Using novel bio-inspired principles to improve adaptability of evolutionary robots in dynamically changing environments

Yao Yao1,2, Kathleen Marchal2,3 and Yves Van de Peer1,2

1Department of Plant Systems Biology, VIB, Technologiepark 927, 9052 Ghent, Belgium
2Department of Plant Biotechnology and Bioinformatics, Ghent University, Technologiepark 927, 9052 Ghent, Belgium
3Department of Microbial and Molecular Systems, CMPG, Katholieke Universiteit Leuven, Leuven, Belgium

Email:
yayao@psb.vib-ugent.be
kamar@psb.vib-ugent.be
yves.vandepeer@psb.vib-ugent.be

Abstract
An important goal in the field of evolutionary computation and robotics is the development of systems that show self-adaptation in dynamically changing environments. However, adaptation to a changing or fluctuating environment is challenging and usually requires a dynamic solution. Here, we present a bio-inspired, agent-based controller driven by an artificial gene regulatory network that enhances the adaptability of robots in dynamically changing environments.

Artificial genome
The Genome consists of two kinds of genes. The ‘regulatory’ gene is in charge of the regulatory functions while the ‘structural’ gene determines the phenotype of the robot through its gene expression product. The interaction between genes and the environment is based on the transcription factor binding process.

Agent based GRN
The dynamics of the GRN, encoded by the artificial genome, and its interaction with the environment, are modeled by an agent-based system.

Results & Conclusion
To demonstrate the advantages of our bio-inspired controller, we also developed an artificial life simulation platform that can provide a dynamically changing environment. Simulation results show that the bio-inspired GRN based controller has a better average adaptability than an evolutionary artificial neural network (ANN) based controller and a signal-based controller when placed in the same dynamically changing environments. Based on the experimental results, we believe the dynamics and the feedback loops of the GRN have great potential to enhance the adaptability of individual organisms in a changing environment.

Figure 1. Artificial genome encoding the regulatory network. Any gene, irrespective of its type, consists of the following components: a transcription start site, a gene identifier (type), a gene length region, a binding site region, an expression level region (default and gene-specific expression region), and a content region which is different for structural, regulatory and signaling genes.

Figure 2. Agent based system modeling the condition dependent instantiation of the GRN encoded by the artificial genome. Three different kinds of agents are distinguished, namely signaling agents modeling the interaction between the environment and the artificial genome, regulatory agents that constitute the active part of the GRN encoded by the artificial genome, and structural agents that translate the encoded information of a structural gene to an output signal, which drives the actuators (e.g. wheel) of the robot. The agents based level is also essential in establishing the feedback from the environment to the system through the agents adaptability values which affect both the agents lifetime, genomic encoding, and mutation rate.

Figure 3. Average energy levels for the three different controllers during runtime. The Y-axis represents the average energy level of the robots while the X-axis represent running time measured in time steps. The red line shows the result for a single simulation experiment based on the GRN controller; the blue curve shows the result for the experiment based on the ANN controller, and the purple curve shows the result for the experiment based on the simple non-evolvable signal-based controller.