Post-Piagetian Constructivism for Grounded Knowledge Acquisition

Harold Henry Chaput

Department of Computer Sciences
Taylor Hall 2.124 [C0500]
The University of Texas at Austin
Austin, TX 78712-1188 USA
chaput@cs.utexas.edu

Abstract

Piagetian constructivism, an attractive model of grounded knowledge acquisition, has been shy on details, making modeling difficult. New research in developmental cogition has shed some light on these details. More accurate and powerful constructivist models can now be built, and one such model – the Constructivist Learning Architecture – is proposed.

Introduction

Constructivism Then and Now

Piaget (1952) proposed a mechanism by which infants integrate experience into progressively higher-level representations, which he called *constructivism*. According to constructivism, infants progress from simple to sophisticated models of the world by use of a *change mechanism* that allows the infant to build higher-level representations from lower-level ones. Constructivism is a powerful model of grounded knowledge acquisition that has been applied to grounded knowledge acquisition tasks with considerable success (Drescher 1991; Cohen et al. 1997).

Constructivism, though, has long been criticized for its vagueness regarding the precise nature of the change mechanism. The lack of detail in this area has hampered the production of more powerful models of cognitive development, and has led some to suggest that the primitives of the infant's world model (such as solidity and causality) are innate (see Spelke et al. 1992). However, recent studies of infant cognitive development (Cohen and Younger 1984; Cohen and Amsel 1998; Cohen et al.1998) have provided strong evidence that these primitives are indeed acquired and, in doing so, they have shed light on the details of the change mechanism itself.

Cohen (1998) has integrated several of these studies to produce a set of principles that describe constructivist development using an information processing approach. Specifically, Cohen and Cashon (2001) postulate that infants organize stimuli into categories based on criteria such as frequency, invariance and co-occurrence. Then, infants build higher-level representations by applying these criteria to lower-level representations. Given this work, it is now possible to implement a more accurate computational model of developmental cognition. In addition, these studies provide a body of empirical data against which developmental models can be tested.

Approach

Constructivist Learning Architecture

The Constructivist Learning Architecture (CLA) is such a model. Based on the principles of constructivist learning described by Cohen and Cashon (2001), CLA uses a hierarchy of Self-Organizing Maps, or SOMs (Kohonen 1997), to build representations of observed stimuli at progressively higher levels of abstraction. The SOM is recognized as a useful tool for the development of categories. By connecting the SOMs hierarchically, higher-level representations can be built from the activation of lower-level representations.

As illustrated in Figure 1, sensory information is introduced to CLA as a feature vector. As multiple feature vectors are introduced to CLA over time, the first layer of CLA uses a SOM to generate categories. This layer is then used to create an *activation matrix* by measuring the euclidean distance between the stimulus vector and the generated categories. This activation matrix then becomes a new feature vector for the next layer. This process continues up to arbitrarily higher layers, and forms the foundation of CLA. Other layer connection techniques – such as delay, recursion, and many-to-one connections – can be employed to create more sophisticated architectures.

In this way, high-level representations can be built from raw stimuli, and all representations are ultimately defined in terms of the system's sensorimotor apparatus. The resulting representations are distributed, both laterally (within a layer) and hierarchically (across layers). Also, since all levels of processing are maintained throughout development, confusion at a higher level can be handled gracefully by falling back to a lower level. Finally, CLA's modular design makes it well suited for temporal and cross-modal knowledge acquisition.

CLA has been used to replicate various studies from developmental cognition, like infants' acquisition of causality and word boundary detection. CLA has also been applied to autonomous robotic control by building a world

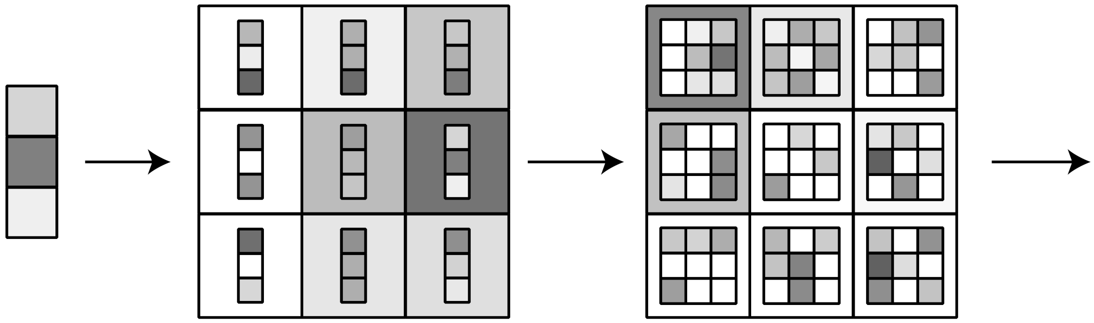

Figure 1: The progression of information in the Constructivist Learning Architecture. Layer 1 organizes several input vectors into categories. These categories are then compared to the Input Vector to generate an activation matrix. The activation matrix then becomes the input vector for Layer 2, when also generates an activation matrix, and so on.

model through interaction with the environment and using this world model to develop environment-appropriate behaviors and recover from sensor trauma.

Conclusion

Developmental cognition is a powerful model for grounded knowledge acquisition. The new discoveries coming out of developmental psychology are providing the details necessary to create a new generation of infant learning models that are more accurate and more powerful. Robots can use these models to generate the knowledge necessary for robust and sophisticated behavior. Indeed, the developmental approach can be employed in a wide variety of domains that would benefit from grounded representations, such as language and common sense reasoning. And by building models of developmental cognition, we can further understand the process of human learning itself.

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