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How Evolution Shapes the Way Roboticists Think

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Abstract

Interdisciplinary research in the 21st century is characterized by bidirectional flows: one domain provides inspiration to another, which, after an advance, provides inspiration back to the donating domain. In this abstract I outline three such flows between the domains of evolutionary biology and robotics. First, biological evolution shapes all aspects of an organism's body and brain simultaneously. This led to work in which artificial evolution optimizes the morphology and neural control of robots such that they perform increasingly sophisticated tasks. Second, evolution causes change over evolutionary time, but also over the lifetime of the organism. This led to work in which virtual robots change body plans as they evolve to perform more complex tasks, but their bodies also change as they perform those tasks. Finally, evolution always works on populations. This led to work in which populations of humans collaborate and compete to evolve increasingly sophisticated robots.

Keywords: robotics; evolutionary computation; embodied cognition

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1. Evolutionary Robotics

Evolutionary robotics [1,2] is an interdisciplinary field that incorporates ideas from biological evolution to enable the automatic design of autonomous robots. Typically, an evolutionary robotics experiment (1) acts on populations of virtual robots operating in a simulated environment; (2) assigns a 'fitness' to each robot; (3) those that perform poorly at the desired task (such as locomotion or object manipulation) are discarded; and (4) those that remain are copied, and slight random changes are made to the copied robot. As generations of virtual robots elapse, the robots become increasingly adapted to their environment: they are increasingly able to perform the desired task, without requiring the investigator to program the robots directly.

2. Evolving Body and Brain

The first of three lessons that biological evolution has to teach roboticists is that in nature, all aspects of an organism are subject to evolutionary change. In robotics however, usually the morphology (body plan) of the robot is designed by hand, and then optimization algorithms are used to improve the controller of the robot. In past work I and others [3] have evolved both the body plan and neural control of robots: Fig. 1 shows an ancestor (Fig. 1a) and descendent (Fig. 1b) robot evolved to push a large object in their environment.

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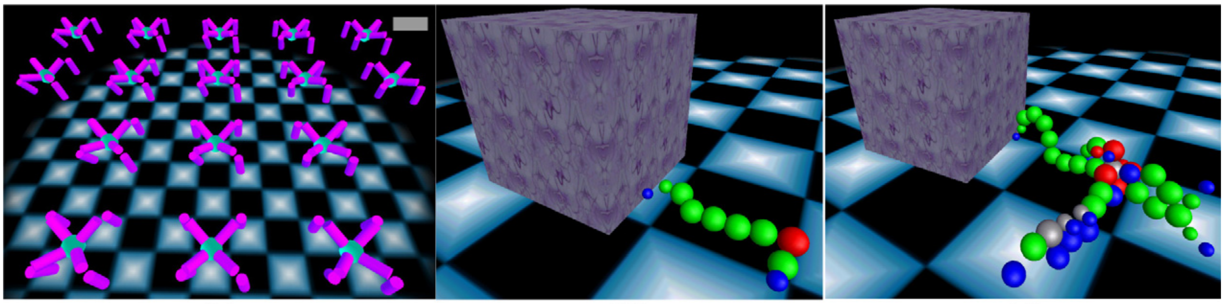

(a) (b) (c)

Fig. 1. Overview of evolutionary robotics. A population of robots (a) evolves so that simple robots (b) capable of rudimentary behaviors evolve into more complex robots (c) capable of more challenging tasks.

3. Evolving at Different Times Scales

The second of three lessons that biological evolution has to teach roboticists is that in nature, organisms' body plans and nervous systems change over many different time scales. Most importantly, many organisms undergo dramatic body plan change, accompanied by dramatic changes in their nervous systems: One example is the transformation of frogs from infant, water-based tadpoles to the legged land-based adult form. Recently I showed [4] that if virtual robots change body plans over their lifetime (Fig. 2a)—and this developmental change itself changes over evolutionary time (Fig. 2a,b)—it is possible to evolve behaviors for the physical version of the robot (Fig. 2c) more rapidly compared to populations in which the robots' body plans never experienced the infant form (Fig. 2b).

4. Evolving in Hybrid Populations

The third lesson biological evolution has to teach roboticists is that evolution always deals with populations, rather than individual organisms. Within evolving populations, complex patterns of implicit and explicit cooperation and competition occur. This observation can be used to expand the evolutionary robotics paradigm to encompass human groups. Fig. 3 shows the prototype of a crowdsourced evolutionary robotics experiment in which users within a team pool their computational resources to evolve the best team of robots they can; this forms the collaborative component of the human group. Teams of multiple users than compete to evolve the best robot teams they can in as short a time period as possible: This forms the competitive component of the human group. Current experiments are underway to investigate whether this hybrid population composed of humans cooperating and competing to evolve robot teams that in turn cooperate and compete produces better robots than a single user evolving a single robot team.

(a) (b) (c)

Fig. 2. Overview of developmental and evolutionary change in virtual robots. At the outset of evolution, robots selected to walk toward a target object transition from an infant legless form to an adult legged form (a). Later in evolution the robots lose the infant legless form (b). Finally, the evolved controller from the virtual robot can be transferred to a physical robot (c).

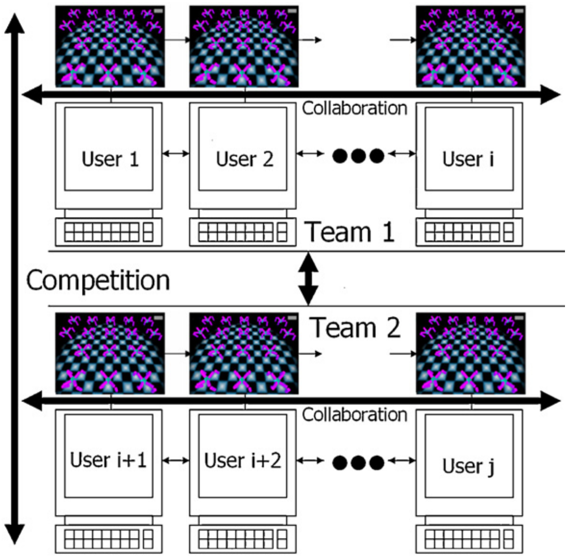

Fig. 3. Overview of a crowdsourced evolutionary robotics platform. User 1 begins by evolving a team of robots to perform a rudimentary version of some collaborative task. User 1 then broadcasts their partially-evolved robot team to members of their social network $u_2, \ldots, u_i$. In parallel, user $i+1$ evolves a partial solution and broadcasts it to their peers. The two teams contribute computational effort to evolve the best robot team in the short time possible. This platform thus combines collaboration among robots, collaboration among members of a human team, and competition between human teams.

References

[1] S. Nolfi, D. Floreano, Evolutionary robotics: The biology, intelligence, and technology of self-organizing machines, MIT Press, Cambridge, 2000.

[2] I. Harvey, P. Husbands, D. Cliff, A. Thompson, N. Jakobi, Evolutionary robotics: The Sussex approach, Robotics and Autonomous Systems 20 (1997) 205–224.

[3] R. Pfeifer, J. Bongard, How the body shapes the way we think: A new view of intelligence, MIT Press, Cambridge, 2006.

[4] J. Bongard, Morphological change in machines accelerates the evolution of robust behavior, Proceedings of the National Academy of Sciences 108 (2011) 1234–1239.