

Physical Perspectives on Computation, Computational Perspectives on Physics

Although computation and the science of physical systems would appear to be unrelated, there are a number of ways in which computational and physical concepts can be brought together in ways that illuminate both. This volume examines fundamental questions which connect scholars from both disciplines: is the universe a computer? Can a universal computing machine simulate every physical process? What is the source of the computational power of quantum computers? Are computational approaches to solving physical problems and paradoxes always fruitful? Contributors from multiple perspectives reflecting the diversity of thought regarding these interconnections address many of the most important developments and debates within this exciting area of research. Both a reference to the state of the art and a valuable and accessible entry to interdisciplinary work, the volume will interest researchers and students working in physics, computer science, and philosophy of science and mathematics.

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Edited by Michael E. Cuffaro , Samuel C. Fletcher

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Preface

Historically, philosophers have devoted a great deal of attention to the interrelations between computational concepts and both mathematical concepts and the concepts of intelligence and mind. There has been much less work, however, on the interrelations between computational concepts and those of the natural sciences. Our goal, in putting this edited volume together, was to begin to fill in this gap with a book dedicated to the connections between computation and physics, and to encourage further work in this area.

To this end, we have gathered together an interdisciplinary group of twenty-three of the world's leading physicists, computer scientists, mathematicians, and philosophers of science and mathematics. Together they have contributed twelve original chapters representing diverse perspectives on various questions related to the general topic. These include questions such as: Is the physical universe computable? Is the universe a computer? Can a universal computing machine simulate every physical process? What is the source of the computational power of quantum computers? Is "hypercomputation" possible? When do physical systems implement a computation? Can general principles for physical computation be given? What can we learn from physics-like models of computation? How do methodologies derived from physical practice illuminate computer science? How does framing physical theories in computational language illuminate their characteristic features? Are computational approaches to solving physical problems and paradoxes always fruitful?

Our volume is addressed to philosophers, physicists, and computer scientists interested in the connections between physics and computation. Among philosophers, this includes several groups. Philosophers of physics will find, in this volume, some of the latest computational perspectives on traditional questions in the interpretation of physical theory. Philosophical logicians and philosophers of computer science, conversely, will gain exposure to the latest perspectives from physics to reimagine the nature and interpretation of computation. Philosophers of science interested in more general questions will see how these two scientific fields have provided and continue to provide cross-fertile ideas. And philosophers of mind will learn about the connections

between physics and computation with a view to informing computational theories of mind. Finally, physicists and computer scientists interested in new ideas and approaches to the foundations of their theories will find this volume to be a stimulating font of ideas.

This volume includes many completely new ideas and insights by leading specialists, and we have collected these essays together, in part, with the aim of providing a reference to the state of the art. That said, the book's contributors have all made a substantial effort to keep the technicality of each chapter at a level that is accessible to a reader with no more than an undergraduate training in mathematics, physics, or computer science. This accessibility is aided by the pedagogical introduction and overview that begins the work. We therefore expect that the book will be quite useful as part of a graduate seminar on the topic.

A work of this magnitude could not have been completed without the help of numerous others of our friends and colleagues. Particular thanks are due to Hilary Gaskin, who encouraged and supported this project through all of its various stages; to Stephan Hartmann, whose advice was enormously useful to us as we prepared our final proposal for this volume in the autumn of 2015; to Sophie Taylor, for her helpful advice regarding the finer details of the manuscript's compilation; to Philippos Papayannopoulos, who compiled the index; and to Sona Ghosh, for her advice regarding the same. We are also indebted to Jeffrey Bub, Giuseppe Castagnoli, Martin Davis, Walter Dean, Nicolas Fillion, Leah Henderson, Kevin Kelly, Jan van Leeuwen, Chiara Marletto, Stephan Mertens, Wayne Myrvold, Michael Rescorla, and Jos Uffink for the guidance they provided to us as we prepared this manuscript for publication.

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