The Singularity is Near

by Ray Kurzweil - 2006

This book is extremely dense and the reader must want to get through it. However, the subject is what is happening in our future and the author spends a great deal of time documenting his projections and the reasons for them. Since he has a good record of making accurate predictions over the last 20+ years, the reader is encouraged to pay attention to what he is saying.

Prologue

The author reviews his upbringing and fascination with the early IBM mainframe computers and how he became an inventor in the 1970s. His interest in technology trends and their implications led him to books documenting where he thought these trends would take us in the near future. His underlying rule is that progress is not linear, but geometric in nature and that civilization has reached an 'elbow point' where the acceleration of progress is becoming impossible to ignore.

Ch 1 - The Six Epochs

The Singularity is a future period during which the pace of technological change will be so rapid, its impact so deep, that human life will be irreversibly transformed. This epoch will transform the concepts that we rely on to give meaning to our lives, from our business models to the cycle of human life, including death itself.

The inherent acceleration of the rate of evolution, with technological evolution as a continuation of biological evolution, is what the author calls the law of accelerating returns. The key idea underlying the impending Singularity is that the pace of change of our human-created technology is accelerating and its powers are expanding at an exponential pace. Exponential growth starts out almost imperceptible and then explodes with unexpected fury when an 'elbow point' is reached. This is not a discontinuous curve, but the logarithmic change becomes clearly noticeable only after a certain amount of time.

The author argues that within several decades information-based technologies will encompass all human knowledge and proficiency, ultimately including the pattern-recognition powers, problem-solving skills, and emotional and moral intelligence of the human brain itself. The Singularity will allow us to transcend the limitations of our biological bodies and brains and merge with our technology. Currently we are in the early stages of this transformation, with artificial body parts, pacemakers, and chemicals that adjust our bodies.

Evolution is a process of creating patterns of increasing order. Each stage, or epoch, uses the information-processing methods of the previous epoch to create the next epoch. The Singularity will begin Epoch Five and will spread from Earth to the rest of the universe in Epoch Six.

Epoch One: Physics and Chemistry

We can trace our origins to a state that represents information in its basic structures: patterns of matter and energy. A few thousand years after the Big Bang, atoms began to form. Chemistry was born a few million years later as atoms came together to create relatively stable structures called molecules. Carbon, being the most versatile, was able to give rise to complicated, information-rich, three dimensional structures.

Epoch Two: Biology Information in DNA

Several billion years ago, carbon-based compounds became more and more intricate until complex aggregations of molecules formed self-replicating mechanisms, and life originated. Ultimately, biological systems evolved a

precise digital mechanism (DNA) to store information describing a larger society of molecules.

Epoch Three: Brains

DNA-guided evolution produced organisms that could detect information with their own sensory organs and process and store that information in their own brains and nervous systems. The early third epoch began with animals that could recognize patterns and finally humans arrived who were able to create abstract mental models of the world and contemplate the rational implications of these models.

Epoch Four: Technology

Combining the endowment of rational and abstract thought with our opposable thumb, our species ushered in the fourth epoch: human created technology. Ultimately, with sophisticated computational and communication devices, technology was itself capable of sensing, storing, and evaluating elaborate patterns of information.

If we look at the evolution of life and technology on a logarithmic scale we find a reasonably straight line (continual acceleration), with biological evolution leading directly to human-directed development.

Epoch Five: Merger of Technology and Human Intelligence

The Singularity will begin with the merger of the vast knowledge embedded in our own brains with the vastly greater capacity, speed, and knowledge-sharing ability of our technology. Think Goggle Search and Wikipedia within our internal capabilities.

Epoch Six: The Universe Wakes Up

Intelligence derived from its biological origins in human brains and its technological origins in human ingenuity, will begin to saturate the matter and energy in its midst. It will achieve this by reorganizing matter and energy to provide an optimal level of computation to spread out from its origin on Earth.

Ch 2 - A Theory of Technology Evolution

Evolution increases order, which may or may not increase complexity (but usually does). A primary reason that evolution - of life forms or of technology - speeds up is that it builds on its own increasing order, with ever more sophisticated means of recording and manipulating information.

Moore's Law: In the mid-1970s, Gordon Moore observed that we could squeeze twice as many transistors into an integrated circuit every twenty-four months. Given that the electrons would have less distance to travel, circuits would run faster, providing an additional boost to overall computational power. The result is exponential growth in the price-performance of computation. We see the same types of trends in essentially every technology or measurement that deals with information.

Ch 3 - Achieving the Computational Capacity of the Human Brain

- Nanotubes were first synthesized in 1991 and are used to store memory bits and act as logic gates.

- Computing with molecules was first suggested in the early 1970s and reverse engineered in 2002.

- Self-assembly of nanoscale circuits was first demonstrated in 2004.

- Computing with DNA allows for testing each of the trillions of strands simultaneously and was demonstrated in 2003.

- Computing exploiting the spin of electrons for memory and computation is theoretically possible.

- Quantum Computing is a radical form of SIMD parallel processing and is at a very early stage of development, as of the publication of this book in 2006.

The computational capacity of the human brain is estimated to be around 10^{15} cps (instructions per second) and this is arrived at using several different approaches.

In the early 2030s it is estimated that $1000 will buy computation equivalent to 10^{17} cps.

By the mid 2040s $1000 should by computation equal to 10^{26} cps, or about one billion times more powerful than all human intelligence today. That is when the author estimates the Singularity will create a profound and disruptive transformation in human capacity.

Ch 4 - Achieving the Software of Human Intelligence: How to Reverse Engineer the Human Brain

There are good reasons to believe that we are at a turning point, and that it will be possible within the next two decades to formulate a meaningful understanding of brain function. At about the turn of the century we passed a detectable turning point in both neuroscience knowledge and computing power. For the first time we collectively know enough about our own brains, and have developed such advanced computing technology, that we can now seriously undertake the construction of a verifiable, real-time, high-resolution model for significant parts of our intelligence - *Lloyd Watts, neuroscientist.*

- New brain-imaging and modeling tools

- The software of the brain -- once any breakthrough is made the advantage of nonbiological intelligence is that machines can easily share it.

- Analytic vs neuromorphic modeling of the brain is a good example of the divergence between human and contemporary AI. As we understand the brain it becomes easier to replicate the brain processes and include these in brain modeling.

- The brain's circuits are very slow, but massively parallel and the brain combines analog and digital phenomena.

- The brain rewires itself

Many new brain-scanning technologies now in development are dramatically improving both temporal and spatial resolution. This new generation of sensing and scanning systems is providing the tools needed to develop models with unprecedented fine levels of detail.

Although largely noninvasive means of scanning the brain from the outside the skull are rapidly improving, the most powerful approach to capturing every salient neural detail will be to scan it from the inside - using nanobot technology, estimated to be viable in the 2020s.

While understanding the methods of the human brain will help us to design similar biologically inspired machines, another important application will be to actually interface our brains with computers. The Defense Advanced Research Projects Agency is currently highly involved with this area of research.

A more controversial application than the scanning-the-brain-to-understand-it scenario is scanning the brain to upload it.

Ch 5 - GNR: Three Overlapping Revolutions

G - Genetics

N - Nanotechnology

R - Robotics

We are in the early stages of the "G" revolution today. The "N" revolution will enable us to redesign and rebuild - molecule by molecule - our bodies and brains and the world with which we interact. The most powerful impending revolution is "R": human-level robots with their intelligence derived from our own, but redesigned to far exceed human capabilities.

Intelligence is the most powerful "force" in the universe and, if sufficiently advanced, is smart enough to anticipate and overcome any obstacles that stand in its path.

Genetics: The intersection of information and biology -- benefits of these advances

- RNA Interference - or turning off specific genes by blocking their mRNA

- Cell Therapies

- Gene Chips

- Somatic Gene Therapy

- Reversing Degenerative Disease

- Combating Heart Disease

- Reversing Aging

Nanotechnology: The intersection of information and the physical world -- the tools to rebuild the physical world atom by atom

- New manufacturing and processing technologies

- Nanobots in the bloodstream

Robotics: Strong AI -- the creation of nonbiological intelligence that exceeds that of unenhanced humans

- Military and Intelligence

- Space Exploration

- Medicine

- Science and Math

- Business, Finance, and Manufacturing

- Speech and Language

- Entertainment and Sports

Ch 6 - The Impact…

Intelligence on and around the Earth will continue to expand exponentially until we reach the limits of matter and energy to support intelligent computation. As we approach this limit in our corner of the galaxy, the intelligence of our civilization will expand outward into the rest of the universe.

…on the Human Body

A new way of eating - eating totally for pleasure due to the digestive system being redesigned and having programmable blood and an optional heart.

…on the Human Brain

being integrated with machine capacity and speed, while being able to adjust personalities and expand the mind.

…on Human Longevity

Life expectancy has moved from Cro-Magnon (18), Ancient Egypt (25), 1400 Europe (30), 1800 Europe & U.S. (37), 1900 U.S. (48), to 2002 U.S. (78). By combining with non-biological materials we have to redefine what is human because death becomes something that may not be necessary.

…on Warfare

As weapons have become more intelligent, there has been a dramatic trend toward more precise missions with fewer casualties. Non-biological tools are now being integrated into the individual soldiers and robotics means the soldiers no longer have to be in the field of combat. Swarm intelligence and nanoweapons are bringing entirely new strategies into combat situations.

…on Learning

Science is organized knowledge; wisdom is organized life (Emmanuel Kant). On-line courseware and computerized learning is not only radically changing the approach to learning, but it is extending education's reach into third world countries as hardware costs drop. In step one students of any age will be able to access the best education in the world at any time and from any place. In step two the nature of education will change again as the non-biological part of our brains are able to download the interneuronal connection and neurotransmitter patterns that represent our learning.

...on Work

With the advent of MNT-based manufacturing (molecular nanotechnology), the cost of making any physical product will be reduced to pennies per pound, plus the cost of the information guiding the process, with the latter representing the true value. The intellectual properties associated with making the product becomes the most valuable commodity. This type of manufacturing will be highly distributed - both from a choice and a security standpoint - and the centralized technologies of office building and cities will be obsolete. People will be able to choose the type of society they want to live in.

...on Play

Play is just another version of work and has an integral role in the human creation of knowledge in all of its forms. By the 2020s, full-immersion virtual reality will be a vast playground of compelling environments and experiences. By the late 2020s these environments will be indistinguishable from real reality and will involve all the senses, as well as neurological correlations of our emotions. As we enter the 2030s there won't be clear distinctions between human and machine, between real and virtual reality, or between work and play.

...on the Intelligent Destiny of the Cosmos: Why We Are Probably Alone in the Universe

What we know now is that the cosmos appears silent -- that is, we've detected no convincing evidence of ETI transmissions. An evolutionary process inherently accelerates, moreover, the evolution of technology is far faster than the relatively slow evolutionary process that gives rise to a technology-creating species in the first place -- we went from pre-electricity to sophisticated computational and communications technologies in less than 200 years. The author's projections show that within another century we will multiply our intelligence by trillions of trillions. Thus we can say, once a species creates electronics and sufficiently advanced technology to beam radio transmissions, it is only a mater of a modest number of centuries for it to vastly expand the powers of its intelligence. Once we have maximized the computing power available in our solar system, we will expand extremely rapidly throughout the universe. Therefore, it is unlikely that any other similar life form is ahead of us on the evolution scale in our universe, because we cannot either see or feel any signals at this time.

Why intelligence is more powerful than physics --

As intelligence saturates the matter and energy available to it, it turns dumb matter into smart matter. Although smart matter still nominally follows the laws of physics, it is so extraordinarily intelligent that it can harness the most subtle aspects of the laws to manipulate matter and energy to its will.

Once a planet yields a technology-creating species and that species creates computation, it is only a matter of a few centuries before its intelligence saturates the matter and energy in its vicinity, and it begins to expand outward at least the speed of light. Such a civilization will then overcome gravity and other cosmological forces -- or to be fully accurate, it will maneuver and control these forces -- and engineer the universe it wants. This is the goal of the Singularity.

Ch 7 - Ich bin ein Singularitarian

A Singularitarian is someone who understands the Singularity and has reflected on its meaning for his or her own life. It is not a process that is ever complete. The author started pondering the relationship of our thinking to our computational technology as a teenager in the 1960s, studied the acceleration of technology in the 1970s, and wrote his first book on the subject in the 1980s.

The attempt to understand technology trends was practical: an attempt to time his inventions and to make optimal tactical decisions in launching technology enterprises, i.e. he didn't want to bring an invention or business out before it could succeed in the society. Over time this modeling of technology took on a life of its own and led him to formulate a theory of technology evolution. It was not a huge leap from there to reflect on the impact of these crucial changes on social and cultural institutions. While being a Singularitarian is not a matter of faith, but one of understanding and pondering the scientific trends, this discussion engenders new perspectives on the issues that traditional religions have attempted to address: the nature of morality and immorality, the purpose of our lives, and intelligence in the universe.

By the late 2020s we will have completed the reverse engineering of the human brain, which will enable us to create nonbiological systems that match and exceed the complexity and subtlety of humans, including our emotional intelligence. Then the vexing question of conscious begins to rear its head. There exists no objective test that can conclusively determine the presence of consciousness.

Who am I? What am I?

A related but distinct question has to do with our own identities. Since biological entities are in a constant state of change (elements of our bodies completely change in anywhere from seconds to weeks), the only thing that remains relatively constant is the patterns - both matter and energy - in our bodies. Even these change or we would neither grow up, nor grow old.

We replace parts of our body for any number of reasons and we consider that we remain ourselves. At what point in our replacement of our body parts do we cease to become ourselves? If this never happens, then how do we determine that a nonbiological entity that displays outward evidence of consciousness is not a conscious human being, with all their rights and responsibilities?

The Singularity denotes an event that will take place in the material world, the inevitable next step in the evolutionary process that started with biological evolution and has extended through human-directed technological evolution. However, it is precisely in the world of matter and energy that we encounter transcendence, a principal connotation of what people refer to as spirituality.

"To transcend" means "to go beyond," but this need not compel us to adopt an ornate dualist view that regards transcendent levels of reality to be not of this world. We can "go beyond" the "ordinary" powers of the material world through the power of patterns. Since the material stuff of which we are made turns over quickly, it is the transcendent power of our patterns that persists. It is the power of the pattern that differentiates random brush strokes from art on a canvas.

Ch 8 - The Deeply Intertwined Promise and Peril of GNR

With ever greater technological understanding, comes ever greater ability to corrupt not only the society, but ultimately life itself.

The diverse GNR technologies are progressing on many fronts and full realization will result from hundreds of small steps forward, not single large leaps. Therefore, barring a world-wide totalitarian state - something that has gone in the reverse direction in recent memory - a system that relinquishes progress is not possible.

We have to address defenses against corruption of emerging technologies as we are developing these technologies. A strong factor in favor of positive evolution is the rapid increase in intelligence, because the expanding intelligence will be working to maintain and expand itself, not stunt its growth or return to the past.

Relinquishment is a part of the desire to slow advances until we have the means to safeguard them.

- Broad Relinquishment: Forgo certain fields as being too dangerous. The fact that many small steps occur across the globe independently make this approach impractical.

- Fine-Grained Relinquishment: The concept of ethical guidelines in conducting research is a constructive example of this approach. A ban on self-replicating physical entities that contain their own codes for self-replication is another example.

- Dealing with Abuse: An example of this approach is how we are dealing with one such technological issue - computer viruses.

- The Threat from Fundamentalism: This concept reflects the idea that humanity will be better off without change and, while understandable, is no more practical than Broad Relinquishment.

- Fundamentalist Humanism: Opposition to any change in the nature of what it means to be human. This effort will fail because the demand for therapies that can overcome the suffering, disease, and short life spans inherent in our version 1.0 bodies will ultimately prove irresistible.

Development of Defensive Technologies and the Impact of Regulation

- Protection from "unfriendly" strong AI: Inherently there will be no absolute protection against strong AI, however, maintaining an open free-market system will provide the most constructive environment for technology to embody

widespread human values. Strong AI emerging from many diverse efforts will be deeply integrated into our civilization's infrastructure; intimately embedded in our bodies and brains, it will reflect our values because it will be us. Attempts to control these technologies via secretive government programs would only foster an unstable environment in which dangerous applications would be likely to become dominant.

- Decentralization: The current movement from centralized technologies to distributed ones will mitigate danger in the same way the Internet reduces our reliance on single source defenses.

- Distributed energy: With increasingly independent systems single attacks become less an issue.

- Civil liberties in an age of asymmetric warfare: The secretive nature of our opponents and their lack of respect for human life, including their own, will deeply test the foundations of our democratic traditions.

The most urgent recommendation is to greatly increase our investment in defensive technologies, with the bulk being in antiviral medications and treatments, since we are already in the G (genetic) era.

Ch 9 - Response to Critics

This chapter reviews and answers a number of criticisms that have arisen from publication of previous books on our technological future.

- It is a mistake to extrapolate exponential trends indefinitely, since they inevitably run out of resources to maintain the exponential growth.

- We are making exponential gains in hardware, but software is stuck in the mud.

- Digital computation is too rigid because digital bits are either on or off, while biological intelligence is mostly analog, so subtle gradations can be considered.

- The information processes in the interneuronal connections are far more complex than the simplistic models used in neural nets.

- The microtubules in neurons are capable of quantum computing, and such quantum computing is a prerequisite for consciousness.

- There are broad classes of problems that cannot be solved by any Turing machine.

- Computer systems are showing alarming rates of catastrophic failure as their complexity increases.

- The pervasive and complex support systems required by such fields as energy and transportation are blocking innovation, so this will prevent the kind of rapid change envisioned for the technologies underlying the Singularity.

- Computers cannot understand what they are doing, since they are just following rules.

- It's likely that through these technologies the rich may obtain certain opportunities that the rest of humankind does not have access to.

- Governmental regulation will show down and stop the acceleration of technology.

- The criticism from theism that materialism is predictable, whereas reality is not.

- The criticism from holism that organic forms can be created only through biological processes, and such forms are "immutable,...impenetrable, and ...fundamental realities of existence."

Each criticism is answered with a detailed explanation that would be a book itself if covered here. If any of these concern you then I suggest you buy the book or check it out of your local library.