Exploring the concept of open-ended evolution

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Introduction

The term ***open-ended evolution (“OEE”)*** is used by the ALife community to refer to the kind of long-term evolutionary dynamics observed in the biosphere. It is generally taken to refer to evolutionary systems which display a continual production of adaptively significant innovations.

For ALife practitioners who seek to build virtual worlds capable of OEE, there is a need for ***a particular type of understanding*** of the issues involved; in addition to the ***analytic*** understanding of evolutionary dynamics provided by theoretical biologists, there is also the need for a ***synthetic*** understanding of how to design systems that can produce these dynamics.

This work presents an attempt to unpack the concept of OEE into a number of separate (but related) issues, with particular focus on issues which apply to the synthesis of OEE systems.

Three basic requirements for open-ended evolution:

1) Practically unlimited space of potential phenotypes

If a system is to be capable of the continual production of new organisms without practical limit, there should be a practically unlimited space of potential organisms that could be represented in the medium.

2) Mutational pathways of practically unlimited length between potential phenotypes

It is insufficient to require just an unlimited space of potential phenotypes; these potential forms must be reachable by the evolutionary process. OEE requires that pathways of practically unlimited length exist in this possibility space from the original ancestral organisms to an wide variety of possible future organisms.

3) Changing adaptive landscapes to drive continual evolution

The first two requirements endow a system with the ***potential*** for OEE. If that potential is to be realized, without external assistance, the system must generate an intrinsic ***drive*** for continual adaptive evolution. This requires that the adaptive landscape experienced by organisms is changing rather than static, at least over evolutionary time scales. This can be introduced into a virtual world through the property of ***connectedness***.

Connectedness

The fitness of an organism will depend on its local environment if there is a ***connectedness*** between organism and environment. Such connectedness can be built into the system in a number of ways, including:

Food webs

If organisms engage in the consumption, transformation and excretion of nutrients and energy, food webs can emerge that connect a whole ecosystem of organisms.

Physical phenomena

Connectedness can arise through physical aspects of the environment, such as the transmission of forces, the transmission of signals, or modification of physical aspects of an ecosystem.

The effect of connectedness, however it is achieved, is that changes in the behavior of one organism in the system, or the introduction of a new type of organism, or removal of an existing type, will have significant consequences for other organisms in the system.

Connectedness therefore means that organisms in an ecosystem live in a delicate balance, and evolutionary change in one species will change the adaptive landscape of other species in the ecosystem.

Design issues for connectedness

When designing a system which has rich connectedness, a number of issues arise, including:

Conservation of matter

Without this, there is no need for resources to be recycled, hence no need for food webs.

Embeddedness

Ideally, all components of an organism should be subject to the same laws of physics as the rest of the environment. Otherwise some aspects will be hard coded and not subject to evolution.

Complex physical environments

The richer the range of phenomena available in the environment, the richer the potential for organisms to evolve ways of capturing and manipulating those phenomena for their own purposes.

Next steps

The subject of connectedness has been under-explored in work to date. I am commencing an empirical study of how the issues outlined above affect the evolutionary dynamics of an ALife system.