Special Session: Training in Robotics for Development of Cognition (RobotDoC)

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I. Introduction to Special Session

This special session will present recent advances in robotic modelling of cognitive development as well as behavioural studies with implications for robotics. It summarises the main results of the European Marie Curie doctoral training network RobotDoC. The special session is part of the co-located RobotDoC Conference that will be held in Osaka on August 16-18.

Research in the RobotDoC training network specifically focuses on interdisciplinary approaches to developmental cognitive robotics (Asada et al., 2001; Cangelosi & Schlesinger, to appear). In particular, we present here a syncretic overview of new models and experimental results in: (i) Dimensionality reduction for efficient motor control and new hardware implementations for sensorimotor systems, (ii) using sensorimotor representations for developing adaptive robots and for grounding abstract knowledge, (iii) social attention and visual action prediction for interactive robots, and (iv) developmental approaches to social interaction and robot feedback in human-robot interaction. Moreover, we will discuss insights and lessons learned on training methodology for researchers in developmental robotics.

II. Advances in Designing Hardware and Modelling for Motor Control

C. Alessandro, N. Kuppuswamy, C. Li, W. Sieklicki,

Embodied agents perceive and operate in the environment using their sensorimotor systems. Research presented in this session focuses both on the control mechanisms that, relying on such apparatus, regulate the movements of the agent, and on novel hardware implementations of such systems. With respect to hardware design, a 1-axis torque sensor was designed to minimize force readouts hysteresis and non-linearities; such sensors will be embedded in the iCub robot to support joint-level force control. Additionally, two rehabilitation systems for human fingers as well as the human-machine-interface for a teleoperated artificial hand were designed and will be presented. In the context of motor control, all the studies that will be discussed are motivated by the same fundamental question: which mechanisms does the central nervous system (CNS) employ to cope with the complexity of the musculoskeletal system? The framework of control dimensionality reduction is used to analyse formally the long-standing hypothesis that the CNS regulates only a reduced number of variables (Bernstein, 1967). In particular the roles of the task and body properties on dimensionality reduction are analysed. Two specific forms of dimensionality reduction observed in biological organisms, muscle synergies (Tresch & Jarc, 2009) and central pattern generators (CPG, McCrea & Rybak, 2007), are examined in detail. A mathematical formulation of the hypothesis of muscle synergies will be presented. Such a model provides various insights on this hypothesis, and it proves successful in controlling a simulated kinematic chain. Finally, a neural network-based implementation of a CPG is proposed to allow the NAO robot to learn to walk on different slopes.

III. Sensorimotor Information for Concrete and Abstract Knowledge Representation

N. Navarro-Guerrero, M. Rucinski, F. Stramandinoli, J. Zhong

The dream of seamless interaction between humans and robots requires understanding of agent's biomechanics, motion control and cognitive (subcortical and cortical) processes. In this session we focus on the latter. We argue that sensorimotor information is important not only for motor control but also for internal regulation of states and for high-order cognitive processes. The first discussed experiment focuses on sensory percepts essential for agents' self-protection and adaptation. We use a minimal set of interoceptive signals, such as hunger and pain, to drive energy-seeking and other self-protective behaviours based on fear learning. Although many such behaviours are innate or hard-wired they are insufficient to cope with highly dynamic environments. We present how fear-based online learning enables robots to safely cope with domestic environments. The second experiment addresses the challenge of generating timely responses in dynamical and unconstrained environments, due to the delay produced by sensory information processing, decision-making and final action execution. We address the role of predictive circuits at the sensor information level and how these predictions are used to produce faster and smoother reactions. Finally, we discuss the role of sensorimotor representations in hierarchical knowledge building and grounding of abstract words. Specifically, we investigate how proprioceptive information such as pointing gesture aids numerical representation in early development stages and how spatial representation remains coupled to the learned numerical representation. We also show how sensorimotor skills and experience grounded in primitive actions, such as reaching and grasping, can be hierarchically subsumed, enabling the abstract language to emerge.

IV. NEW ATTENTION MODELS AND PSYCHOPHYSICAL STUDIES FOR SOCIAL LEARNING

N. Wilkinson, C. Elsner, K. Kiryazov, N. Vikram

Taking the action-oriented stance on social cognitive development implies encountering the topics of attention, motivation, affect and prediction. We have been looking to the embodied beginnings of social attention in newborns, finding that innate knowledge of the “like-me” is embedded in the sampling regime implied by sensory morphology. In one study, a face naive iCub robot reproduced face preferences observed in human newborns (Johnson et al., 1991). Other work has shown how socially naive exploratory eye movements can enact socially sensitive perceptual distinctions. Simultaneously, we have taken a computational perspective, developing visual attention algorithms based on random sub-sampling, and methods for facial emotion recognition. A number of widely used salience models were compared against real infant looking behaviour, with results indicating that current visual attention models are far from complete. Indeed, social interaction is highly dependent upon, and causal of, affective state in humans. We have been exploring the grounding of appraisal theoretic models of motivation and affect in metabolic process and energetic requirements, finding that “artificial emotions” can improve efficiency both in learning from human-robot interaction and in managing limited resources. Such social and organismic effects are rarely considered in attention models. In psychophysical studies, we have investigated details of predictive action observation. An adult study employed TMS to investigate the role of task-relevant motor cortex in goal prediction. The results provide strong evidence of a causal connection between task-associated motor activity and visual action prediction. Together, these findings shed light on mechanisms and developmental processes underlying social instinct, learning, cognition and interaction.

V. FACETS OF INTERACTION: INSIGHTS FROM DEVELOPMENTAL AND ROBOTIC RESEARCH

A. Handl, K. Lohan, J. Szufnarowska, A-L. Vollmer

In order to engage with others, infants need to both perceive and interpret their communicatory signals (Csibra, 2010). The field of developmental robotics draws its inspiration from these early social learning processes (e.g. Lungarella & Metta, 2003). We introduce recent work from both developmental and robotic research that focuses on different aspects of social interactions. In the first part of the talk, we look at the developmental side of the coin. Recent findings have shown that mothers use, among other practices, contingent multimodal stimulation when interacting with their 3- and 6-month-old infants. In turn, infants are giving feedback that provides their interlocutors with cues about their understanding. Furthermore, from 9 months onwards, infants use others’ body orientation as a cue to understand interactions. In the second part, we focus on two studies investigating how naive users are influenced by feedback from and beliefs about their robot interaction partner. In both studies, human participants interact with a humanoid robot, the iCub robot. The first study examines if and to what extent human users align their own actions to iCub's actions. The second study focuses on the iCub’s attention to the user and the usage of communicative cues in, for example, its keyword spotting system as a feedback mechanism. This talk informs about the variety of work on interaction within the RobotDoC project across methodologies and disciplines.

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