Potential and Promise of Open-Ended Evolution in Artificial Life

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Abstract

Since Bedau et al. identified the simulation of open-ended evolution in digital life media as one of the key problems in the field of Artificial Life (Bedeau et al., 2000, Artificial Life 6, p.363), no attempt has convincingly solved the problem until this day. Creating open-ended evolution ultimately boils down to creating niches: A new evolutionary feature can only be retained if there is an ecological niche in which it becomes an innovation. An environment with a limited potential for hosting niches is inherently restricted as far as evolutionary innovations and open-ended evolution are concerned. Moreover, static niches, even in a very large number, are not enough to enable open-ended evolution, they need to appear persistently.

Here, we present an in-silico system in which ecological niches are not explicitly defined, but arise as the consequence of the combination of the environmental layout and the adaptation of its resident population. The population consists of three-dimensional, autonomously foraging, blocky creatures (Sims, 1994, Artificial Life 1, p.353)(Chaumont et al., 2007, Artificial Life 13, p.139) with sensory-motor capabilities that are controlled with a neural network, coexist in the world, and compete for its resources. In this implementation they reproduce asexually, and the genome that codes for its morphology and behavior (via the neural network that controls its motions) undergoes mutations during reproduction. The world in which the creatures live is a three- dimensional, physically simulated environment where energy resources are continuously replenished, decay, and eventually absorbed by foragers. Creatures die if their energy is depleted, and are born from a parent that has accumulated enough energy to reproduce. There is no explicit fitness function in this system; however since poor foragers quickly die out, we witness a strong selective pressure to pass on genes for increasingly sophisticated foraging behavior to the offspring. Niches are not explicitly defined either. Since there is a wealth of possible foraging behaviors, the actual number of niches is impossible to determine. Moreover, as the population changes in number and in foraging strategies, the opportunities for any individual organism change as well, creating or removing niches dynamically as the population evolves in time.

In the initial construction of the world, we included several types of food sources placed at varying heights on pedestals, in addition to food sources distributed at ground level (See Figure 1). We believe that specialized morphological traits or behaviors that are necessary to exploit a particular resource can, if coupled with sexual recombination, allow disruptive selection to split the initial population into two or more morphologically distinct groups that will become increasingly isolated post-zygotically (Via, 2001, Trends Ecol. Evol., 16, p.381). Thus, in such an Artificial Life system new species can in principle emerge by speciating in sympatry, parapatry, or allopatry.

We believe that in such a system, open-ended evolution as understood by the Artificial Life community (Bedeau et al., 2000, Artificial Life 6, p.363) can ultimately be observed. A number of as yet un-implemented features are possible that will aid in open-ended evolution, such as the definition of chemical pathways that dictate a creature's affinity to metabolize specific food sources, and the possibility of emergence of trophic levels, by specifying that the blocks from which the creatures are created have nutritional value, and can either be scavenged, or hunted.

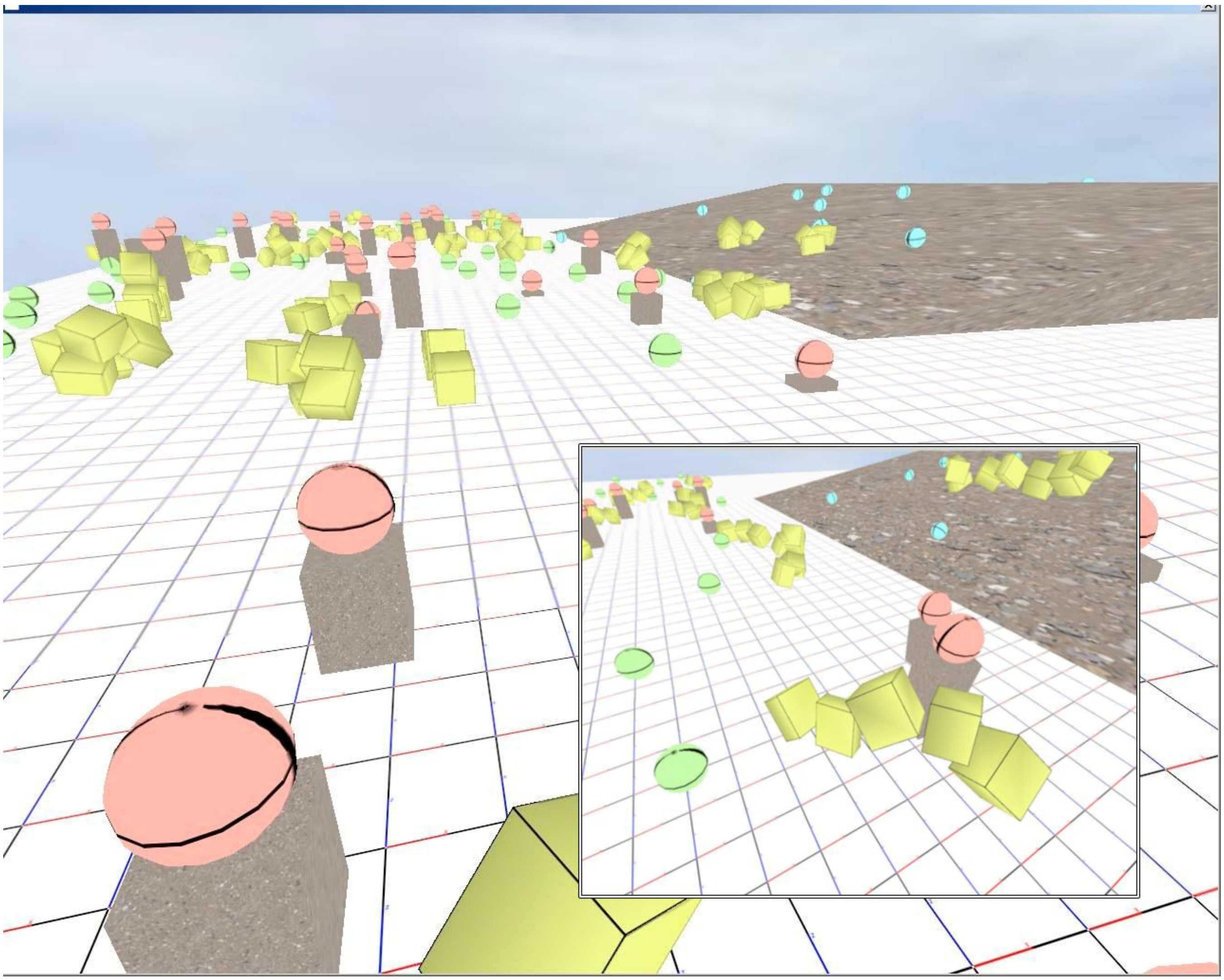

Figure 1: A snapshot of a world with three types of resources (green, red, and blue spheres) that require different morphologies or behaviors access. 3D organisms are yellow. In the inset, a virtual creature is toppling a pedestal to reach a red resource sphere.The blue resources are on inclines and require a form of locomotion that can counteract the low friction of the surface. Standard organisms cannot climb this incline.