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A Connectionist Encoding of Schemas and Reactive Plans

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Introduction

The necessity to act quickly in an uncertain and dynamic world requires agents to develop representations that can tightly couple action, perception, reasoning, and execution monitoring. Our work on language learning also requires that agents internalize their knowledge of verbs by simulating the associated actions and sensorimotor states. We refer to such *active* representations as X-schemas (Feldman et. al, 1996) (the *X* refers to *executing*). In this work, we develop a structured connectionist realization of X-schemas based upon our previous work on SHRUTI, a connectionist model of reflexive reasoning (Shastri & Ajjanagadde, 1993), and "routines" (Feldman & Shastri, 1984).

X-schemas must satisfy a number of requirements. They must deal with sequential and partially ordered activation of actions, concurrency, iteration, conditional action, event-based interruption, and termination. It should also be possible to form complex X-schemas composed of other X-schemas. X-schemas should support a broad notion of action. This includes actions that affect the environment and seek information from the environment. It also includes actions that update and query various forms of memory (this includes retrieval and inference). Since X-schemas operate in dynamic and wide-ranging situations, they must get *dynamically bound* to different entities at run time and execute with different parameter settings (e.g., amount of force).

Connectionist Encoding

The connectionist encoding of X-schemas makes use of *focal clusters* and feedback loops, the propagation of dynamic bindings via temporal synchrony, and a uniform mechanism for interaction between schemas, sensory-motor processes, as well as high-level reasoning and memory. Many of these connectionist mechanisms have been drawn from SHRUTI (Shastri & Ajjanagadde, 1993; Shastri & Grannes, 1996).

X-schemas are composed of interconnected focal clusters that may contain parameter nodes, role nodes, and control nodes such as +, –, and ?. The significance of nodes in a focal cluster is as follows: the activation of parameter nodes sets parameter values in the invoked schema. For example, in an X-schema for *push*, the firing rate of a suitable parameter node may indicate the relative force to be applied. Role nodes provide a mechanism for dynamically binding a schema role with a filler at the time of schema invocation. For example, an X-schema for *push* may have a role for indicating the intended object of the push action. A dynamic binding between a role and its filler is expressed by the synchronous firing of the role node and the focal node representing the filler of this role. Such bindings are communicated among role nodes by the synchronization of the activity of connected role nodes as in SHRUTI. Neurophysiological evidence suggests that such propagation of synchronous activity is neurally plausible (Singer, 1993).

The ?, +, and – nodes serve a control and coordination function. The ? node can be viewed as an *initiate* or *query* node. A process initiates an action (or poses a query for information) by activating the ? node of the appropriate focal cluster. The + and – nodes indicate the outcome of schema execution. The activation of the + (–) node of a focal cluster by a schema indicates the successful (unsuccessful) *completion* of the schema.

Conclusion

It is interesting that the same mechanisms seem sufficient for reflexive reasoning as well as perceptual motor schemas. This is not surprising if one takes seriously the notion that conceptual structures are grounded in our body and shaped by our motor and perceptual systems. In ongoing work, we and our colleagues are investigating the implications of this work for language acquisition, reasoning, and metaphoric inference.

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