Title
Towards a Computational Theory of Cognitive Development

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 18(0)

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Publication Date
1996

Peer reviewed

Towards a Computational Theory of Cognitive Development

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Introduction

This research challenges the traditional approach of theory construction in cognitive development by using the framework of robot learning. Traditionally, researcher in cognitive development (e.g., developmental psychologist) has focused on general and abstract description of experimental data as an explanation for the observations. In contrast to this approach, we propose using autonomous robots as the subject of cognitive development, and constructing computer programs by which robots can behave analogously to infants.

The advantage of using robots is twofold. First, we can utilize a robot's various sensors and actuators as the inputs and outputs of a model. In comparison to standard computer simulation framework this aspect allows us to construct a more realistic model. Second, we can construct a theory absorbing *activeness* in cognitive development. Recently, researchers have emphasized the importance of activeness (i.e., mobility) of infants during development (Thelen and Smith, 1994). However, the theory derived from this stream needs to be tested and refined in more detail. We believe that using robot leads us to a more concrete theory.

Modeling the Process of Spatial Learning

As a first step to constructing an complete computational theory of cognitive development, we are trying to explain the empirical results of Acredelo, Asams & Goodwyn (1984). They conducted experiments to test the role of self-locomotion as opposed to passive transport concerning infant's spatial cognition. Their results suggest the importance of active movement with visual tracking. However it is not clear what information is central in promoting the change from *egocentric representations* to *landmark-based* or *allocentric representations*.

In order to focus on the change, we adopt the idea of *representational redescription* (Karmiloff-Smith, 1992) as a key concept for constructing learning robots. In accordance with this idea we have developed a method called *feature abstraction* (Hiraki,1994). Feature abstraction dynamically defines abstract sensors from primitive sensory information and makes it possible to learn appropriate sensory-motor constraints. This method has been implemented on a real mobile robot as a learning system called ACORN-II.

Even though feature abstraction is a method for changing representation, it has limitations as a general model of developmental change. We are addressing the following issues.

1. **Efficient methods for exploring the feature space (Attention mechanism).** ACORN-II has a small number of sensors/actuators that enable exploration of representational space. On the other hand infants have enormous sensory organs. We need more sophisticated criterion such as attention mechanism.
2. **Mechanism for simulating drastic change(Self-organization).** The change from egocentric behavior to non-egocentric seems to need a drastic change of spatial representation. Though feature abstraction dynamically redefines representation, its basic mechanism is based on the supervised learning framework. In order to simulate infant's representation change, we need a systematic way based on the unsupervised framework.

There are some studies that share some parts of our goal. For instance, Brooks & Lynn (1993) are constructing a humanoid type robot that can simulate part of infant's behavior. They focus on the hardware level instead of developmental changes of representation. However, we believe that the necessity of implementation on real robots provides valuable insights into cognitive mechanisms. As for Acredelo's experiments, we can control the information which is supposed to be perceived by infants during locomotion, and we can verify the hypothesis on self-movement.

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