Editor: George Cybenko
Send announcements to kclark-fisher@computer.org

UNDERSTANDING QUANTUM COMPUTING

By George Cybenko

Quantum Computation and Quantum Information, by Michael A. Nielsen and Isaac L. Chang, Cambridge Univ. Press, Cambridge, UK, 2000, ISBN 0-521-63503-9, $48.

THE WORLD CONSISTS OF TWO KINDS OF PEOPLE—THOSE WHO UNDERSTAND QUANTUM MECHANICS AND THOSE WHO DON'T. YOU SHOULDN'T FEEL BAD IF YOU DON'T, BECAUSE TRULY DEEP UNDERSTANDING SEEMS POSSIBLE ONLY IF YOU CAN develop intuition about how quantum mechanics describes our world, as it seems to do at a very basic level. Moreover, the leading physicists of the 20th century continue to debate the true meaning and interpretation of things quantum, so it appears that this requisite intuition is highly personal.

Fortunately, understanding quantum computation is a different matter. You can begin with a quantum-mechanical formalism based on familiar mathematics and treat most of how it applies to computation in a formal, almost axiomatic, way. This is different than profoundly understanding quantum mechanics but is, in my opinion, achievable with less effort and by more people.

Michael Nielsen and Isaac Chuang have written an excellent book. It is readable and comprehensive; its close-to-conversational tone is unusual in a book on this subject. The authors write as if they were talking with readers, rather than lecturing at them, resulting in a pleasing style. However, the material is dense and the reader must be dedicated, motivated, and alert at all times.

Just shy of 700 pages, *Quantum Computation and Quantum Information* covers several important developments in the subject through 2000, which is more than enough for someone who wants to get a solid grounding in quantum computing and its implications. The authors do not provide references to original sources as they develop material, deferring citations to a section at the end of each chapter. This leads to unnecessary suspense about who did what, and when. I referred to this section every few pages, just to satisfy my curiosity; folding the history discussion in with the idea presentation would have been more effective and consistent with the writing style.

Quantum Computation and Quantum Information consists of three parts: fundamental concepts, quantum computation, and quantum information. Appendices cover some of the required background material. Because quantum mechanics is largely understandable in terms of probabilities and unitary operators, the half page devoted to unitary operators and two pages of background on basic probability send a clear message that the reader must have a significant mathematical background before tackling even the first part of this book.

Part One, "Fundamental Concepts," covers the basic ideas underlying quantum computing. This section uses the traditional notation, which is highly compact and subject specific. The text could be presented in the notation and terms of Hilbert space analysis, with which mathematicians and engineers are more familiar. Because my background is in mathematics, I must map the notation and logic into the functional analysis and matrix theory with which I am comfortable. For example, the notation and use of "bra" and "ket" seems to be the norm in this field, which is dominated by researchers trained in physics. A development of quantum computing using von Neumann's language and notation would appeal to many trained in those terms.

Part Two, "Quantum Computation," builds on Lov Grover and Peter Shor's key results by building a framework common to several quantum computing algorithms. The authors develop several fundamental results about quantum factoring, searching, and counting. The detailed discussion of realizing general quantum operations using elementary gates is especially appealing.

Part Three, "Quantum Information," covers quantum information concepts—namely, the issues that arise when dealing with quantum systems that are not closed but instead interact with a larger environment. This quickly gets into Shannon theory and coding, which most readers will consider advanced material.

The authors have done a remarkable job of compiling a vast amount of relatively recent research into a readable volume. As Charles Bennett writes on the back cover, "An independent student could spend an enjoyable year reading this book…." CiSE

1521-9615/02/$17.00 © 2002 IEEE