Boson sampling and continuous variables

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The seemingly straightforward task of simulating random samples from the measurement of linearly scattered bosons has been shown by Aaronson and Arkipov to be an inefficient problem for a classical computer [1]. Naturally this task is straight forward to implement efficiently on a quantum computer, or if universality is not required, directly implemented using linear optics, single photon sources and detectors. This result has generated a lot of interest in achieving a near-term demonstration of the power of quantum computing over classical computing without the need to construct a universal quantum computer.

In this work we study boson sampling problems involving Gaussian states and operations. For Gaussian states and measurements efficient simulation is possible using classical resources for evolutions under any linear network [2]. More recently a scheme using Gaussian input states but with Fock basis detection can reproduce the result of Aaronson and Arkipov [3]. In this work we reverse the sources and detectors and study Gaussian measurements from the output of linear network fed with Fock basis states. As the detection outputs are continuous the computational complexity of probability *densities* must be considered.

The measurement we propose to use is a 50:50 beam-splitter between a prepared Fock 0 or 1 state and the output network mode. After mixing the modes are detected in a squeezed state basis. The continuous variable measurement results are then binned into “success” if both detectors produce results near the origin and “failures” otherwise. This converts the probability densities to true probabilities. Does sampling from the outputs of this scheme admit a classical computational hardness proof?

Following [1] there are two types of sampling algorithms considered. Exact sampling where the algorithm produces samples from a distribution exactly that of the desired task. This is a physically implausible requirement but can be useful in proofs. Approximate sampling allows sampling from a distribution close to that of the desired task. It is possible for exact sampling to be inefficient whilst approximate sampling is efficient. As shown in [1] both exact and approximate sampling are hard when using Fock basis inputs and detections. We find that in our scheme exact sampling hardness still holds with some additional caveats. In the more realistic case of approximate sampling, we find that there are a number of issues that conspire to render the quantum speed-up unable to be definitively shown.

[1] S. Aaronson and A. Arkhipov, Theory Comput. 9, 143 (2013).

[2] S. D. Bartlett, et al., Phys. Rev. Lett. 88, 097904 (2002).

[3] A. P. Lund, et al., Phys. Rev. Lett. 113, 100502 (2014).