Homeostasis via chaos: implementing the uniselector as a dynamical system

Inman Harvey

University of Sussex
inmanh@gmail.com

Ashby's Homeostat (Ashby, 1952, Design for a Brain, Chapman and Hall) was a demonstration of how an extended form of homeostasis, defined by him as ultrastability, could be achieved with a relatively simple mechanism. Homeostasis refers to the process whereby an organism, or a machine, actively maintains certain 'essential variables' (EVs) within the critical bounds of viability. The simplest form is negative feedback, but a higher order of homeostasis can sometimes be observed when an EV, on approaching a critical value, triggers one or more periods of *positive* feedback that reorder the dynamics until a new stable equilibrium (based once again on negative feedback) is found. This ultrastability can be viewed as an interaction between two coupled dynamical systems (DS): the primary DS comprises the EVs, and their direct, parameterised interactions; the secondary DS only kicks in temporarily when the EVs of the first are threatened, and then it alters the parameters of the first DS until some equilibrium is found that no longer threatens the EVs. Hence this is a form of selection between multiple possible steady states.

In Ashby's Homeostat, the secondary DS was implemented by the 'Uniselector'. Under normal circumstances it maintained a fixed set of parameters for the first DS. When it was triggered, it picked a different set of parameters (in practice drawn from a lookup table of random numbers), and continued doing so until the triggering factor ceased. In Evolutionary Robotics one common method for designing an artificial 'nervous system', coming from the DS perspective on cognition, is to evolve the parameters (weights, biases and time constants) for a Continuous Time Recurrent Neural Network (CTRNN; Beer, 2006, Neur. Comp. 18(12). p. 3009). One way of implementing an Ashbyan ultrastability mechanism would be to incorporate the Uniselector as an add-on to the CTRNN. An alternative approach proposed here is to incorporate the Uniselector-effects within the CTRNN, rather than as a separate add-on.

We require a very large number of different attractors (corresponding to different sets of random numbers in the Uniselector); and a trigger mechanism that initiates random or chaotic jumps to a new attractor. This can be done with a core of just 3 interconnected variables, equivalent to 3 nodes of a CTRNN if we extend the class of transfer functions at each node to include sine waves as well as sigmoids. Drawing on a result of Thomas (Kaufman et al., 2003, C. R. Biologies 326, p. 205), we show how this can be implemented; we can switch between chaotic 'search' and settling into one amongst many possible attractors. These attractors are cyclic or strange, but can be used to set parameters for the remaining part of the CTRNN that comprises the 'primary DS'. There remain practical issues, somewhat glossed over by Ashby, in orchestrating how long is spent 'evaluating' each attractor visited before abandoning it for another one.

This approach demonstrates the possibility of composing a Homeostat entirely of such an (extended) CTRNN, with the Uniselector-substitute as a distinct hand-designed sub-circuit or module. Further evolution can maintain the desired ultrastable characteristics, whilst relaxing these architectural constraints of modularity.