How to certify a quantum computer

SNSF-funded researchers have developed a protocol for checking that quantum computer components function as they should. That’s a critical step in making the promise of quantum computing – including unprecedented computing power – a reality.

Quantum computers are being developed by teams working not only at universities but also at Google, IBM, Microsoft and D-Wave, a start-up company. And things are evolving quickly, says Nicolas Sangouard, SNSF Professor at the University of Basel. “In a few years at most, I expect the computing power of quantum computers to significantly outstrip the computing power of ordinary computers. We call that ‘quantum supremacy’.”

Sangouard and his co-workers recently showed how to check that these computers are fit for purpose. For they are not just powerful but also very delicate: some operate at temperature extremes as low as 270 degrees below zero. The researchers’ approach enables them to certify all the components of a quantum computer – from short- and long-term memory, to information processors, to the converters required to connect the computer to a secure quantum communications network. The protocol offers an additional advantage: it only uses the components already in the computer, thus obviating the need for additional devices. In principle, the protocol will work with any type of quantum computer, whatever the technology behind it.

A machine that tests itself

“The power of quantum computers is what makes them difficult to certify”, says Sangouard. “Even the fastest ordinary computers are too slow to check the calculations made by such devices.” Moreover, quantum computers will eventually be able to communicate with each other securely through a dedicated quantum communications network. So it’s important to make sure that they aren’t a weak link, says Sangouard.

That’s why the research team has developed a completely quantum certification method that uses the computer’s own building blocks. “We were inspired by Bell tests, which were devised by a physicist working at CERN in the 1960s”, says Sangouard. “Normally, these tests are used to check whether particles are behaving according to quantum rules. We modified the tests to enable them to check the operation of the various components of a quantum computer. Because such a device is basically capable of doing the tests, our procedure is very simple to set up and doesn’t require any special skills.”

“What prompted the project was a seminar talk by a scientist invited to the University of Basel”, says Sangouard. “The talk dealt with a complicated aspect of quantum physics, but we were motivated to translate it into a useful method for quantum computers. For me, that’s a perfect example of how a conference is not just a means of learning in a passive way but also offers significant opportunities to innovate.”
The research was carried out at the University of Basel during an SNSF Professorship – a scheme that has since been replaced by the SNSF Eccellenza Professorial Fellowships – and at the University of Innsbruck, thanks to a mobility grant. Nicolas Sangouard is an associate member of the National Centre of Competence in Research (NCCR) “QSIT – Quantum Science and Technology”, an SNSF funding scheme. He also takes part in the project Quantum Internet Alliance, part of the new FET Flagship programme “Quantum Technologies”.

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Quantum computing

First proposed in the early 1980s, the concept of the quantum computer aims at exploiting the strange laws that govern the microscopic world to perform calculations that are impossible to do using ordinary computers. A quantum processor manipulates information and at the same time uses each quantum bit ("qubit") to encode a continuum of numbers – not just the 1s and 0s encoded by ordinary digital bits. The pace of industrial development is accelerating: in November 2017, IBM announced that it had tested a 50-qubit computer.

Switzerland and Europe are on board

Switzerland is home to many world-class research groups working on quantum technologies. Most of them are participants in the National Centre of Competence in Research (NCCR) “QSIT – Quantum Science and Technology”, the goal of which is to develop technologies that exploit quantum physics, and in particular computers, communication protocols and quantum sensors. The NCCR is headed by Klaus Ensslin of ETH Zurich and co-directed by Richard Warburton at the University of Basel. In Europe, 20 projects have been selected on 28 October 2018 for the new FET Flagship «Quantum Technologies», which has a budget of one billion euro. Scientists from the universities of Basel, Geneva and Neuchâtel as well as from ETH Zurich and CSEM participate in the programme; two projects are coordinated by Swiss groups.

The text of this press release, a download image and further information are available on the website of the Swiss National Science Foundation:

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