Binding Analogue Feedback to Digital Genomes: Bio-inspired Regulatory Control for Analogue Devices

Kester Clegg, Susan Stepney
Department of Computer Science, University of York, UK

E-mail: kester@cs.york.ac.uk

Abstract: We propose a bio-inspired control mechanism for dynamically programmable analogue devices. Our control mechanism is evolved using conventional genetic algorithms; its uniqueness lies in a feedback loop that allows the devices to change their configuration *by interacting with the evolved genome* as internal or external conditions alter. In our proposed mechanism, a digital genome encodes for the components and configuration of (potentially many) analogue circuits. Most solutions in evolutionary computation contain the complete realisations of the genotype and there is no interaction with the genome once the solution has been achieved. Our system uses circuit outputs that feedback into the digital genome, triggering a regulatory control mechanism. As the circuit's inputs change, outputs are able to match binding sites on the genome, allowing the "expression" of new circuits. The binding signature sequences are evolved with the genome, and can be specific or contain "wildcard" positions, making the matching process flexible. The genome is represented in a form suitable for Cartesian Genetic Programming (Harding & Miller, 2005). It encodes an analogue circuit as a feed-forward directed graph, with each node in the graph specifying the configuration of an analogue component. As the circuit responds to its inputs, the outputs are Fourier transformed and digitised, to give a series of bin values. These output values are matched against binding signatures on the genome. If a match is found, the circuit reconfiguration specified by that binding site takes place. Our experiment uses dynamically programmable Analogue Signal Processors (*dp*ASPs) from Anadigm™ to achieve rapid re-configuration. These chips are destined to replace many ASICs and offer potentially disruptive technology wherever digital logic has to interface with the real world. The technology permits us to investigate the complex world of analogue signal processing with evolutionary search algorithms that can be tested *in silico* rather than in simulation. The ability to reconfigure analogue circuits within a *single clock cycle* means that a new breed of analogue control systems can be created. Our next steps are to evolve genomes that encode a set of reconfigurable circuits capable of performing a variety of tasks in changing environments. For example, a filter might reconfigure as input signal characteristics change; a robot controller might reconfigure from vision to ultrasound as light levels change, or from exploitation to exploration behaviour when inputs indicate that a resource is being exhausted.

References

Anadigm™ http://www.anadigm.com/

S. Carroll. *Endless Forms Most Beautiful: the new science of evo devo and the making of the animal kingdom*. Weidenfeld & Nicolson 2006

S. Harding, J. F. Miller. Evolution of robot controller using cartesian genetic programming. *Euro GP 2005, Lausanne, Switzerland, March 2005*. LNCS **3447**:62-73, Springer 2005

A. Thompson. Silicon evolution. *Genetic Programming 1996, Stanford University, CA, USA*. pp. 444–452, MIT Press 1996