On the Power of Hybrid Classical and Low-depth Quantum Computation

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It is foreseeable that in the near term, quantum computation will be restricted to have low depth. Hence, it is natural to consider hybrid computation models of classical and low-depth quantum computation, which capture the computation power available in the near term. However, the power of such hybrid models is not clear. On one hand, it is known that Shor's factoring algorithm can be done in such hybrid models with poly-logarithmic quantum depth, and Richard Jozsa conjectured in 2006 that any polynomial-time quantum computation can be simulated in a hybrid model motivated by measurement-based quantum computation. On the other hand, Scott Aaronson conjectured an oracle separation between BQP and another type of hybrid model (first mentioned in 2005, and also in 2011 and 2014).

In this talk, I will present our oracle separations between BQP and both hybrid models, which proved Aaronson's conjecture and showed that Jozsa's conjecture cannot hold relative to oracles. In fact, we prove a stronger statement that for any depth parameter d, there exists an oracle that separates quantum depth d and $2d+1$ in the presence of classical computation. As a side note, the same conclusion is independently proved by Coudron and Menda using a different oracle problem, but we showed a shaper separation that doubling the quantum depth is strictly more powerful for both hybrid models relative to some oracles.

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