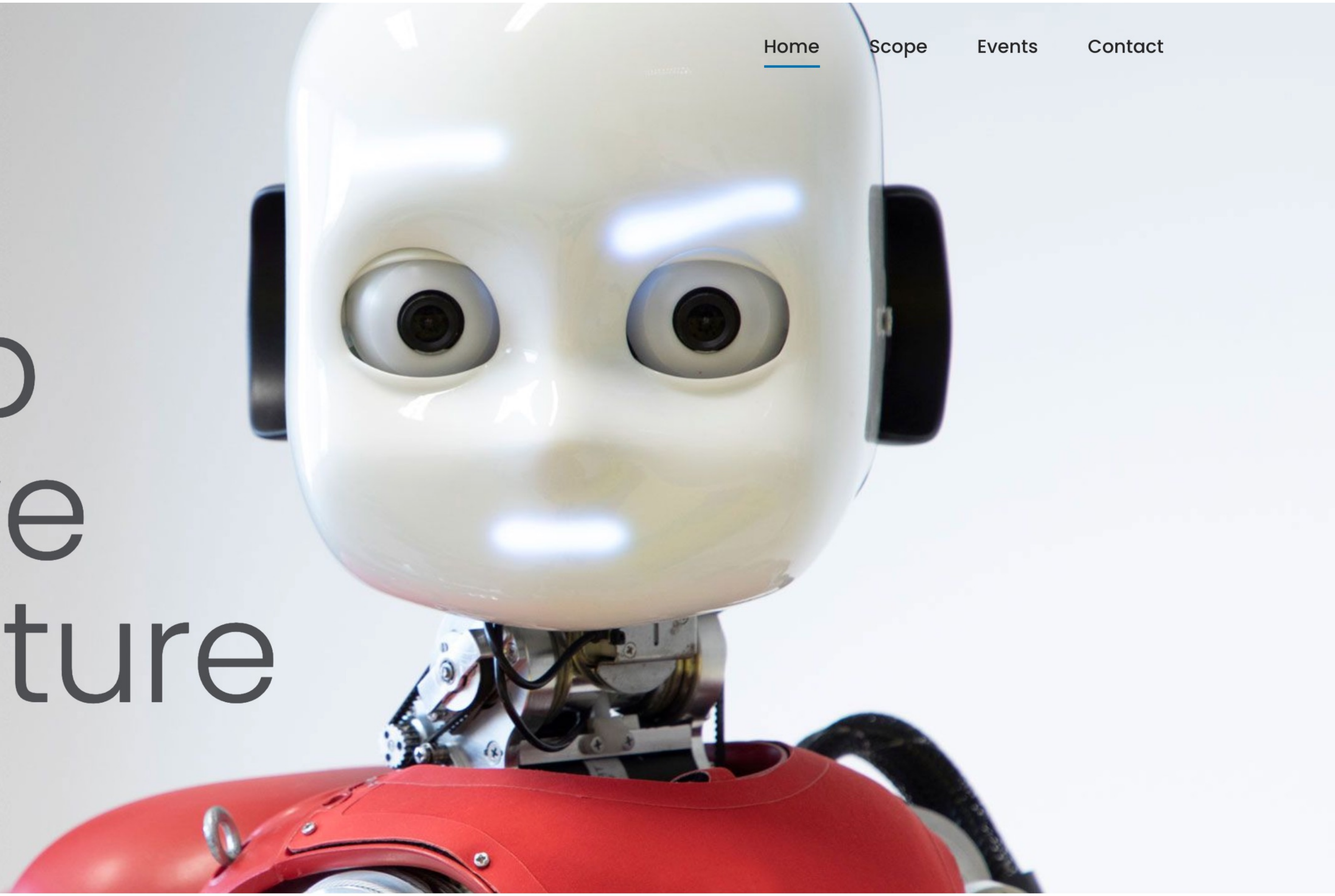

iCub
Explained
A documentary by
Paolo Parmiggiani and Giulio Sandini

ISTITUTO ITALIANO DI TECNOLOGIA
THE ICUB COGNITIVE ARCHITECTURE

Home Scope Events Contact

iCog.

The iCub Cognitive Architecture



iCog is an open source initiative started at IIT with the goal of advancing our knowledge of human cognition by designing, building, and sharing a common cognitive architecture for an embodied artificial system such as the iCub humanoid robot.

euCognition

The European Network for the Advancement of Artificial Cognitive Systems

Home | More Info | News | Outreach | Outlook | Education

Definitions of Cognition & Cognitive Systems

The following definitions were contributed by members of euCognition in response to a questionnaire. If you haven't completed the questionnaire, please consider doing so.

The definitions are listed in the order in which they were submitted.

Cognition is the ability to relate perception and action in a meaningful way determined by experience,learning and memory.
Mike Denham

A cognitive system possesses the ability of self-reflection (or at least self-awareness).
Horst Bischof

Cognition is gaining knowledge through the senses.
Majid Mermehdi

Cognition is the ability to ground perceptions in concepts together with the ability to manipulate concepts in order to proceed toward goals.
Christian Bauckhage

An artificial cognitive system is a system that is able to perceive its surrounding environment with multiple sensors, merge this information, reason about it, learn from it and interact with the outside world.
Barbara Caputo

42 definitions

☹️

http://www.vernon.eu/euCognition/definitions.htm

Cognition

"Cognition is the process by which an autonomous system

perceives its environment,

learns from experience,

anticipates the outcome of events,

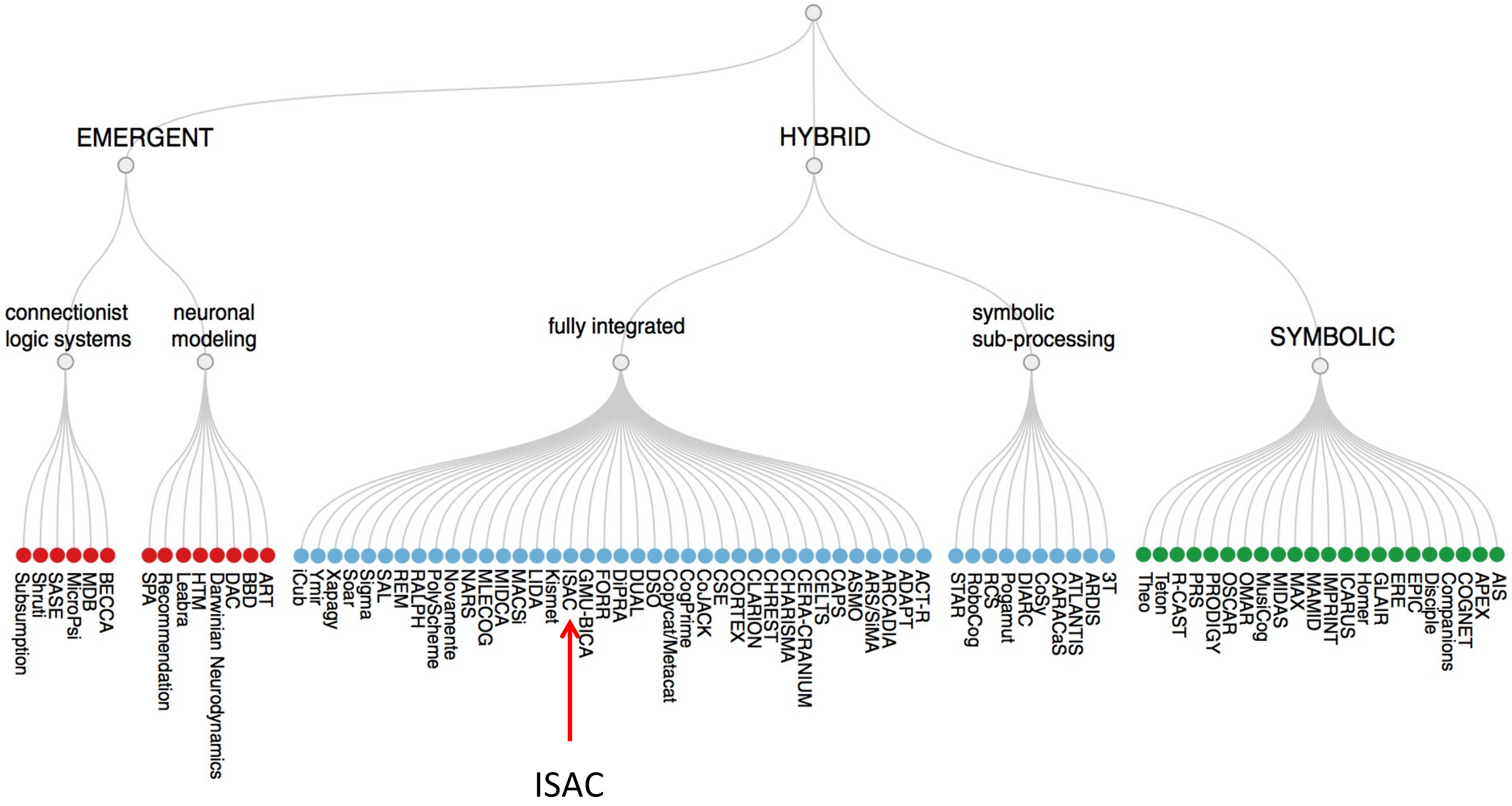
acts to pursue goals, and

adapts to changing circumstances."

D. Vernon, Artificial Cognitive Systems – A Primer, MIT Press, 2014

Orchestrating all this requires a cognitive architecture

Soar
Clarion
BBD / Darwin
HAMMER
ISAC
CRAM
...



I. Kotseruba and J. Tsotsos. 40 years of cognitive architectures: core cognitive abilities and practical applications. Artificial Intelligence Review, Vol. 53, No. 1, pp. 17-94, 2020.

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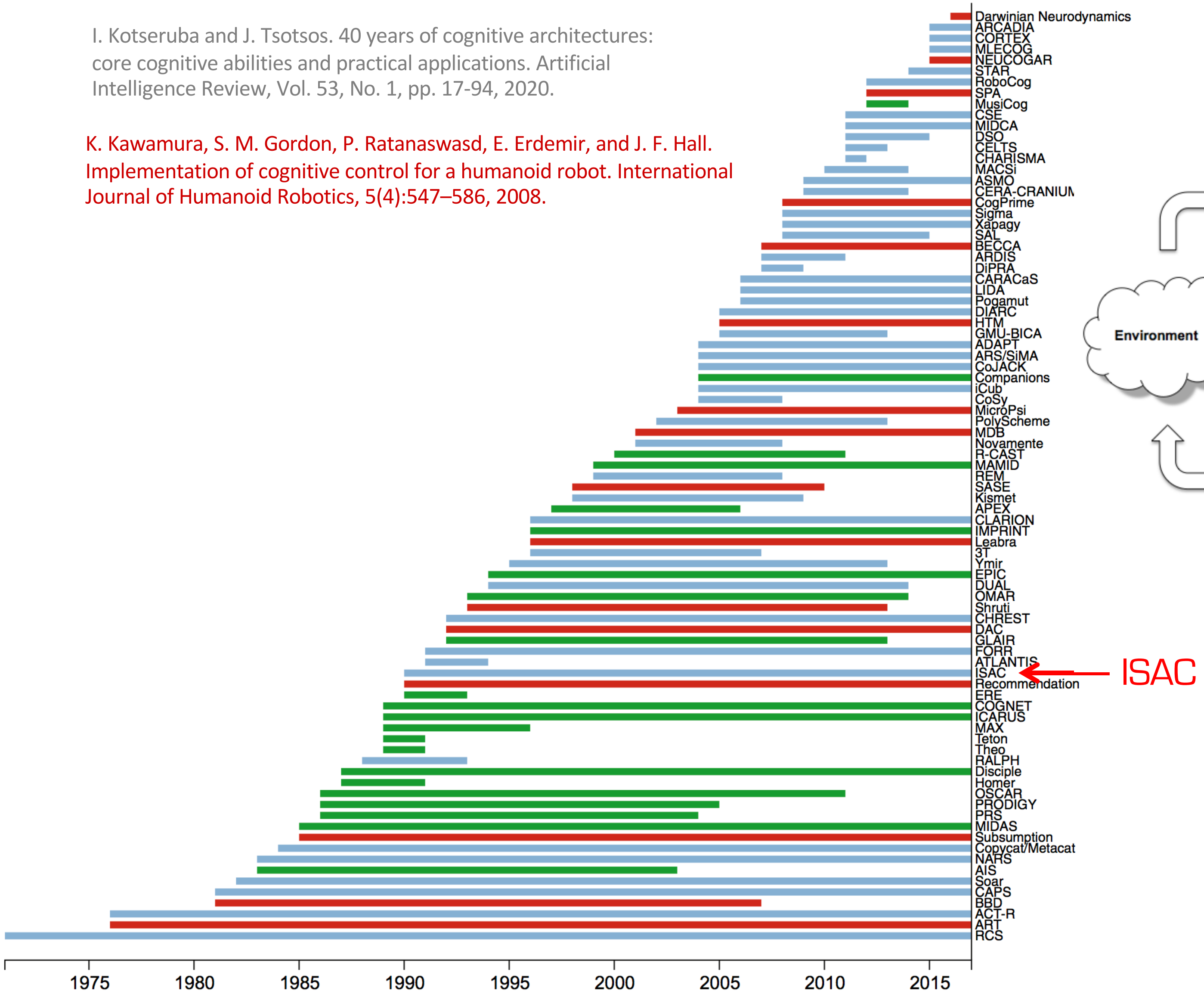
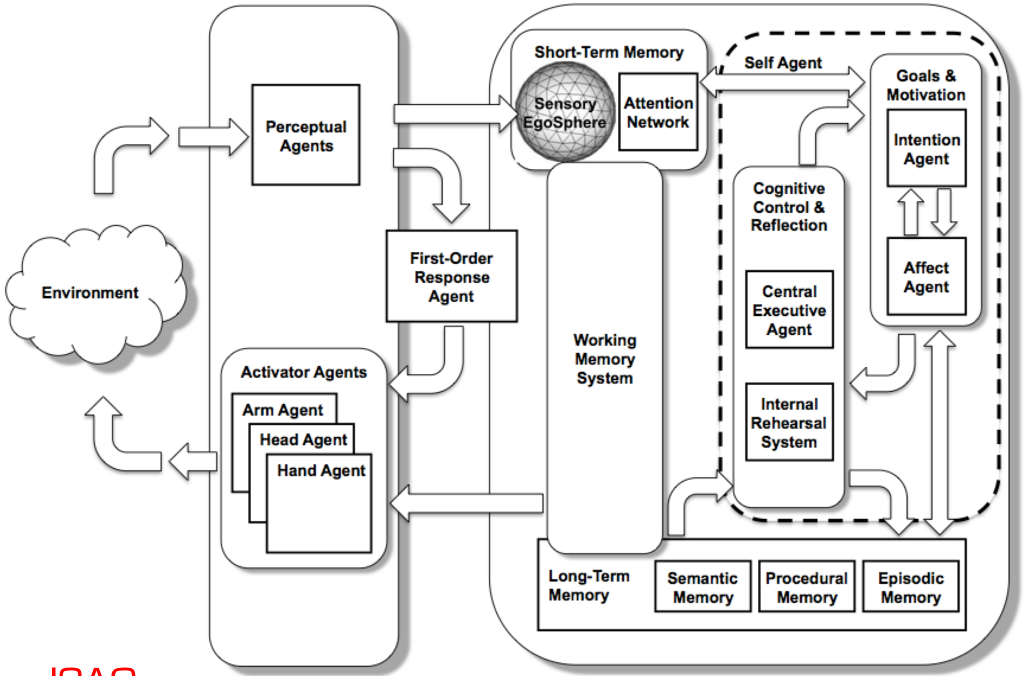
K. Kawamura, S. M. Gordon, P. Ratanaswasd, E. Erdemir, and J. F. Hall. Implementation of cognitive control for a humanoid robot. International Journal of Humanoid Robotics, 5(4):547–586, 2008.

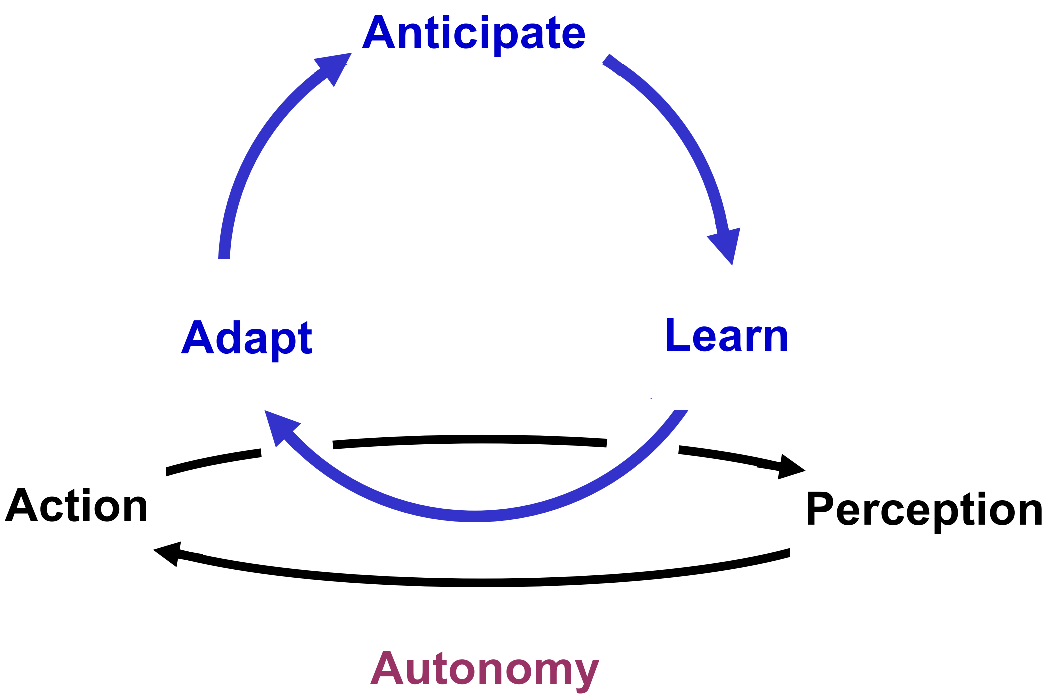




Short videos on several cognitive architectures can be found at the 2021 TransAIR Workshop on Cognitive Architectures for Robot Agents

https://transair-bridge.org/workshop-2021/

Cognition



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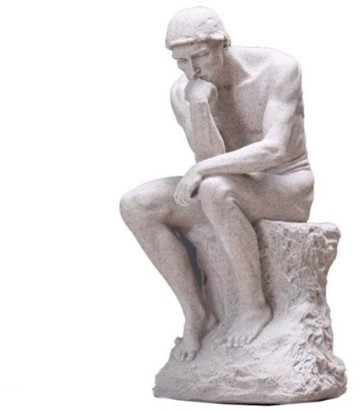
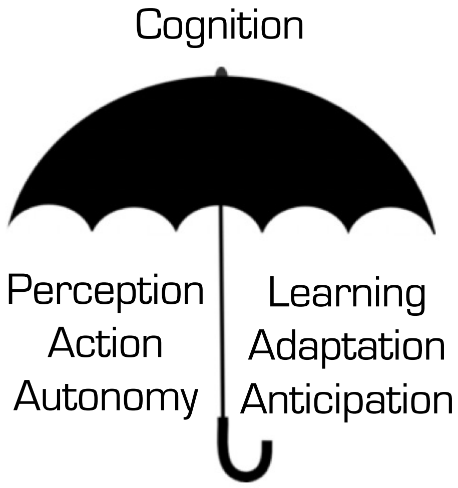


The Thinker
Auguste Rodin

One view of cognition



An alternative view

"Cognitive vision is a lot about being able to assert that something is there,

given very little visual evidence,

and even perhaps despite evidence to the contrary"

Aaron Bobick

"Cognitive robotics is a lot about being able to achieve goals,

given very little guidance,

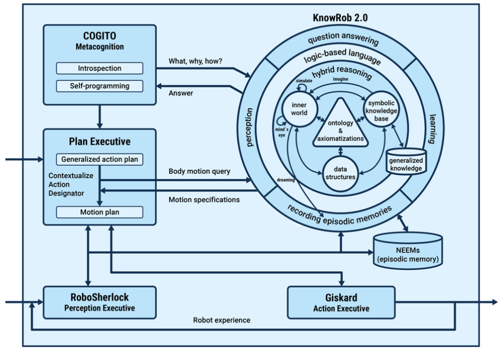
but with a lot of knowledge and the ability to reason."

Paraphrasing Michael Beetz

Design Principle of the CRAM Cognitive Architecture

Implicit-to-explicit manipulation: “fetch the spoon and put it on the table”

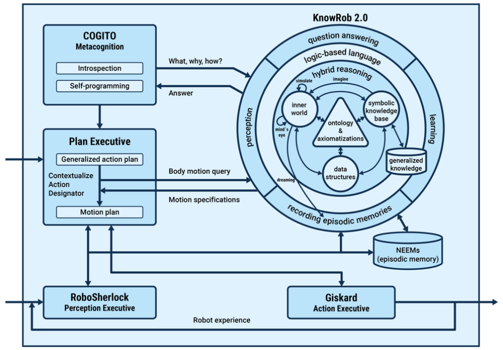
Vaguely-stated high-level goal → Specific low-level motions required to accomplish the goal



Design Principle of the CRAM Cognitive Architecture

Implicit-to-explicit manipulation: “fetch the spoon and put it on the table”

Generalized Action Plan → Motion Plan



Core abilities of a cognitive system

Perception
Attention
Action selection
Memory
Learning
Reasoning
Meta-reasoning

Kotseruba, I. and J. Tsotsos. 40 years of cognitive architectures: core cognitive abilities and practical applications. Artificial Intelligence Review 53(1), 17 – 94, 2020.

… and prospection

– the capacity to anticipate the future –

is, arguably, the hallmark of cognition

Full text provided by www.sciencedirect.com

ScienceDirect

ELSEVIER

Control strategies in object manipulation tasks

J Randall Flanagan[1], Miles C Bowman[1] and Roland S Johansson[2]

The remarkable manipulative skill of the human hand is not the result of rapid sensorimotor processes, nor of fast or powerful effector mechanisms. Rather, the secret lies in the way manual tasks are organized and controlled by the nervous system. At the heart of this organization is prediction. Successful manipulation requires the ability both to predict the motor commands required to grasp, lift, and move objects and to predict the sensory events that arise as a consequence of these commands.

Addresses
[1] Department of Psychology and Centre for Neuroscience Studies, Queen's University, Kingston, ON, K7L 3N6, Canada
[2] Section for Physiology, Department of Integrative Medical Biology, Umeå University, SE-901 87 Umeå, Sweden

Corresponding author: Flanagan, J Randall

and another object or surface. Importantly, these contact events give rise to discrete and distinct sensory events, each characterized by a specific afferent neural signature. Because these sensory events provide information related to the functional goals of successive action phases, they have a crucial role in the sensory control of manipulations. In object manipulation, the brain not only forms action plans in terms of series of desired subgoals but also predicts the sensory events that signify subgoal attainment in conjunction with the generation of the motor commands. By comparing predicted sensory events with the actual sensory events, the motor system can monitor task progression and adjust subsequent motor commands if errors are detected. As discussed further below, such adjustments involve parametric adaptation of fingertip actions to the mechanical properties of objects, triggering

J Randall Flanagan, Miles C Bowman, and Roland S Johansson. Control strategies in object manipulation tasks. *Current opinion in neurobiology*, 16(6):650–659, 2006.

Prospection

Anticipation
Prediction
Intention
Planning
Simulation
Episodic future thinking
Future oriented cognition

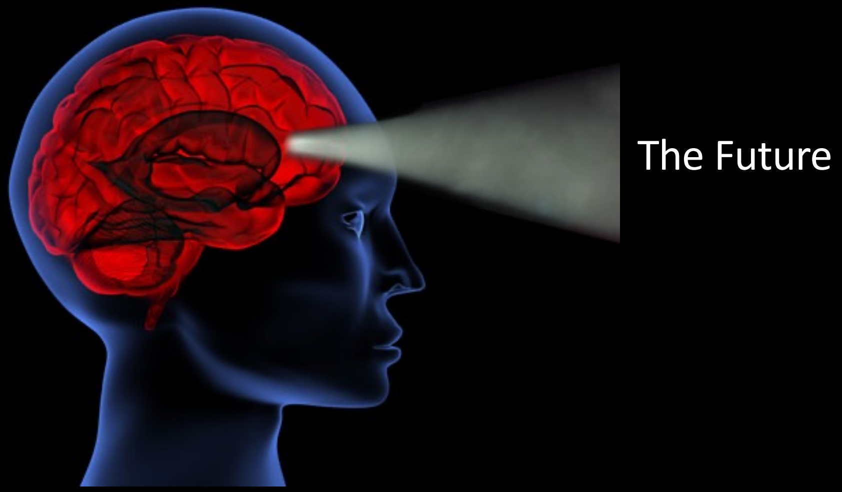
K. K. Szpunar, R. N. Spreng, and D. L. Schacter, A taxonomy of prospection: introducing an organizational framework for future-oriented cognition, PNAS 111(52), 18414–18421, 2014.

Cognition

"The brain constantly attempts to anticipate future events"

Schulkin J. Social allostasis: anticipatory regulation of the internal milieu. *Frontiers in evolutionary neuroscience*, *2*, 111, 2011.

Cognition: breaking free of the present and the limitations of perception

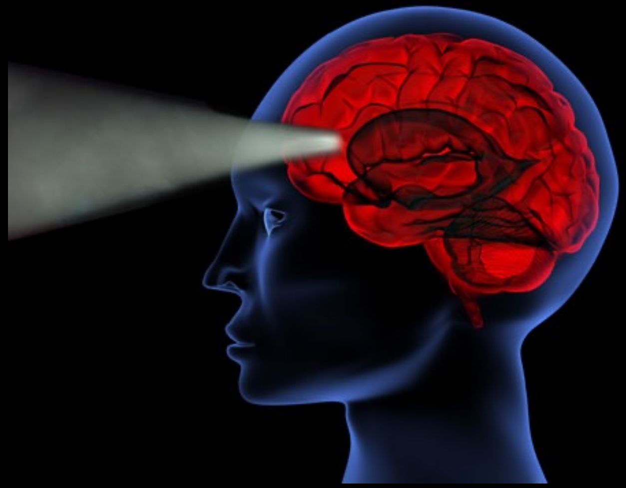


Timescale increases through cognitive development

Episodic Memory

Specific instances of
the agents' experience

The Past



Past events are
reconstructed ...

Episodic Memory

The Past

The Future

Past events are
reconstructed ...

To allow the agent
to **pre-experience** the future

Episodic Future Thinking

The Past

The Future

Past events are
reconstructed …

To allow the agent
to **pre-experience** the future

C. M. Atance and D. K. O'Neill, "Episodic future thinking," Trends in Cognitive Sciences, vol. 5, no. 12, pp. 533–539, 2001.

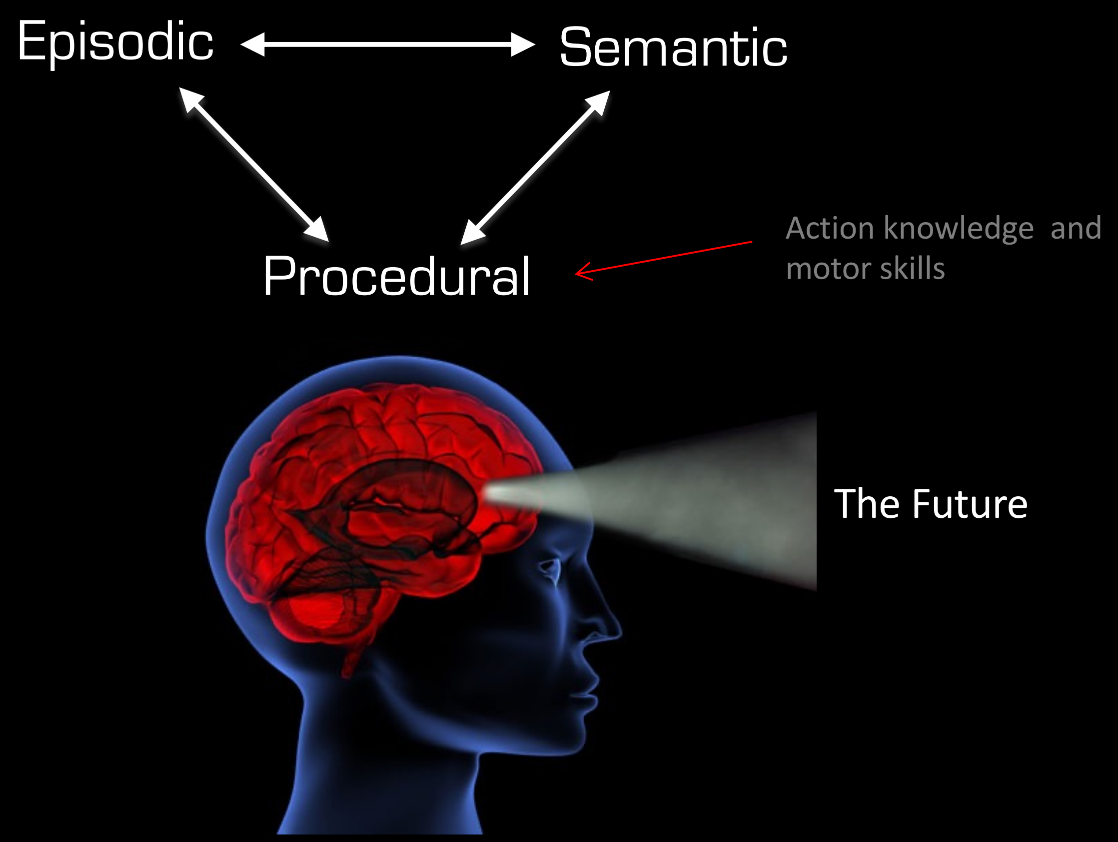
D. L. Schacter and D. R. Addis, "The cognitive neuroscience of constructive memory: Remembering the past and imagining the future," Philosophical Transactions of the Royal Society B, vol. 362, pp. 773–786, 2007.

Episodic ⟷ Semantic

General knowledge
about the agent's world

The Future

K. K. Szpunar, R. N. Spreng, and D. L. Schacter, A taxonomy of prospection: introducing an organizational framework for future-oriented cognition, PNAS 111(52), 18414–18421, 2014.

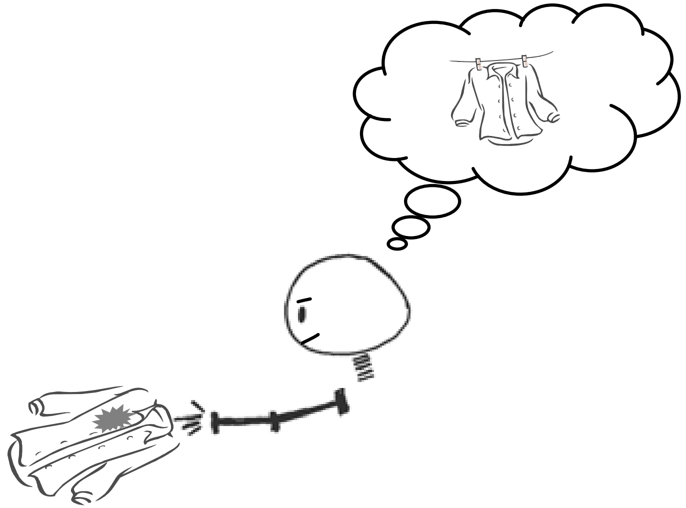


K. K. Szpunar, R. N. Spreng, and D. L. Schacter, A taxonomy of prospection: introducing an organizational framework for future-oriented cognition, PNAS 111(52), 18414–18421, 2014.

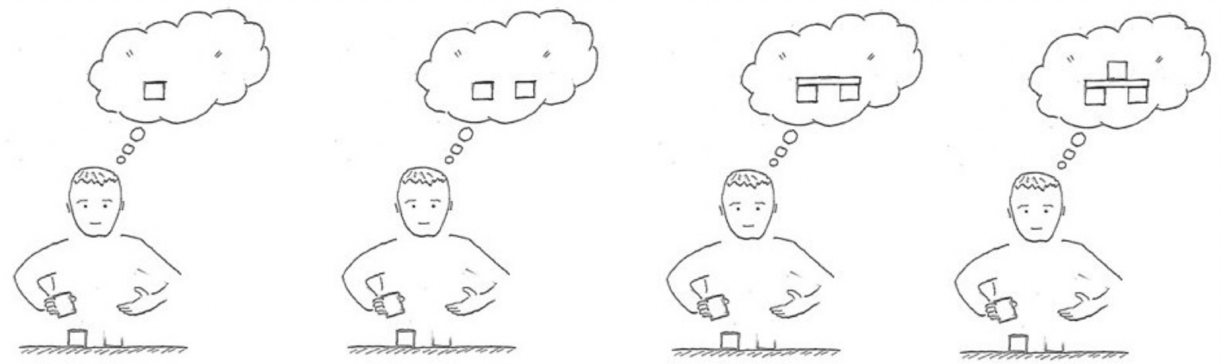
Cognitive systems continually predict

The need for action
(self and others)

The outcome of those actions



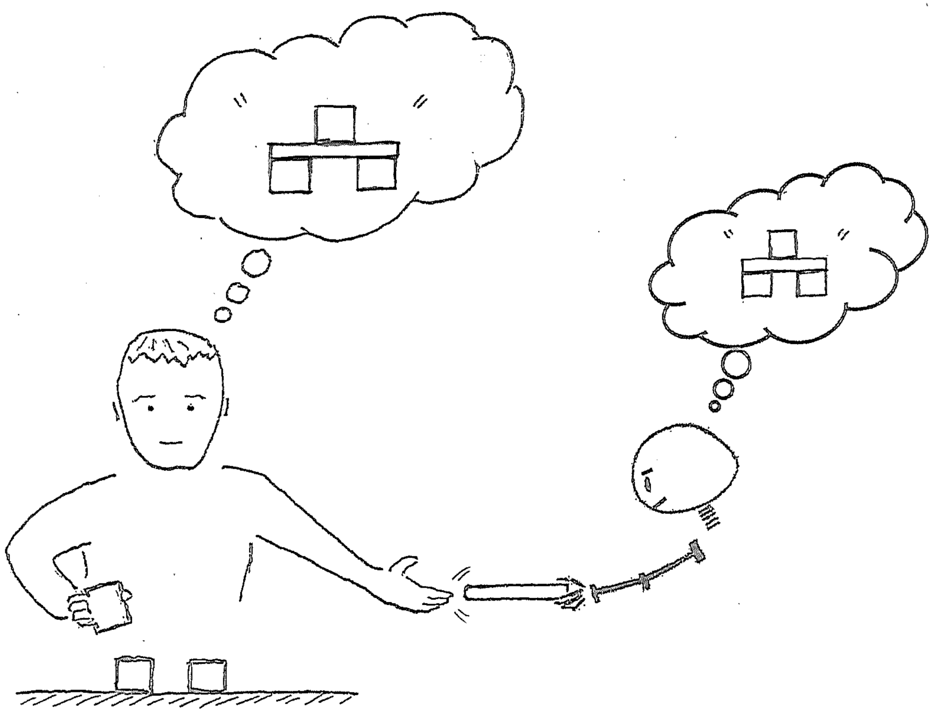
Everyday activities: apparently routine but often complex and demanding



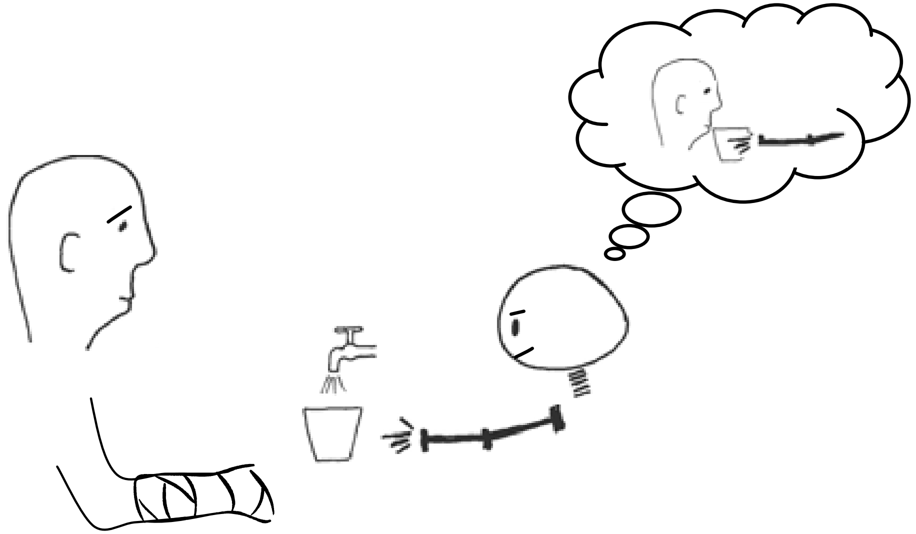
"Actions are goal-directed
and
are guided by prospective information"

Claes von Hofsten

D. Vernon, C. von Hofsten, and L. Fadiga, A Roadmap for Cognitive Development in Humanoid Robots, vol. 11 of Cognitive Systems Monographs (COSMOS). Berlin: Springer, 2010

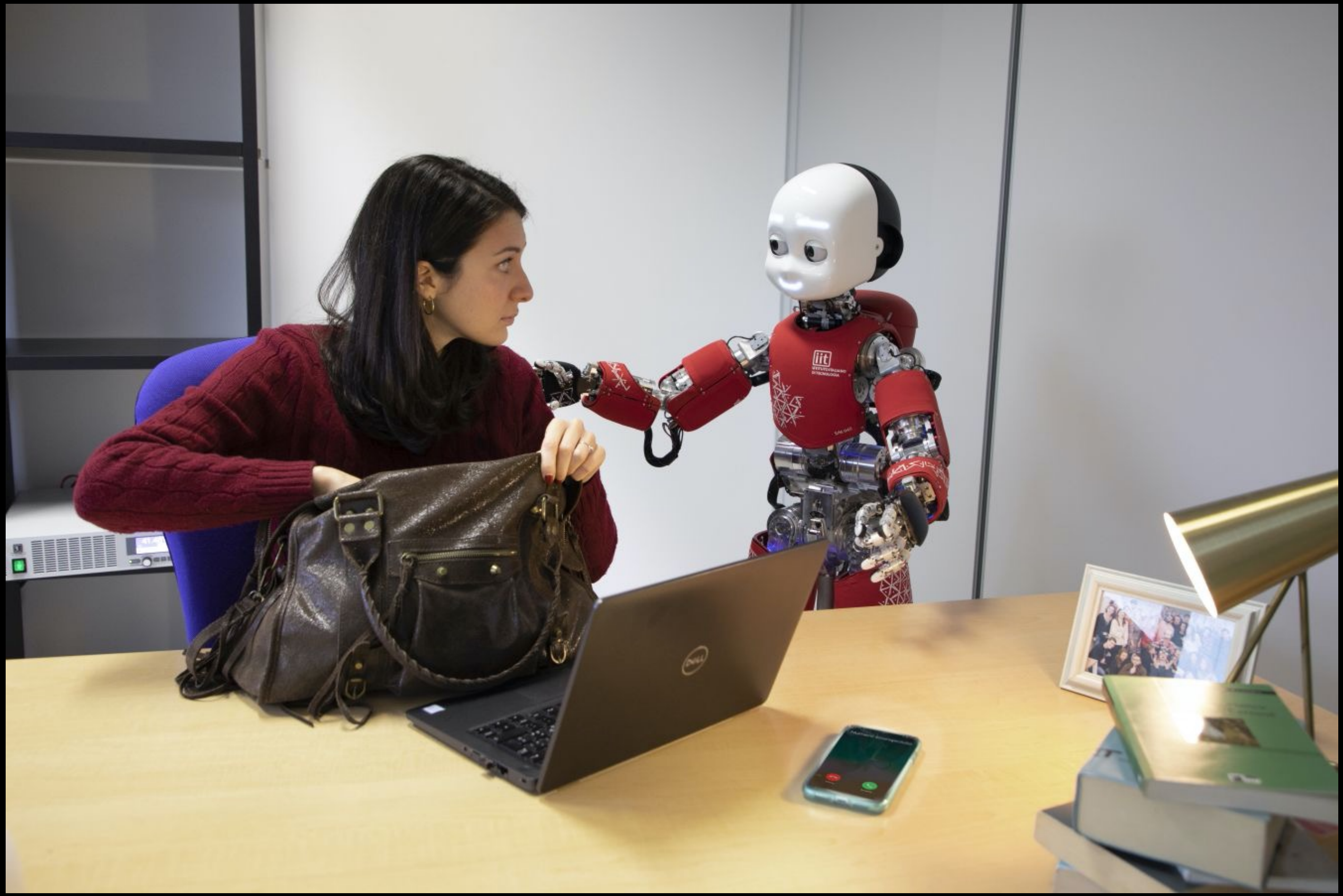


Anticipate the needs of others



Anticipate the needs of others

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



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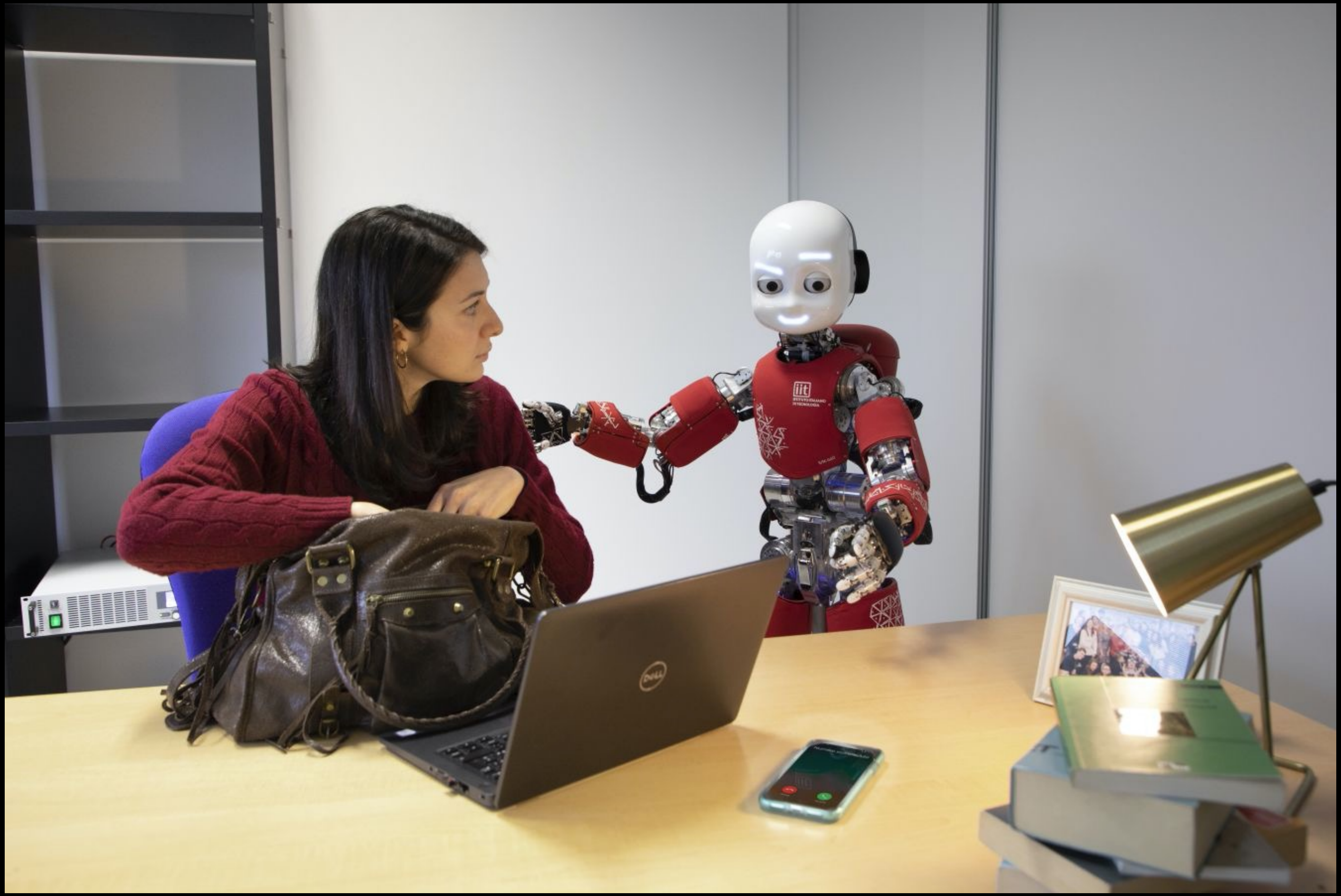

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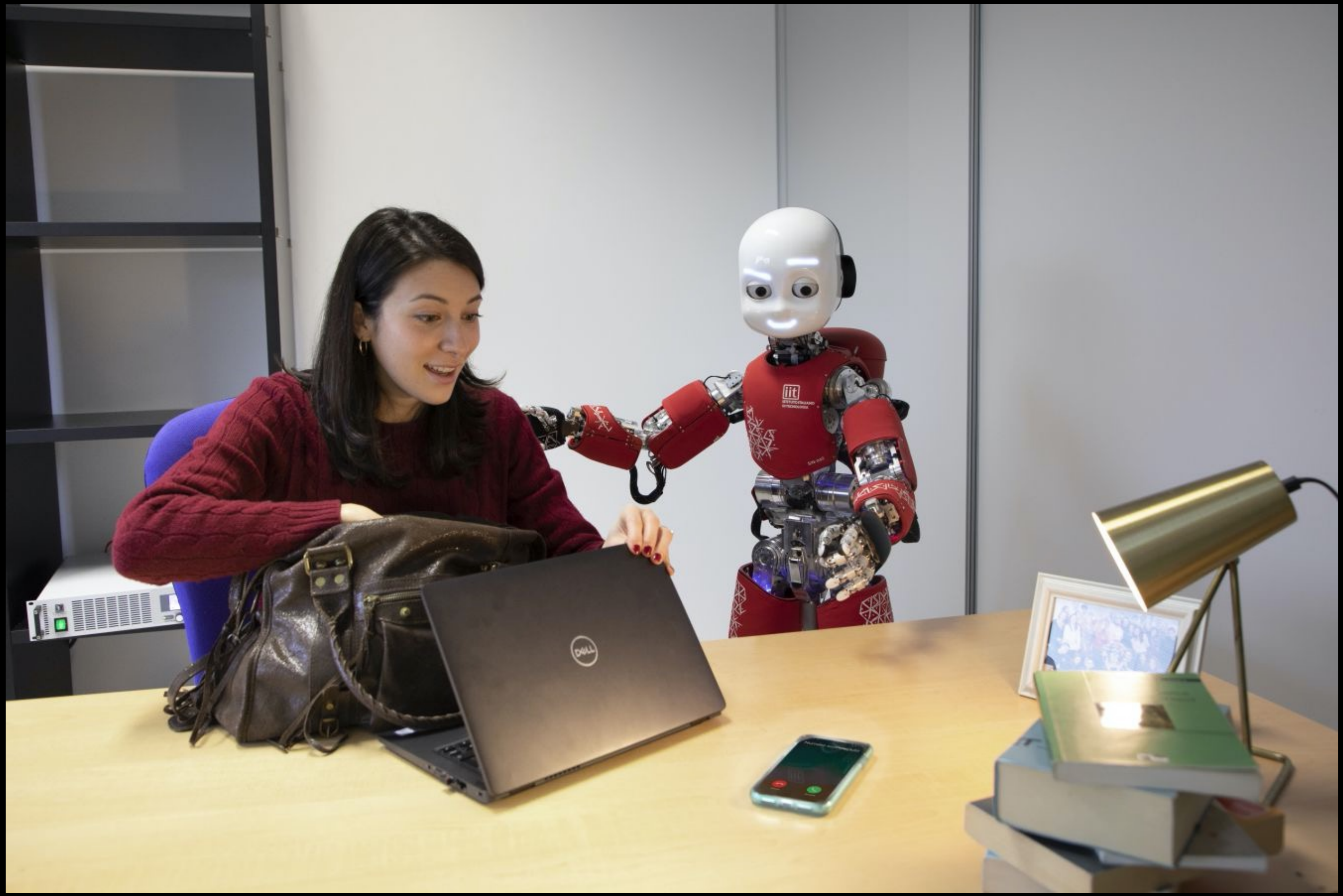


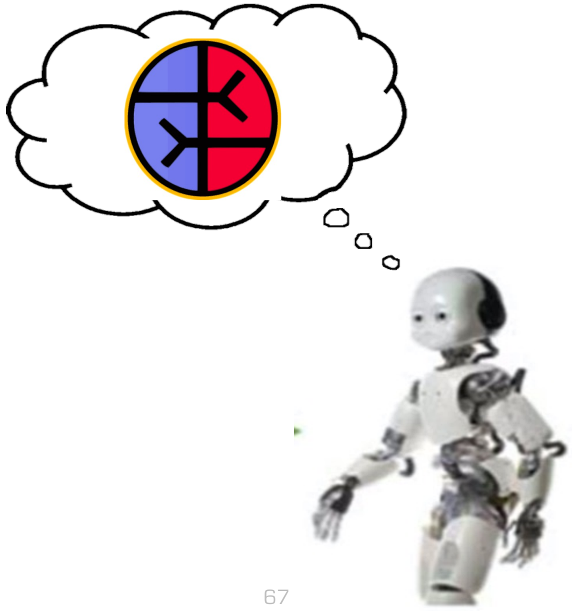
Sandini, G., A. Sciutti, and D. Vernon. Cognitive Robotics. In M. Ang, O. Khatib, and B. Siciliano (Eds.), Encyclopedia of Robotics. Springer, 2021.

"Robots need to "be considerate of people," i.e., maintain a model of humans in order to understand and predict human needs, intentions and limitations

...

robots need to use ways of communicating and cooperating that are intuitive for the human partner."

A. Sciutti, M. Mara, V. Tagliasco, and G. Sandini,
Humanizing Human-Robot Interaction:
On the Importance of Mutual Understanding,
IEEE Technology and Society Magazine,
37 (1), 22—29, 2018.

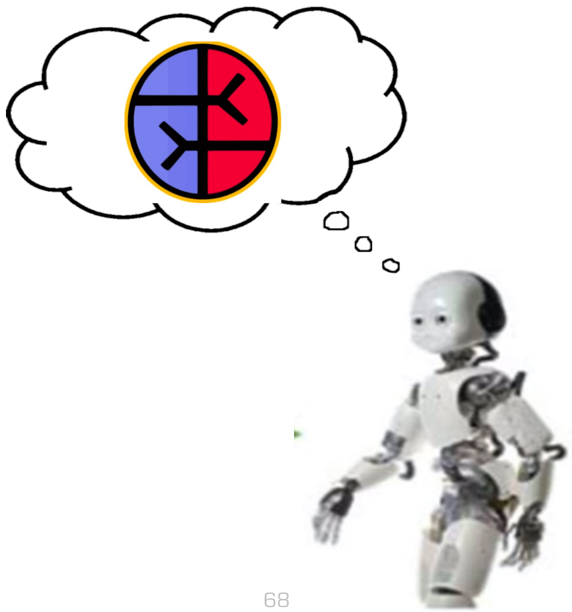


Empathy symbol from
www.EmpathySymbol.com

"The highest form of knowledge is empathy,
for it requires us to suspend our ego and live in another's world"

George Eliot

Pen name of Mary Ann Evans



Empathy symbol from
www.EmpathySymbol.com

Cognitive Robotics

An introductory course for the IEEE Robotics and Automation Society Technical Committee for Cognitive Robotics

Instructors: send an email to request the complete set of PowerPoint slides. Example code is available on Github.
If you already have a copy, check the Version History to make sure you have the most recent version. If you don't, please send an email to request it.

A PR2 robot pours popcorn from a saucepan (left) and sets a table (right) during demonstrations of cognitively-enabled robot manipulation using CRAM.
Image courtesy of the Everyday Activity Science and Engineering (EASE) interdisciplinary research center at the University of Bremen, Germany.

Course Description | Learning Objectives | Content | Lecture Notes | Course Textbook | Recommended Reading | Software | Resources | Acknowledgements

Cognitive Robotics

"The word cognition derives from the Latin verb *cognosco*, a composition of *con* (meaning related to) and *gnosco* (to know). Cognitive robotics, then, is the branch of robotics where knowledge plays a central role in supporting action selection, execution, and understanding.

It focuses on designing and building robots that have the ability to learn from experience and from others, commit relevant knowledge and skills to memory, retrieve them as the context requires, and flexibly use this knowledge to select appropriate actions in the pursuit of their goals, while anticipating the outcome of those actions when doing so.

Cognitive robots can use their knowledge to reason about their actions and the actions of those with whom they are interacting, and thereby modify their behavior to improve their overall long-term effectiveness.

In short, cognitive robots are capable of flexible, context-sensitive action, knowing what they are doing and why they are doing it."

Sandini, G., Sciutti, A., and Vernon, D. (2021) "Cognitive Robotics", in Ang M., Khatib O., Siciliano B. (eds), *Encyclopedia of Robotics* . Springer, Berlin, Heidelberg.

www.CognitiveRobotics.net

A More Detailed Definition of Cognitive Robotics

"The word cognition derives from the Latin verb cognosco, a composition of con (meaning related to) and gnosco (to know). Cognitive robotics, then, is the branch of robotics where knowledge plays a central role in supporting action selection, execution, and understanding.

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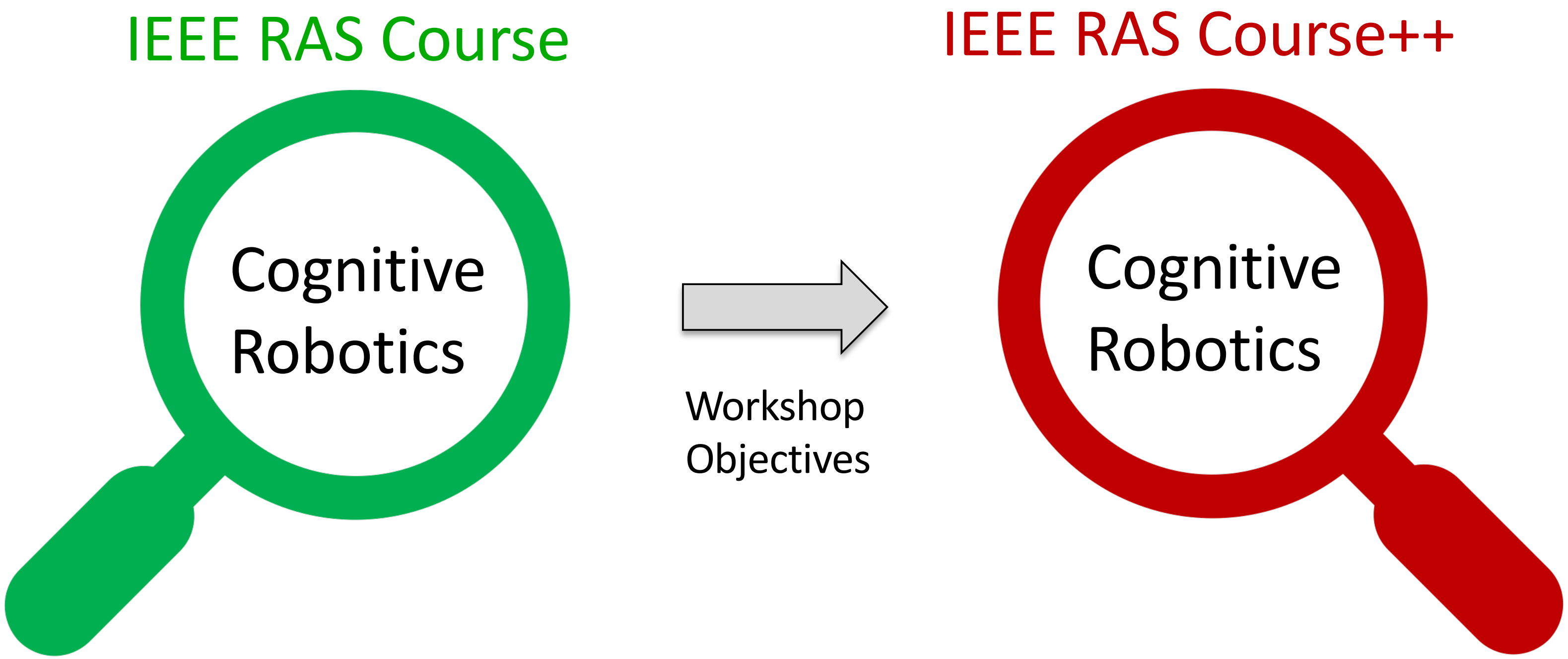
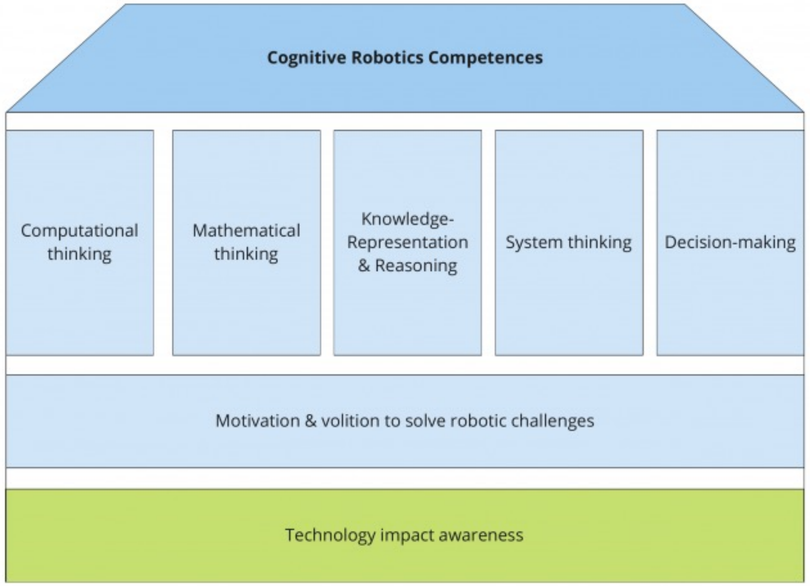

IEEE RAS Course
Cognitive Robotics
Workshop Objectives
IEEE RAS Course++
Cognitive Robotics

Workshop Objectives

1

Competences of Cognitive Roboticists
System thinking, computational thinking, mathematical thinking, decision making, technology impact awareness, active learning



Workshop Objectives

1

Competences of Cognitive Roboticists
System thinking, computational thinking, mathematical thinking, decision making, technology impact awareness, active learning

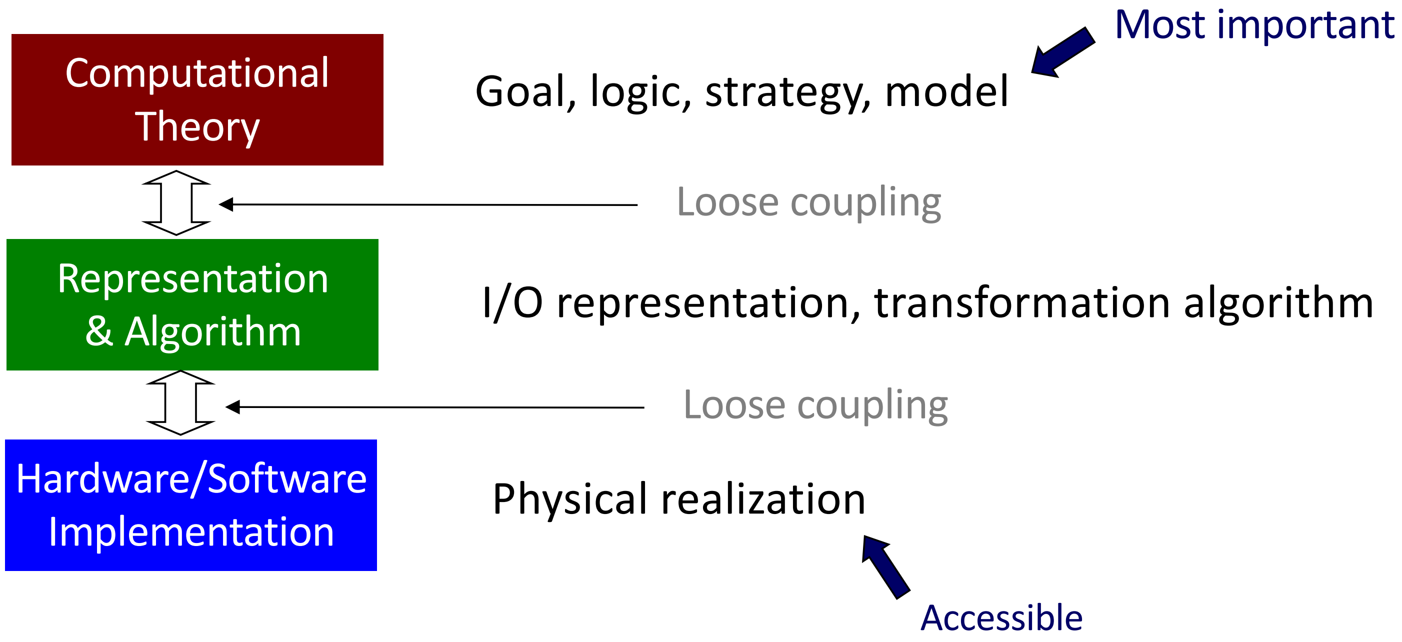
"Ten Unsafe Assumptions When Teaching Topics in Software Engineering" (Vernon, 2020)

It is unsafe to assume that students can ...

1. Understand how to decompose problems
2. Know that systems have to be specified at different levels of abstraction
3. Know how to bridge different levels of abstraction
4. Understand how software and hardware reflect these different levels
5. Can follow instructions and pay attention to detail
6. Can easily follow oral or written explanations
7. Are able to stress test their own software
8. Understand the relevance of professional practice
9. Are adept at self-criticism
10. Understand the relevance of examples

Modelling Systems

Marr’s hierarchy of abstraction / levels of understanding framework



Workshop Objectives

1

Competences of Cognitive Roboticists
System thinking, computational thinking, mathematical thinking, decision making, technology impact awareness, active learning

2

To Understand how Cognitive Robotics can be Taught
Constructive alignment, i.e., align **teaching** and **assessment** with learning outcomes (Bloom's Taxonomy). Research-focused teaching.

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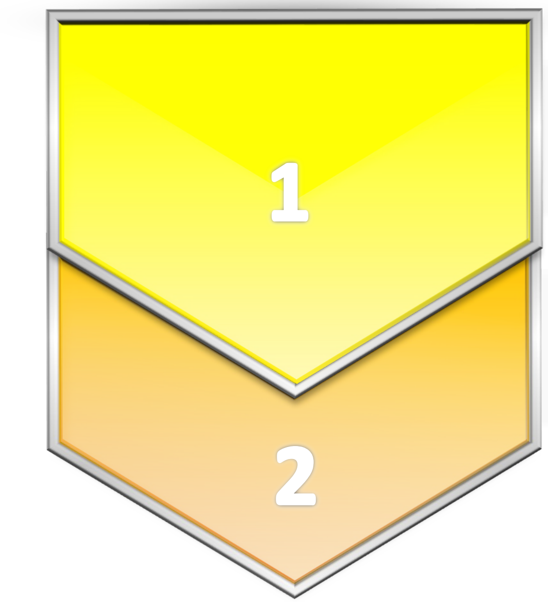

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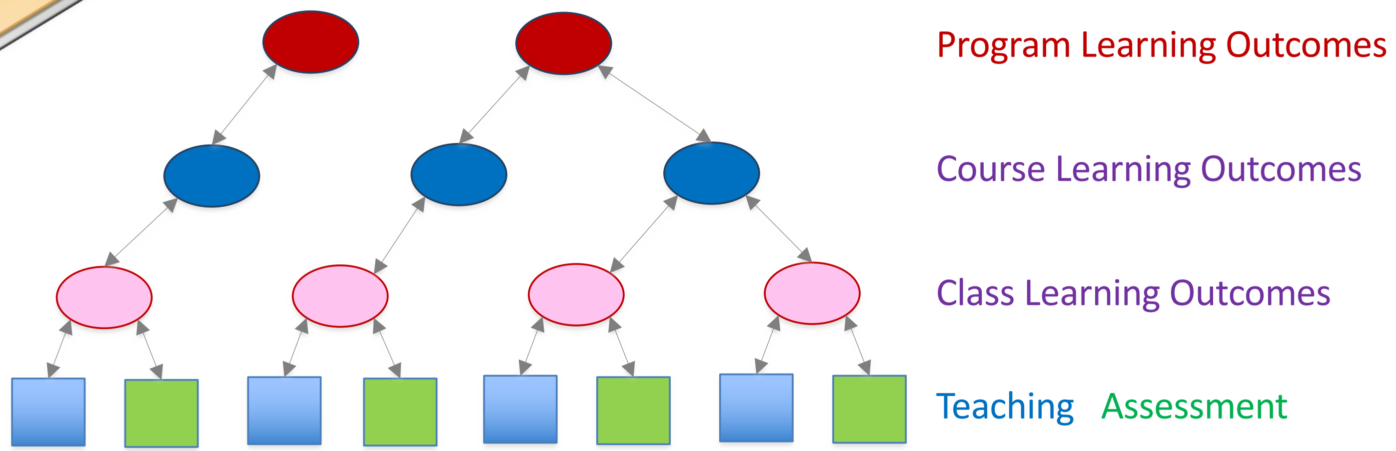

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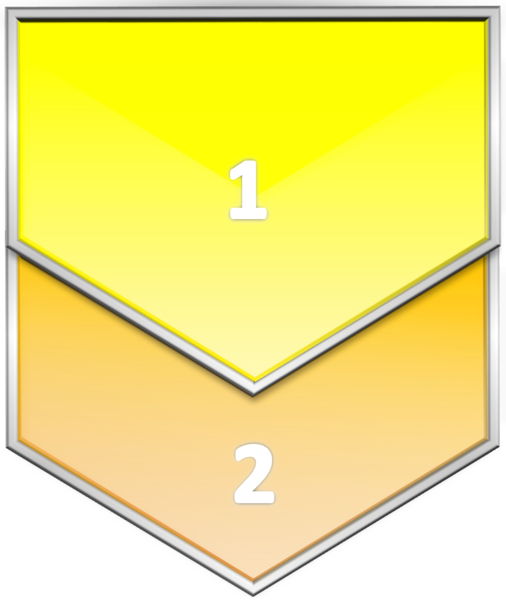
Teaching Foundations First vs. Teaching at & beyond the state of the art

Students (and teachers) need a roadmap

Workshop Objectives



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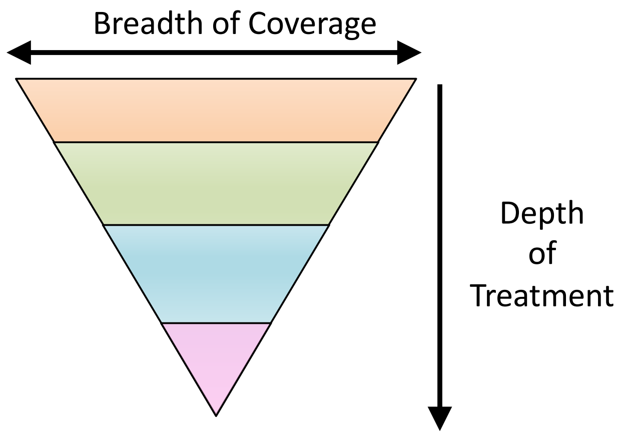
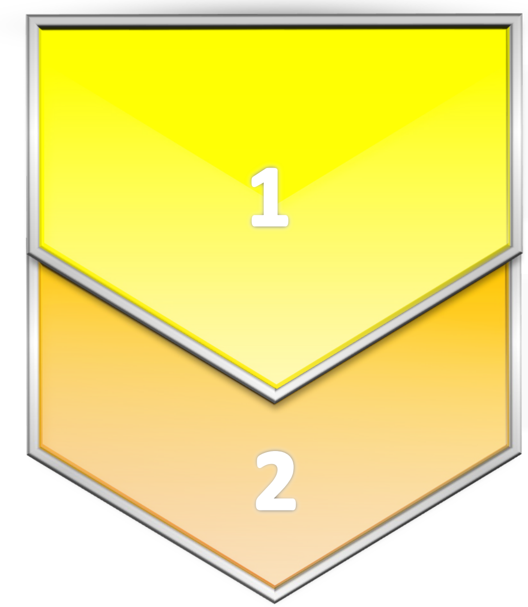


Progressive Deepening

Workshop Objectives



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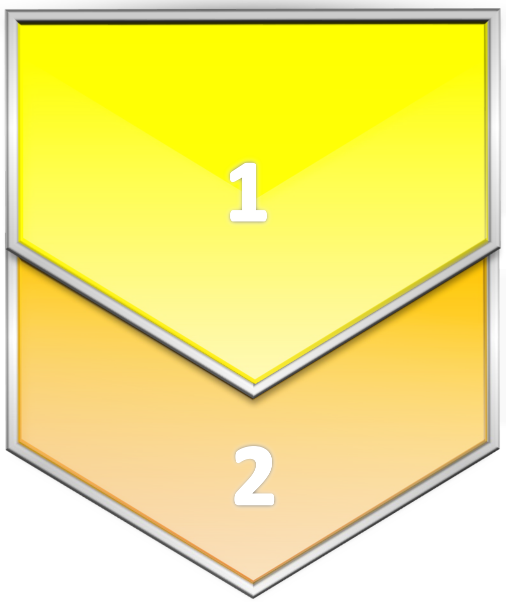
There are “known knowns,” “known unknowns,” and “unknown unknowns”

- known knowns: Things we know we can do
- known unknowns: Things we know we can't do yet
- unknown unknowns: Things we have no idea about. Opportunities here

Workshop Objectives

"One thing a person cannot do, no matter how rigorous his analysis or heroic his imagination, is to draw up a list of things that would never occur to him."

Thomas Schelling
Nobel Prize winner
in economics



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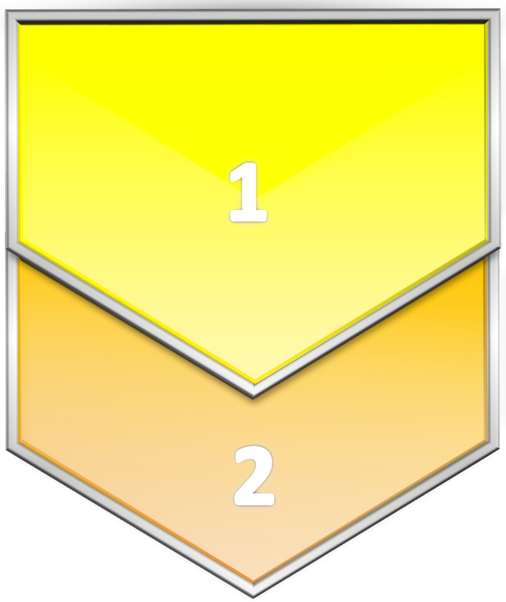

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Multidisciplinary ResearchTeams

Workshop Objectives

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System thinking, computational thinking, mathematical thinking, decision making, technology impact awareness, active learning.

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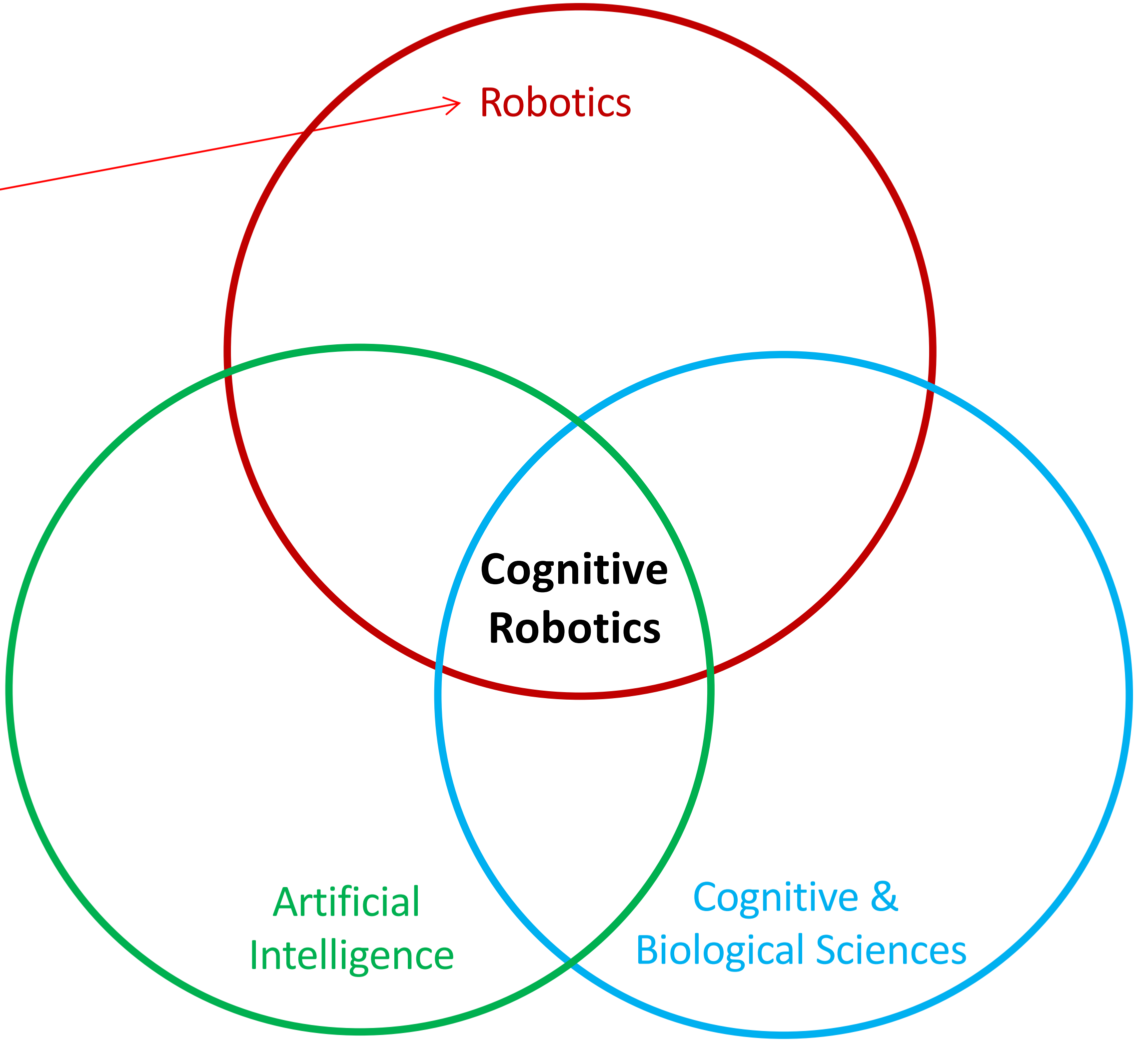
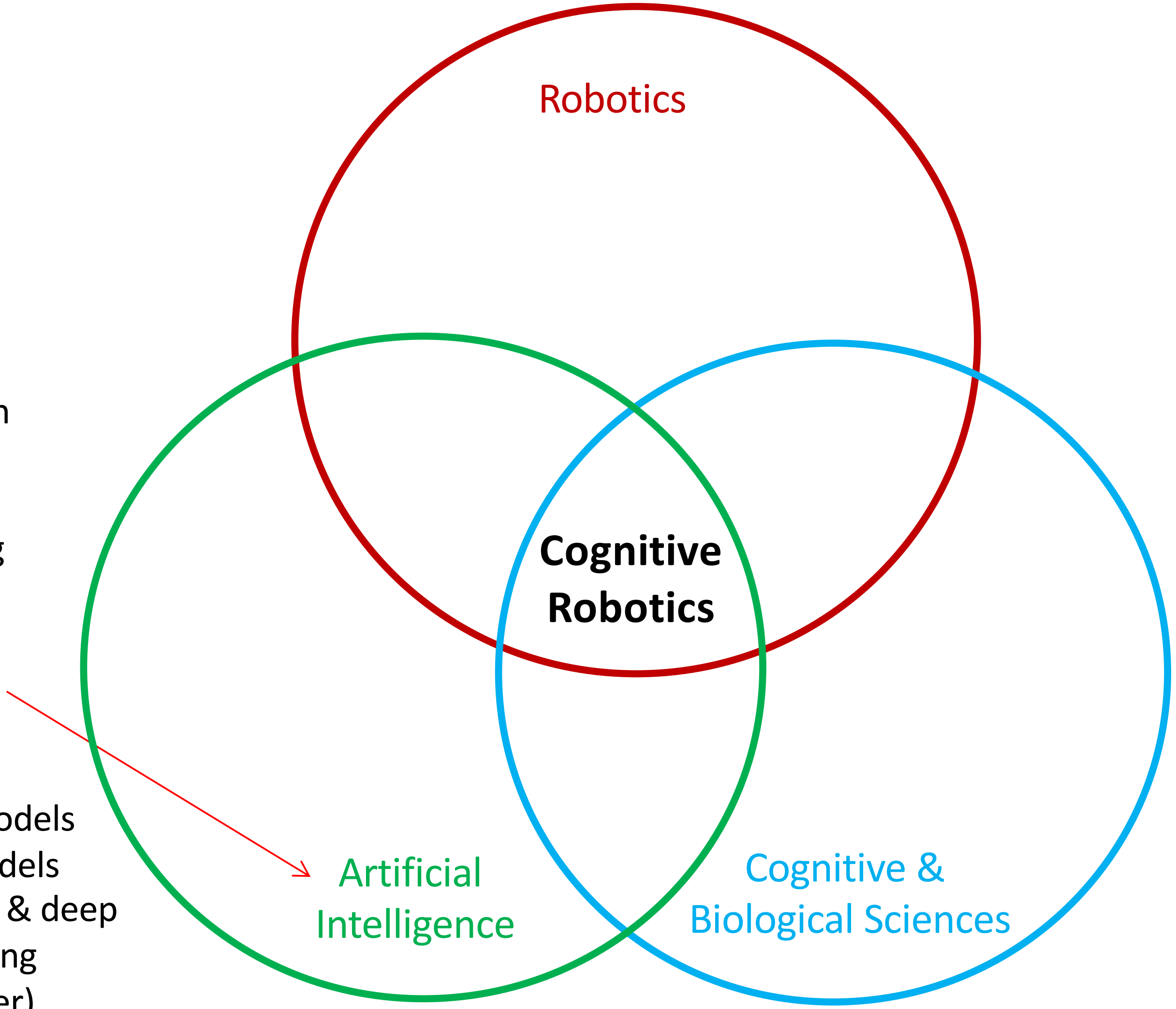
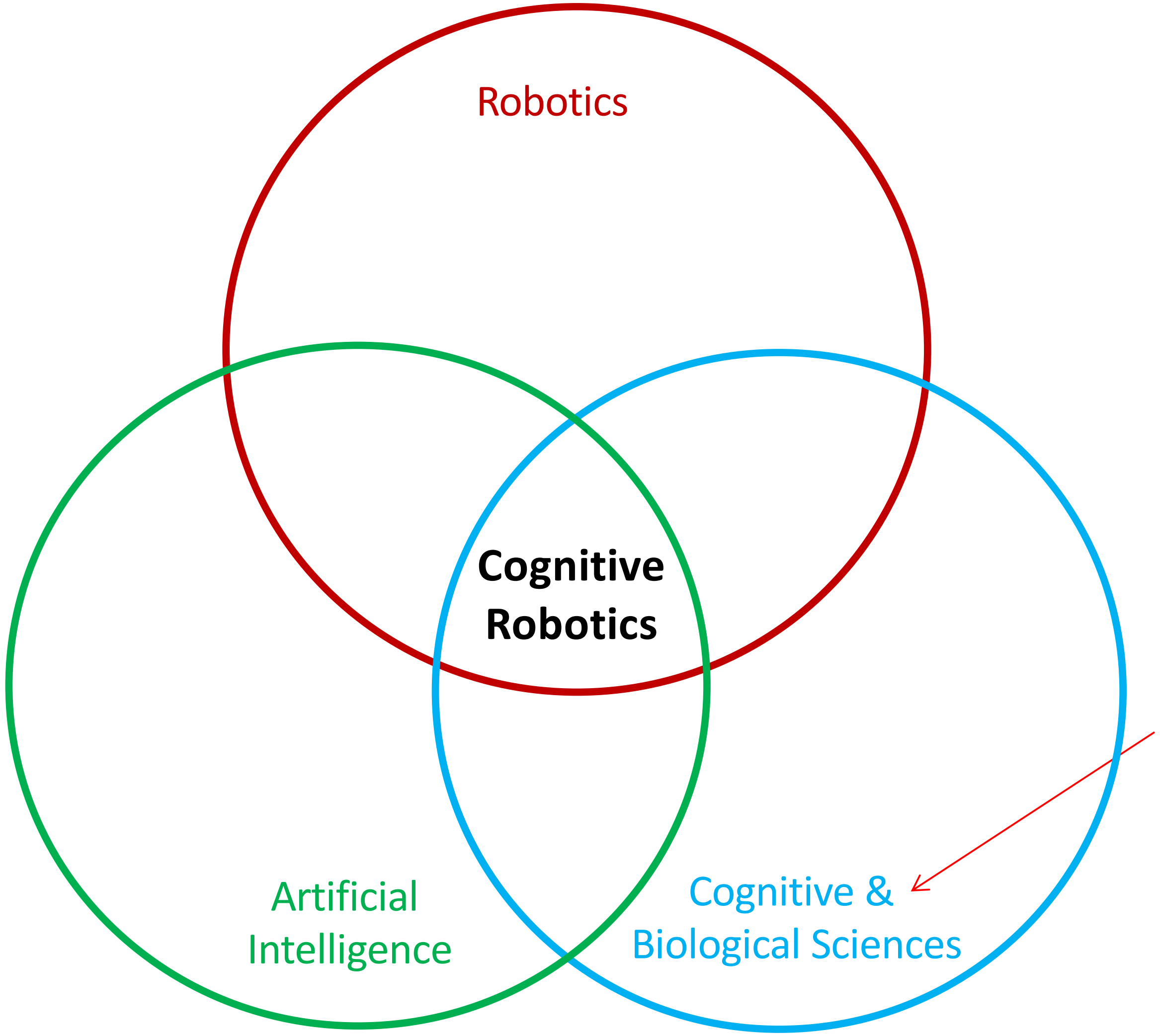
3. **How Can We Create a Cognitive Robotics Competence-aware Curriculum**
Identify the topics that span the space of cognitive robotics.
Decide on the program- or course-dependent depth of treatment

Linear algebra
Calculus
Actuators
Effectors
Sensors
Control
Kinematics
Dynamics
Locomotion
Navigation
SLAM
Vector & quaternion
  pose specification
Manipulation
Planning
Social robotics
Human-robot interaction
...



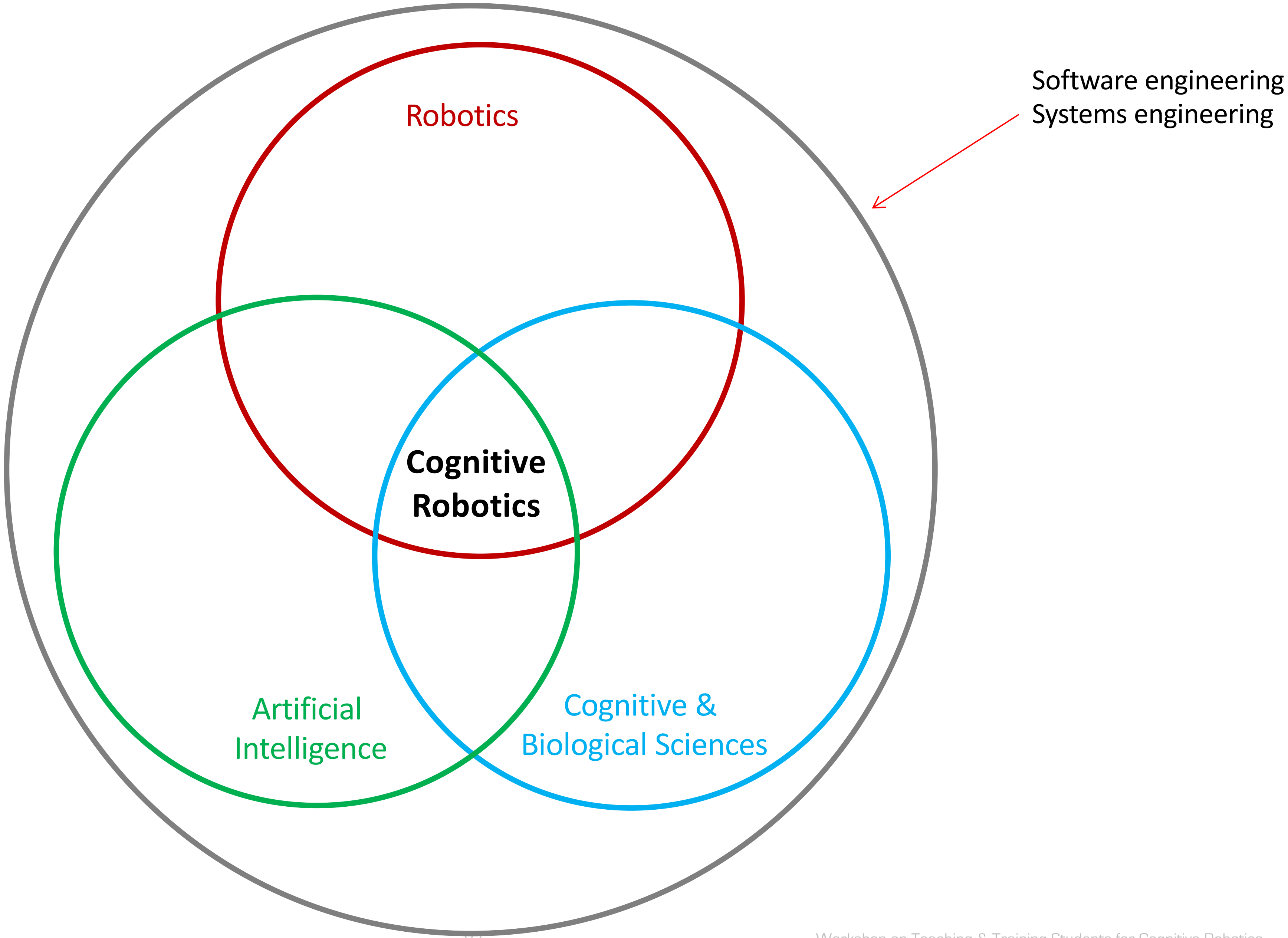
Knowledge representation
Reasoning
Inference
Classical machine learning
Deep machine learning
Reinforcement learning
Supervised learning
Unsupervised learning
Self-supervised learning
Vision-language-action models
Probabilistic graphical models
Computer vision, classical & deep
Natural language processing
Cybernetics (1^{st} & 2^{nd} order)
Unified theories of cognition
Cognitive architectures x n
...





Cognitive science
Neuroscience
Developmental psychology
Social science
Ethnography
...

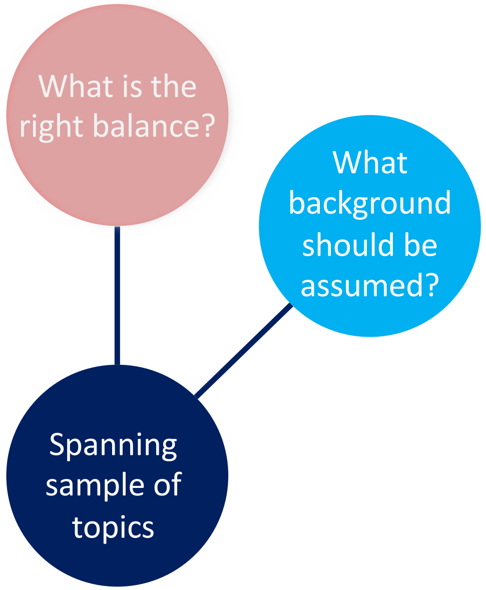
Unified theories of cognition
Cognitive architectures x n
Semantic memory
Procedural memory
Episodic memory
Working memory
Associative memory
Dual process theory: system 1 & 2
Theory of mind
Joint action
Joint attention
Shared intention
Shared goals
Biological motion
Non-verbal, verbal communication
Autonomy
Self-organization
Emergence
...

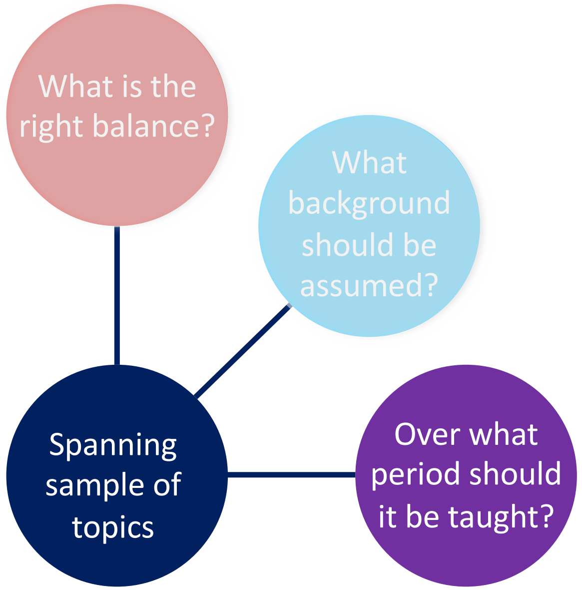

Robotics
Cognitive Robotics
Artificial Intelligence
Cognitive & Biological Sciences
Software engineering
Systems engineering

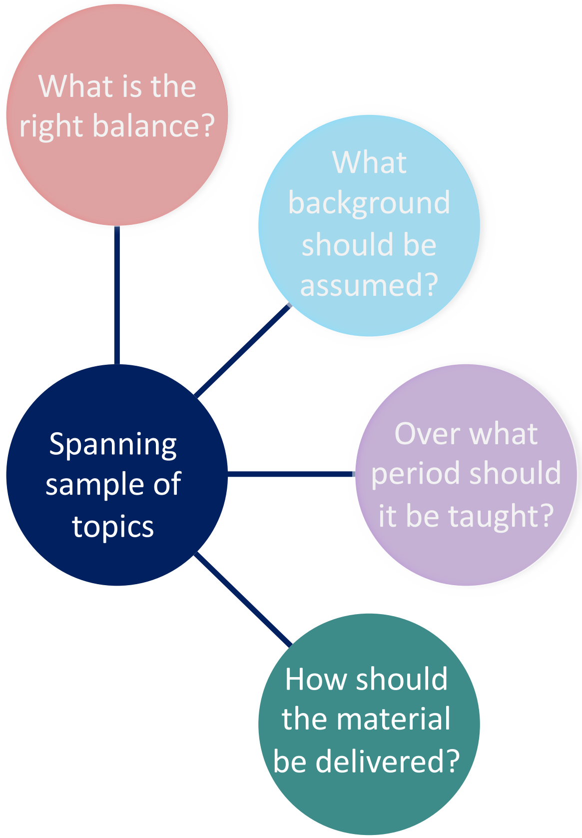
Spanning sample of topics

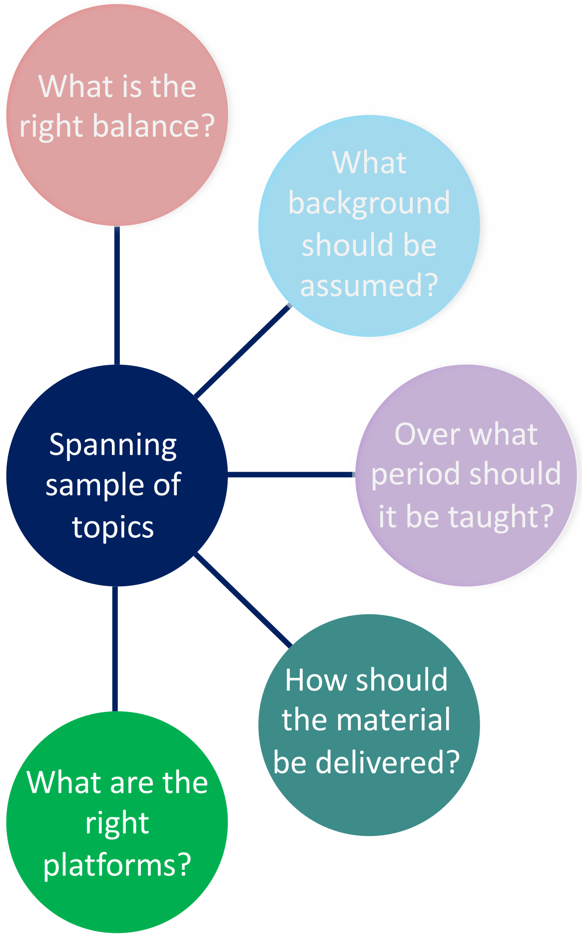
What is the right balance?

Spanning sample of topics


What is the right balance?
What background should be assumed?
Spanning sample of topics


What is the right balance?
What background should be assumed?
Spanning sample of topics
Over what period should it be taught?


What is the right balance?
What background should be assumed?
Spanning sample of topics
Over what period should it be taught?
How should the material be delivered?


What is the right balance?
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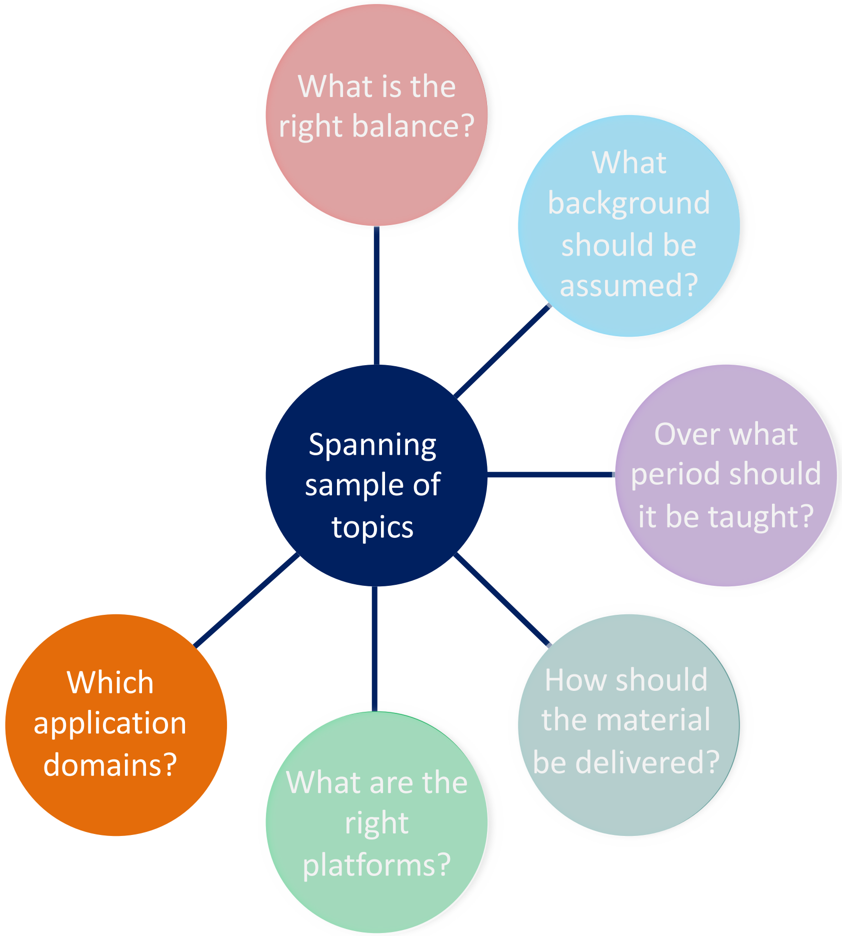
Spanning sample of topics
Over what period should it be taught?
How should the material be delivered?
What are the right platforms?


What is the right balance?
What background should be assumed?
Over what period should it be taught?
How should the material be delivered?
What are the right platforms?
Which application domains?
Spanning sample of topics


What is the right balance?
What background should be assumed?
Over what period should it be taught?
How should the material be delivered?
What are the right platforms?
Whics application domains?
How much HRI?
Spanning sample of topics


What is the right balance?
What are the superordinate goals?
What background should be assumed?
How much HRI?
Spanning sample of topics
Over what period should it be taught?
Whics application domains?
What are the right platforms?
How should the material be delivered?

Workshop Objectives

1. **Competences of Cognitive Roboticists**
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Embrace interdisciplinarity

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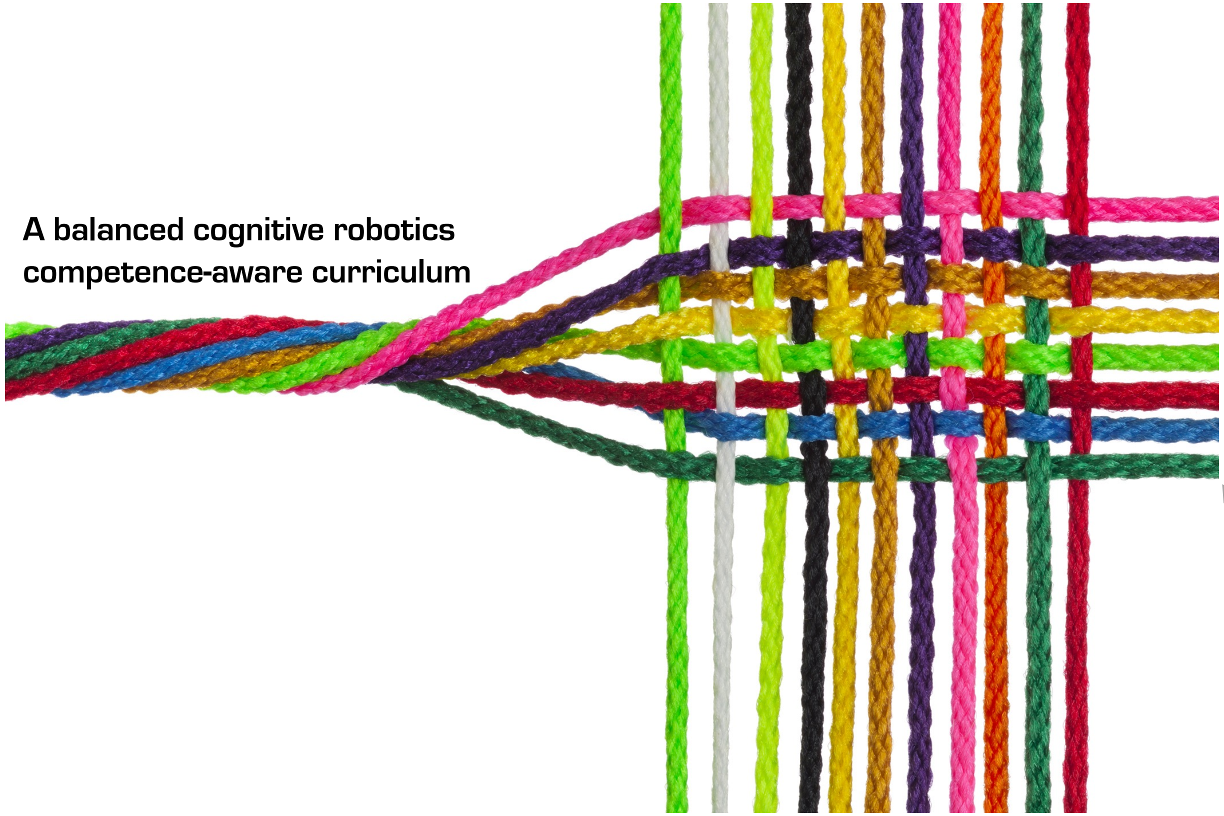
~~Embrace interdisciplinarity~~

Be scientifically empathetic of each other's complementary perspectives

Spanning sample of robotics, AI, and cognitive & biological science topics

A balanced cognitive robotics competence-aware curriculum



https://fashion-history.lovetoknow.com/fabrics-fibers/weave-types

Systems engineering

Computational modelling

Mathematical modelling

Decision making

Awareness of societal need & technology impact

Active, outcome-driven learning

Spatial reasoning

Critical appraisal
(e.g., Transformer VLA models can't solve everything)

Teaching & Training Students for Cognitive Robotics
IROS 2023
1st October 2023

Experience in Teaching Cognitive Robotics

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