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Biological Limbic Systems: A Bottom-Up Model for Deliberative Action

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Evolution of Deliberative Actions

While bottom-up approaches to studying cognition have proved insightful in many ways, top-down approaches are still better at explaining deliberative cognitive processes. Deliberative actions are those that go beyond simple sensory-motor loops and seem to require some type of internal model, map or logical reasoning. Examples of deliberative actions include planning a route to navigate to a goal or performing a chain of logical inference to determine a likely course of action.

Bottom-up approaches such as Walter's tortoise (1951) and Braitenberg's vehicles (1984) are excellent models of how simple sensory-motor loops can combine to produce complex intentional behavior. Such behaviors are still mainly of the tropic type (e.g. phototropic, chemotropic), which rely on detecting and following some type of perceptual gradient in the environment. More recently, models such as Brook's (1990) subsumption architecture have shown us how collections of behavior patterns can combine in relatively flexible chains, in an emergent manner, to produce even more complex behaviors. Simple tropic behaviors are present in even the simplest of single celled organisms, while the more complex collection, chaining and combining of such sensory-motor behavior patterns appear with fish and insects.

Deliberative actions appear to require the development of more long-term memory mechanisms that allow for the storage of past experiences and for these experiences to be brought to bear on current situation. Evolutionarily, the development of the limbic system in simple vertebrates, such as amphibians, marks the first appearance of primitive hippocampal structures. The hippocampus plays the role of forming and remembering more long-term representations of experiences. It is known to participate in the formation of episodic memory, logical reasoning and cognitive maps (Dusek & Eichenbaum, 1997; Arbib, Érdi & Szentágothai, 1997). Building more deliberative systems in a bottom-up whole-system approach would therefore appear to potentially benefit from a more complete understanding of the biological limbic system.

K-IV: Basic Limbic System Model

The K-IV architecture is a model of what biologists believe may be the simplest neural architecture capable of basic intentional and deliberative actions, the limbic system (Kozma, Freeman & Érdi, 2003). The purpose of the K-IV is to model a complete autonomous organism, in a bottom-up manner, to understand better the neurodynamical mechanisms involved in intentional and deliberative behavior. The K-IV uses a neural population model (called K-sets) to describe the activity of large populations of neurons (as opposed to single unit or more abstract ANN models). It is a highly-recurrent multi-layer model of the important neurological structures of the basic limbic system.

We have been developing pieces of the K-IV for use as control mechanisms in autonomous vehicles for exploration and navigation problems for NASA. We have developed discrete simplifications of the K-set neural population models for use in such autonomous agent simulations (Harter & Kozma, submitted). In this work we will present some of our results on modeling and implementing pieces of the K-IV model, including how nonconvergent dynamics form perceptual categories (Harter & Kozma, in press) and how such dynamics may be used to learn and control behaviors in an autonomous agent (Harter & Kozma, 2004).

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