MVA2005 IAPR Conference on Machine VIsion Applications, May 16-18, 2005 Tsukuba Science City, Japan

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Cognitive Development of a Humanoid Robot

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Abstract

The role of technology for the study of brain functions has always been fundamental in providing new tools for the acquisition/analysis of biological data. However the increasingly complex picture of brain functions emerging from neuroscience research is now posing a new challenge: how to extend our knowledge beyond the scope of specific experiments and methodologies? Is it possible to find new tools enabling neuroscientists to verify new theories and to guide new experiments beyond the, now established, methods of mathematical modeling and systems theory? The reasons why we believe that this has to be pursued are, essentially, two: the first stems from the very high complexity and punctuated nature of our current knowledge of brain functions; the second is because the physical world (in a general sense) is far too complicate to be "simulated" realistically preventing an adequate pure mathematical testing of new theories and ideas.

Although simulating and getting inspiration from biological behaviors is certainly not a new endeavor in robotics [1, 4] and computer vision [2] to name a few, we have taken a novel direction which fully acknowledges the importance of embodiment and the interaction with the environment for the emergence of motor skills, perception, sensorimotor coordination, and cognition in its widest possible meaning [3]. In particular, the guiding philosophy – and main motivation – is that cognition cannot be hand-coded but it has to be the result of a developmental process through which the system becomes progressively more skilled and acquires the ability to understand events, contexts, and actions, initially dealing with immediate situations and increasingly acquiring predictive capabilities. As an example of this approach, we report about our investigation on action understanding in the brain [5,6,7]. We are taking here a three-pronged approach relying on recent results of neurophysiology, on modeling of human movement, and on the implementation of the model on a robotic setup interacting in a natural environment.

In the context of human cognition, implementing "artificial systems" as explicit physical models of biological ones requires the realization of humanoid robot systems. In particular, we thus focus on the use of humanoids as tools to understand human cognition and, more specifically, how adaptation develops through interaction with the external environment. Our reference framework is human sensorimotor and cognitive development and we approach the problems by trying to actually implement motor and cognitive abilities in the humanoid robot. Is it possible to "program" a system to "have cognition" as we program a robot to assemble a car? Is cognition similar to motor control and sensorimotor coordination? Do we know enough about our own cognitive abilities to transfer them into an artificial being? How do we interact safely and "intelligently" with other humans (and machines)? How do we predict the effects of our actions? How do we adapt our behavior to unpredictable situations? How do we anticipate what other humans are doing? Can all (or even some) of these abilities be hard coded into a humanoid robot? These are some of the questions we would like to find an answer for. Looking at natural systems it seems that it is not possible to pre-code cognitive and adaptive behaviors (we believe that adaptive behaviors cannot be pre-programmed).

In this talk we will claim that if future robots have to have cognitive abilities, they will have to go through a developmental progression similar to that observed in human babies. We will do that from a multidisciplinary perspective by presenting findings derived from studies of human motor and cognitive development as well as a robotic implementation of the first few months of "existence" of a robot-cub (Babybot). In doing so we will stress the consequences that this multidisciplinary approach has in discovering new technologies and the relevance that robotics research will continue to have as a research tool to understand human cognition.

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Acknowledgments: Research described here has been supported by grants from the UE: MIRROR, ADAPT, ROBOTCUB