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Time to put real problems to the quantum machines

There is a lot to learn before quantum computers can be applied to specific financial problems

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Quantum computers may soon outperform the most powerful classical computers, and scientists, researchers – and bankers – are trying to understand how these new super-machines might be used, ready for when that moment arrives.

An influential work on quantum computing in the field of finance is a paper published on May 29 on *Risk.net*, ***Beyond Markowitz with quantum annealing***, by Davide Venturelli, a quantum computing science lead at the USRA Research Institute for Advanced Computer Science in the US, and Alexei Kondratyev, a managing director and head of data analytics in the electronic market solutions team at Standard Chartered Bank in London.

The pair picked a classical problem to solve – portfolio optimisation.

The process of selecting the best mix of assets from all possible combinations, as pioneered by Harry Markowitz, is as old as modern finance, but it is still a notoriously complex problem to solve in its discrete form – assuming that assets are traded in specific units – when the number of underlying assets gets large.

With 100 assets, for instance, optimisation requires constructing a 100 by 100 correlation matrix, which can make computations hugely time-consuming. Typically the process is done through brute force techniques that run multiple classical computers in parallel.

Through a quantum phenomenon known as superposition, though, the units of information in quantum computers – known as qubits – can hold more information than their equivalents in classical computing, meaning quantum computers can handle a large number of calculations simultaneously.

That makes them potentially ideal for solving optimisation problems.

Classical computing bits have two states, one and zero. But qubits can exist in a combination of the two at once. Their behaviour is also correlated – or ‘entangled’ – which makes reading information from the system quicker because observing one qubit can tell you something about the state of others.

Reverse annealing

Kondratyev and Venturelli adopted a quantum computing technique called reverse annealing, using the D-Wave quantum annealer located at NASA’s Ames Research Center to optimise a portfolio of 60 assets. The number of assets is limited by the available number of qubits in today’s quantum computers, though that number is projected to grow fast.

In essence, they replicated the mathematical problem as a physical problem using quantum particles. The physical problem can be solved more rapidly because of the quantum phenomenon.

Variables such as asset returns and correlations are mapped into variables or properties of quantum particles: the so-called ‘spin’ of a particle, for example, or fluctuations in the forces between particles.

The objective function of the problem – which in this case relates to the risk-adjusted return of the portfolio – is mapped into the energy state of particles.

> **Quantum computers can handle a large number of calculations simultaneously**

Once the problem has been ‘translated’ into physics, the reverse annealer can find the lowest energy state, the optimal value, which can be translated back to reveal the optimal portfolio.

“We are engineering a physics process to map into the solution of a mathematical problem,” says Venturelli. “You map one asset into one spin, which is one qubit… then you couple the energy levels of all these variables so that the covariance matrix becomes the real energy of magnetic inductance between these qubits – so you are essentially mapping energy into coefficients of your problem.”

The reverse annealer generates results 100–1,000 times faster than a classical technique if overhead times for running the quantum annealer are not added. The next generation of D-Wave quantum computers, expected to be ready by 2020, should be able to optimise portfolios of three times the number of assets, says Venturelli.

The research lays the foundations for learning how such problems need to be defined for the quantum annealer, which is as important as proving the technology can achieve faster calculations. Many studies in this field focus purely on the best way to run algorithms on quantum computers such that they actually work, as this can be challenging to figure out.

“Now if a new person comes and says: ‘I want to try the machine to do this kind of problem’ they have an idea what kind of parameters are good for it, whereas before it was not known,” says Venturelli.

The door is open for researchers to define other problems so that quantum computers might get to work on them.

Listen to the authors discussing their work here