Review: The Nature of Computation

By Moore and Mertens

While cross-fertilisation between theoretical computer science (TCS) and statistical physics has started over 30 years ago, it has increased and broadened considerably in the last 15 years. Researchers from both communities have invested a considerable effort in learning more about the other discipline, overcoming the language barrier and differences in the methodology and techniques used.

The new book by Moore and Mertens is not only about the difficult problem of crossing the bridges of Koenigsberg, but mostly about building bridges between disciplines; it aims to provide a broad overview of key subjects in theoretical computer science in a manner that is accessible to non-specialists, by minimising the technical details and providing simple and clear examples. From a pedagogical point of view, having multiple exercises throughout the book and problems at the end of each chapter make it easier to use it as a text book at both advanced undergraduate and postgraduate levels. The proofs included aim to provide insight rather than to focus on mathematical details; they are presented in a manner that is accessible to a broad audience. The presentation is light and informal at times and links are drawn, in various places throughout the book, between the TCS definition of problems and the statistical physics framework.

The book covers a good range of subjects, essential for introducing the reader into the world of complexity, hard computational problems and their link to sampling and statistical physics methodology.

The first few chapters (1-2) introduce the reader to a number of well known examples of hard computational problems and use the opportunity to guide the reader through the various terms and definitions that are extensively used in the TCS literature, such as scaling rules, adversary and asymptotic behaviour. Following the introduction of commonly used algorithms, the authors cover elegantly, in a clear and broadly accessible manner the complexity classes, the P=NP problem and their relation to the universal computer and fundamental questions and concepts related to computability (chapters 3-7). Along the way, they introduce the reader to essential tools and gadgets used in this area, which are essential for understanding more advanced texts. Chapter 8 looks at the interplay between computing time and space to introduce new complexity classes and their relation. In Chapter 9 they cover optimization problems and a broad range of methods commonly used for solving them and their relation to statistical physics.

In Chapters 10-11, Moore and Mertens tackle more advanced material that is typically not addressed in text-books of this type, aimed at non-experts. They successfully introduce the concept of randomised algorithms, Probabilistically Checkable Proofs, approximability and how they are interlinked. Their presentation is one of clearest and most accessible I have read.

The next group of chapters (12-15 with the exception of 14, which is incomplete) address questions that relate issues of complexity and computability to other fields, primarily statistical physics and quantum computation. Moore and Mertens used their deep understanding of both TCS and the related areas to draw interesting links and highlight similarities between the different domains and methodologies; these will be particularly useful for readers with expertise in the other disciplines.

In summary, Moore and Mertens guide the reader through the interesting field of computational complexity in a clear, broadly accessible and informal manner, while systematically explaining the main concepts and approaches in this area and the existing links to other disciplines. The book is comprehensive and can be easily used as a textbook, at both advanced undergraduate and postgraduate levels, but is equally useful for researchers in neighbouring disciplines, such as statistical physics, who are keen to learn more about the methodology and approaches used in TCS. Some of the material covered, such as approximability issues and Probabilistically Checkable Proofs are typically not presented in books of this type, and the authors do an excellent job in presenting them very clearly and convincingly.