Quantum machine learning

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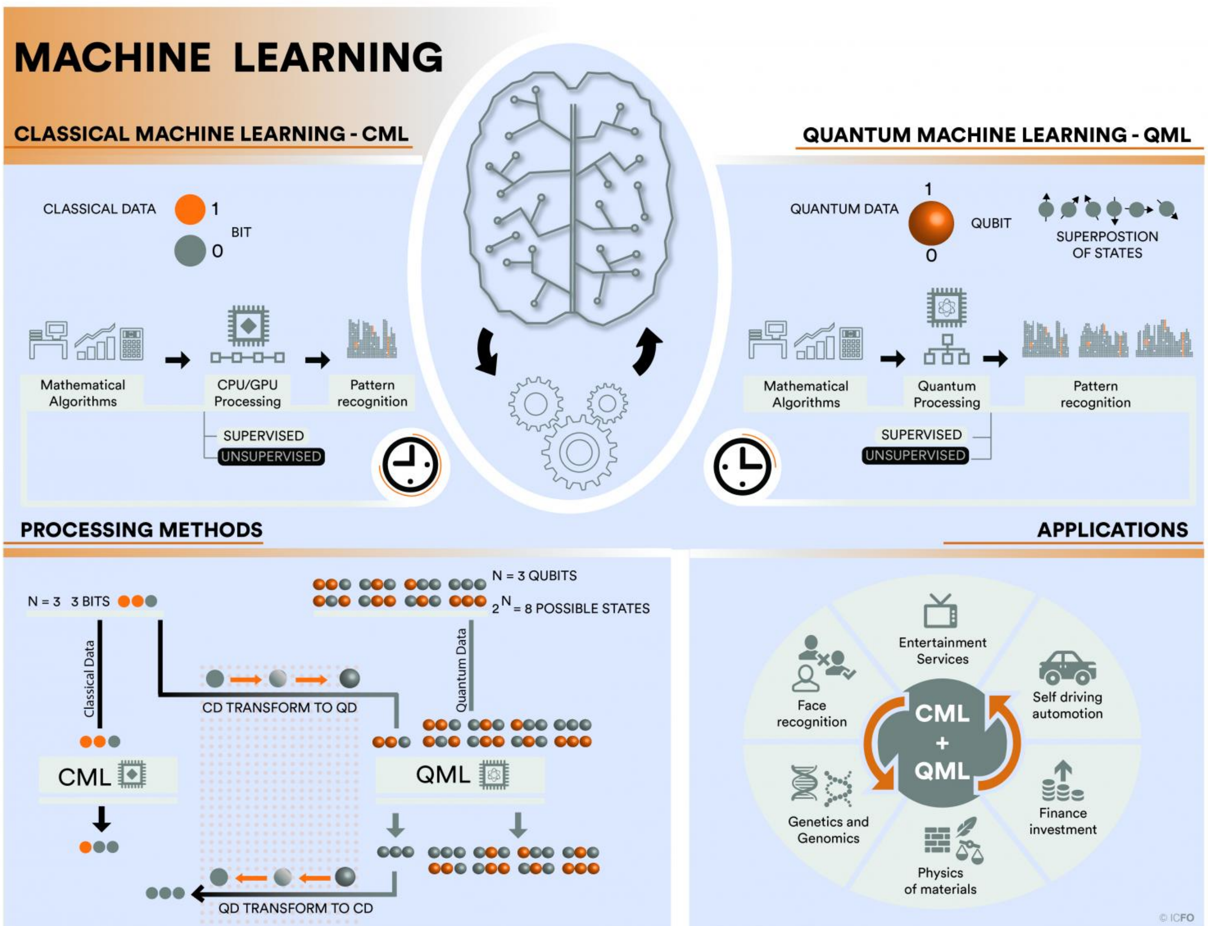

An international team of scientists presents a thorough review on quantum machine learning, its current status and future prospects. The reports contrasts machine learning using classical and quantum resources, identifying opportunities that quantum computing brings to this field. Credit: ICFO

Language acquisition in young children is apparently connected with their ability to detect patterns. In their learning process, they search for patterns in the data set that help them identify and optimize grammar structures in order to properly acquire the language. Likewise, online translators use algorithms through machine learning techniques to optimize their translation engines to produce well-rounded and understandable outcomes. Even though many translations did not make much sense at all at the beginning, in these past years we have been able to see major improvements thanks to machine learning.

Machine learning techniques use mathematical algorithms and tools to search for patterns in data. These techniques have become powerful tools for many different applications, which can range from biomedical uses such as in cancer reconnaissance, in genetics and genomics, in autism monitoring and diagnosis and even plastic surgery, to pure applied physics, for studying the nature of materials, matter or even complex quantum systems.

Capable of adapting and changing when exposed to a new set of data, machine learning can identify patterns, often outperforming humans in accuracy. Although machine learning is a powerful tool, certain application domains remain out of reach due to complexity or other aspects that rule out the use of the predictions that learning algorithms provide.

Thus, in recent years, quantum machine learning has become a matter of interest because of is vast potential as a possible solution to these unresolvable challenges and quantum computers show to be the right tool for its solution.

In a recent study, published in *Nature*, an international team of researchers integrated by Jacob Biamonte from Skoltech/IQC, Peter Wittek from ICFO, Nicola Pancotti from MPQ, Patrick Rebentrost from

MIT, Nathan Wiebe from Microsoft Research, and Seth Lloyd from MIT have reviewed the actual status of classical machine learning and quantum machine learning. In their review, they have thoroughly addressed different scenarios dealing with classical and quantum machine learning. In their study, they have considered different possible combinations: the conventional method of using classical machine learning to analyse classical data, using quantum machine learning to analyse both classical and quantum data, and finally, using classical machine learning to analyse quantum data.

Firstly, they set out to give an in-depth view of the status of current supervised and unsupervised learning protocols in classical machine learning by stating all applied methods. They introduce quantum machine learning and provide an extensive approach on how this technique could be used to analyse both classical and quantum data, emphasizing that quantum machines could accelerate processing timescales thanks to the use of quantum annealers and universal quantum computers. Quantum annealing technology has better scalability, but more limited use cases. For instance, the latest iteration of D-Wave's superconducting chip integrates two thousand qubits, and it is used for solving certain hard optimization problems and for efficient sampling. On the other hand, universal (also called gate-based) quantum computers are harder to scale up, but they are able to perform arbitrary unitary operations on qubits by sequences of quantum logic gates. This resembles how digital computers can perform arbitrary logical operations on classical bits.

However, they address the fact that controlling a quantum system is very complex and analyzing classical data with quantum resources is not as straightforward as one may think, mainly due to the challenge of building quantum interface devices that allow classical information to be encoded into a quantum mechanical form. Difficulties, such as the "input" or "output" problems appear to be the major technical challenge that needs to be overcome.

The ultimate goal is to find the most optimized method that is able to read, comprehend and obtain the best outcomes of a data set, be it classical or quantum. Quantum machine learning is definitely aimed at revolutionizing the field of computer sciences, not only because it will be able to control quantum computers, speed up the information processing rates far beyond current classical velocities, but also because it is capable of carrying out innovative functions, such quantum deep learning, that could not only recognize counter-intuitive patterns in data, invisible to both classical machine learning and to the human eye, but also reproduce them.

As Peter Wittek finally states, "Writing this paper was quite a challenge: we had a committee of six co-authors with different ideas about what the field is, where it is now, and where it is going. We rewrote the paper from scratch three times. The final version could not have been completed without the dedication of our editor, to whom we are indebted."

More information: Quantum Machine Learning, Jacob Biamonte, Peter Wittek, Nicola Pancotti, Patrick Rebentrost, Nathan Wiebe and Seth Lloyd, *Nature* 549, 195–202 14 September 2017 DOI: 10.1038/nature23474

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