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Book review

Ray Kurzweil, The Singularity Is Near: When Humans Transcend Biology, Viking Adult, ISBN 0670033847, September 2005, 672 pages.

Kurzweil's argument for the success of AI

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"Positive feedback" is one of those phrases that sounds like it ought to mean something good, when it actually means something that is almost always bad: a runaway process whose output forces its inputs further in the direction they are already headed. A chain reaction in an atomic bomb is a classic example, where the production of neutrons is proportional to the number of atoms split, which is in turn proportional to the number of neutrons. Of course, a bomb is one of the few cases where the *goal* is to produce a runaway process. Even in this case, positive feedback has the property that it quickly destroys the conditions that made the positive feedback possible. This is a hallmark of the breed. Take any other example, such as the multiplication of rabbits, whose output—rabbits—is proportional to the number of rabbits. This simple model assumes that food is abundant; the exponentially increasing rabbit population soon violates that assumption.

In Ray Kurzweil's book, *The Singularity is Near*, it is argued that the evolution of humanity and technology is driven by a positive feedback, and that the resulting destruction of many of the truths we hold dear will result in a post-human world of wonders. It's hard to argue with the claim that a positive feedback is going on, especially after Kurzweil has pounded the point home with graph after graph; and so it is hard to disagree that this feedback will destroy the conditions that make the feedback possible (see above). Such arguments have driven pessimists from Malthus to Gore to conclude that humanity is in for some stormy weather. Kurzweil, however, believes that evolution has always managed to avoid the consequences of its manias by leapfrogging from one medium to another. Genetic evolution produced cultural evolution and now cultural evolution will produce a new phase in which people gradually replace themselves with bio-mechanical hybrids, where the seams between the carbon-based and silicon-based parts will be blurred by the nanobots crawling through them. At this point our new incarnations will begin to guide their own evolution, presumably toward ever more complex technological embodiments. Our future selves will be superintelligent, able to merge with others in ways that will cause our current conceptions of individuality to break down. Because all our assumptions about what happens past that point break down, he calls it the Singularity.

It's hard not to picture the Borg from *Star Trek* when thinking about Kurzweil's vision of post-human beings swimming through silicon. It was generally assumed in *Star Trek* that assimilation into the Borg was to be avoided, although none of the assimilated ever complained. Kurzweil can hardly wait. He is even watching his health to make sure he survives to the year 2045, which is roughly when the Singularity will be consummated. He acknowledges that there are perils in the technologies he visualizes, including especially AI, but he is confident humanity can conquer them.

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I don't know whether humanity or its successors will succeed in installing enough negative feedbacks to avoid the world-ecological analogue of too many rabbits; or whether political mechanisms will defeat the forces pushing us toward post-humanity; or whether transition into the new world order would be an improvement on the human race or the irreparable annihilation of something beautiful (or both). What seems appropriate to discuss, given the venue for this review, is where AI fits into all this.

First, let me sketch the role that Kurzweil thinks AI will play. He is an AI practitioner with solid credentials, having been the first person to have brought many pattern-recognition technologies to market. He believes that any talk of AI having "failed" in the 1980s is hogwash, an artifact of the usual bubble that accompanies the arrival of new technologies, which invariably overexcite the public. Instead, he sees AI flourishing everywhere. However, he describes existing AI systems as "narrow", and looks forward to the day that "strong AI" is here. Strong AI is defined as "aptitude resembling the broad, deep, and subtle features of human intelligence, particularly its powers of pattern recognition and command of language" (p. 92).[1]

It's odd that he chose the adjective "strong", since he says he means "broad and deep", and he uses "narrow" as its opposite. It's almost as if he wants to mess up the terms introduced by John Searle, "weak" and "strong AI". Searle's strong AI is not an aptitude but a philosophical position, that mind can be explained entirely in terms of computation. I don't really mind the injection of confusion into Searle's basically absurd[2] dichotomy, but there is always the danger that Kurzweil will suffer from the blowback of having his terms taken as somehow having a Searlian sense.

This issue, of how to get from narrow to strong AI, is of concern to others besides Kurzweil. At a recent symposium of AAAI Fellows, held in conjunction with the fiftieth anniversary of Dartmouth, there were several discussion groups on topics such as "Can we design an architecture for human-level intelligence?" and "Can we build a never-ending natural language learner?" (If we could, it could learn all it needed to know by reading the World Wide Web, although it could end up with a mighty odd set of beliefs.) There was a palpable sense of impatience in the air; we've been working on this for fifty years, and accomplished so much; shouldn't we be a bit further along? Personally, I think this impatience is misguided. We've achieved a steady rate of progress that we can be proud of, and it will eventually reach the goal. We may never come up with a satisfying theory of superhuman intelligence, but we (and our compatriots in other branches of cognitive science) will come up with a theory of average human intelligence, and that will be quite a feat.

Ray Kurzweil has no doubts about AI—at least, not about its likelihood of producing a theory of superintelligence. "The most powerful impending revolution is ... [robotics]: human-level robots with their intelligence derived from our own but redesigned to far exceed human capabilities. [Robotics] represents the most significant transformation, because intelligence is the most powerful 'force' in the universe. Intelligence, if sufficiently advanced, is, well, smart enough to anticipate and overcome any obstacles in its path" (p. 206). He does have doubts, or musings anyway, about whether the superintelligent computers will be conscious; I'll come back to this topic.

In this journal, it may seem bad form to take issue with Kurzweil's argument that AI is inevitable—practically already here—but in fact I found it surprisingly weak. The argument is repeated several times, but not really amplified on. It boils down to these points:

1. Given Moore's Law[3] and other indications of exponential technological progress, we will soon equal and surpass whatever computational power the brain might possess (pp. 124ff, 147, 167ff).
2. To duplicate human intelligence, it is sufficient to duplicate the structure of all the neurons in the brain. To reproduce a particular individual's persona may require very fine-grained duplication. Brain-scanning technology is advancing at a rapid clip, so will soon get to that resolution (pp. 124, 162ff, 196ff, 265, 293, 439).

[1] On p. 260, he defines it as "artificial intelligence that exceeds human intelligence", which is not quite the same thing. I will use the phrase in the first sense, taking "strong AI" as approximately *equivalent* to human intelligence.

[2] Searle's seemingly attractive "weak AI" position is in fact incoherent. Those who create computational models of mind while claiming to reserve judgment on the true nature of what they're modeling are either kidding themselves or are modeling something noncomputational; I have yet to see or hear of anyone in the latter group, unless someone has actually created a computational model of quantum coherence in microtubules or cold fusion in the pineal gland.

[3] The celebrated prediction by Gordon Moore [7] that the number of transistors on a chip would double every 18 months or so; Kurzweil interprets this loosely to mean that computational power from whatever source will continue to grow exponentially.

3. It may not be necessary or sufficient to copy the neuronal or sub-neuronal structure. It might work better to mimic brain function at a "software" level, that is, understand what a piece of brain is computing and compute that by using whatever device is most convenient (pp. 145, 148, 153, 178ff, 440).
4. Computers won't suffer from human limitations, so as soon as they get level with people[4] in intelligence, they will "soar past them". One reason is that once you have an intelligent system, you can make many copies. Another is that intelligent machines will have access to all the world's databases, as well as to each other (so they can share what they know and work on problems in teams). Machines have faster components and bigger memories, and they don't suffer from fatigue (pp. 26, 145, 260, 261).

The page references after each item in this list are to the many places where each part is restated. The book's repetitiveness is enough to put the reader into a deep coma. A good editor would have cut it by two-thirds.

I of course agree with Kurzweil that the brain is essentially a computer, in the sense that what it does for its owner is compute things (just as what hearts do for their owners is pump blood). But a powerful computer to compute X will not compute Y no matter how much you boost its power. So Moore's Law by itself doesn't get us anywhere. Kurzweil knows this, and the other prongs of his argument can be read as meeting this objection.

The second part of the argument is that the brain can be *physically* duplicated. The emphasis is on brain scanning: "Scanning and sensing tools are doubling their overall spatial and temporal resolution each year. ... We have demonstrated that our ability to build detailed models and working simulations of subcellular portions, neurons, and extensive neural regions follows closely upon the availability of the requisite tools and data" (p. 197). At what detail do we need to scan? To build an intelligent copy of the brain might, Kurzweil speculates, require scanning at the level of cortical regions, whereas, "... if we want to 'upload' a particular person's personality ..., then we may need to simulate neural processes at the level of individual neurons, such as the soma ..., axon ..., dendrites ..., and synapses .... For this we need to look at detailed models of individual neurons. The 'fan out' ... per neuron is estimated at 10^3. With an estimated 10^{11} neurons, that's about 10^{14} connections. With a reset time of five milliseconds, that comes to about 10^{16} synaptic transactions per second" (p. 124).

These humongous numbers are piled up only to make it all the more impressive that Moore's Law, another friendly exponential process, will overcome them. Whether or not you find that plausible, it's clear that being able to scan neurons down to the level of quarks would by itself not get us that far toward achieving machine intelligence. There are two reasons for this: (1) No matter how detailed a picture you had of the inside of a brain, you wouldn't know which details were important. (2) Even if you could duplicate a brain "down to the quarks," all you would have accomplished would be to duplicate that one brain. You wouldn't have a theory that explained the computational underpinnings of thought. These two points are closely related, but subtly distinct. The first objection, about knowing what to copy, addresses the issue of how good brain scanning would have to be before you could confidently transmit a copy of yourself somewhere. The second addresses the question whether the ability to transmit copies would tell you much about how intelligence works.

Let me elaborate on the first point. Although we take for granted now that the brain is made of neurons that operate by transmitting electrochemical signals along membranes and across synapses, the brain is actually a sloppy mess. It's only within the last 150 years that controversies about what kind of cells and connections exist were resolved. We are now pretty sure that neurons are important, and that the more numerous glial cells are there only to play a supporting role. So we don't have to scan those. A 19th-century scientist contemplating copying down the human brain would have assumed you have to copy the whole thing. What else can we neglect? Does it matter how many vesicles are present at a synapse and exactly how much neurotransmitter is in each one, or can we average over them somehow? But what about questions regarding the distribution of synapses? How much of the metabolic structure of the cell can we neglect? Since there is a proposal on the table [3] that microtubules might be the site of quantum-mechanical effects, I guess we have to scan those. Should we worry about the scan disturbing those quantum effects? (They are said to be very easy to disturb!) Perhaps there are effects like that elsewhere; perhaps there are holographic interference patterns running across the cortex that we haven't looked for and so haven't found; if you scan under circumstances when the patterns aren't just so, you'll miss the important stuff.

4 More precisely, above-average people like scientists and engineers (p. 262).

One may find these possibilities all equally absurd (as I do), but that's because we think we know something about what neurons *compute and how*. Since understanding the brain at the computational level is the whole game for the field of AI, why does brain scanning get so much of Kurzweil's attention? Obviously improvements in brain-scanning technology are important and exciting, but they get us somewhere *only if accompanied by deepening of our understanding of the computations neurons do*. So the possibility of scanning is a very weak argument that our understanding is sure to deepen.

The second objection is that even if we succeeded in duplicating a person to the point where we couldn't tell the copy from the original, that wouldn't even *confirm* AI, let alone contribute to it. We have to be careful to distinguish AI from materialism in general. The latter is the doctrine that, as philosophers put it, "the mental supervenes on the material": What physical state a creature is in completely determines its mental state. AI, which in this context also goes by the name "computationalism", is a much stronger doctrine that "the mental supervenes on the computational", i.e., that (a) there is such a thing as the computational state of a creature, which can be characterized independently of the physical substrate used to implement it; and (b) what computational state a system is in completely determines its mental state.[5] My point is that the ability to make perfect copies of a person would confirm only materialism, not computationalism.

Kurzweil is a smart person, and he understands these objections. After the quote above, he continues, "The performance of neurons and subcellular portions of neurons often involves substantial complexity and numerous non-linearities, but the performance of neural clusters and neuronal regions is often simpler than their constituent parts" (p. 197). Clearly, this observation can be true only if there is a computational level of description of pieces of brain that abstracts away from many details of how the computation is performed. Most readers of this journal will have no trouble agreeing, and will share Kurzweil's enthusiasm for computational models of mental functions, some directly inspired by the physiology of the brain, some less so. It's not so clear that the word "software" is appropriate for describing the computations the brain does; or for describing any other aspect of the brain. He defines the "software of intelligence" on p. 145 as "the organization and content of these resources"—"these resources" being the "hardware computational capacity" of the brain. One might decide that this way of drawing a line between "hardware" and "software" is basically harmless, but I often wish that people could just stop trying to impose categories from technology on biological systems where they are simply inappropriate. The lay reader, including the average journalist, will come away from books like these with some vague sense that the brain is sort of like a digital computer that has something sort of like programs—somewhere. They probably got a similar impression from something else they read a couple of years back, so the misconception just lives on.

Anyway, laying this issue aside, the key question is whether the successes in brain modeling and AI provide evidence that strong AI is in the offing. Here is an edited copy of Kurzweil's list of the successes to date:

- Lloyd Watts's model of the human auditory system.
- Hebbs's model of learning in neurons, and related models by more recent researchers.
- Detailed computational models of the cerebellum.
- Poggio's work on the visual system.
- A rapidly growing set of commercial applications.
- Cruise missiles and unmanned aerial vehicles (UAVs).
- Mars-exploring robots.
- The model-based reasoner aboard the Deep Space One spacecraft.
- Various pattern-recognition systems, including several developed by Kurzweil and his associates. For instance, electrocardiograms are now routinely scanned by machine for signs of heart problems.
- The "robot scientist" of [4] that designs and carries out experiments in biology (using the results to design new experiments).
- The proof of the Robbins Algebra conjecture (which had gone unsolved for decades).
- The success of several autonomous vehicles on the 2005 "DARPA grand challenge", completing a 131.2-mile course in the Mojave desert.
- Google.

[5] There are enough technical flaws with these formulations to keep several philosophers employed for a month fixing them; but I was not provided with a budget for this.

- Automated customer-support programs based on speech recognition.
- Machine translation—at a level that is commercially viable if not perfect.

I have winnowed Kurzweil's list by eliminating programs whose descriptions have a whiff of hype to them. Others would draw the line slightly differently, I'm sure, and I apologize to anyone whose feelings are hurt by my choices one way or the other.

So, the question is, does this list of successes, which all seem to me to fall in the category of "narrow" AI, add up to an argument that "strong" AI is inevitable? I'm willing to believe they do. But I believed it before I read the book (or rather I accepted it as a working hypothesis). Why would a skeptic be convinced? Well, on page 439 we get a paragraph headed "The Ultimate Source of Intelligent Algorithms," which says, "The most important point ... is that there is a specific game plan for achieving human-level intelligence in a machine: reverse engineer the ... methods used in the human brain ... ." We're back to scanning, or perhaps "mining", the brain again. If that doesn't convince you, think about Moore's Law again, or meditate on the possibility of intelligent algorithms bootstrapping their way to superintelligence. Still puzzled? Go back over that list of successes of narrow AI ... .

Let's take a deep breath and try to get back on the path, and go on to the part of the argument we have yet to examine: the idea that once we achieve "strong AI" we will "soar" on to what I will call *superstrong AI*. Once more, I don't think the case is proven. The problem is that we might get to strong AI in more than one way. We might asymptotically approach human intelligence, adding mental abilities one by one until we reach a reasonable facsimile of an average person; or research might build steam and burst through that ceiling quickly. Or it might be the case that superstrong AI is achieved by the inevitable momentum that computers will derive from their inherent advantages over biological systems once they reach the neighborhood of human intelligence. This last scenario is the one Kurzweil wants to argue for. I listed computers' advantages above: they can be duplicated, they can share information, they don't get tired, and they have big memories and fast components. Plus (p. 28), "Machine intelligence will improve its own abilities in a feedback cycle that unaided human intelligence will not be able to follow". The last argument is, alas, circular, as far as I can see. Until machine intelligence gets past the human level, it won't be able to do all that smart stuff.

Do the listed powers of computers really allow us to bootstrap from ordinary strong AI to the superstrong variety? Who knows? Copying a fairly smart computer exactly several times might lead to a committee of fairly smart computers that tended to agree on mundane solutions to problems. Having access to huge amounts of information might result in a system overwhelmed by trivia. One's confidence is not inspired by statements such as these: "Machines have exacting memories. Contemporary computers can master billions of facts accurately, a capability that is doubling every year" (p. 261). It's not clear what definitions of "fact" and "master" Kurzweil is using here, but they can't be what we normally mean we say a person has mastered a fact.

For Kurzweil it seems fairly obvious that human intelligence is an arbitrary level along a one-dimensional scale; it's the "level ... sufficient to enable us to outwit the competitors in our ecological niche ..." (p. 152). But "intelligence" is a slippery concept. Academics tend to regard themselves as smart people, but at a gathering of professors from different departments it becomes clear quickly that outside their areas of expertise they can often be quite thick. And it's parochial to suppose that the kinds of brains academics pride themselves on are the only important kind. We evolved as hunter-gatherers, and had to develop incredibly quick wits to survive. How many graduate students, plunked down in the savanna, could earn the equivalent of a Ph.D. in paleolithic survival skills?

On p. 265, Kurzweil compares intelligence to Bernoulli's principle:

> It's the nature of technology to understand a phenomenon and then engineer systems that concentrate and focus that phenomenon to greatly amplify it. For example, scientists discovered a subtle property of curved surfaces known as Bernoulli's principle: a gas (such as air) travels more quickly over a curved surface than over a flat surface. Thus, air pressure over a curved surface is lower than over a flat surface. By understanding, focusing, and amplifying the implications of this subtle observation, our engineering created all of aviation. Once we understand the principles of intelligence, we will have a similar opportunity to focus, concentrate, and amplify its powers.

Here's what wrong with this analogy: It may well be true that there are principles underlying "ordinary" thinking. Indeed, it's this assumption that gives us reason to believe that a sufficient stock of narrow AI skills will get us to strong AI. But Kurzweil wants to burst through the ordinary level and "focus and amplify" intelligence to the point where "Machines will be able to reformulate their own designs and augment their own capacities without limit" (p. 27). Are there really principles of intelligence that would support limitless insight the way Bernoulli's principle supports the design of various kinds of lifting surfaces? It just seems to me that intelligence can't be boxed in that way. Sure, there can be principles underlying the kinds of intelligence that have already appeared, and as cognitive scientists we believe such principles exist and are being steadily, if slowly, mapped. But to say one creature is more intelligent than another in some regard is to say that it can see connections the other can't. The kinds of connections there are between different things in the universe could be, for all we know, inexhaustible. Suppose we define a "genius" as someone who taps into a new kind of connection, one that, almost by definition, transcends existing sets of principles. Our sense of excitement at the prospect of the future intellectual development of humanity is sustained by our hope that we will keep producing geniuses, and so keep making new connections and escaping the bounds imposed by principles.

I am not proposing that geniuses violate the basic assumptions of cognitive science, that their brains do things that can't be explained as computations. If we "reverse engineer" the brain of the next Richard Feynman, I am willing to grant that we will understand how she arrives at solutions to problems that other people struggle even to formulate properly. But it simply doesn't follow that after reverse engineering any number of brilliant brains we will then know how to produce all possible brilliant brains.[6]

My conclusion is that Kurzweil does not make his case for strong, or superstrong, AI. As I said at the outset, I won't address the ecological or political ramifications of his book.

But there is one other aspect that I find somewhat discordant given his faith in the continued progress of AI, and that is his attitude toward consciousness. He believes that there is a hard distinction between the subjective and the objective, and that "*there exists no objective test that can determine its presence*", that is, the presence of consciousness. (Page 378, emphasis in original.) Furthermore, there is no obvious reason why "my" consciousness is associated with "my" body. To mix one of Kurzweil's examples with a scenario due to William James, if Kurzweil and Alanis Morrissette are in the same room, what links the stream of Kurzweil's experiences to the body with that name? Why don't the streams of consciousness get mixed up, or switch, so that some of the time the experiences of the singer are connected to the body of the inventor?

These questions sound like those of a classical dualist, but if so we're talking about a very confused dualist. Dualists traditionally want to believe that the events taking place in the stream of experiences influence the actions performed by the bodies they're attached to. I[7] don't just experience a moldy taste when I bite into an old piece of cheese found in the refrigerator; the experience drives me to spit it out and find something to wash the taste out of my mouth. But if you're a materialist, and Kurzweil is, then all the events causing me to spit and then grab for a Diet Dr. Pepper Berries and Cream soda are taking place in my body. Therefore it only *seems* as if the subjective experience is causing anything. This position is called "epiphenomenalism", and, though Kurzweil doesn't explicitly endorse it, I suppose that's where he ends up. But it's a scary position for a Singularitarian to be in. He says

> Consciousness is the most important ontological question. After all, if we truly imagine a world in which there is no subjective experience (a world in which there is swirling stuff but no conscious entity to experience it), that world may as well not exist (p. 380).

One page earlier he writes

> ... We cannot safely dismiss the question of consciousness as merely a polite philosophical concern. It is at the core of society's legal and moral foundation. The debate will change when a machine—nonbiological intelligence—can persuasively argue on its own that it/he/she has feelings that need to be respected. Once it can do so with a sense of humor—which is particularly important for convincing others of one's humanness—it is likely that the debate will be won (p. 379).

Wait a minute. There is no objective test for subjectivity. Over and over Kurzweil says merely *claiming* to have experience wouldn't prove you do. The only exception he's willing to grant is when you have a brain that works with

[6] The point is elaborated in Chapter 2 of [5].
[7] Following Kurzweil's lead, I emphasize the subjectivity involved in the example by putting it in the first person.

neurotransmitters the way his does (p. 378). So we would have absolutely no evidence that a persuasive machine with a sense of humor actually had experiences. Worse, the only way it could possibly have experiences is if one of those streams of consciousness got created and attached to it the way Alanis Morrissette has hers attached. Yet we should upload ourselves into machines like that, possibly ceasing to experience anything, and risk putting the universe into a state where it might as well not exist?[8]

This position is hopelessly incoherent, and mainly interesting as a snapshot of the confusion of a typical scientist trying to think about this issue. However, there is no need for alarm. I have confidence that our successes in narrow AI will soon be joined by successes in "narrow consciousness" as we come to understand how the brain models itself as having experiences, and to understand how machines could do the same. These successes will eventually culminate in a theory of "strong consciousness" that completely explains consciousness computationally, without the need for a mysterious quality called "subjectivity", and without any puzzles about whether people's streams of consciousness can come unglued. For some arguments to this effect see [1,2,5,6].

One last appeal. Although I don't think Kurzweil has proved his case about AI (and I have had nothing to say about his arguments on genetics, nanotechnology, politics, or ecology), he may be right. But right or wrong, I wish he would stop writing these books! The field of AI is periodically plagued by "hype hurricanes" that seem to surge up from the slightest perturbation. We came dangerously close to a calamity with "agent technology", which was all the rage for a couple of years in spite of not actually existing; fortunately, that ripple seems to have died down without getting beyond the tropical-depression stage. Most of these storms are started or spun up by journalists, venture capitalists, or defense-department bureaucrats. But there are a very small number of people within the field of AI who contribute to the problem, and Kurzweil is the worst offender. He may think that the Singularity is such a world-shattering event that we should be thinking about it even if the chance of its happening is small, and that the possible damage done to AI is a trifle by comparison. Furthermore, if overhyping AI now causes all the funding to be sucked out of the field for a few years, his charts show that such events are negligible glitches in an inexorable exponential march. But his negligible glitch could be somebody else's wrecked career. This business is tough enough without us shooting ourselves in the foot. Holster your gun, Ray!

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[8] I'll skip over the possibility that there will be enough higher mammals left around to experience the world for us and keep it going.