Quantum Computing: Life after Moore's Law

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- There are no guarantees that we can build a quantum computer
- Competition is against the unbelievably large computing power of already existing technologies
- Deep learning requires a lot – how can we keep up with it?
- Crash Course into Quantum Mechanics
  - The direct consequence of quantum mechanics is the fact that objects have size
  - Seeming randomness of quantum mechanics is not a good way to look at quantum mechanics
  - There are excited atom states stable enough to allow computation
  - Instead of conducting computations over the separate values of 0 and 1, superposition of quantum states allows the computation over a range of *fuzzy* values.
  - The processing power of a quantum computer grows exponentially with the number of qubits
  - If there are 300 qubits, the amount of parallelism is bigger than the number of atoms in the universe
- Qubit Systems
  - Light is much bigger than an average molecule – how can we control it?
  - We can make special molecules, of size comparable to the wavelength of light

  - Another way is to build electrical circuits that can behave as quantum mechanical objects, which are easier to control due to the bigger size
  - Most of these circuits are made of aluminium alloys
  - One of the aspects of the strange behavior these circuits show is the bidirectionality of currents in the same conductor
  - This technology is hard to make work

- Qubit Operations
  - A qubit oscillates and changes its state
  - A qubit is projected into the state, and if the conditions are right, we can utilise its probability distribution
  - The oscillations of qubits can be used to construct gates (it is relatively easy to obtain a not-gate, for example)

- Practical Challenges
  - The most difficult part of building a quantum computer nowadays is in cryogenics
  - The cycle of designing and producing a qubit system takes less than 4 weeks

- Achieving Supremacy
  - Can be viewed as a big guy vs a little guy struggle – verifying the operation of a 49-qubit computer designed at Google would require the most powerful supercomputer
  - The plan is to verify the execution of a random algorithm
  - Supremacy is possibble with some margin
  - From 3 qubits to 9 qubits, the error of prediction per cycle ratio grows from 0.6% to 2.9%

- Theory of Quantum Matrials
  - A 9-qubit device can be easily modelled with existing technology
  - Quantum simulators allow the computational modelling of experiments which cannot be usually conducted in the lab – for example, theoretical prediction of the effect of 10000 T magnetic field is feasible

- Toward a Useful Quantum Computer
  - Feynman have proposed a quantum simulator to study quantum chemistry
  - The advances in quantum computing would help us design more efficient methods of producing ammonia
  - There is a huge progress in algorithms from 2005 to 2017, with the complexity decreasing from $O(poly(N))$ to $O(N)$
  - See the research of Ryan Babbush, McClean, Wecker, Poulin, Hastings, Toloni, Perruzo, Seeley, Whitfield, Aspuru-Guzik
- Is Useful QC now possible?
  - We do not know yet.
- People
  - Mikhail Lukin (Harvard, RQC)