Abstract

We present an evolutionary robotics model of an agent controlled by a homeostatically plastic neural network where the connectivity is modified by a pre-synaptic Hebbian rule when the firing rate of neurons goes out of pre-specified bounds. The very same underlying architecture supports a developmental process, an operant conditioning task and the spontaneous formation of sensorimotor habits (never selected during the evolutionary phase). The task consists on distinguishing two different colored food sources with changing profitability (food source types alternate in random intervals from “profitable” to “poisonous”). The agent has two arrays of sensors (one for each color) and an additional sensor to evaluate the profitability of the food-source. The control architecture is a fully connected Continuous Time Recurrent Neural Network with presynaptic Hebbian rule that is activated if the activity of pre or post-synaptic neuron is either to high or to low. Learning rule parameters are evolved to optimize the operant conditioning task with an additional fitness reward for internal stability. The agents are initialized to optimize the operant conditioning task with an additional fitness reward for internal stability. The agents are initialized to optimize the operant conditioning task with an additional fitness reward for internal stability. The agents are initialized to optimize the operant conditioning task with an additional fitness reward for internal stability.

The Task

The agent has to learn this association that changes during its lifetime (typically every 8 food presentations)

The Agent

CONTROLER: Continuous Time Recurrent and Totally Connected Neural Network with Homeostatic Plasticity

SENSORS: One energy sensor and 6 laser-like visual sensor for each color.

The Task

The agent has to select between two (differently colored) falling food sources. Each food color has an associated energy profitability that the agent can sense (poisonous -10 energy, profitable +10 energy).

Results 1: development and operant conditioning

Homeostatic plasticity generates and stabilizes a network configuration during development (left), this configuration is capable to sustain operant conditioning (right).

Neural Activation Equation

\[ \text{Hebbian Presynaptic Rule and Homeostatic Plasticity Rule} \]

\[ \Delta w_{ij} = \alpha \left( -1 + \frac{1}{1 + e^{-\theta_{ij} \text{Spike}_{ij}}} \right) \]

where \( \theta_{ij} \) is the degree of plastic local facilitation explained below, \( \mu_i \) depends linearly on the value of \( p_{ij} \) or \( p_{ij} = 1 - 0 \) if \( \theta_{ij} = \min \text{Neuron}_i \) is the goaldirection specificity.

Results 2: spontaneous habit formation

When both food sources are profitable the agent develops a “preference” to choose the food on its right (that this behaviour is not an innate preference can be shown on early trials not biased systematically towards the right)

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