Powering correlations with information

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Abstract. Quantum communication is commonly quantified in terms of the dimension of Hilbert space. Here, we introduce and investigate correlations that arise from informationally restricted communication. This information-based framework makes no reference to dimension and instead employs entropic quantifiers of information. We fully characterise classical correlations and show that quantum correlations violate such constraints. We also prove that information-bounded quantum correlations are strictly stronger than dimension-bounded quantum correlations. We present a semidefinite programming hierarchy to characterise the quantum set and discuss how the concept applies to other topics in quantum information science and quantum foundations.

Keywords: Quantum correlations, quantum communication, information

Communication of quantum systems can give rise to stronger correlations than any classical model with the same amount of communication. For a long time, the standard approach to quantifying such communication and analyzing the resulting correlation phenomena has been based on the dimension of Hilbert space: qubits can outperform bits etc. In this talk, we propose a new framework for analyzing quantum communication and the correlations it gives rise to based on the information content of communication [1, 2] (see https://arxiv.org/abs/1909.05656). This approach departs entirely from dimension-based ideas and instead embraces operational entropic quantifiers of communication. We present a complete characterization of the classical correlations that can be generated with limited information (it is a polytope) and show that quantum correlations can beat these limitations. We also determine the limits of correlations that can be obtained in any post-quantum theory based solely on the information content of post-quantum systems. In particular, this leads to theory-independent device-independent witnesses of information.

Then, we discuss the relation between information-bounded quantum correlations and standard dimension-bounded quantum correlations. We prove that the latter is a special case of the former. More strikingly, we prove that one bit of quantum information encoded in a noisy high-dimensional system can give rise to strictly stronger correlations than standard qubits. This points to the conceptual difference between encoding quantum bits in informationally restricted ensembles as opposed to two-level systems. We then proceed to address the outstanding question of characterising the set of information-bounded quantum correlations. We show that such a characterisation can be achieved by means a semidefinite programming hierarchy [2]. We conclude with an outlook and discuss how this new foundational concept and the tools developed can apply to interesting, already established, problems in quantum information science and quantum foundations. In particular, we briefly discuss its relation to contextuality and to entanglement-assisted quantum and classical communications.

References

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