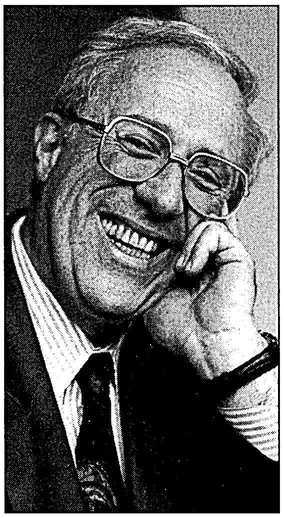
BOOKS: COMPUTING

Toward the Invisible Computer

Martin Greenberger

Michael Dertouzos's eighth and final book is an important one. Convincingly perceptive about computers past and present, *The Unfinished Revolution* sets a human-centered agenda for the future of computing. It is a persuasive book and for me a nostalgic one as well. Dertouzos, the director of the Laboratory for Computer Science at the Massachusetts Institute of Technology (MIT) for 27 years and someone I knew for nearly 40, passed away this year in August.



Michael Dertouzos.

Michael came close to naming the book "Doing More by Doing Less," a phrase he invokes in almost every chapter. He had a long-standing interest in productivity, which he personified in his own career. But given the broad sweep of the book's concerns, *The Unfinished Revolution* is a better title. Dertouzos admonishes the computing industry for mistreating people, and he prescribes as the remedy a major redirection of research and development. The book emphasizes the essential roles to be played by users of future computer technology and the necessity of having the technology fit better with human needs and human nature.

The Unfinished Revolution
Human-Centered Computers and What They Can Do For Us
by Michael Dertouzos
HarperCollins, New York, 2001. 240 pp. $26, C$39.50, £10.99. ISBN 0-06-662067-8.

Although improved efficiency is one argument for developing a better human fit, the book offers an even worthier reason. Making computers less formidable and less demanding would extend their benefits to much larger numbers of people worldwide. Such "democratization of computing" was very much on Dertouzos's mind.

The phrase "unfinished revolution" recalls personal computer–pioneer Alan Kay's line, "The computer revolution hasn't happened yet." Kay draws an analogy with the history of an earlier information technology, the printing press. He believes the printing revolution did not happen with Gutenberg's invention of movable type in the mid-15th century or with Aldus Manutius's development of portable books 50 years later. The revolution occurred only when educated people began routinely thinking and writing in the style of reasoning that printing made possible; that took a good 200 years.

Dertouzos earned a doctorate in electrical engineering from MIT in the early 1960s. It was a time when, aided by funding that J. C. R. Licklider arranged from the U.S. Department of Defense's Advanced Research Projects Agency, we were establishing MIT's Project MAC ("Multiple Access Computer" or "Machine-Aided Cognition") to develop human-computer symbiosis within a time-sharing, utility-like operation. Computer networks were coming into vogue by 1974, when Dertouzos became the fourth director of Project MAC. To make the mission seem less transitory and to better reflect the researchers' expanded range of activities, he changed its name to Laboratory for Computer Science.

In Dertouzos's vision, formulated in 1980 (shortly before personal computers began to blossom), time-sharing systems and information utilities were the "opening lines of a fast-moving play." They would lead to a decentralized "information marketplace," where millions of interconnected people would buy, sell, and exchange information and services, much as goods were traded in the Athens flea market he knew as a boy. Dertouzos's information marketplace foreshadowed the World Wide Web, whose inventor, Tim Berners-Lee, he helped and encouraged. He arranged for Berners-Lee to come to MIT in 1994 to work in the Laboratory for Computer Science and to form the Web Consortium there.

Dertouzos thought the information revolution would not be complete until computers were as invisible, pervasive, essential, and effortless to use as oxygen in the air. To help transform that vision into reality, in 1999 he and his collaborators initiated an ambitious research program at MIT called "Project Oxygen." He devotes one chapter of the book to outlining the program's five research areas (speech recognition, automation, information access, collaboration, and customization), which he believed could bring us closer to human-centric computing.

In a remembrance, Charles Vest, the president of MIT, observed that Dertouzos was "larger than life...a leader, builder, visionary and caring human being." Michael could also be provocatively eloquent, as at the end of *The Unfinished Revolution*:

> What does reason have to do with the love of a child, the beauty of a flower, the eternity of stone, our origin, our destination?...[We] overrate reason at the expense of spirituality, and technological reason at the expense of humanistic ideas.
>
> The highest meaning of "human-centric," and its biggest benefit to us, will be determined by what we do to achieve the human goals we set.

By Dertouzos's reckoning, the ongoing information revolution began in the 1950s (others would say it started in the 1940s, or even the late 1930s). He anticipated achieving his stated goals by 2020, and he estimated that an additional two decades would be required to complete the effort. By any account, we are now in the second half of the quest. The end will come only when computers vanish from view. It will take a while, but the ideas and vision that Dertouzos promotes in the book could help us through the final phase of the revolution.

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BOOKS: APPLIED PHYSICS

High-Density Intro to Information Devices

David G. Goodwin

Ever since Samuel Morse transmitted "What hath God wrought?" by telegraph from Washington to Baltimore in 1844, major advances in information technology have often been the direct result of advances in physics or physics-based technology. The telegraph could only be developed after magnetic induction was discovered. The development of the transistor could not have occurred without a prior understanding of the energy band structure of solids, which in turn was only possible once the underlying quantum mechanics had been worked out.

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But physics is only half the story of the evolution of modern information technology. Equally important have been the breakthroughs in information theory, data compression, error correction, encryption, and computation that make it possible to reliably, efficiently, and securely transmit, process, and store information. The questions addressed by these "information sciences" have been largely independent of the physical representation of information; they apply equally well to information transmitted by telegraph, satellite, or optical fiber. Therefore, most academic programs in the information sciences include little physics. Conversely, traditional academic programs in physics rarely expose students to the information sciences.

The Physics of Information Technology
by Neil Gershenfeld
Cambridge University Press, Cambridge, 2000. 384 pp. $39.95, £24.95. ISBN 0-521-58044-7.

Neil Gershenfeld, in *The Physics of Information Technology*, makes the point that because "circuits cannot have wires smaller than an atom, signals faster than light, or charge carriers smaller than an electron," questions regarding the ultimate limits of information technology require an understanding of both physics and the information sciences. In addition, the approaches, such as quantum computing, that are being pursued to circumvent the limits of current technology require a more complete blend of the physical and information sciences than before. In this book of fewer than 400 pages, he attempts to bridge the gap—to present a synthesis of the fundamental results in selected areas of physics and the information sciences and to show how both are used in the technologies of communication, information storage, and computation.

Gershenfeld, of the Massachusetts Institute of Technology's Media Lab, acknowledges the inevitable difficulties inherent in summarizing much of physics, electrical engineering, and computer science in one book. In the preface, he expresses the hope that his "presumption in covering so many important areas in such a limited space is justified by the value of covering so many important areas in such a limited space." The extraordinarily broad range of topics encompasses noise, information theory, electromagnetic theory, optics, transmission lines, waveguides, tomography, lasers, liquid crystals, magnetic storage, error correction, cryptography, superconductivity, relativity, nonequilibrium thermodynamics, and quantum computing.

With such a range, each topic must be treated very briefly and most are allocated only a few pages. The chapter on semiconductor materials and devices, for example, occupies 24 pages. It includes sections on quantum statistical mechanics; electronic structure; *p-n* junctions, diodes, and transistors; and logic gates. In addition, there is a short discussion (unrelated to semiconductors) of irreversible and reversible computation. Most other chapters are similarly condensed.

In the book's two-page introduction, the author poses several questions meant to demonstrate that familiar information technologies operate near fundamental physical limits. For each question, he gives a very brief, and sometimes cryptic, answer. To take one example, "Why does computation require energy?"

> Because there must be some irreversibility to ensure that calculations go forward in time (from inputs to outputs) and not in reverse, and because logical erasure necessarily implies dissipation because of the compression of phase-space.

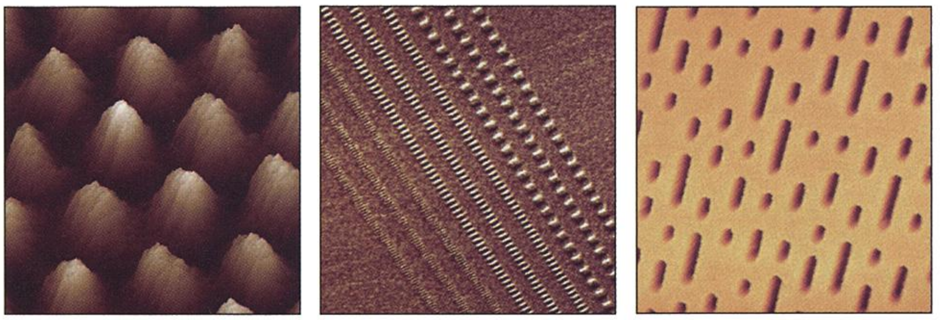
For those readers who know what phase-space is and how to compress it, this explanation may be enlightening. But such readers probably already know why computation requires energy. The answer is likely to leave everyone else at least a bit puzzled.

The book was developed from lecture notes for a class, and passages like this one read literally like notes jotted down to be explained in more depth in lecture. Indeed, throughout the text Gershenfeld retains much of the conversational tone and spontaneity of a lecture. At its best, this makes for enjoyable reading, with interesting tidbits and asides that enliven the discussions. In some parts, however, the approach is too scattershot: topics are briefly discussed using terminology that is not explained, and then the author abandons them to move on to something entirely different.

Gershenfeld's presentation is the most quantitative when he discusses areas of fundamental physics, and it becomes much more qualitative when he turns to areas closer to technology. The chapter on electromagnetic fields and waves, for example, offers a standard vector calculus–based development, which is presented clearly but condensed to 20 pages. The discussion of quantum mechanics in a later chapter plunges immediately into the state vector formulation and then rapidly presents Hilbert spaces, Hermetian operators, commutators, Clebsch-Gordon coefficients, and other aspects of the formal machinery of quantum mechanics. Readers will encounter none of the usual discussions of the physical motivation that supports this mathematical framework.

At the other extreme, the physics of semiconductor devices—arguably the area in which physics has had the greatest impact on information technology—is described at an elementary level. The discussion of doping fails to even mention that donor and acceptor impurities introduce bound states in the energy gap. (That elementary result has many implications, including explaining why semiconductor materials must be extraordinarily pure and defect-free.) The discussion of *p-n* junctions is also surprisingly qualitative, given that quantitative expressions for their characteristics would have been a good application of the electrostatic theory developed in an earlier chapter. And semiconductor lasers, of central importance in high-speed optical fiber communications networks, are described in the briefest of terms.

Of course, any collection of topics as diverse as those in this book will delight some and displease others. Readers seeking an advanced treatment that emphasizes technologically relevant areas like semiconductor or solid-state physics will be disappointed. But Gershenfeld's book will be valuable for physical scientists looking for an enjoyable introduction to the information sciences. And anyone wishing to learn more about diverse areas of physics related to information technology will find it of interest.



Packing the bits in. Atomic force microscopes have been used to achieve terabit-per-square-inch data storage in titanium oxide **(left)**, but the less-dense storage provided by magnetic tracks **(center)** and compact disks **(right)** is sufficient for many purposes.

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