Talking Back to the Machine

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This is the editor's introductory essay for the book, Talking Back to the Machine, published by Copernicus Books (an imprint of Springer-Verlag) in May 1999. This book is the sequel to Beyond Calclulation, published by Copernicus in 1997.

The world's electronic computers, first switched on a little more than fifty years ago, have wrought enormous changes in how we live, work, and see ourselves. In 1947, at the dawn of the computer age, a few far-sighted visionaries founded ACM, the Association for Computing, to help nurture the new field and the people in it. A half-century later, the ACM celebrated its own golden jubilee with ACM97 -- a conference, an exposition, a Web site, and a book, *Beyond Calculation: The Next Fifty Years of Computing* (Copernicus). In what *The New York Times* called "essays of astonishing intellectual reach," 24 leading thinkers in the industry described the future of computing as they envisioned it unfolding. Writing for the general reader, they wove thought-provoking essays of remarkable insight and depth. They discussed everything from new technological developments to how computing may affect children, workplace styles, education, research, and business innovation.

The conference itself was so stimulating, and the interest in the first book so great, that we produced a sequel entitled-*Talking Back to the Machine: Computers and Human Aspiration*. It features discussions of how computers will influence how we live, learn, teach, and communicate with each other in the coming decades. Essayists include the Nobel prize winner Murray Gell-Mann on information quality, former Secretary of Defense William Perry on computers in war, computer pioneer Maurice Wilkes on surprises, international business leader Fernando Flores on business communication, Walt Disney Vice President Bran Ferren on story telling with new media, academic leader Elliot Soloway on education, and TV producer and writer James Burke on connections between people and technologies. These and the other writers describe myriad ways, both good and bad, in which our lives will be altered by information technology and how we might influence the shape of things to come.

Charles Babbage, a visionary mechanical engineer, conceived the first general-purpose computing engine about 150 years ago. He built only part of it. Almost a hundred years passed before electrical engineers teamed with mathematicians to build complete automatic calculating machines. Electronics and a theory of algorithms succeeded where pure mechanics did not. The first electronic computers, built as part of the 1940s war effort, were intended for scientific and mathematical calculation: they figured ballistic trajectories and broke ciphers. Many alumni of these projects started computer companies. They saw the main opportunities for growth in the computer's potential for driving international business and for intelligent actions: IBM and Univac bet on business data processing while the newspapers contemplated the implications of "electronic brains." Thomas Watson, the founder of IBM, opined that at most four or five computers would be needed for scientific calculations worldwide.

Others soon joined IBM and Univac in the computer marketplace, adding names like RCA, Burroughs, ICL, General Electric, and Control Data to the growing cadre of computer companies. (Many of those early companies have since disappeared or left the computer business.) People working in these companies and research labs have produced an amazing array of innovations over the past fifty years. They designed the first programming languages -- Fortran, Algol, Cobol, and Lisp -- and the first operating systems In the mid 1950s. They formed the first computer science departments in universities in the early 1960s. In 1972, Hewlett-Packard's hand calculator made the slide rule obsolete. The first computer chips appeared in the late 1970s along with a plethora of personal computers aimed mostly at hobbyists.

In 1981, IBM transformed the personal computer into a business; the IBM PC became an industry standard, the machine to be imitated (as indeed it was by many clone-makers). Bob Metcalfe invented the Ethernet in 1973 at Xerox, allowing many computers to talk over a single coaxial cable. During the next ten years he transformed the Ethernet into an industry standard for local networks connecting PCs. By 1990, word processing, spreadsheets, computer-aided design systems, and database programs respectively made the clerk typist, clerk accountant, draftsman, and record-keeper obsolete. The Internet, which descended from the ARPANET of the 1970s, and the World Wide Web, which seemed to appear out of nowhere in 1992, propelled personal computers -- linked by local networks and modems -- to the center of international business practice. As computers shrank, mainframes became obsolete -- except as computing engines for large applications in business, science, and engineering.

Over those fifty years, the cost and size of computers dropped steadily: Today $2,000 will buy you a computer that is 1,000 times faster and holds 1,000 times as much data as the $1 million mainframes of the 1950s. The computer revolution has pervaded the lives of vast numbers of people: by the beginning of 1999, there were over 80 million users on 30 million computers serving up more than 400 million Web pages worldwide on the Internet.

In the midst of this chaos and ferment, astute observers have spotted trends of remarkable stability. One of the most famous patterns is Moore's law, an empirical observation of Gordon Moore, one of the founders of Intel. Moore said that the speed of microprocessors doubles every eighteen months. Since the start of the computing age, there have already been 18 such doublings; experts now argue about how many more we can expect before the physical limits of miniaturization halt the process. Similar trends have been identified in the growth of the Internet and in the capacities of data networks to transfer files and images. Extrapolate these trends from curiosities now gestating in research labs, and we have what looks like a solid basis for predicting what will happen with computing in the decades ahead. Or do we?

Fifty Years of Surprises

History teaches us a different lesson. Industry pioneers Gordon Bell and Maurice Wilkes remind us that confidence in long-range predictions may be hubris. Although we have been able to predict certain events by extrapolating trends over a short term, we have been notoriously poor at predicting what people will do with any technology in the long term. What people *do* is part of human practices, which stoutly resist quantitative analysis.

Imagine that Henry Ford could return to see today's automobiles. He would hardly be surprised by the changes in design: Cars still have four wheels, steering, front-mounted internal-combustion engines, transmissions, and the like. But he would be greatly surprised by the changes in human practices that have grown up around the automobile -- for example, hot rods, strip malls, drive-in fast food-chains, rush hours, traffic reports, stereo systems, mobile phones, navigator systems, cruise controls, and more. Alexander Graham Bell would similarly be little surprised by the design of telephone systems but practices like "prestige" exchanges, telemarketing, and telephone pornography would amaze him. Can you imagine trying to explain lava lamps to Edison or frequent-flyer miles to the Wright brothers?

What has happened with computing and telecommunications has certainly been a surprise for me. I was born in the early days of the current revolution. I have been interested in science since childhood, astronomy and botany since grammar school, electronics since middle school, and computers since high school. As a graduate student in the 1960s, I was immersed in the MIT optimism about the possibilities offered by computing technology. We were optimistic that one day computers would shrink to fit on top of a desk (or, at least, *be* the desk). We were optimistic about far-flung networks and resource sharing, about graphics, and about artificial intelligence. Deep down, however, all this seemed like wishful thinking. For if you told me that the slide rule would be obsolete within five years of my graduation, the typewriter within ten years, or the publisher-owned copyright of research papers within thirty; or that Internet addresses (whatever they were) would be displayed on business cards and television ads; that people would give up their home telephones for cell phones; or that new computers would be designed based on DNA, nanotechnology, quantum mechanics, or biological silicon, I would have thought you were crazy. But here we are, with all this and more. I am grateful to have lived to see my romance with computing technology be requited. Go ahead and dream, some of them are likely to come true!

Today Foreseen

In our charge to the authors of *Beyond Calculation* and the speakers at ACM97 to look ahead, Bob Metcalfe and I counseled against baseless predictions. New-millennia predictions are as plentiful (and as cheap) as grains of sand. In response, most of the authors and speakers did one of two things: They looked at trends or at human nature, figuring that they could extrapolate the trends or count on human nature being the same.

Despite all the protestations of the editors and authors, our readers and listeners heard predictions and pondered their accuracy. The speculations are, after all, advanced by the industry's great thinkers. Surely what they say is more likely to come to pass than what others might say.

Fortuitously, an event 100 years ago offers guidance on this question. In 1893, the Fourth World's Columbian Exposition was held in Chicago. It celebrated the 400th anniversary of Columbus's landing in the Western Hemisphere. Like other world's fairs, it sought to demonstrate future possibilities in science, technology, art, and culture. It also featured a look ahead to the Fifth Columbian Exposition in 1993. (Curiously, the expected 1993 Exposition never took place.)

The American Press Association organized a group of 74 leading authors, journalists, industrialists, business leaders, engineers, social critics, lawyers, politicians, religious leaders, and other luminaries of the day to give their forecasts of the world 100 years later. Their 74 commentaries were published in the national newspapers for several months preceding the Exposition. One hundred years later, journalist and historian Dave Walter compiled and republished their commentaries in a volume he called *Today Then: America's best minds look 100 years into the future on the occasion of the 1893 World's Columbian Exposition* [American World & Geographic Publishing, 1992]. In reading these old essays, we learn more about the writers and how they observed their world than we do about our own world.

Among the most striking features of the 1893 forecasts is the remarkable paucity of predictions that actually came true. Some of them seem outlandish, completely disconnected from reality -- but fervently believed by their authors. For example, religious leader Thomas De Witt Talmage thought that longevity would be increased to 150 years. US Senator W. A. Peffer thought that pollution would no longer be a problem. Comptroller of the Treasury Asa Mathews thought the USA would include Canada and Mexico in a total of 60 states (there were 44 then). Publisher and editor Erastus Wiman thought that there would be minimal taxation, worldwide free trade, and no standing army. Engineer George Westinghouse thought that trains would operate at speeds of 40-60 miles per hour and that faster speeds, though possible, were too unsafe. Railroad icon and lawyer T. V. Powderly thought that there would be no very rich or very poor, that no family would have more children than it could sustain, and that divorces would be rare. Commissioner of Indian Affairs Thomas Morgan thought that Indian tribes would disappear and be replaced with a highly-respected Indian cultural tradition. Lawyer and politician Williams Jennings Bryan predicted the abolition of the Electoral College in US Presidential elections.

Many thought railways would be the primary method of transportation, extending from the northernmost parts of Canada to the southernmost parts of South America. They thought that pneumatic tubes would be common modes of transportation for people in cities and of moving mail transcontinentally. They thought government would be smaller and that there would be fewer class differences. Few foresaw the world wars, the communications revolution, or air transportation. None foresaw the interstate highway system, genetic engineering, mass state-sponsored education, or broadcast TV and radio -- or the computer.

These commentators, probably reflecting more widely held opinions of the day, were particularly possessed by two beliefs: that technology would solve society's ills, and that people would change dramatically for the better. Some spoke as if the changes they forecast were inevitable; some simply prayed for solutions to social problems; some attempted to extrapolate trends. The few commentators who came closest to describing the world as we know it today were the most skeptical about the idea of technology solving our problems and about the mutability of human nature.

Animated by Our Beliefs

What can we learn about our own world by reading the forecasts of our ACM97 authors and speakers? What can we learn about *now* by reading about *then*? I discovered six unspoken presuppositions running through many of the essays.

(1) *Technology will continue to progress at an ever-increasing rate, producing generally positive changes.* We believe in extrapolations like Moore's law, the diminishing significance of distance, the flattening of communication costs. We accept the motto "change is the only constant." When Moore's law runs out, we believe that new technologies will be available to continue or accelerate the rate of change, bringing benefits faster. The possibility that some outcomes may be negative is discussed but not taken seriously -- for example, that cost-efficient national medical databanks formed by health management organizations may trample individual privacy rights, that detailed surveillance to deter intruders might enable control-oriented mangers to make the workplace distinctly unpleasant, or that government's power to protect citizens might be eroded by its inability to collect taxes.

Computing research visionary Joel Birnbaum and semiconductor innovator Carver Mead explicitly discuss new technologies that will enable the exponential growth of computing power to continue. Internet pioneer Vint Cerf and former FCC Commissioner Reid Hundt are certain that communication bandwidth will become inexorably cheaper and wider. Robotics pioneer Raj Reddy sees a time when such improvements will permit virtual time travel, virtual teleportation, and immortality for those willing to survive as disembodied intelligences in cyberspace.

(2) *Technology drives social and commercial change, placing technologists in a special stewardship.* Economists want us to believe that prosperity has resulted from policies they have been able to recommend from their simulations of economies. Entertainment companies want us to believe that their story telling abilities and production of worthy content have saved the Internet from being a barren wasteland. Business leaders want us to believe that their spending decisions, driven by customer needs, determine which technologies and services can actually be supported. Baseball players would have us believe (at least in 1998) that the feats of home run hitters Mark McGwire and Sammy Sosa, brought to us by the national networks and backed by sophisticated databases, have elevated the national mood and with it prosperity. We technologists are no

different. We would have others believe that the advances we produce drive all the other changes they cherish. The scenario of the Year 2000 Date Bug bringing on the collapse of civilization strikes us as amusing but unlikely because, after all, *we* will summon the brainpower and the technology itself to overcome the problem at the last minute and keep cyberspace humming. Our technology is supreme!

The truth is that all these factors, and more, play together in an intricately complex game whose evolution we call progress. The possibility that other players and forces might affect change more than our technologies may not appeal to many of us. The possibility that we do control the direction of the technology frightens some of us.

Notable among the dissenters from this view are educator Elliot Soloway, who sees the education of children as a fundamentally human activity; and science fiction writer Bruce Sterling, who believes that the dark side of human nature will express itself at the slightest chance.

(3) *Surprises will abound.* Who hasn't seen the list of off-base predictions such as Bill Gate's claim that no one would ever need more than 640K of memory? Or the claims in the original ARPANET documents that resource sharing rather then e-mail would be the driving force in networking? Or the derisive critiques claiming that 1960s software engineers mistakenly assumed that the Cobol language and database formats would be long dead by the year 2000? These statements might represent surprises, but none is of the magnitude of the sweeping changes that few of the 1893 prognosticators foresaw. We speak of the folly of prediction and then give forecasts with the conviction of an astronomer pinpointing the time of tomorrow's sunrise.

If we really believe the rhetoric about surprises, why don't we look more systematically from whence they came? Technological surprises (breakthroughs) most often come from the "boundaries" -- interactions between people of different domains exploring a common interest. Business surprises come from marginal practices -- those at the boundaries of a field -- that can be broadened to solve a major problem or produce an enormous benefit. (The World Wide Web, which started out as a means for physicists to exchange research papers, was like this.) The more remote the boundary, the bigger the surprise.

Entrepreneurs are more familiar with the phenomenon of boundaries than most researchers. The number of boundaries between information technologists and other domains grows as computers invade ever more diverse fields. Today's boundaries include: biology, notably DNA computing, organic memories, bionic body parts and sensors, 3D real-time imaging; physics, including materials, photonics, quantum computing; massive Internet computations; neuroscience, cognitive science, psychology; large-scale models for climate, economics, aircraft simulation, earthquake prediction, and weather forecasting; data mining from massive data sets; library sciences; workflow and coordination in organizations; humanities, arts, music, and story telling. Researchers give lip service to these boundaries but relatively few embrace them passionately. No wonder so many are surprised when an invader from one of the frontiers crashes through our quiet neighborhoods.

(4) *Computers can -- and should -- be a leveling force, eliminating class differences and pulling up the indigent.* There is much talk on this topic: Information wants to be free, no government can successfully restrict the flow of information (or funds) across its national boundaries, computers offer instant democracy; computers can make education universal, and an individual's personal power increases through access to knowledge via the Internet. A better age is coming, but some help from government is needed in the short term to prevent the gap between the haves and have-nots from widening.

This proposition is none other than the two-century-old belief that technology is capable of solving many of society's problems. Yet the same problems are with us today. This proposition relieves us of personal responsibility to help others -- after all, the technology will do it if we just give it time. It deserves our undying scorn.

(5) *Computers and information are great metaphors for understanding how things work.* Computers have given us new ways of thinking about machines, communications, organizations, societies, countries, and economies. Throughout the ages, every technology has given us metaphors for nature and ourselves. René Descartes's mind-body dualism, for instance, proposed that a spirit inhabited an extraordinarily complicated clock-like device -- the "ghost in the machine." Freud's theory of the unconscious implicitly evoked the image of a steam-engine: impulses blocked from their natural release would build up pressure in the subconscious mind until they blew out elsewhere, often far from their point of origin. Today, neuroscientists routinely talk about feedback loops and brain circuitry; instinctive behaviors are said to be wired or programmed; we possess "software" for certain kinds of mental activity. Educators describe learning as a process of transferring information from a corpus of knowledge to the student.

It is respectable in the 1990s to talk about all mental activities, including visual imagery and memory recall, as algorithmic processes. We have spent a substantial part of the past half century trying to build computers that resemble the mind -- all we have to show for it are minds that think they resemble computers. Computer scientists have not been satisfied to automate our ability to calculate; they have attacked object recognition, language comprehension, reasoning about the world, digitizing the world's libraries, and much more. As the steam engine was an iron horse, the computer is a silicon brain.

Cracks are already beginning to appear in the computing metaphor. A growing number of educators, for example, say that there is much more to learning than transferring information; they say the phenomenon of embodied knowledge, learned through practice and involvement with other people, is a process that cannot be understood simply as information transfer. Terms from biology and genetic engineering are beginning to creep in; for example, more economists describe economies as ecologies rather than as engines of growth.

Who ventures guesses about the great metaphors fifty years hence? Fernando Flores defines the age of identities for the business world, and James Burke defines an age of connections for society.

(6) *Virtual reality blurs the distinction between what is real and what is not.* Some computer scientists have become enamored of virtual reality -- the full-scale simulation of all sensory input that a person can experience such that the person cannot easily distinguish the simulated world from the real world. Virtual reality can help people learn important skills in settings where mistakes don't have real consequences. It is promoted as the courier of great benefits, allow you to "walk" around in your new house or office before committing to construction, teaching pilots how an aircraft feels before they actually fly it, helping people learn French by immersing themselves in a simulated France, training software managers by having them manage a simulated project, and much more. These benefits are real.

Yet it is easy to get carried away with these speculations to the point where you doubt that anyone will care about the everyday world since they will be able to "jack in" to whatever reality interests them at the moment. What we call reality begins to look more and more like a social construction and does not need to be grounded in real phenomena. Extra-scientific phenomena such as telepathy, telekinetics, time transport, hyperspace flight, wormholes, and artificial life are given equal footing with established, well-grounded science. These beliefs aren't restricted to naïve viewers of modern science-fiction movies -- some of the speakers of this volume embrace them, such as software guru Nathan Myrhvold telling his audience (one hopes with tongue in cheek) that the essence of his personality and the genetic code that distinguishes him from anyone else can be captured on a 1.44 MB floppy disk --and that his next life will be spent as a virtual personality roaming the Internet.

Powers of Imagination

Some have said that the great science-fiction writers have been right more often than our leading thinkers. They base their claim with science-fiction stories written fifty years ago that describe scenes familiar today. But, like the six propositions above, this claim is easier to believe than to verify. I've never seen any data analyzing the science fiction literature. I know there is a huge amount of "pulp science fiction" -- throwaway stuff that isn't worth reading. So what if one in fifty thousand stories contains elements of truth about today? That doesn't tell us much about the predictive abilities of science fiction writers or how to find the ones who make sound forecasts.

The importance of the essays in this book does not depend on their value as science fiction. They reinforce something we already know about leadership: Leaders with powerful stories that inspire the imagination and generate worthwhile possibilities for people are the ones who inspire followers to make their dreams come true. Our authors are all industry leaders. The power of their imagination will draw people into the worlds they see.