Cognitive Modelling of Infant Development

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Overview

There is considerable interest in the "developmental" approach to Artificial Intelligence, with the aim of producing robots which can display "ongoing" development. (Prince et al., 2005). Many efforts in in this area are loosely inspired by ideas from developmental psychology, but few works are explicitly focussing on modelling psychological theories. Existing psychological theories of development are described somewhat vaguely; computational modelling of specific episodes in human development can help to flesh out the details of a more complete and precise theory of that development. Our focus in this project is on cognitive development and modelling the infant's interaction with objects.

Psychology

Hypotheses to be tested

The following hypotheses are some of the psychological theories that give some insight into the mechanism of ongoing development, and stage transition.

1. **Means-end behaviours** are initially acquired **through fortuitous coordinations** which result in one known schema facilitating the performance of a second (Willatts, 1999). The successful coordination is remembered, and repeated in new scenarios.
2. **Infants autonomously acquire knowledge about various means** actions through studying their effects in fortuitous coordinations. The knowledge thus acquired can then be applied to allow **effective selection and adjustment of means actions in intentional means-end coordinations** (Piaget, 1936, Bruner, 1973).
3. **Infants develop an experimental ability through searching for the conditions which can cause certain effects**, where those effects are recognised by schemas developed in the previous stage (Piaget, 1936). Experiments lead to new means schemas.

Artificial Intelligence

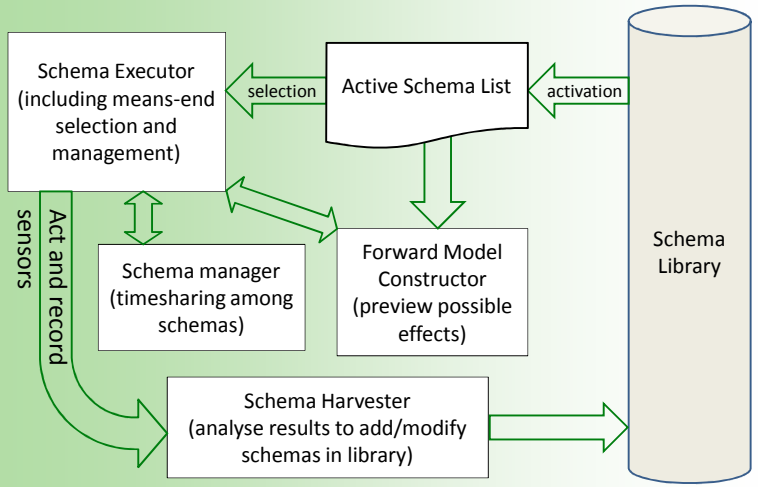
Existing Techniques used for modelling

1. Piagetian Schema Learning Mechanism, broadly similar to the mechanisms of Drescher (1991) and Chaput (2004)
2. Basic Piagetian schemas for skilled movements captured via Neural Fitted Q iteration (Riedmiller, 2005)
3. Hierarchical reinforcement learning used to combine basic schemas (here the schema becomes an option in the reinforcement learning terminology)
4. Self Organising Maps used to harvest new schemas from clusters of sensor data after random actions (Chaput, 2004)
5. Recurrent Neural networks used to cluster schemas with similar effects (recorded as a time-series of sensor values), and to identify schemas which can produce a required effect (for selection in means end behaviours)

New Techniques Required

1. A new cognitive architecture to model infant cognition (most existing architectures aim to model adult competence and knowledge in a specialised domain)
2. Reinforcement learning options with parameters.
3. Refinement of reinforcement learning options based on their efficacy in a means-end combination.
4. Higher order schemas which manage relationships among lower level parameterised options (i.e. An extension to hierarchical reinforcement learning)

Cognitive Architecture



References

Bruner, J. Organization of Early Skilled Action Organization of Early Skilled Action. *Child Development*, Vol. 44, No. 1 (Mar., 1973), pp. 1-11. 1973.

Chaput, H. H. The constructivist learning architecture: a model of cognitive development for robust autonomous robots. PhD thesis, AI Laboratory, The University of Texas at Austin, 2004.

Drescher, G. L. Made-Up Minds, A Constructivist Approach to Artificial Intelligence. MIT Press, 1991.

Guerin, F. and McKenzie, D. A piagetian model of early sensorimotor development. In *Proceedings of the Eigth International Conference on Epigenetic Robotics*, University of Sussex, July 30-31, 2008.

Guerin, F. and Starkey, A. Applying the Schema Mechanism in Continuous Domains. In *Proceedings of the Ninth International Conference on Epigenetic Robotics*, Venice, 2009.

Piaget, J. The Origins of Intelligence in Children. London:Routledge & Kegan Paul, 1936. (French version published in 1936, translation by Margaret Cook published 1952).

Prince, C., Helder, N. and Hollich, G. Ongoing emergence: A core concept in epigenetic robotics. In L. Berthouze, F. Kaplan, H. Kozima, H. Yano, J. Konczak, G. Metta, J. Nadel, G. Sandini, G. Stojanov, and C. Balkenius, editors, Proceedings of EpiRob05 - International Conference on Epigenetic Robotics, pages 63–70. Lund University Cognitive Studies, 2005.

Riedmiller, M.. Neural reinforcement learning to swing-up and balance a real pole. In Int. Conference on Systems, Man and Cybernetics, 2005, Big Island, USA. 2005

Willatts, P. Pulling a support to retrieve a distant object. *Developmental Psychology*, 35:651–667, 1999.