The Importance of Open-Endedness
(for the Sake of Open-Endedness)

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Introduction

A paper in the recent Artificial Life journal special issue on open-ended evolution (OEE) presents a simple evolving computational system that, it is claimed, satisfies all proposed requirements for OEE (Hintze, 2019). Analysis and discussion of the system are used to support the further claims that *complexity* and *diversity* are the crucial features of open-endedness, and that we should concentrate on providing proper definitions for those terms rather than engaging in "the quest for open-endedness for the sake of open-endedness" (Hintze, 2019, p. 205). While I wholeheartedly support the pursuit of precise definitions of complexity and diversity in relation to OEE research, I emphatically reject the suggestion that OEE is not a worthy research topic in its own right. In the same issue of the journal, I presented a "high-level conceptual framework to help orient the discussion and implementation of open-endedness in evolutionary systems" (Taylor, 2019). In the current brief contribution I apply my framework to Hinzte's model to understand its limitations. In so doing, I demonstrate the importance of studying open-endedness for the sake of open-endedness.

A framework for understanding OEE

From my initial forays into OEE (Taylor, 1999) onward, I have always viewed it as an umbrella term, or high-level goal, that encompasses many interlinked topics. Over the last eight years I have made several attempts at making explicit these different facets of OEE and how they fit together (Taylor, 2012, 2015, 2019). The first two of these are, I believe, liable to be misunderstood by some readers because, for the most part, the discussion within them relates to self-reproducing systems (e.g. "Tierra-like" systems)—but this assumption of the specific problem situation of self-reproducing systems was perhaps not sufficiently emphasized in the papers. However, my most recent and expansive attempt, and the one I am most comfortable with, does not suffer from this weakness because it does not make the same assumption; it can be applied to any evolutionary system whether it involves self-reproducing organisms evolving under natural selection or agents that are selected and repro-

duced using extrinsic mechanisms (e.g. fitness functions) (Taylor, 2019).

The framework set out in (Taylor, 2019) attempts to describe the general *design requirements* for open-endedness. The idea is that this will be useful both in guiding the design and implementation of OEE systems, and also in categorizing and comparing the OE potential of existing systems. The framework comprises three interrelated components:[1]

1. The distinction between *exploratory*, *expansive* and *transformational* novelties. This is defined formally in (Taylor, 2019) but can be loosely thought of as the extent to which novelties are of the "more of the same" variety versus more fundamental and unexpected innovations.

2. A formalism of the basic processes required of any evolutionary system, cast as processes of *generation* of phenotype from genotype, *evaluation* of the phenotype, and *reproduction* (with variation) of the phenotype. The formalism makes explicit various influences and interactions between each of these processes, mediated by the laws of dynamics of the system and the biotic and abiotic context in which they occur.

3. The distinction between *intrinsic* and *extrinsic* implementations of each of these processes. Intrinsic processes (i.e. those explicitly implemented within the system itself) can evolve, whereas those implemented extrinsically to the system (e.g. external fitness functions) cannot. The greater the extent to which all three evolutionary processes are implemented intrinsically, the more deserving are the agents of the label *self*-reproducing.

A brief discussion of how the framework could be used to categorize and compare the OE potential of existing systems was presented in (Taylor, 2019, p. 220). I extend that discussion here by applying the framework to the model proposed by Hintze.

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[1]As discussed in (Taylor, 2019), I acknowledge that the framework could be further improved, e.g. by incorporating population-level processes (such as drift and neutral networks) and by adopting a more sophisticated treatment of the relationship between form, dynamics and behavior.

Hintze's model

Overview A simple evolving computational system is presented in (Hintze, 2019). The model comprises a population of agents in a discrete 2D space. Each agent starts life at the center of the space and follows a trajectory defined by its genome. The genome is a sequence of the symbols *right*, *left* and *forward*. Agents only interact indirectly through their shared trajectories; the fitness function considers how many agents traversed each square in the space, and awards points to each agent that traversed a given square in inverse proportion to how many other agents traversed the same square. Hintze finds that the complexity of the agents' genomes (as defined by the Zlib compression size) increases exponentially, as does the diversity *between* runs over generations (as defined by the mean Levenshtein distance between all pairwise comparisons of a single randomly-chosen sequence from each experiment). Hintze claims that his model fulfils all of the hypothesized requirements for OEE suggested in several previous publications, including (Taylor, 2015).[2] Noting that the observed evolution of agent behavior is nevertheless underwhelming, he argues that the results indicate the need for better definitions of the types of complexity and diversity growth required of an open-ended evolutionary system, and suggests that "with the proper definitions of complexity and diversity, open-endedness might be a natural consequence of these systems" (Hintze, 2019, p. 204).

Critique Hintze asserts that "the exciting property of an evolving system is not its openness but instead the complexity of the actual evolved solutions" (Hintze, 2019, p. 200). This is a highly contentious assertion. Of course, evolutionary systems that can evolve complex agents are of great interest in ALife. But following Hintze's suggestion of concentrating on precise definitions of what counts as "interesting enough" complexity and diversity in the context of a given study is a very different research goal to the study of OEE. *Tierra* produced complex and diverse agents in the initial generations, but after a while no further significant innovations were observed (Taylor et al., 2016, p. 418). It is *that* result—the lack of ongoing innovation in Tierra and other computational evolutionary systems—that catalysed the emergence of the field of OEE research. The pursuit of a defined threshold level of complexity in an evolutionary system is a very different goal to the pursuit of ongoing innovation. *Both* are perfectly valid and interesting research goals but they are different goals.

In presenting my framework I argued that OEE "comprises just two essential processes: the ongoing exploration of a phenotype space ... and the discovery of door-opening states in that space that open up an expanded phenotype space" (Taylor, 2019, p. 222). An essential goal for OEE re-

search is to understand the *mechanisms* by which these processes can be implemented. In the original paper I discussed how the first of these could be achieved "by allowing for intrinsic means for ongoing modification of [the processes of generation, evaluation and reproduction]" (Taylor, 2019, p. 216). Hintze's model only allows for ongoing modification of one of these processes: *evaluation*. It does so by allowing a parameter of the evaluation function to change (the biotic context of other agents in the population), but it does not allow for the evaluation function itself to be changed (this is hard-coded and extrinsic). The *generation* of phenotype from genotype, and the genetic operators involved in *reproduction*, are also hard-coded extrinsic processes. The model therefore has some limited capacity for ongoing exploration of phenotype space but only via one of the possible mechanisms. By concentrating on definitions of complexity and diversity, Hintze ignores discussion of the one key aspect of his model that enables its (limited) capacity for open-endedness—the role of the biotic context in the evaluation function.

Furthermore, Hintze's model is completely lacking in the second essential process of OEE—the ability to discover door-opening states leading to expanded phenotype spaces. It is therefore a model of *exploratory* open-endedness only and is incapable of producing *expansive* or *transformational* innovations. The inability to discover expanded phenotype spaces arises partially owing to the fixed one-to-one relationship between genes and their meaning in the model (i.e. the actions *right*, *left* and *forward*). This is due to the impoverished dynamics of the world which lacks any laws of physics or possibility of action beyond what is directly encoded in the genome. The genes in the model directly describe *semantics*. In order for new semantics to evolve, the genes should describe *syntactical* structures (or, stated in physical terms, *boundary conditions*) which interact with the laws of dynamics of the world, out of which interactions semantics *arise*. This is the case in notable examples of interesting evolved agents such as (Sims, 1994) and (Baker et al., 2019), which both involve agents evolving in simulated physical environments. A preliminary discussion of these issues was presented in (Taylor, 2019, pp. 221–222), although they deserve a more elaborate treatment in future work.

More can be said about the strengths and weaknesses of Hintze's model in terms of its capacity for OEE, but the comments above at least demonstrate that the concepts presented in (Taylor, 2019) provide a useful framework upon which to hang such a discussion. OEE research seeks to understand the design of evolutionary systems that exhibit an ongoing generation of creative innovations. This is a different goal to studying the evolution of complexity or diversity by themselves. Many interlinked topics must be assembled to understand how to design and build OEE systems. It is only by studying open-endedness, for the sake of open-endedness, that we might hope to make progress towards this goal.

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[2]I dispute this claim because I believe Hintze has misinterpreted some of the requirements in (Taylor, 2015). However, this is incidental to the main point of the current contribution.

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