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Information and computer technologies. Quantum computing

In the end of 1940s only few key scientists in the world involved into process of the invention of the computer engineering. They were John von Neumann end John Mauchly from the USA, Alan Turing from the UK, Sergey Lebedev from the USSR. The first brain-child of Sergey Lebedev was MESM - the first stored program computer in continental Europe. MESM was created in Kiev in 1949 (70 years ago). The first personal computers (PC) were created in 1960–1970. (The Soviet MIR series of computers was developed from 1965 to 1969 in a group headed by Victor Glushkov in Kiev). Computers have changed out lives globally.

The new page of space evolution of humanity — quantum computing.

The field of quantum computing was initiated by the work of Paul Benioff and Yuri Manin in 1980, Richard Feynman in 1982 and David Deutsch in 1985.

What can we say about quantum computing today?

Quantum computing can be viewed as the ultimate parallel computing utilising the quantum mechanical principle of superposition. Unlike the classical binary digits (bits) that form a two-state system ("0" and "1"), quantum bits (or qubits) can be in a superposition of states. This allows the quantum computer to explore large number of possible paths simultaneously.

The building blocks of quantum computing, qubits, can be realised in many different ways. Any physical system that can exist in a superposition of states can be used for quantum computing. The most popular choices for qubits are electrons (qubit is represented by electron spin), trapped ions (qubit is represented by the internal atom state) and superconducting loops (qubit is represented by the quantum states of electron current in two directions with different magnetic flux). There are also qubits based on photons (polarisation), neutral atoms, etc.

Quantum computing has three major advantages over the classical one. The first is known as quantum speed-up. It has been demonstrated that for a specially constructed problem an existing D-Wave quantum annealer can achieve 10^8 speed-up over its classical counterpart (simulated annealing algorithm run on a classical computer). It remains to be seen what rate of quantum speed-up we can achieve across the wide range of computational problems.

The second is energy efficient computations based on the principle of reversibility (preservation of information). All quantum computing operations are reversible, except the final measurement. In classical computing based on standard universal logic gates (such as NOT AND or NAND logic gate), operations are not reversible — the act of calculation leads to the loss of information. Statistical mechanics and information theory tell us that the loss of information should lead to the increase in entropy, i.e. to the generation of heat.

Finally, quantum computing can solve problems that are not solvable on classical supercomputers in finite amount of time. For example, simulation of complex molecules with numerous applications in chemical and pharmaceutical industries.

We are entering the period known as NISQ (noisy intermediate-scale quantum computing). This period is characterised by the general purpose quantum computers having between 50 and 100 logical qubits and specialised quantum annealers having several thousand physical qubits.

These quantum computers are powerful enough to "prove the concept", but not big enough yet to achieve true quantum supremacy. However, we are witnessing the exponential growth in the power of quantum computers. Also, practically all major technology companies now try to develop their own quantum computing capabilities, often in partnership with large financial institutions.

This means that we are probably closer to the widespread usage of quantum computing than we realise.

Chronology of the last achievements:

2016 - NASA publicly displayed the world's first fully operational ($-15 million) quantum computer made by the Canadien company D-Wave at the Quantum Artificial Laboratory at its Ames Research Center California's Moffett Field.

2017 - IBM announced that it has succesfully built and tested its most powerful universal quantum computing processors. The first is a 16 qubit processor that will allow for more complex experimentation;

- a group of U.S. Researchers announced a quantor simulator (one equation) with 51 qubits. The announcement was made by Mikhail Lukin of Harvard University at the International Conference on Quantum Technologies in Moscow;

- IBM research scientists use a 7 qubit device to model the largest molecule, Beryllium hydride, ever by a quantum computer (journal Nature);

- IBM announced the availability of its most -powerful 20 qubit commercial processor, and the first prototype 50 qubit processor.

2018 - Google Quantum AI Lab announced a 72 qubit processor called Bristlecone.