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Ben Jones, Yaochu Jin, Bernhard Sendhoff, Xin Yao

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Evolution of neural organization in a hydra-like animat

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Neural systems have a phylogenetic and ontogenetic history which we can exploit to better understand their structure and organization. In order to reflect this evolutionary influence in our analysis, we have to break down the overall functional benefit (from an evolutionary perspective within a certain niche) of a neural system into properties which are more constructive and which lead directly to constraints of a developing neural system. We therefore take the stance that all advanced neural organization can be traced back to a common ancestor from which major evolutionary transitions provided innovation and ultimately, survivability. In the literature, this organism is often considered to be a hydra-like organism with a radially symmetric body plan and a diffuse nerve net, since an actual freshwater hydra is phylogenetically the simplest biological organism having such features. For this reason, we also adopt the freshwater hydra as a model organism. Our objective for this research has been to understand the organizational principles behind wiring brain networks as a foundation of natural intelligence and our guiding hypothesis has been that neural architecture has likely evolved to maximize the efficiency of information processing. The simulation environment which we have devised is based on a three dimensional cylindrical animat. It further adopts a network of integrate and fire spiking neurons simulated by the Neural Simulation Toolkit (NEST) which serves to provide rudimentary 'wobbling' movements. The architecture of this network (neuron localities) is evolved to minimize energy loss (or maximize its conservation) and maximize functional advantage which is to cause the animat to catch food particles falling from the top of the environment. This functional advantage both utilises energy due to the spiking network and gains energy whenever a food particle is caught (note that a unit of energy is expended whenever a neuron spikes, and the magnitude of this loss is further proportional to the connection length). Therefore, the task is essentially about a trade-off between energy loss and energy gain. Over a process of simulated evolution, we observe that the neural architecture emerges, (i), to afford maximal functional benefit (that of obtaining food particles) and (ii), with an innovative minimalistic structure, in which motor neurons, which are part of the nerve net, arrange themselves to be proximal to the sensory neurons located around the head of the animat. This result firstly shows how the efficiency of information processing is directly related to neural architecture: closely connected neurons expend less energy as well as providing functional advantage. This finding suggests that evolution can discover efficient information processing through neural architecture adaptation. Secondly, lifetime architectural perturbations of the neurons which we further introduce to reflect more closely the continual movements of neural cells in real hydra, are seen to increase the prevalence of this structure that promotes efficiency. The latter result indicates that a system can become robust to inherent lifetime plasticity by essentially strengthening the feature which helps its survival. Such robustness is an emerged property and comes about entirely as a by-product of evolution.