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BOOK REVIEW

Computer simulation and philosophy of science

Eric Winsberg: Science in the age of computer simulation. Chicago: The University of Chicago Press, 2010, 168pp, $24.00 PB

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For more than a decade, Eric Winsberg has been publishing insightful and important papers on computer simulation. His trailblazing work has helped to lay a foundation for other philosophers of science, more and more of whom are now taking a serious interest in the topic. This book brings together the central ideas and arguments of Winsberg's impressive body of work to produce what is to my knowledge the first book-length study of computer simulation from a philosophy of science perspective. The epistemology of simulation receives the most attention, but Winsberg also puts computer simulation into contact with familiar topics in philosophy of science, including confirmation, experiment, realism, reduction and values—in many cases challenging traditional ideas. The book is both philosophically rich and grounded in concrete yet accessible examples, making it valuable reading for anyone interested in computer simulation and its place in contemporary scientific practice. It is a significant contribution, one that prompts us to think again about how science really works.

The introductory chapter gives a very brief history of computer simulation and motivates the idea that computer simulation is of philosophical interest. Winsberg contends that science is currently in the "age of computer simulation" (2), in which major developments in fundamental theory are slow to come but novel applications of existing theory are occurring at an impressive rate, thanks in part to the digital computer. As Winsberg sees it, computer simulation is very often a complex and messy exercise in *theory application*, a topic largely neglected by philosophers of science, who have been more concerned with theory justification; this is one reason why computer simulation might require its own epistemology, one that is itself "motley" and complex. He also suggests that new methods and technologies—like those employed in computer simulation—might be just as significant for philosophy

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of science as fundamental theory change, a claim that the book as a whole is intended to support.

The second chapter, “Sanctioning Models: Theories and Their Scope”, begins by discussing the complex process through which simulation models are constructed, emphasizing that theory often guides, but rarely determines, this process. In fact, in order to arrive at models that are computationally tractable, scientists may need to deviate significantly from theory, drawing on their physical intuition and using various techniques and tricks (16). Winsberg then argues that the “sanctioning” of simulation results often cannot come by justifying separately one’s choice of modeling equations and one’s techniques for solving them, as is sometimes suggested, but instead involves the *simultaneous confluence* of theoretical, mathematical and empirical considerations. This is an important point, and it would be valuable to see an example worked out in detail. He concludes by challenging the idea that computer simulations should be thought of as revealing the empirical content of theories relied upon in their construction, advocating instead the view that simulation models mediate between our theories and the world in richer and more varied ways.

Chapter 3, “Methodology for a Virtual World”, pursues the idea that the epistemology of computer simulation is an empirical one, rather than a logical or mathematical one, with noteworthy similarities to the epistemology of experiment. In the first part of the chapter, Winsberg surveys several existing views of the relationship between simulation and experiment, finding none of them fully satisfactory. In the second part, he highlights important similarities between the epistemologies of experiment and simulation. He illustrates, for instance, that many of the strategies identified by Allan Franklin (1986) for building confidence in experimental results have analogs in computer simulation. Turning to Ian Hacking’s (1988) claims that experiments have “lives of their own” and that experimental practice is “self-vindicating”, he argues that the same is true in the context of simulation: computer simulation tasks evolve and are retooled over time, and simulation techniques—like the “piecewise parabolic method” that he discusses—can come to “carry their own credentials” in light of a history of successful use.

In Chapter 4, “A Tale of Two Methods”, Winsberg examines the intuition that, whatever their similarities, there is also a fundamental difference between the investigative activities we call “simulations” and those we call “experiments”. Identifying insights as well as shortcomings of existing proposals, he ultimately settles on the view that what distinguishes these activities is the kind of background knowledge we rely upon to justify our choice of object (i.e., that which we study directly, often in place of a target system) and thus to justify our results. Winsberg maintains that, in simulations, we argue that we have a reliable toolkit for building dynamical models of the target, whereas in experiments we argue that we have controlled for confounders and that the target and object are, in relevant respects, the same kind of system. He concludes by noting that while the knowledge needed to run a good simulation often comes from a long history of experimenting, it does not follow that experiments are (as a class) more epistemically powerful than simulations.

Chapter 5, "When Theories Shake Hands", explores the philosophical implications of parallel multi-scale modeling, in which individual simulation models are constructed using mutually incompatible theoretical frameworks that operate at different levels of description (e.g., continuum mechanics, molecular dynamics and quantum mechanics). Winsberg points out that, here, attempts to reconcile such theoretical frameworks are driven not by mereology but by physical insight. For instance, in nanomechanical models, inconsistent theories are made to mesh (or "shake hands") with the help of "silogen" atoms, fictitious entities that have some properties of silicon and some properties of hydrogen. Reflecting on this example, Winsberg offers a sophisticated characterization of *fictions* in science: they are representations that, according to the community's norms of correct use, are not reliable guides to the properties and behaviors of their prima facie representational targets. Moreover, he contends, the case of silogens illustrates one way fictions can be useful in science, namely, by "extending the useful scope of theories and model-building frameworks beyond the limits of their traditional domains of application" (87). Winsberg also argues in this chapter that parallel multi-scale models constitute *models of an inconsistent set of laws* (86), but it is unclear what he means; he acknowledges that (formally) an inconsistent set of laws can have no models, and yet he seems to mean something more here than that the construction of multi-scale models is *informed by* mutually inconsistent laws.

Chapter 6, "Models of Climate: Values and Uncertainties", combines work from two papers on climate modeling, one co-authored with Johannes Lenhard and one co-authored with Justin Biddle. It is an ambitious and wide-ranging chapter that reaches some provocative conclusions. First, Winsberg argues that strong coupling among components of climate models makes it virtually impossible to attribute the successes and failures of climate models to particular modeling assumptions; climate modelers face a particularly vexing sort of confirmation holism, one that cannot be overcome with Duhemian *bon sens*. Exacerbating the difficulty, according to Winsberg, is the fact that later additions to a complex climate model are strongly constrained by choices made earlier in model construction—a situation he calls "entrenchment" (105), making an apt analogy with William Wimsatt's (2007) notion of generative entrenchment in evolutionary biology. Exactly why entrenchment in climate modeling exacerbates confirmation holism, however, is not clearly explained. Building on this idea that climate models are "products of their specific histories", Winsberg then challenges Richard Jeffrey's (1956) claim that scientists can assign probabilities to hypotheses in a value-neutral fashion. In a nutshell, he argues that the decision to prioritize some climate prediction tasks over others is *invariably* influenced by social, political and/or economic considerations and that this prioritizing impacts the probabilities assigned to hypotheses about future climate change. While the argument may not ultimately succeed, it is not easily dismissed either, presenting a novel challenge to those who side with Jeffrey.

In Chapter 7, "Reliability without Truth", Winsberg explores the implications of earlier chapters for the issue of scientific realism. He argues that model-building techniques used in simulation—in particular techniques that involve fictions—can provide counterexamples to a suitably formulated no-miracles rule. One example is the technique that introduces "artificial viscosity" to avoid problems in simulating shock waves in fluids: artificial viscosity plays a genuinely central role in making systematically successful predictions and interventions that are sufficiently specific and fine-grained, but it is not true, even in some qualified sense, that real fluids display a viscosity proportional to the square of the divergence of their velocity field, as the technique assumes (128–130). Taking inspiration from Arthur Fine (1991), Winsberg suggests that artificial viscosity be construed as *broadly reliable*: in a specified domain, it can be used to make successful predictions, to achieve engineering goals and to produce results that fit well into our web of previously accepted observations, intuitions and paper-and-pencil analyses. Of course, artificial viscosity only delivers these successes in conjunction with many other modeling assumptions. This is a complication acknowledged by Winsberg but largely dismissed; it merits further discussion.

A closing chapter returns to two general claims made in the book's introduction: first, that new methods and technologies might significantly impact philosophy of science, just as fundamental theory change has in the past; second, that there is real philosophical work to be done in understanding the application of theories, not just their justification. Winsberg concludes—quite rightly I think—that the ground he has covered in the book does indeed provide support for these important ideas.

How could the book be improved? Some of its weaknesses stem from its heavy reliance on previously published papers. For instance, the discussion often achieves only a certain level of depth—that typical of a journal article; important arguments sometimes go by too quickly to be fully persuasive. Likewise, in chapters based on older papers, the book passes up some easy opportunities to reference work that has appeared in the meantime, a drawback for today's readers. Also unfortunate are numerous minor editing problems, such as missing words, which were sometimes distracting. Lastly, it is worth noting that the book is admittedly biased toward simulation in the physical sciences. Those working in the biological and social sciences may rightly feel that some especially salient questions about computer simulation—e.g., questions related to explanation—have been overlooked.

Nevertheless, the book is already impressively broad in scope. It is also creative and provocative, providing a rich starting point further philosophical investigation. *Science in the Age of Computer Simulation* is an important contribution to philosophy of science, one that is likely to remain a touchstone for work on computer simulation for many years to come.

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