Adaptation Without Natural Selection

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Extended Abstract

How can a system become better adapted over time without natural selection? Although some argue for 'organismic' properties such as robustness and self-sustaining regulation in non-evolved systems [1,5,11], others insist that natural selection is the only source of true adaptation [3]. We suggest that understanding how adaptation can occur without natural selection remains a fundamental open question for the Artificial Life community. For example, the origin of life, the origin of evolution, and the origin of new units of selection in the major evolutionary transitions/biological dynamical hierarchies, all seem to imply an adaptive process, or at least a non-arbitrary organisational process, that precedes the onset of natural selection proper (at each level of organisation).

In recent work we have been developing a number of inter-related concepts that approach this question from different angles [2,6,7,8,9,10,12,13,14,15]. In a general sense, it is known that a complex dynamical system can self-organise in a manner that reflects structure in external perturbations. But more specifically, we find that when variables in the system have a bi-modal distribution of decay constants (some fast and many slow), slow variables spontaneously act in a manner functionally equivalent to the weights of a neural network undergoing Hebbian learning, thereby modulating the behaviour of the fast variables such that the resultant internalised structure takes the form of an associative memory [4]. The proximal cause of these changes is merely that such a configuration is less resistant to, and hence less affected by, the perturbations to the system (c.f. homeostasis). But the system-scale consequences of this structuring is that such a system can 'recall', 'recognise' or 'classify' stimuli and, given appropriate structure in the perturbations, generalise to previously unseen stimuli, in just the same manner as a trained neural network [4].

This provides a framework to connect the concepts of a dynamical system merely 'doing what it does naturally' at one scale of explanation with interpretation as an *adaptive* system at another. In particular, in the joint phase space of both fast and slow variables the system merely decreases in energy, as one would expect from any purely mechanistic explanation. But induced structure in the slow variables improves the ability to dissipate energy from the fast state variables. Thus with respect to the fast system variables only, systems organised in this manner do not merely minimise system energy but *get better* at minimising energy over time. When the external environment of the system corresponds to an optimisation problem, the system thus improves its ability to solve that problem over time. It is in this sense that we can understand the system, not just as self-organised, but adapted. We present an abstract model and simulation of this process and discuss how it relates to a number of different domains: the evolution of evolvability in gene regulation networks [12], the evolution of new units of selection [10] via symbiosis [15] and 'social niche construction' [8,9], games on adaptive networks [2], distributed optimisation in multi-agent complex adaptive systems [13,14] and multi-scale optimisation algorithms [6,7].

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