Algorithms for quantum causal discovery

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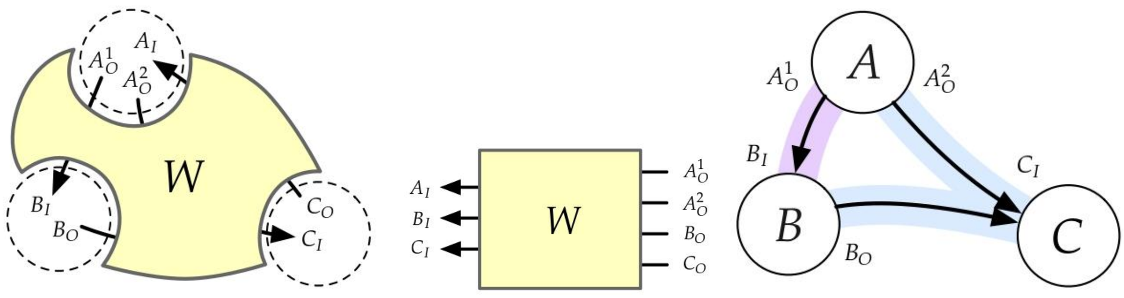
Correlation does not imply causation—but then what does, especially in the quantum world? The discovery of causal relationships is an integral part of every scientific discipline. Even though causal modelling is a well developed field in classical physics [1], it is not straightforward in the quantum setting due to measurement playing a non-trivial role [2]. Existing quantum causal discovery algorithms require knowledge about the complete process, which in turn requires process tomography to be performed with an informationally complete set of operations in order to detect the quantum causal model and the precise mechanisms behind the causal relations [3, 4]. The development of witnesses of quantum causal orders is an improvement over full process tomography, however it still requires a significant number of operations.

In this work, we build an artificial neural network based machine learning algorithm that detects the causal structure of a multitime process using statistics from an informationally incomplete set of operations. The model exhibits exceptional accuracy, averaging to 98 percent and is robust against multinomial noise as well as Gaussian noise. Taking into account experimental and computational limitations, we further provide an alternative approach to detect causal connections given a quantum causal network of any size. The new approach is based on reduced processes and scales polynomially in comparison to exponential scaling in other approaches, thereby decreasing the computational complexity.



The W matrix represents a process that connects the parties and corresponds to a matrix transforming party outputs to inputs.
A directed acyclic graph representing a quantum causal model with two channels connecting parties, T^{AO1B} shaded purple and T^{AO2BOC} shaded blue.

References

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