Levins and the legitimacy of artificial worlds

Seth Bullock[1] and Eric Silverman[2]

[1] Science and Engineering of Natural Systems Research Group
School of Electronics and Computer Science
University of Southampton, Southampton, UK
[2] Ikegami Lab, University of Tokyo
3-8-1 Komaba, Meguor-ku, Tokyo 153-8902, Japan

Abstract. For practitioners across a growing number of academic disciplines there is a strong sense that simulation models of complex real-world systems provide something that differs fundamentally from that which is offered by mathematical models of the same phenomena. The precise nature of this difference has been difficult to isolate and explain, but, occasionally, it is cashed out in terms of an ability to use simulations to perform "experiments", e.g., [9]. The notion here is that empirical data derived from costly experiments in the real world might usefully be augmented with data harvested from the right kind of simulation models. We will reserve the term "artificial worlds" for such simulations.

In this paper, rather than tackle the problems inherent in this type of claim head on, we will approach them obliquely by asking: what is the root of the attraction of constructing and exploring artificial worlds? By combining insights drawn from the work of Levins, Braitenberg, and Clark, we arrive at an answer that at least partially legitimises artificial worlds by allocating them a useful scientific role, without having to assign the status of empirical enquiry to their exploration.

Our starting point in this exercise is simulation modelling work within the field of artificial life, where models and artefacts (robots, artwork, "realisations" of "digital life", etc.) are used to explore fundamental biological questions. The field as a whole has struggled with the notion of a special role for simulation models. Some attribute the status of "digital naturalism" to their use, as though software entities represent an additional kingdom of living creatures [10]. Others claim that they are models, but that in the right circumstances they nevertheless have the capacity to settle empirical questions [1]. Still others have cast them as just another kind of reasoning aid to be placed in the scientific modelling toolbox alongside equational models, physical replicas, games, thought experiments, etc., being distinct from the others only in terms of their immaturity and in so far as they involve an added layer of indirection and complicatedness brought about by the involvement of automatic machinery [4]. One aim of the current paper is to probe this relationship between automaticity and complicatedness.

In his seminal 1966 paper "The strategy of model building in population biology", Richard Levins presents a trade-off between the aims that a modeller might attempt to meet in a single model [5]. No useful model, Levins claims, can maximise precision, generality and realism. Orzack and Sober [8] have shown that a strict three-way trade-off between precision, realism and generality cannot hold since it is surely possible to decrease all three properties by simplifying a model. In line with recent analysis by Odenbaugh [6], we argue that this fatally misconstrues Levins' trade-off. Levins, in fact, explicitly invokes *four* inter-dependent dimensions since he states that *useful* models may not simultaneously maximise realism, generality and precision. Apparently, Levins didn't think it necessary to point out that increasing realism, precision and generality would not be sensible if it were achieved at the expense of what we will term a model's *tractability*: our ability to make use of the model to shed light on the system being modelled.

That Levins felt a need to warn of the dangers inherent in attempting to build models that are simultaneously precise, general and realistic is reason enough to assume that seeking to combine all three properties might motivate some modellers. Moreover, Odenbaugh's [7] argument that Levins was responding to a growing trend in what he termed "Fortran ecology", the use of large computer models that could be parameterised to represent a wide range of ecosystems and purported to generate precise, realistic predictions, suggests that this motivation might be felt by simulation modellers in particular. But on the face of it, the attraction of general, precise, realistic models should be felt quite generally across scientific modelling paradigms. Why would simulation modellers be particularly vulnerable to it?

Braitenberg's [2] law of "downhill design and uphill analysis" offers a glimpse of one answer by halving the notion of tractability into components related to constructing and understanding, respectively. For manually constructed mathematical models these two halves are tightly coupled, proceeding in step, and arriving either at an intelligible model or a conceptually intractable (i.e., failed) model. However, in simulation modelling this coupling is loosened until, for some simulations, constructing *forgoes* understanding. This account is redolent of work by Clark [3] on explanation in the context of artificial neural networks, where the automatic nature of the neural network algorithm can propel a modeller from a competence-level description of the problem to a working implementation of a solution without visiting the algorithmic level of representation necessary in order to achieve an understanding of that solution. By analogy, simulation modellers enjoy increased tractability in the design phase, relying on the automaticity of their models to produce interesting behaviour, but suffer during the analysis phase where model behaviour may remain analytically intractable.

By this point we have a rather bleak account: simulation modelling of complex systems can tempt modellers to build systems that are beyond their comprehension in a misguided effort at combining generality, precision and realism. An illusion of tractability is created by the powerful automaticity of computational tools. But there is no free lunch, in that what is won on the swings of easy construction is lost on the roundabouts of intractable analysis. This situation can force simulation modellers to make do with systems that are to some extent general, precise and realistic, but not fully understood. Consequently such systems can come to resemble the mysterious real world rather than a traditional scientific model, lending an empirical flavour to their exploration.

However, while there is a clear pathology at work here, there is something to be salvaged by noting that the divide between tractable and intractable is not set in stone. Improved physical or mechanical power can bring previously unscalable heights within reach. Likewise, improved simplifying assumptions, theoretical frameworks, representational re-descriptions, organising concepts, etc., can simplify previously intractable problems, bringing them within reach of existing analytical tools. Working at a "tractability ceiling" is the right place to achieve these kinds of insight and by projecting us through such ceilings, albeit temporarily, even a less-than-fully understood simulation model can give us, not a window on a new artificial world of empirical facts and findings, but a new perspective on an existing world of ideas, assumptions, commitments and questions.

References

1. Bedau, M.A.: Philosophical content and method of artificial life. In: Bynum, T.W., Moor, J.H. (eds.) The Digital Phoenix: How Computers Are Changing Philosophy, pp. 135-152. Blackwell, Oxford (1998)
2. Braitenberg, V.: Vehicles. MIT Press, Cambridge, MA (1984)
3. Clark, A.: Connectionism, competence and explanation. In: Boden, M.A. (ed.) The Philosophy of Artificial Intelligence. OUP, Oxford (1990)
4. Di Paolo, E., Noble, J., Bullock, S.: Simulation models as opaque thought experiments. In: Bedau, M.A., McCaskill, J.S., Packard, N., Rasmussen, S. (eds.) Proceedings of the Seventh International Conference on Artificial Life, pp. 497-506. MIT Press, Cambridge, MA (2000)
5. Levins, R.: The strategy of model building in population biology. American Scientist 54, 421-431 (1966)
6. Odenbaugh, J.: Complex systems, trade-offs, and theoretical population biology: Richard Levins' "Strategy of model building in population biology" revisited. Philosophy of Science 70, 1496-1507 (2003)
7. Odenbaugh, J.: The strategy of "The strategy of model building in population biology". Biology and Philosophy 21, 607-621 (2006)
8. Orzack, S.H., Sober, E.: A critial assessment of Levins's "The strategy of model building in population biology". The Quarterly Review of Biology 68, 533-546 (1993)
9. Peck, S.L.: Simulation as experiment: A philosophical reassessment for biological modelling. Trends in Ecology & Evolution 19, 530-534 (2004)
10. Ray, T.S.: An evolutionary approach to synthetic biology: Zen and the art of creating life. Artificial Life 1, 179-209 (1994)