Cognitive Development and Architectures for Cognitive Robotics

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A key feature of humans is the ability to entertain models of other agents, to anticipate what they are going to do and to plan accordingly a collaborative action. Analogously the focus of cognitive robotics is on predictive capabilities: being able to view the world from someone else's perspective, a cognitive robot can anticipate that person's intended actions and needs. Hence, a fundamental aspect of cognition, both natural and artificial, is about anticipating the need for action and developing the capacity to predict the outcome of those actions. But how does this capability develop in humans and how can it be developed in robots?

The goal of this symposium is to address these questions by investigating aspects of cognitive development through the development of cognitive robots. The discussion will focus on what is a cognitive architecture, on how predictive learning could lead to social cognition, and how bio-inspired cognitive architectures in robotics could prove fundamental for (physical) interaction. The session will start with an overview on artificial cognitive architectures by Professor David Vernon (University of Skövde), followed by talks on different aspects of cognitive robotics with a focus on learning and development by selected speakers as Professor Yukie Nagai (Osaka University) and Professor Jochen Steil (Bielefeld University). Professor Giulio Sandini (Istituto Italiano di Tecnologia) and Professor Minoru Asada (Osaka University) will chair the session providing an introduction and a link between the different perspectives of developmental cognitive robotics and discussing its relevance for a multidisciplinary understanding of cognition.

This symposium is part of the CODEFROR project (COgnitive Development for Friendly RObots and Rehabilitation, https://www.codefror.eu/), which aims at joining the forces and expertise of the participating partners (Italian Institute of Technology, Bielefeld University, Osaka University and Tokyo University) to help the establishment of an international community of researchers that shall effectively bridge the expertise of the different disciplines as robotics and cognitive sciences in the investigation of cognitive development.

Introduction on cognitive robotics

Giulio Sandini

In this talk I will introduce the symposium by presenting how the study of artificial intelligent systems has evolved from addressing separately the sensory, motor and cognitive aspects of intelligence to an integrated "embodied" approach. Using examples from our current studies of visually driven human-robot interaction and human sensorimotor development I will explain how this change of perspective is now building a new scientific community composed of robotics engineers and neuroscientists studying the central role of the body in mediating the integration between multiple sensory representations of space and actions.

Artificial cognitive systems

David Vernon

This talk offers a review on the emerging field of artificial cognitive systems. Cognition, both natural and artificial, is about anticipating the need for action and developing the capacity to predict the outcome of those actions. Drawing on artificial intelligence, developmental psychology, and cognitive neuroscience, the field of artificial cognitive systems has as its ultimate goal the creation of computer-based systems that can interact with humans and serve society in a variety of ways. In this talk a working definition of cognitive systems will be provided—broad enough to encompass multiple views of the subject and deep enough to help in the formulation of theories and models. Moreover, a brief survey of the different paradigms of cognitive science - the cognitivist, emergent, and hybrid paradigms will follow. These definitions will enable a discussion of the broad range of existing cognitive architectures, which represent the effective blueprints for implementing cognitive systems. The aim of the talk is to provide an understanding of the scope of the domain, the different perspectives and their underlying differences, to gain an idea of the issues that need to be addressed when attempting to design an artificial cognitive system

Predictive learning as a key for cognitive development: New insights from developmental robotics

Yukie Nagai

Human infants acquire various cognitive abilities such as self/other cognition, imitation, and cooperation in the first few years of life. Although developmental studies have revealed behavioral changes in infants, underlying mechanisms for the development are not fully understood yet. We hypothesize that predictive learning of sensorimotor information plays a key role in infant development. To verify the hypothesis, we have proposed computational models for robots to learn to acquire cognitive functions. Predictive learning is defined as a process to minimize a prediction error between an actual sensory feedback and a predicted one. For example, the prediction error of the self's body should become zero because the state change of the self can be perfectly predicted after learning. In contrast, the body of other individuals produces a prediction error due to the influence of a context even after learning. Infants therefore can discriminate the self from others based on the prediction error. Social behaviors such as imitation and cooperation may emerge through the process of minimizing the prediction error. A failure in others' action induces a larger prediction error and thus triggers the execution of infants' own action to reduce the error, which results in the accomplishment of the failed action. My talk will present our robotics studies investigating how infants acquire the ability of self/other cognition, goal-directed action, and altruistic behavior. Furthermore, a potential of our hypothesis to understand the mechanism of autism spectrum disorders (ASD) will be explained.

Biomorphic control as key for cognitive soft robotics

Jochen Steil

The new scientist describes it as: " I AM in Jochen Steil's lab, grasping a segmented, whiplashing tentacle that resists and tries to push me away. It feels strangely alive, as though I am trying to throttle a giant alien maggot. In fact, I am training a bionic elephant's trunk to do real-world jobs like picking apples or replacing light bulbs – something non-experts haven't been able to do until now." (Paul Marks, 13.03.2014).

The talk presents the scientific work behind this experience with the futuristic bionic handling assistant (BHA) soft robot, which indeed was modelled after an elephant's trunk by its producer FESTO. The BHA is a large-scale pneumatically operated, flexible, soft and compliant continuum robot, which is inherently safe to interact with. We show how to use advanced learning methods to establish a proper mixture of adaptive controller approximations, and autonomous exploration for this challenging platform. We discuss how by means of a coherent software architecture this biomorphic control is enabled and how it can be a blueprint for more general cognitive architectures in softer robots for performing actual grasping tasks, kinesthetic teaching, and accelerated online-learning in physical interaction.

Conclusion: Affective and cognitive developmental robotics

Minoru Asada

This talk will conclude the symposium by reviewing and discussing the different approaches proposed. Moreover it will introduce the concept of Affective and Cognitive

Developmental Robotics, aimed at understanding human affective and cognitive developmental processes by synthetic or constructive approaches. Its core idea is "physical embodiment," and "social interaction" that enables information structuring through interactions with the environment. Finally, future issues involved in the development of a more authentic form of artificial cognition and empathy will be discussed.

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