Towards New Principles of Unbound Embodied Evolution

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This position paper proposes a road map for extending today's evolutionary computation (EC) in order to address some challenging aspects of engineering emergence in complex systems. We consider EC to be a very fit candidate for contributing to the algorithmic machinery for accomplishing engineered emergence. Evolutionary computation is an powerful paradigm for generating solutions of optimization and design problems inspired by biological evolution. It has been successfully applied in many branches of engineering, business, artificial biological (synthetic biology) and technological (robotics) systems. Evolution-based models of computation in a broader sense are now 'invading' new interdisciplinary research areas in innovative fields within bio-chemistry, on-chip factories, reconfigurable and evolvable hardware, molecular computing, and pervasive adaptive systems. The resulting systems are permanently driven by internal and/or external forces with long-term evolve-ability, unbound developmental processes, and very strong embodiment. Traditional evolutionary computing does not provide knowledge about such novel systems.

Vision – We have a long term vision of having artificially built evolutionary systems for information processing (computing), where: the units (individuals, agents) are physical objects, rather than pieces of code inside a computer; selection and reproduction are asynchronously and autonomously executed by the units themselves, without central control; reproduction creates new objects, rather than replaces existing ones; survivor selection effectively terminates objects so that they really cease to exist; selection is geared towards survival in general as well as user preferences that represent a given computing task; evolution is, in principle, open ended (unbound), but deliberately aiming at continuous improvement of the computing capabilities.

Motivation – The motivation behind this vision lies in the expected benefits of this radically new kind of non-von-Neumannian information processing (computing) systems that could regulate available computing power through adjusting the population size to the requirements of the moment, optimize energy and material consumption by producing units when needed and terminating units when they are not necessary anymore, and finally, undergo a continuous evolution towards better computing capabilities.

Challenges – For successfully pursuing this vision, the following major technical and scientific challenges can be identified: 1) designing the physical units (that can be electro-mechanical, bio-chemical, hybrid of these two), 2) equipping the units with computing capabilities of their own and make the population one big computational entity that can do more than the sum of its parts, 3) designing the (evolutionary) reproduction and inheritance mechanisms for the physical units, 3) managing the population size to prevent explosion as well as implosion (selection), 4) interfacing the user's computational task to the evolutionary system, and 5) striking a good balance between the driving forces towards general survival (improving computing capabilities) and task dependent fitness (improving solution quality).