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The Digital Revolution

Bob Merritt

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The Digital Revolution

Bob Merritt
Convergent Semiconductors

SYNTHESIS LECTURES ON EMERGING ENGINEERING TECHNOLOGIES #5

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ABSTRACT

As technologists, we are constantly exploring and pushing the limits of our own disciplines, and we accept the notion that the efficiencies of new technologies are advancing at a very rapid rate. However, we rarely have time to contemplate the broader impact of these technologies as they impact and amplify adjacent technology disciplines.

This book therefore focuses on the potential impact of those technologies, but it is not intended as a technical manuscript. In this book, we consider our progress and current position on arbitrary popular concepts of future scenarios rather than the typical measurements of cycles per second or milliwatts. We compare our current human cultural situation to other past historic events as we anticipate the future social impact of rapidly accelerating technologies.

We also rely on measurements based on specific events highlighting the breadth of the impact of accelerating semiconductor technologies rather than the specific rate of advance of any particular semiconductor technology.

These measurements certainly lack the mathematic precision and repeatability to which technologists are accustomed, but the material that we are dealing with—the social objectives and future political structures of humanity—does not permit a high degree of mathematic accuracy.

Our conclusion draws from the concept of Singularity. It seems certain that at the rate at which our technologies are advancing, we will exceed the ability of our post–Industrial Revolution structures to absorb these new challenges, and we cannot accurately anticipate what those future social structures will resemble.

KEYWORDS

Makimoto's Wave, Moore's Law, Singularity, artificial intelligence (AI), artificial emotions (AE), robotics, Industrial Revolution, digital revolution, brain-machine interface, uncanny valley, noosphere, braingate, DARPA

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Bob Merritt
January 2016

Introduction

Computer scientist and science fiction author Vernor Vinge predicted four ways that a rapid expansion of machine intelligence could occur:[1]

1. The development of computers that are superhumanly intelligent and "awake."
2. Large computer networks (and their associated software devices) that may "wake up" as superhumanly intelligent entities.
3. Computer/human interfaces may become so intimate and tightly bound to a human that those users may reasonably be considered superhumanly intelligent.
4. Biological science may find ways to improve upon the natural human intellect.

The challenge is that the impact of new technologies can be both beneficial as well as destructive, yet the ability to anticipate that impact is very difficult.

For example, the patents granted to a Swedish chemist in the 1800s demonstrate one classic example of this delicate balance. Scientist Alfred Nobel's work in developing explosives was initially intended for use in his family's mining operations in Africa. Unexpectedly, the destructive force of these new high-powered explosives was later used to cause massive destruction in the Crimean War and subsequent conflicts. Recognizing the worldwide impact and destruction resulting from his invention, Nobel laid the foundation for worldwide recognition to be granted to individuals based on their positive contributions to our human condition.

Another consideration of successfully integrating new technology is the rate at which new information is being discovered and integrated into industries, relative to the amount of time until societies can absorb the possibilities and broader implications of that information.

What does the future hold as new technologies are being developed? There are a number of possible scenarios.

An excellent example of a future vision of the integration of technology is the silent movie *Metropolis*, directed by Fritz Lang in 1927. This fascinating story of a humanoid robot programmed by its evil genius inventor to cause havoc is available on the Internet, set to music from various contemporary artists.

Another classic view of the future is George Orwell's book *1984*. This book was required reading in high school in the 1950s and 1960s. First published in 1949, Orwell presented a dysfunctional society in which government employees were continuously re-writing or eliminating

[1] http://mindstalk.net/vinge/vinge-sing.html

historical references that were not supportive of the current political goals. This book also introduced the idea of governments waging continuous warfare against vaguely defined and ever-changing external enemies in order to maintain tight control of the society, while distracting the public's attention from the slow decline in their quality of life and the growing encroachment of government into their private lives and personal freedoms.

In the book and 1968 movie *2001: A Space Odyssey*, directed by Stanley Kubrick and co-written with Arthur C. Clarke, HAL, the omnipotent computer, evolved in an unanticipated intellectual direction and eventually wanted to maintain his own level of control. That movie dealt with the elements of an artificial intelligence intent on inserting its own control over that of its human co-worker.

Arnold Schwarzenegger's series of "*Terminator*" movies presents another point of view, with "good" robots battling against "bad" robots for the preservation of mankind.

While each of these scenarios offer different themes for futuristic technologies, this collection of futuristic visions also provides a reference point for evaluating the progress of our current stage of technical evolution. For example, today's level of mobile devices for transferring information has already surpassed the bi-directional yet permanently attached "speakwrite" screen described in the book *1984*. Likewise today's communications channel between computer and human operator exceeds many aspects of the artificial intelligence (AI) interface with HAL in *2001: A Space Odyssey*.

Although it was written from a technologist's point of view rather than as a fictional novel, the book that has arguably comes closest to describing our current condition both technically and socially is *Digital Nomad*, published in 1997 by Dr. Tsugio Makimoto and Mr. David Manners. The concepts and technologies in the book were not described to sensationalize the material but to offer the opinions of a scientist who was deeply involved in the development of advanced technologies.

Dr. Tsugio Makimoto was formerly the chief technology officer at Hitachi Semiconductor and later chief scientist of Sony's robotics program. He is generally recognized as one of the leading engineering talents of Japan and is credited with leading the Organization of Senior Engineers in Japan. He was also recently honored by IEEE as one of the five leading scientists whose contributions have most impacted the electronics industry. Mr. David Manners, a well-known technology commentator and author of numerous articles, remains active as an analyst and commentator of semiconductor events. They published *Digital Nomad* in 1997, which offered a broad view of the new age Internet lifestyle that is now taken for granted. The book was extremely accurate as it envisioned a future business environment supported by high-level professional employees who could reside practically anywhere on the planet. The "work place" became any location from which one's mobile device could achieve access to their personal data.

That Digital Nomad lifestyle anticipated access to three essential elements that were not widely available at that time. These included foremost a relatively inexpensive "Nomadic Toolset," envisioned as portable two-way information devices weighing less than 2 pounds, driven by a high-performance processing element and supported by an adequate amount of operational memory—all combined into a portable device. For all intents and purposes, this "digital toolkit" eventually became today's laptop PCs and tablets.

The next critical ingredient consisted of access to relatively inexpensive high-bandwidth communications at worldwide locations, which of course eventually emerged as today's high-speed Internet.

A final ingredient was unrestricted and affordable travel. The original concept forecasted that professional-level individuals with access to these elements had the option of a nomadic lifestyle if they wished—or a very international network of acquaintances and business partners with whom they could communicate without having to travel at all. The technical conditions for the Digital Nomad lifestyle have thus essentially been met, and to a great extent the lifestyle does exist.

The growth in wireless communications that was a foundation of Digital Nomad was also the critical element in Dr. Makimoto's forecast of a second Digital Wave of semiconductor development that we are now entering. While many in the technology industry were surprised by the decline in demand of PCs and the rise of mobile devices, Dr. Makimoto had predicted this technology crossover several years ago. Dr. Makimoto's other technology forecasts extended past the scenario of the Digital Nomad.

What was unique about Dr. Makimoto's vision was that desktop personal computers were expected to be only the first of several waves of the Digital Revolution. In actuality, the PC wave symbolically crested in the final quarter of 2012. Semiconductor-based Dynamic Random Access Memory, or DRAM, was the primary memory technology used in combination with the processing element for PCs, servers, and large computers. Up to that time, PCs absorbed more DRAM than any other single applications.

However, in the final quarter of 2012, the PC consumption of DRAMs fell to less than 50% of the total DRAM consumption for the first time since the 1980s. That was also the same quarter in which Samsung and other handset manufacturers reported higher than anticipated profitability. Tablets and cell phones as the instruments of choice had become equally necessary items relative to PCs within the Digital Nomad toolkit.

As the primary target for the development of new technologies began to shift, these events foretold a major shift in the technological advances of computing components. The validation of Dr. Makimoto's vision relative to this second digital wave certainly calls for a closer look at the impact and timetable of his later forecast of a third technology wave of the Digital Revolution driven by robotics—particularly when the potential magnitude of that end application is forecasted to exceed the impact of the two previous semiconductor technology waves.

CHAPTER 1

The Next Technology Wave

We are at a historic point in the development of new technologies. In the case of the technologies being presented—just as in many cases in the past—the technical community often knows the most likely path that technologies will follow and what the technologies are generally capable of achieving. Some of the anticipated trends discussed here have been following consistent and predictable paths as forecasted for years.

What technologists don't always know regarding new technologies—and generally haven't been concerned with in the past—is the final commercial form those technologies might take in future applications. Nor have we traditionally been too worried about the political impact, the eventual social compromise, and the cultural integration of the cost/benefits.

However, some long-held theories describing the rate of growth of computing technologies lead to the conclusion that several of these technologies are accelerating fast enough to create substantial social change within the lifetime of most people living today. The concern is that some technical advances are capable of altering our societies faster than can be comfortably assimilated.

The essence of the issue can be captured in two distinct observations that will be presented later in greater detail.

The primary elements of that formula can be stated as:

1. One of the dominant trends in the development of semiconductor technologies associated with computing has been the aggressive rate at which new technologies are being developed. This rate has been recognized as a doubling of those capabilities approximately every two years.

2. As machines, computers have the ability to perform previously defined functions extremely fast. Currently, the ability of a computer to "think" and emulate the human intellect has been estimated to be equivalent to only 0.03% of the human brain.

3. If it is assumed that the intellectual skills of future computing devices continue to progress at the same rate we have seen demonstrated over the past 50 years, mankind should eventually encounter computing devices whose personality is indistinguishable from humans and whose logic and information base exceed that of mankind within the lifetime of the majority of people living today.

Many technologists are in rough agreement with the historic validity of those observations. However, there is strong debate as to whether the trends will continue unchanged into the future—and the degree to which those observations are linked together in the future.

In this book, we are not as interested in the specific measurable rate of advance so much as the rate of advance of those technologies relative to the ability of societies to absorb the implications of those technologies. While the technologies and applications themselves are fascinating, they serve only as the "cause" of our story while our true interest is in their "effect."

Rather than continuing the technical debate over how to precisely forecast the rate of growth of certain technologies, several advancing technological trends in the general area of computers and robotics are presented at a very high level.

We select two active development paths that exemplify technical objectives beyond which we cannot anticipate the absorption of those concepts into every-day life. We have identified the current status of those activities and have considered the possibility of the social impact of what those technologies may ultimately achieve within the lifetime of most readers.

Both of these applications offer solid measurable points of their current status as well as easily identifiable criteria for measuring future developments. In both cases, progress in the development along the technology path of this particular technology would require a major shift in our visions of society.

The first example is the merging of humans and machines to the point that a separate distinction is no longer meaningful. Such applications typically include advanced exoskeletons and computing devices driven by human thoughts via direct hardware connections to the human brain.

The second application promises faster intellectual collaboration and development of other new and emerging technologies—while it also suggests the prospect of an accelerated biological evolution of human intellect through direct connections among a number of human brains.

In the second application, we already know that brain-machine interfaces are becoming more efficient. In 2012, a team at Brown University demonstrated a computer that could interpret the commands of a 58-year-old woman who had been paralyzed by a stroke for almost 15 years. The computer is attached to inserts in her brain and controls a mechanical arm. Based on her mental commands, the computer and associated hardware is capable of selecting a bottle of water or preparing a cup of coffee and lifting those items to serve a drink to her or to a visitor. The actions of the mechanical arm are completely under the command of her thoughts and corresponding brain waves. Any Internet search of "BMI" (brain-machine interface) will provide an update of the growing amount of research in this area.

And what about Cathy Hutchinson, the brave subject of that program? Her latest achievements will be presented in a later chapter.

The reality of the physical linkage between machines and human brain activity has therefore already been proven. The next step is to extend the range of commands and complexity of activities. Expanding those activities eventually requires complex mapping of the interior of the human brain in order to find additional specific contact points, and scientists in several countries have programs under way to complete this task.

On a less global scale however, remarkable progress has already been made in connecting prosthesis devices to undamaged nerve endings and bypassing areas that have been damaged. Progress in this area has led to replacement of hands with a rudimentary ability to duplicate the sense of touch and feeling of surface textures. The market area of medical devices will be the proving ground for many of these technologies.

The second technology path leads toward physically linking together multiple human brains to achieve faster collaboration in the development of new and emerging technologies—while also exploring the prospect of an accelerated *biological* evolution of human intellect.

Significant progress is also being made in this area. While the current state of development in humans is at a very basic level to transferring signals over the Internet from one subject to another that control muscle responses, lab experiments have extended to rats the ability to sense ultra-violet lights—as well as possibly establishing a wired transmission channel between two subject rats.

Integrating the wave of future technologies is emerging as a daunting social challenge. However, mankind has been in this situation previously. From a historic point of view, there is one relatively recent example of technologies advancing faster than could be absorbed into social structures. That example is the 50-year core period of the Industrial Revolution.

At the beginning of that industrialization cycle no one living in the feudal social structure could have ever anticipated the technological, cultural, and political changes that lay ahead, and we will review some of the challenges associated with that period of rapidly advancing technologies.

Based on the accelerated rate of development of new technologies, we are rapidly approaching another similar transitional period. We still don't know the commercial forms that the new technologies might take or how difficult it will be to integrate them into our societies.

However, the difference this time is that we are forewarned of the challenges ahead.

CHAPTER 2

Makimoto's Technology Waves

In December 2013, *Computer Magazine*, which is published by the IEEE Computer Society, devoted a section to the review of "some of the most popular computing laws introduced in the past century and to see where they stand now and what they tell us about the future."

Five specific observations were chosen for the "transformative impact on the essence and appeal of computing, each—with its particular technical focus—helps our rapid progression from giant, multi-ton government machines to the Internet of Things (IoT), digital nomads, and wearable computers."[1]

Two of these computing laws are tangential to the observations in this book, while the other three laws are directly relevant.

The three computing laws that have the most impact on our topic are Metcalfe's Law, Moore's Law, and Makimoto's Wave.

Metcalfe's Law, from Bob Metcalfe, states that the value of a network grows as the square of the number of its users. While difficult to quantify, the law explains the motivation and attraction of increasing the number of users on any particular network. This concept is also the driving force behind increasing the user base of subscribers for applications such as e-mail and other online services.

Moore's Law, first published in 1964, predicts that the chip capacity for logic circuitry doubles at a predictable rate. That rate has slowed somewhat over the past 50 years, but the observation has been the driving power behind the growth in semiconductors and computers. In practice, it meant that if you consider the laptop computer in your hand, the version available at a similar size and price in approximately two years would likely contain twice as much circuitry and processing capability.

More recent surveys indicate that many semiconductor business leaders believe that the performance advances implied by Moore's Law might slow somewhat in the future. However, there is no thought that some insurmountable technical challenge is waiting ahead.[2]

Makimoto's observation was more relevant to the original equipment manufacturers (OEMs). Makimoto's Wave pointed out the predictable 10-year swing of technology development and manufacturability between standardization and commoditization. The standardization cycle encourages manufacturing efficiencies, cost containment, and growth in market share while the opposite cycle of commoditization leads toward competition based on product differentiation, increased performance, and decreased power consumption.

[1] http://www.ask2know.net/blog/2014/02/16/computing-laws-origins-standing-and-impact/
[2] http://www.eetimes.com/author.asp?section_id=36&doc_id=1325641

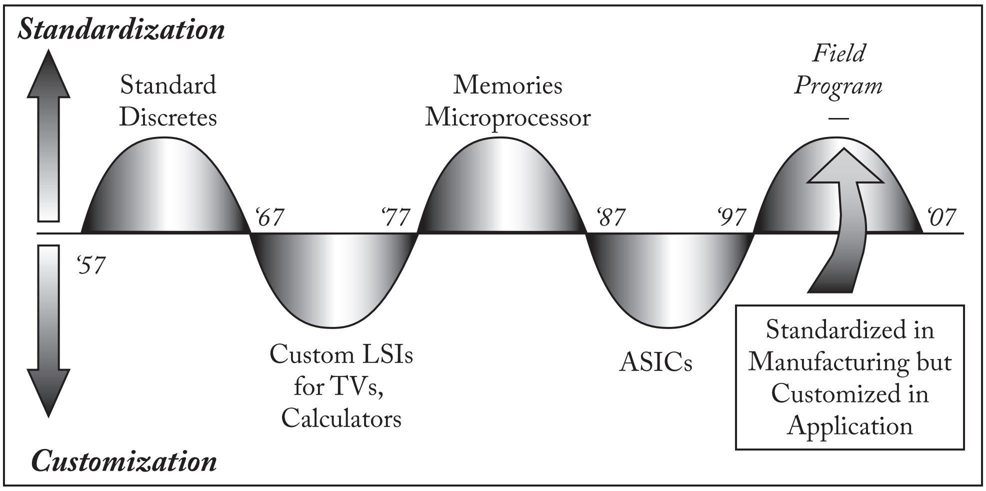

Figure 2.1: Makimoto's Wave. Source: Dr. Tsugio Makimoto, Sony Corporation, paper titled "The Hot Decade of Field Programmable Technologies," published in 2002.

Though many technologists have presented their opinion of the future impact of advanced technologies, we want to specifically consider other forecasts from Dr. Makimoto.

His point of view also separated the Digital Revolution itself into separate waves of technology development with a corresponding impact on societies and businesses.

The IEEE International Electron Devices Meeting (IEDM) is one of the largest international conferences on semiconductor process and device technology. Every year at IEDM, three plenary talks, one each for the European, U.S., and Asian areas, are given as keynote speeches. The subjects of these talks are chosen from the technological trends around the world. On the first day of the IEEE-sponsored conference of 2002, Sony's Dr. Tsugio Makimoto presented the Asian area plenary talk, titled "Chip Technologies for Entertainment Robots—Present and Future." Dr. Makimoto had prepared his presentation in conjunction with Sony's Dr. Toshitada Doi (corporate executive vice president), the originator of Sony's robot development program. The over riding message of his forecast was that at some point soon after 2010, the market influence of digital PCs would be exceeded by that of a different technologically driven product, and the market significance of PCs would decline. Propelled by digital consumer products and data network infrastructure, the forecasted second wave was anticipated to overtake PCs in 2012–2013 and that new wave would support an even larger contribution to the Digital Revolution.

We have already experienced the social and economic impact of PCs, and we are now seeing the shift of market strategies as PCs have yielded to the second technology wave of digital consumer devices and mobile networks.

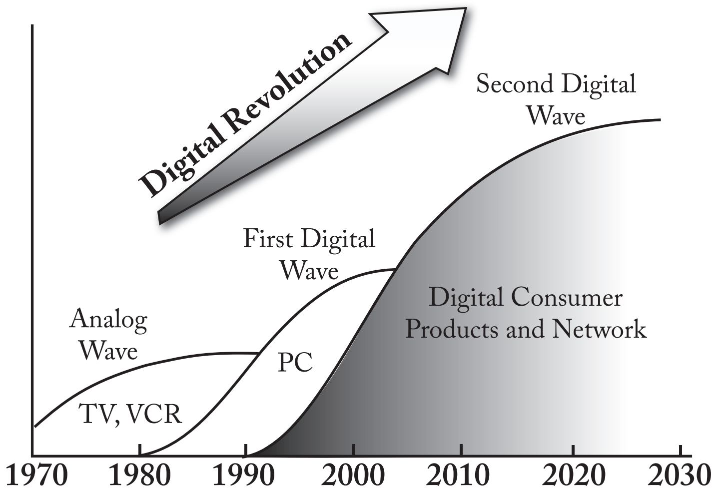

Figure 2.2: The Digital Revolution. Source: Dr. Tsugio Makimoto, Sony Corporation, paper titled "The Hot Decade of Field Programmable Technologies," published in 2002.

A further application of his wave theory relative to end markets identified the primary commercial application of new technologies. His previous outlook had forecasted the transition from PCs to digital consumer and network applications. However, his more recent outlook forecasted the rising wave of robotics as the future target application for the development of new semiconductor technologies.

This particular chart is startling for two reasons. The first reason is the prescience at which he anticipated the timing of the decline in PCs as the driving force for new technologies and the emergence of a second digital wave driven by consumer and networking applications.

The second reason is the anticipation of an equally disruptive technology transition that is still to come.

The Digital Revolution does not end as the market influence of PCs declines or as the cycle of Moore's Law slows from 2 years to 2.5 years. We are only now just beginning to ride this new second wave of networks and mobility—while another wave driven by technologies focused on robotics is still to come.

One of my favorite authors, historian Niall Ferguson, visited the technology development centers of Silicon Valley in California in 2012. He was not impressed by the technical enthusiasm or the futuristic arguments, and he published his reaction.

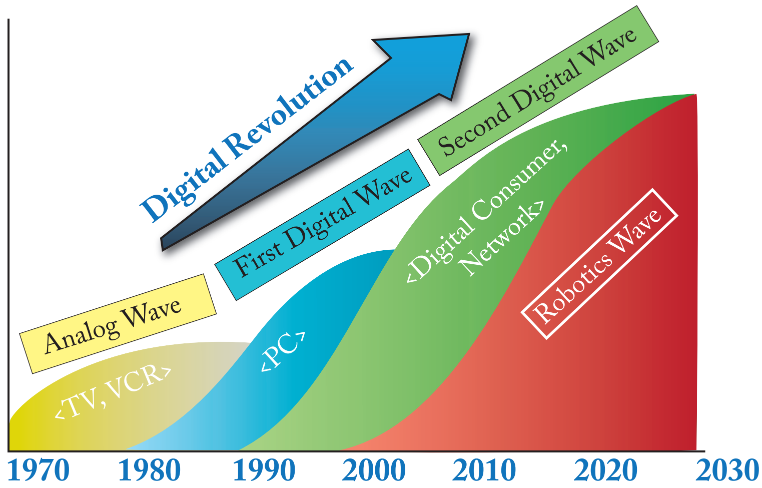

Figure 2.3: The Digital Revolution.

"Are you a technoptimist or a depressimist? This is the question I have been pondering after a weekend hanging with some of the superstars of Silicon Valley. I had never previously appreciated the immense gap that now exists between technological optimism on the one hand and economic pessimism on the other. Silicon Valley sees a bright and beautiful future ahead. Wall Street and Washington see only storm clouds. The geeks think we're on the verge of The Singularity. The wonks retort that we're in the middle of a Depression… My pessimism is supported by a simple historical observation. The achievements of the last 25 years were actually not that big a deal compared with what we did in the preceding 25 years, 1961–1986 (e.g., landing men on the moon). And the 25 years before that, 1935–1960, were even more impressive (e.g., splitting the atom). In the words of Peter Thiel, perhaps the lone skeptic within a hundred miles of Palo Alto: In our youth we were promised flying cars. What did we get? 140 characters.

Moreover, technoptimists have to explain why the rapid scientific technological progress in those earlier periods coincided with massive conflict between armed ideologies. (Which was the most scientifically advanced society in 1932? Germany.)

So let me offer some simple lessons of history: More and faster information is not good in itself. Knowledge is not always the cure. And network effects are not always positive.

I wish I were a technoptimist. It must be heart-warming to believe that Facebook is ushering in a happy-clappy world where everybody "friends" everybody else and

> we all surf the net in peace (insert smiley face). But I'm afraid history makes me a depressimist. And no, there's not an app—or a gene—that can cure that."[3]

The theme of this book is not the debate about the rate at which new disruptive technologies are being developed, or the division between "technoptimist" and "depressimist," or about the market integration challenges of Makimoto's third wave of the Digital Revolution. The focus of this book is on the social integration of those technologies. Our interest is on the challenge ahead as societies struggle to integrate these future waves of disruptive technologies.

The future impact of new technologies that are continuing to present new challenges as they are integrated into the markets does not depend on technologies continuing to double computing performance infinitely into the future. The theme of this book is that technologies already on our intellectual horizon will be quite sufficient to trigger a substantial change in our social values and political norms.

[3] http://www.newsweek.com/niall-ferguson-dont-believe-techno-utopian-hype-65611