Embodied Cognition and Robotics Approaches to Human Cognition and Learning

Chen Yu (chenyu@indiana.edu)
Department of Psychological and Brain Sciences, and Cognitive Science Program,
Indiana University, Bloomington, IN, 47405 USA

Brian Scassellati (scaz@cs.yale.edu)
Department of Computer Science
Yale University, New Haven, CT 06520-8285 USA

Recent studies in both human learning and machine intelligence show that the world and social signals encoded in multiple modalities play a vital role in learning. For example, young children are highly sensitive to correlations among words and the physical properties of the world (see an example in Smith, Jones and Landau, 1996). They are also sensitive to social cues and are able to use them in ways that suggest an understanding of speaker's intent (e.g., Tomasello, 1992). One problem with the hypothesis that human learners utilize social-cognitive cues in everyday learning is that the empirical evidence is based on macro-level behaviors (e.g., head orientation or pointing) in constrained unnatural contexts (e.g. laboratory environments). To truly understand mechanisms of learning, however, we may need to focus on more micro-level behaviors (e.g., gaze and body position) as they unfold in real time, for example, changes in eye gaze and shifts in body position as they are linked to objects, events, and actions of the social partner. The studies at the macro-level demonstrated many intelligent behaviors in learning but they have not as yet led to a formal account of the underlying mechanisms. Thus, we want to know not only that learners use social cues but also *how* they do so in terms of the real-time processes in the real-time tasks in which authentic learning must take place.

A new trend in Cognitive Science is the use of artificial agents and systems to investigate learning and development of complex natural organisms in natural environments (Ballard, et al. 1997). Recent computational models, in contrast with traditional AI, take into account principles of neural function and development, elaborate afferent and efferent potentials, and most importantly the interactions between brain, body and environment, to test and falsify formal theories about specific emerging cognitive functions, and to measure and analyze a rich history of interaction in real time and space within highly diverse environments.

The value of this approach can be summarized as three research directions. First, one exciting line of inquiry in embodied modeling is generating formal models of the complexities of social and cognitive learning (Scassellati, 2002). By grounding high-level theories into robotic systems, we can address different aspects of how social-cognitive capabilities, such as gaze following and face preference, can be learned through sensorimotor interactions.

Second, with the advances in computer vision, speech processing and machine learning, now we have the capabilities to process visual, audio and other sensory data collected from real-world interactions (Yu, Ballard, & Aslin, 2005). In this way, we can measure and analyze physical and social regularities in real world. A better understanding of the learning environment can provide unique opportunities to study underlying mechanistic nature of human cognition and learning.

Third, artificial systems (e.g. physical robots and virtual humans) can interact with people in everyday contexts, which not only provides a way to enrich experimental methods but also has applied utilities. For example, embodied models (e.g. baby robots) can learn from adults (e.g. caregivers). For another example, teaching robots can interact with young children to facilitate their learning.

This tutorial will bring a set of researchers from multiple disciplines including computer science, cognitive science and psychology. We will introduce various computational techniques to study embodied cognition, from physical robots to virtual reality techniques, and from cognitive behavioral studies to computational modeling. The tutorial will inspire more cognitive scientists to utilize state-of-art computational and robot techniques to study human cognition and learning.

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