On Causal Explanations of Quantum Correlations

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Abstract

The framework of causal models is ideally suited to formalizing certain conceptual problems in quantum theory, and conversely, a variety of tools developed by physicists studying the foundations of quantum theory have applications for causal inference. This talk reviews some of the connections between the two fields. In particular, it is shown that certain correlations predicted by quantum theory and observed experimentally cannot be explained by any causal model while respecting the core principles of causal discovery algorithms. Nonetheless, it is argued that by understanding quantum theory as an innovation to the theory of Bayesian inference, one can introduce a quantum generalization of the notion of a causal model and salvage a causal explanation of these correlations without fine-tuning. Furthermore, experiments exhibiting certain quantum features, namely, coherence and entanglement, enable solutions to causal inference problems that are intractable classically. In particular, while passive observation of a pair of variables cannot determine the causal relation that holds between them according to classical physics, this is not the case in quantum physics. In other words, according to quantum theory, certain kinds of correlation *do* imply causation. The results of a quantum-optical experiment confirming these predictions will be presented.
This talk is based on the work described in Refs. [1] and [2].

References

[1] Christopher J. Wood and Robert W. Spekkens, *The lesson of causal discovery algorithms for quantum correlations: Causal explanations of Bell-inequality violations require fine-tuning*, preprint arXiv:1208.4119, (2012).

[2] Katja Ried, Megan Agnew, Lydia Vermeyden, Dominik Janzing, Robert W. Spekkens and Kevin J. Resch, *Inferring causal structure: a quantum advantage*, preprint arXiv:1406.5036, (2014).