Chapter 1

Biologically–Inspired Learning and Intelligent System Modeling

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ABSTRACT

Artifacts having to perform in the real world should be able to cope with uncertain situations and react quickly to changes in the environment. Living systems, starting from a pre-structured set of functions, develop competence to better adapt to the environment all life long, from childhood to maturity. This phenomenon is called growing up. A developmental intelligence for growing up robots must be able to generate autonomously representations for unknown knowledge and skills. Models of development can play an important role in specifying the minimal preferences, faculties, and processes needed for this skill to emerge. A perspective on the analysis of some adaptive learning processes originating from literature and experiments in natural world result in some suggestion intelligent system architecture modeling.

INTRODUCTION

Biological organisms have evolved to perform and survive in a world characterized by rapid changes, high uncertainty, indefinite richness, and limited availability of information. Industrial systems, in contrast, operate in highly controlled environments with no or very little uncertainty. Artifacts having to perform in the real world should be able to cope with uncertain situations and react quickly to changes in the environment. Over the last decade, a number of researchers have suggested a developmental perspective on artificial intelligence and robotics. The ultimate shared goal among them seems to be the idea of bootstrapping high-level cognition through a process in which the agent interacts with a real physical environment over extended periods of time (Kuniyoshi, Y. and Berthouze, L.. 1998; Metta, G. et al. 1999; Asada, M. et al., 2000). Although many challenges remain, concepts from biologically inspired (bio-inspired) artifacts can enable researchers to engineer machines for the real world that possess at least some of the
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desirable properties of biological organisms, such as adaptivity, robustness, versatility, and agility. Natural systems provide an exceptional source of inspiration. Given the vastness of the information available, the question arises as to what insights from biology could and should be exploited for designing robots. Simply copying a biological system is either not feasible (even a single neuron is too complicated to be synthesized artificially in every detail) or is of little interest (animals have to satisfy multiple constraints that do not apply to robots, such as keeping their metabolism running and getting rid of parasites), or the technological solution is superior to the one available in nature (for example, the biological equivalent of the wheel has yet to be discovered). Rather, to work out some principles of biological systems that can be in some way used as inspiration in robot design is very important. Epigenetic systems, whether natural or artificial, share a prolonged developmental process through which varied and complex cognitive and perceptual structures emerge as a result of the interaction of an embodied system with a physical and social environment. The usage of robots to instantiate and investigate models, originating from developmental psychology, and the necessity to design robotic systems with a better autonomy, adaptability and sociability by means of the application of the insights gained from the ontogenetic development studies are suggested. Interdisciplinary theory and empirical evidence are used to inform epigenetic robotic models, and these models can be used as theoretical tools to make experimental predictions in developmental psychology and other disciplines studying cognitive development in living systems. From one hand, biologists and psychologists can provide the detailed empirical findings and theoretical generalisations that can guide the implementations of robotic systems capable of cognitive development. On the other hand, these implementations can help in clarifying, testing, and even developing psychological theories, which, due to the complexity of the interaction processes involved, often cannot be exhaustively tested (Bertouze, L. and Prince, C.G. 2003). Biologically motivated intelligent computing has in recent years been successfully applied to solving complex problems. Biological organisms have evolved to perform and survive in a world characterized by rapid changes, high uncertainty, indefinite richness, and limited availability of information. Industrial systems, in contrast, operate in highly controlled environments with no or very little uncertainty. Artifacts having to perform in the real world should be able to cope with uncertain situations and react quickly to changes in the environment. New approaches where intelligence is not given to the system from outside, but is acquired by the system through learning, have proven much more successful.

BACKGROUND

One of the fundamental methodological assumptions is, that cognition is embodied, which means that it arises from bodily interactions with the world and that it is continuously meshed with them (Lakoff, G. and Johnson M. 1980; Johnson, M. et al. 1998; Varela F.J. et al., 1991, Lungarella M. et al.2001). In other words, thinking emerges from real life experiences, from sensory-motor coordinated interactions, and from exploration of the surrounding environment. Robotic models are fundamentally preferable to standard computer models for capturing distributed cognition and/or social interaction. Computer models, indeed, make many more presumptions about how information about the world is reduced, encoded, and represented. The environmental context of learning (physical setting, spatial arrangement of people and objects, etc.) is centrally important. Modelling the ‘real’ environment would be prohibitively difficult, and any simulation of it requires so many assumptions that its results could be questionable. Robotic models, on the contrary, circumvent this problem by using a
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