McKinsey&Company

JANUARY 2011

McKinsey Quarterly

STRATEGY PRACTICE

IT growth and global change: A conversation with Ray Kurzweil

The inventor, businessman, and author explains how the exponential growth of technologies will transform industries and pose new opportunities—and hurdles—for business and society.



Every executive recognizes the fast pace of technological development but grapples with the billion-dollar question: what happens next, and when? Ray Kurzweil has precise answers based on his thesis that information technology will continue to develop exponentially, leading to a not-so-distant future when artificial intelligence dominates our daily lives, genes can be reprogrammed away from cancer, and solar power can provide the world with all the energy it needs.

Some observers describe Kurzweil's predictions as science fiction, and some academics question his underlying thesis. Yet the well-argued theories of this best-selling author, serial inventor, and recipient of honors (from three US presidents) have not gone ignored. Kurzweil not only has a growing band of followers among technology executives but also has advised the US Army on responses to biological terrorism and the US and Israeli governments on renewable energy.

Kurzweil spoke with McKinsey Publishing's Lars Föyen about the basis for his predictions, how industries will change when they come to pass, and the double-edged nature of his vision.

The merger of men and machines

Information technology's growing exponentially: that's really my main thesis. And our intuition about the future is not exponential; it's linear. People think things will go at the current pace—1, 2, 3, 4, 5, and 30 steps later, you're at 30. The reality of information technology, like computers, like biological technologies now, is [that] it goes exponentially—2, 4, 8, 16. At step 30, you're at a billion.

This is not an idle speculation about the future. When I was a student at MIT,[1] we all shared a computer that cost tens of millions of dollars. This computer [his cell phone] is a million times cheaper, a thousand times more powerful. That's a billionfold increase in MIPS[2] per dollar, bits per dollar, bits of communication per dollar or per euro, compared to when I was a student. And we'll do it again in 25 years.

It's not just gadgets; it's also anything we can measure [in] information technology. So the singularity comes from two implications of that. One is that we'll have hardware powerful enough to simulate the human brain by 2029. The software, the intelligence that'll come with that, is also expanding exponentially as we learn more about how the human brain works. And that's also an exponential progression.

[These developments] make the case [that] we'll have human-level intelligence in a machine by 2029. Now, that's not the singularity—that's the beginning of it. Ultimately,

[1]The Massachusetts Institute of Technology.

[2]Million instructions per second.

[machine intelligence] will continue to grow exponentially. By 2045, that nonbiological portion of our civilization's intelligence will expand a billionfold. Our biological intelligence is very impressive, but it's fixed. It's not going to expand. So, ultimately, we'll be dominated by nonbiological intelligence.

The merger [between biological and machine intelligence] has already started. I mean, first of all, this [his cell phone] is not inside my body and brain, but it's pretty close. But there are people with computers in their bodies and brains [already]. There are computerized artificial pancreases that act just like the real organ. What started it was the genome project[3], and that was exponential too. Halfway through the project, the skeptics [were] saying, "This isn't working. I mean, here you are, seven and a half years into a 15-year project, and you finished 1 percent of the project. This is a failure, just like we said it was going to be."

That's actually right on schedule for an exponential progression: you start out doubling little numbers. By the time you get to 1 percent, you're only seven doublings away from 100 percent—2, 4, 8, 16, 32—and that's exactly what happened. It continued to double every year and was finished seven years later. So that was an exponential progression. Our [current] reverse engineering [of] the genome to actually understand how genes produce proteins and how proteins interact with three-dimensional simulations and so on—that's also progressing at an exponential pace.

So we've gone from hit or miss to where we can actually sit down at a computer with a real model and simulation of human biology [and] actually design interventions just the way you would design a new aircraft on a computer. It's a whole different era, and this will really gain fruit very dramatically 10, 15, 20 years from now.

What this all means for life sciences, energy, and other industries

We have three profound overlapping revolutions, sometimes called GNR: *G* for genetics, which is biotechnology; *N* for nanotechnology, which is basically reprogramming matter and energy at the level of molecules, using information processes; *R* stands for robotics, but it really refers to artificial intelligence—creating intelligent machines whether they're robots or not. These are interacting in many ways. Ultimately, every industry is certainly affected. Those industries that actually become information technologies go from linear progress—1, 2, 3, 4, 5—to exponential progress—2, 4, 8, 16—and that's a very profound change.

Health and medicine [are] now an information technology. In terms of business models, it's already stratifying into different types of firms "de-risking" projects at different levels. You

[3]The US Human Genome Project was a 13-year-long effort to identify all of the genes contained in human DNA and determine the chemical base pairs of which DNA consists. The US Department of Energy and the National Institutes of Health coordinated the project.

have lots of little companies that sit down, actually, at computer terminals and design new interventions, and they may take the drug through, possibly, just simulated trials and pass it off to somebody else. Then somebody does animal trials and, finally, there's another set of firms that do Phase 1 FDA[4] trials, and so on.

I think these new drugs that really get into the advanced part of biotechnology are going to be so much significantly better that they're going to be less risky to try. And they'll go through more quickly. If something really works dramatically, the FDA can work more quickly. The data [become] obvious more quickly. It becomes unethical not to give people the drug.

The FDA actually is starting and has a whole road map on using simulators rather than trials. It'll soon be the case that using a simulator of human biology is a better simulation of humans than animals are. Ultimately, you'll see very dramatic results because these are information processes. And when we really understand how the software of life works, we can really reprogram it away from cancer, away from heart disease.

I think intellectual property is going to continue to be a huge issue. You know, 20-year protection for a patent—that was put in place when 20 years was part of a generation, a product generation, or a technology generation, so you kind of get a head start. Maybe you got half a generation ahead. Now, with information technology, how many generations is 20 years? I mean, in the computer industry, it's at least 20, so intellectual property will be very important.

[Google cofounder] Larry Page and I were asked by the National Academy of Engineering, in the United States, to study the different emerging-energy technologies and actually come up with a plan for the United States and the world for energy. We looked at all the different emerging-energy technologies. A number of them are interesting and promising, but one that's really very exciting—and that's on an exponential rise—is solar energy. It's been doubling every two years, and has doubled ten times already, very smoothly. If you look on a logarithmic scale, it's a very smooth, exponential rise. And it's only eight doublings away from meeting 100 percent of our energy needs.

I presented this to the prime minister of Israel, and he said, "But, Ray, do we have enough sunlight to do that with? Can we double eight more times?" And I said, "Actually, we have 10,000 times more than we need." After we get done doubling eight more times, 16 years from now, we'll be using 1 part in 10,000 of the sunlight that falls on the Earth. We could use, even with inefficient solar farms, a small percentage of the world's unused deserts—and there's a lot of them in the neighborhood of Israel—and produce enough energy for the

[4]The US Food and Drug Administration.

world with a resource, right now, that's not used, which is deserts, which have a lot of sunlight.

I've talked to some of the leaders of energy companies in the Arab oil-producing nations, and their belief is that they don't have an infinite amount of time. They think they have a couple of decades [when] there'll continue to be tremendous demand for oil, and then they think other technologies will take over. And so their strategy is, in fact, to diversify. And you do see major energy companies making very large investments in these renewable energies, particularly solar.

Electric cars [are] the wave of the future, particularly as we find inexpensive ways of producing electricity, as we apply nanotechnology to more powerful and lightweight energy storage devices. We can actually use the entire network of cars as an energy storage facility for society. And I also think self-driving cars [are] coming.

Most of the experts I've talked to who are working on this technology field [think] we're less than ten years away from [when] this will be a very common technology that actually can save energy. We can put more cars on the road and make driving a more pleasant experience, not to mention saving hundreds of thousands of lives per year, which are lost worldwide to car accidents.

The challenge for business models

One area of advice that I like to give is to actually take the discipline of writing down what the underlying technologies that affect your business will be a year from now, two years from now, three years from now—or even every six months, which is what I do now in my projects.

When I read other people's business plans, much of the time they kind of assume not much is going to happen over the next three, four years; cell phones will get a little smaller, but otherwise the world will be the same as it is today. And we know that's not the case. You can look back three, four, five years ago—most people didn't use social networks, wikis, blogs. The world was very different just a few years ago. And it's going to change even more, at an even quicker pace, in the years ahead.

You can't describe everything that's going to happen, but you can actually describe, in very precise terms, what the underlying technologies will be. The power of computers, the power of communications, what the data rates will be for different kinds of wireless communication, and so on. So actually take the discipline of writing that out.

It is small entrepreneurial groups that create the new technologies of the future. That doesn't mean it has to come from small businesses; large businesses can also create that kind of entrepreneurial environment by setting up small groups—entrepreneurship—

Related articles

"Clouds, big data, and smart assets: Ten tech-enabled business trends to watch"

"Personalized medicine: An interview with Esther Dyson"

"Evaluating the potential of solar technologies"

"Electrifying cars: How three industries will evolve"

where they create these kinds of incentives within their organizations. The kind of organization that's not going to succeed [is one that is] overly attached to the old business model.

You have new organizations—you know, Google or Facebook—which create whole new industries. But that can come from the old industries as well. Some companies, like IBM, have been very successful in redefining themselves continually. You've got to be willing to take those kinds of risks with your entire company.

Utopia or dystopia?

I think technology has been a double-edged sword ever since we had fire and stone tools and the wheel. I mean, fire kept us warm, it cooked our food, but it was also used as an instrument of war.

These new technologies are quite powerful. The same technology that we can use to reprogram [human] biology away from cancer and heart disease could also be deployed right now by a bioterrorist to reprogram a biological virus to be a new weapon. In fact, I brought that specter to the US Army's attention.

I would argue strongly that the constructive applications outweigh the peril. You know, people sometimes long for the good old days before technology wrecked our lives. They're living in a dream world. I suggest that they read Thomas Hobbes or even Charles Dickens as to how incredibly harsh and difficult and cruel life was only two, three hundred years ago.

So we've made a lot of progress, [although] there's still a lot of suffering to overcome. I don't think it's accurate to say that these technologies are the province only of the wealthy. People say, "Oh, only the wealthy will have access to these tools." And I say, yeah, right—like cell phones. You know, five billion people have cell phones. Thirty percent of Africans. Half the farmers in China.

By the time the technologies are very powerful and work really well, they're in almost everybody's hands. And it's going to be true of these health technologies as well. In fact, you can look at AIDS drugs: they were $30,000 per patient per year 15, 20 years ago and didn't work very well. Today, in sub-Saharan Africa, it's $100 per patient per year, and they work, actually, pretty good, pretty well, and people are getting them. So at any one point in time, there's a have–have not divide, but the technology itself is moving in the right direction. Ultimately, these will be very widespread technologies.

Whether it's poverty, or the environment and energy, or disease and longevity, the answers to these challenges [lie] only in exponentially growing information technologies.

Copyright © 2011 McKinsey & Company. All rights reserved.