Ray Kurzweil on how AI will transform the physical world

The changes will be particularly profound in energy, manufacturing and medicine, says the futurist

illustration: dan williams

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By the time children born today are in kindergarten, artificial intelligence (ai) will probably have surpassed humans at all cognitive tasks, from science to creativity. When I first predicted in 1999 that we would have such artificial general intelligence (agi) by 2029, most experts thought I'd switched to writing fiction. But since the spectacular breakthroughs of the past few years, many experts think we will have agi even sooner—so I've technically gone from being an optimist to a pessimist, without changing my prediction at all.

After working in the field for 61 years—longer than anyone else alive—I am gratified to see ai at the heart of global conversation. Yet most commentary misses how large language models like Chatgpt and Gemini fit into an even larger story. ai is about to make the leap from revolutionising just the digital world to transforming the physical world as well. This will bring countless benefits, but three areas have especially profound implications: energy, manufacturing and medicine.

Sources of energy are among civilisation's most fundamental resources. For two centuries the world has needed dirty, non-renewable fossil fuels. Yet harvesting just 0.01% of the sunlight the Earth receives would cover all human energy consumption. Since 1975, solar cells have become 99.7% cheaper per watt of capacity, allowing worldwide capacity to increase by around 2m times. So why doesn't solar energy dominate yet?

The problem is two-fold. First, photovoltaic materials remain too expensive and inefficient to replace coal and gas completely. Second, because solar generation varies on both diurnal (day/night) and annual (summer/winter) scales, huge amounts of energy need to be stored until needed—and today's battery technology isn't quite cost-effective enough. The laws of physics suggest that massive improvements are possible, but the range of chemical possibilities to explore is so enormous that scientists have made achingly slow progress.

By contrast, ai can rapidly sift through billions of chemistries in simulation, and is already driving innovations in both photovoltaics and batteries. This is poised to accelerate dramatically. In all of history until November 2023, humans had discovered about 20,000 stable inorganic compounds for use across all technologies. Then, Google's gnome ai discovered far more, increasing that figure overnight to 421,000. Yet this barely scratches the surface of materials-science applications. Once vastly smarter agi finds fully optimal materials, photovoltaic megaprojects will become viable and solar energy can be so abundant as to be almost free.

Energy abundance enables another revolution: in manufacturing. The costs of almost all goods—from food and clothing to electronics and cars—come largely from a few common factors such as energy, labour (including cognitive labour like r&d and design) and raw materials. ai is on course to vastly lower all these costs.

After cheap, abundant solar energy, the next component is human labour, which is often backbreaking and dangerous. ai is making big strides in robotics that can greatly reduce labour costs. Robotics will also reduce raw-material extraction costs, and ai is finding ways to replace expensive rare-earth elements with common ones like zirconium, silicon and carbon-based graphene. Together, this means that most kinds of goods will become amazingly cheap and abundant.

These advanced manufacturing capabilities will allow the price-performance of computing to maintain the exponential trajectory of the past century—a 75-quadrillion-fold improvement since 1939. This is due to a feedback loop: today's cutting-edge ai chips are used to optimise designs for next-generation chips. In terms of calculations per second per constant dollar, the best hardware available last November could do 48bn. Nvidia's new b200 gpus exceed 500bn.

As we build the titanic computing power needed to simulate biology, we'll unlock the third physical revolution from ai: medicine. Despite 200 years of dramatic progress, our understanding of the human body is still built on messy approximations that are usually mostly right for most patients, but probably aren't totally right for you. Tens of thousands of Americans a year die from reactions to drugs that studies said should help them.

Yet ai is starting to turn medicine into an exact science. Instead of painstaking trial-and-error in an experimental lab, molecular biosimulation—precise computer modelling that aids the study of the human body and how drugs work—can quickly assess billions of options to find the most promising medicines. Last summer the first drug designed end-to-end by ai entered phase-2 trials for treating idiopathic pulmonary fibrosis, a lung disease. Dozens of other ai-designed drugs are now entering trials.

Both the drug-discovery and trial pipelines will be supercharged as simulations incorporate the immensely richer data that ai makes possible. In all of history until 2022, science had determined the shapes of around 190,000 proteins. That year DeepMind's AlphaFold 2 discovered over 200m, which have been released free of charge to researchers to help develop new treatments.

Much more laboratory research is needed to populate larger simulations accurately, but the roadmap is clear. Next, ai will simulate protein complexes, then organelles, cells, tissues, organs and—eventually—the whole body.

This will ultimately replace today's clinical trials, which are expensive, risky, slow and statistically underpowered. Even in a phase-3 trial, there's probably not one single subject who matches you on every relevant factor of genetics, lifestyle, comorbidities, drug interactions and disease variation.

Digital trials will let us tailor medicines to each individual patient. The potential is breathtaking: to cure not just diseases like cancer and Alzheimer's, but the harmful effects of ageing itself.

Today, scientific progress gives the average American or Briton an extra six to seven weeks of life expectancy each year. When agi gives us full mastery over cellular biology, these gains will sharply accelerate. Once annual increases in life expectancy reach 12 months, we'll achieve "longevity escape velocity". For people diligent about healthy habits and using new therapies, I believe this will happen between 2029 and 2035—at which point ageing will not increase their annual chance of dying. And thanks to exponential price-performance improvement in computing, ai-driven therapies that are expensive at first will quickly become widely available.

This is ai's most transformative promise: longer, healthier lives unbounded by the scarcity and frailty that have limited humanity since its beginnings. ■

Ray Kurzweil is a computer scientist, inventor and the author of books including "The Age of Intelligent Machines" (1990), "The Age of Spiritual Machines" (1999) and "The Singularity is Near" (2005). His new book, "The Singularity is Nearer: When We Merge with AI", will be published on June 25th.