Editorial Introduction to the 2024 Special Issue on Open-Ended Evolution

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There has been general agreement in the first four Workshops on Open-Ended Evolution (OEE) and associated publications (Packard et al., 2019b, 2019a; Taylor et al., 2016) that it is productive to define OEE by its behavioral hallmarks, which give rise to different kinds or categories of OEE. There is a significant degree of consensus about these behavioral hallmarks, but there is less agreement about hypothesized requirements or mechanisms for the generation of OEE's behavioral hallmarks. The editorial introduction to the first 2019 *Artificial Life* special issue on OEE (*25*[1]) emphasizes two hallmarks of OEE: the ongoing generation of adaptive novelty of different kinds and the ongoing growth of complexity. Adaptive novelty can come in many forms, ranging from new adaptive features or new kinds of entities to major transitions in evolution and the evolution of evolvability. In addition to "interesting new kinds of entities and interactions," the editorial introduction to the second 2019 special issue on OEE (*25*[2]) specifically identifies and distinguishes major transitions in evolution, the evolution of evolvability, and semantic evolution.

This special issue presents work that either follows on from the fourth Workshop on OEE (at the 2021 Conference on Artificial Life) or has been developed since then to build on the two previous special issues. We solicited articles presenting new results, articles on the key challenges in OEE, and articles on the main lessons learned and milestones achieved in recent work. All submissions were independently peer reviewed, and the recommendations of the reviewers were unanimous.

The articles in this special issue address open-ended evolution from a variety of perspectives, as you can see in the following short summaries of each contribution to the current special issue.

"Kuhnian Lessons for the Study of Open-Ended Evolution" by Bedau argues that the study of OEE seems to illustrate Kuhnian "normal science," with negligible controversy over fundamentals, negligible overt disagreement over which problems and methods are legitimate scientific pursuits, and many universally recognized scientific achievements that provide the field with model problems and model solutions to them, but nevertheless a relative dearth of exemplars of OEE. It proposes a sequence of projects to create and refine a set of OEE exemplars and so fuel productive activity in the study of OEE: First identify an initial set of candidate exemplary OEE models and measures, then evaluate if they would be good exemplars by comparing the measures across the models, and reevaluate and refine the set of exemplars through a review paper, a software tutorial, and a textbook on OEE.

"A Procedure for Testing for Tokyo Type 1 Open-Ended Evolution" by Channon brings together five methods of analysis to form a procedure for testing for Tokyo Type 1 OEE, a category of OEE that includes systems exhibiting the ongoing generation of adaptive novelty and ongoing growth in complexity. The approach is based on measuring adaptive novelty, accumulation of adaptive success, and diversity and complexity; qualitative classifications are determined through analyzing trends in these measures. The procedure is presented with clear rationales for its steps, which help identify five key challenges in OEE in terms of developing and evaluating exemplary OEE models against specific measures. The most significant of these challenges is achieving a higher order of complexity growth within a system exhibiting indefinitely scalable complexity. Promising approaches to this include also achieving Tokyo Type 2 OEE (ongoing evolution of evolvability) or Tokyo Type 3 OEE (ongoing generation of major transitions), presenting one answer to why these other types of OEE are important and suggesting a unified view of OEE.

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"Open-Endedness in Genelife" by Packard and McCaskill presents novel results from Genelife, an extension of Conway's Game of Life cellular automaton in which each "live" cell has a genome that determines the local update rules. Evolutionary dynamics are reported in terms of spatial dynamics and evolutionary activity, for genome (update rule) encodings of increasing specificity and for variants in which the choice of encoding/specificity is itself encoded on the genome. The results demonstrate a rich range of evolutionary dynamics across these different configurations. In terms of evolutionary activity and OEE, multiple configurations demonstrate new activity remaining positive. The results are of interest in their own right, and there is clearly potential for further work on OEE using Genelife.

"On the Open-Endedness of Detecting Open-Endedness" by Stepney and Hickinbotham demonstrates a range of innovative and possibly open-ended behaviors involved in countering a parasitic arms race within the spatial version of the Stringmol automata chemistry. Results are reported in terms of first system-generic measures (primarily Droop and Hickinbotham's measure for quantifying non-neutral evolutionary activity) and then system-specific measures dedicated to analyzing some of these innovations. It argues that a process of analysis starting with system-generic measures, such as evolutionary activity measures, but going on to system-specific measures will be needed wherever the phenomenon of open-endedness is involved.

"Evolved Open-Endedness in Cultural Evolution: A New Dimension in Open-Ended Evolution Research" by Borg et al. argues that the study of cultural evolution in humans and other animals can provide important perspectives in the study of OEE in general. It introduces various distinctions that can be drawn in cultural evolution (cumulative vs. noncumulative, tall vs. wide, bounded vs. unbounded) and shows how these apply to human and nonhuman cultures. It suggests that humans are the only species to exhibit unbounded, cumulative cultural evolution and that the study of how this evolved can contribute much to the study of open-endedness. It further suggests that Bedau et al.'s evolutionary activity statistics could be usefully improved if they could provide insight into the type of evolution happening (e.g., tall vs. wide) and asks new questions that become apparent once we consider cultural evolution within the framework of OEE.

Together, the articles in this special issue advance our understanding of a number of aspects of OEE. These include new results from two specific models (Genelife and Stringmol). One of the key challenges in the study of OEE is identifying and evaluating candidate exemplary OEE models using generally accepted OEE measures. Furthermore, this special issue reminds us of the need also to employ system-specific measures. In addition, the special issue illustrates how human cultural evolution seems to be a real-world example of OEE. Recognizing cultural evolution as a distinctive instance of OEE could lead to new insights about the diversity and power of open-ended evolution. The editors hope that the special issue will inspire readers to produce further work that leads to novel insights into the key challenges in the study of OEE.

References

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