Understanding Google's announcement about the D-Wave machine

A note by the European Virtual Institutes for Quantum Technology

Google announced on December 8th their latest results experimenting with the D-Wave quantum annealer (not to be confused with a quantum computer) on specially designed problems. According to Google's blog, *"The problems were designed to demonstrate that quantum annealing can offer runtime advantages for hard optimization problems characterized by rugged energy landscapes. We found that for problem instances involving nearly 1000 binary variables, quantum annealing significantly outperforms its classical counterpart, simulated annealing. It is more than 10^8 times faster than simulated annealing running on a single core."* [1]

These results are a significant proof-of-principle demonstration that quantum effects in annealing can, in some cases, lead to substantial performance gains for particular special calculations.

What has been demonstrated by Google is an algorithm that has constant-factor speedup with respect to specific classical algorithms on problems that are chosen to take maximum advantage of the limited quantum power of the device. For more general algorithms, the D-Wave machine provides no speed-up. [2] Therefore the outcomes reported in the blog should not be taken as a demonstration that quantum annealers outperform all classical optimization methods. [3] In the own words of the authors of the Google paper[4],

"Based on the results presented here, one cannot claim a quantum speedup for D-Wave 2X, as this would require that the quantum processor in question outperforms the best known classical algorithm. This is not the case [here] because a variety of heuristic classical algorithms can solve [the problems we consider] much faster than the D-Wave 2X".

Further, the performance gains shown by Google do not increase as the size of the calculation (number of variables) grows. This is in contrast to quantum computers where the performance advantage increases as the calculation size increases.

Taking thus the Google claim *cum grano salis*, it points to the necessity to identify the classes of application problems where quantum annealing can have a winning advantage over even the (truly) best classical algorithms. It also suggests the need for higher-precision control of qubits.

Importantly, the results that have been announced, together with a plethora of other results obtained during the last years, do show that large scale quantum devices are feasible. Development of these devices, through sustained investment leading to major progress, will enable the realization of the full potential of quantum technologies.

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[1] http://googleresearch.blogspot.de/2015/12/when-can-quantum-annealing-win.html
[2] More details in the previous references and http://www.scottaaronson.com/blog/?p=2555.
[3] http://qurope.eu/db/news/recent-developments-quantum-annealing
[4] http://arxiv.org/abs/1512.02206 , page 5.