Artificial-Life Ecosystems: What are they and what could they become?

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Abstract

This paper summarises the history of the terms *ecology* and *ecosystem*, before examining their application in the early and recent literature of A-Life agent-based software simulation. It investigates trends in A-Life that have led to a predominance of simulations incorporating artificial evolution acting on generic agents, but lacking a level of detail that would allow the emergence of phenomena relating to the transfer and transformation of energy and matter between the virtual abiotic environment and biota. Implications of these characteristics for the relevance of A-Life's virtual ecosystem models to Ecology are discussed. We argue a position that the inclusion of low-level representations of energetics, matter and evolution, in concert with pattern-oriented modelling techniques from Ecology for model validation, will improve the relevance of A-Life models to Ecology. We also suggest two methods that may allows us to meet this goal: artificial evolution can be employed as a mechanism for automating pattern-oriented ecological modelling from the level of individual species up to that of the ecosystem, or it may be employed to explore general principles of ecosystem behaviour over evolutionary time periods.

Introduction

As even a cursory survey of the early and current literature reveals, within the fields of Artificial Life and Ecological Modelling, agent (individual)-based virtual ecosystem model construction has been widely practiced ([1-4] are some early examples from A-Life, also see [5], for surveys of ecological examples [6], and more recently [7, 8]). Of course there is overlap between Ecological Modelling and A-Life publications in this regard, but a careful elucidation of the differences between the historical and current trends in the fields' approaches to virtual ecosystem construction allows us to recommend a mechanism for overcoming some of their limitations. We suggest this may be achieved by melding the approaches of both fields into models that explicitly represent energetics, matter (chemical stoichiometry) and evolution within a single simulation framework. The need for including these three frameworks was noted in the literature some time ago [9, 10]. Additionally, any purportedly descriptive simulations must be validated against ecological data.[1] One method to achieve this is through *pattern-oriented modelling* [11], a technique summarised below.

We will discuss two under-explored ways in which hybrid A-Life/Ecology ecosystem simulations of this kind may be built. Firstly, models of energy and matter transfer adopted from A-Life's artificial chemistry simulations may be incorporated within generic ecosystem simulations. In this context, artificial evolution may be employed to select agent parameters producing general patterns that may be validated against ecological field data, without regard for the behaviours of particular species or habitats. This would allow for studies of the generic properties of ecosystems.

Secondly, artificial evolution may be used to select parameters for pattern-oriented modelling from the level of specific species up to the level of specific ecosystems. Once a set of patterns has been matched, the evolution algorithm can be disabled and the ecosystem simulation may be used to answer questions concerning that specific ecosystem over sub-evolutionary time periods (or over longer periods, disregarding the effects of evolution).

By adopting such approaches it is possible to extend the range of questions that may be answered by ecosystem simulations for both Ecology, by locating parameters that match field data, and A-Life, by answering questions of ecological relevance whilst permitting exploration of the general properties of ecosystem behaviour outside the familiar domain of evolution.

Before investigating the application of ideas from Ecology and A-Life to the construction of virtual ecosystems, we shall give a brief overview of significant and relevant stages in the development of these fields.

Ecology and the Ecosystem

Ernst Haeckel coined the term *ecology* in *Generelle Morphologie der Organismen* (1866) to give form to the study of Natural History in the context of Darwin's ideas that organisms must struggle for survival. Ecology was to be the study of animals, their relationships amongst themselves, with plants and with the inorganic environment that affected their

[1] Some A-Life researchers will feel that there is no need for A-Life models to reflect reality in the way this paper proposes. It is true that many A-Life models are interesting regardless of their ability to represent reality. However, this paper examines how A-Life and Ecology may be of mutual benefit to one another. Hence we discuss ways of improving the correspondence between virtual and real ecosystems.