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Which four technologies might change your world?

As a technology nerd, I'm always looking to the future. For the last 16,000 years, humans have produced a steady stream of new technologies that have drastically improved our lives. Early inventions such as agriculture or copper tools took thousands of years to spread around the world. Newer inventions such as the internet or smartphones become global in a decade.

What's next? A few technologies that I see as potentially world-changing are: CRISPR, quantum computers, self-driving cars, and nuclear fusion.

1) CRISPR - CRISPR (pronounced "crisper") is a class of DNA sequences found in bacteria and archaea which constitute the immune system of the cells. CRISPRs are found in ~50% of bacteria and ~90% of archaea. Each CRISPR contains a snippet of DNA which matches a virus seen at some point in the cell's evolutionary past. These snippets allow CRISPR to detect and destroy similar viruses during subsequent attacks.

In 2013, scientists figured out how to hijack CRISPR to perform highly targeted genome edits. As such, CRISPR provides us with an unparalleled tool to change life as we know it. Just one year later, in 2014, over 1000 research papers discussed how to use CRISPR to change human cells, modify yeasts to make biofuels, alter crop strains, and change mosquitos to eliminate malaria. By the start of 2018, 86 people in China have already had their genes edited by CRISPR. It is a brave new world.

2) Self-driving cars - In the not too distant future, taxi drivers and bus drivers will be a thing of the past, and you will be able to take a nap or check your email while commuting to the office.

The 2004 DARPA Grand Challenge was a battle between autonomous vehicles to navigate the Mojave Desert. The "winning" vehicle only completed 7 miles of the course. Today, 14 years later, the two leading autonomous driving companies -- Waymo (Google) and Cruise (GM) -- have logged millions of autonomous miles, and both companies average 5,000 or more miles between any human interventions.

Next year, GM will begin production of a car without a steering wheel or pedals. The future is coming quickly.

This rapid surge in autonomous vehicle technology has been made possible by new artificial intelligence algorithms as well as massive performance leaps in GPU (Graphics Processing Unit) and TPU (Tensor Processing Unit) hardware to run such algorithms.

Traditional computer algorithms execute a set of instructions devised by their human creators. These creators can then devise tests to ensure that the programs are performing the prescribed rules. However, the new AI algorithms that power autonomous vehicles are very different. The AI algorithm creators lay out how the AI "brain" is wired up. Then, the human creators feed the AI algorithms massive amounts of data so that the AI algorithms can "learn" what to do. As a result, the machines are now programming themselves. We can no longer understand what the program is doing, examine how it is making decisions, or even test that the machine is doing what we want. Because of this, using an autonomous vehicle is effectively a leap of faith that the machine has learned to drive better than a human.

3) Nuclear Fusion - The media typically describes nuclear fusion as a technology that is always 30 years away. Performing nuclear fusion is not a challenge. Right now, it is possible to perform nuclear fusion in your garage. Instead, the challenge is performing fusion in such a way that it produces more energy than it consumes.

With little media fanfare, fusion technology has steadily improved at a massive rate. Compared to the fusion of the 1960s, today's nuclear fusion has a 100,000+x improvement in the triple

product (temperature x density x confinement time). In the coming decades, better numerical simulations and new, innovative reactor designs may finally push nuclear fusion over the break-even threshold as a commercially viable energy source.

4) Quantum Computers - Quantum computers were first proposed in the 1950s by Nobel Prize winning Caltech physicist Richard Feynman. Standard computers store information as and compute upon bits -- zeros and ones. By contrast, quantum computers store information as and compute upon qubits (quantum bits) -- a fuzzy blur somewhere between zero and one.

Quantum computers have proven extremely difficult to build. Tiny atomic vibrations create enough noise to destroy a quantum state and to ruin a computation. Physicists have been developing ways to avoid these errors by creating computers that run at temperatures near absolute zero and by coupling multiple qubits in special ways to correct for errors.

Quantum hardware has progressed at a rapid rate. In 1998, the first working 2-qubit computer was created. Today, Google has created a 72-qubit computer named Bristlecone. Within the next year or so, quantum computers will have enough qubits to be more powerful than any classical computers for certain types of problems.

One important problem that quantum computers excel at is factoring integers. While this may seem unimportant, integer factorization underlies essentially all of the cryptography which keeps our computers and our communications secure. Right now, there is an arms race between the speed of new quantum computers and the technology that keeps our computers and communications secure. Let's hope that cryptography makes rapid progress before quantum computers allow anyone to decrypt and read all internet traffic.

Cordially,

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