Dual-Network Connectionist Modelling of Development

Lorna Peters (L.Peters@herts.ac.uk)
Department of Computer Science; University of Hertfordshire, Hatfield, Herts. AL10 9AB. U.K.

David Messer (D.J.Messer@herts.ac.uk)
Department of Psychology; University of Hertfordshire, Hatfield, Herts. AL10 9AB. U.K.

Pam Smith (P.M.Smith@herts.ac.uk)
Department of Psychology; University of Hertfordshire, Hatfield, Herts. AL10 9AB. U.K.

Neil Davey (N.Davey@herts.ac.uk)
Department of Computer Science; University of Hertfordshire, Hatfield, Herts. AL10 9AB. U.K.

Neville Austin (N.G.Austin@herts.ac.uk)
Department of Psychology; University of Hertfordshire, Hatfield, Herts. AL10 9AB. U.K.

This work is the modelling complement to empirical studies which have been carried out at the University of Hertfordshire into the theory of Representational Redescription (RR; Karmiloff-Smith, 1992). This important theory is currently central to psychological theories of development and has been described using a balance beam task (Karmiloff-Smith, 1992). This task is representative of a whole class of early learning skill problems but has not been modelled before. In a new approach to modelling cognitive development a method proposed for solving reinforcement learning tasks, reward-driven learning (Gullapalli, 1995), is applied.

A developmental sequence in the balance beam task has been identified whereby the child can balance beams of all types, regresses to balancing only symmetrical beams and then becomes successful at balancing all beams again. Recent studies (Messer et al., 1996; Pine & Messer, 1995; Peters, submitted) have provided a high degree of correspondence with Karmiloff-Smith's (1992) descriptions of the RR Model in relation to this task but have also indicated a more complex sequence of development. Modelling the balance beam task within a connectionist framework therefore presents an interesting and challenging problem.

In the first phase of this project, a model of the initially successful balancing behaviour is being developed. Beams are balanced through trial and error without any explicit information about gravitational centres being available to the child. The standard supervised learning method, where a 'correct' teaching signal is supplied, is therefore inappropriate and instead a psychologically plausible approach, based on Munro's dual back-propagation scheme (1987) is applied. The model consists of a supervisory network and an activity network. Using the generalized delta rule (Rumelhart et al., 1986), the supervisory network is trained on a variety of beam configurations and positions. The supervisory network then trains the activity network to produce, for each beam presented, a fulcrum placement that will cause the beam to balance. When trained as a perceptual model, the network showed at early stages of training, an initial preference for beams to be placed around the middle before going on to develop generalised responses to novel beams. This raises interesting issues about the empirical data gathered on very young children which suggests that initial beam placements tend to be around the center. When trained as an environmental model, analysis of the supervisory network indicates the development of a counterbalancing 'rule', in which two entities (dimensions) must sum to the same level of activity for balancing to occur. Thus, the network has learned to represent torque correctly.

This network is now being used to train the activity network where movement sequencing will be incorporated via a recurrent connection and importantly, comparisons between the movements generated will be made with real beam placement data gathered from young schoolchildren.

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