

Quantum Advantage: a Tensor Network Perspective

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Abstract

We review the recent quantum advantage experiments by IBM[1], D-Wave[2], and Google[3], focusing on cases where efficient classical simulations of the experiment were demonstrated or attempted using tensor network methods. We assess the strengths and limitations of these tensor network-based approaches and examine how the interplay between classical simulation and quantum hardware has advanced both fields. Our goal is to clarify what these results imply for the next generation of quantum advantage experiments. We identify regimes and system features that remain challenging for current tensor network approaches, and we outline directions where improved classical methods could further raise the standard for claiming quantum advantage. By analyzing this evolving competition, we aim to provide a clear view of where genuine, scalable quantum advantage is most likely to emerge[4].

References

- [1] Y. Kim *et al*, Nature 618, 500-505, (2023)
- [2] A. D. King *et al*, Science 388, 6743, 199-204 (2025)
- [3] F. Arute *et al*, Nature 574, 505-510 (2019)
- [4] D. A Abanin *et al*, 646, 825-830 (2025)

- [5] A. Kshetrimayum, S. S. Jahromi, S. Singh, R. Orus, arXiv:2603.18825, (2026) page (Century Gothic 11) Indicate references with sequential numbers within [square brackets].

Figures

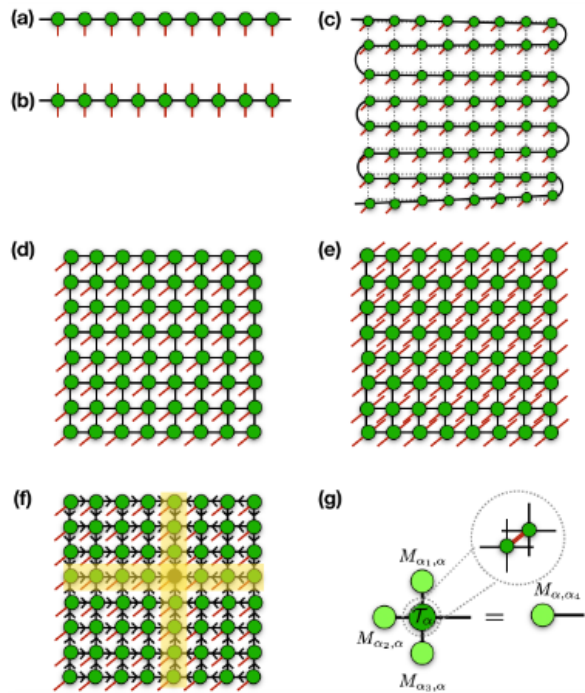


Figure 1: Different Tensor network ansatzes for quantum advantage experiments

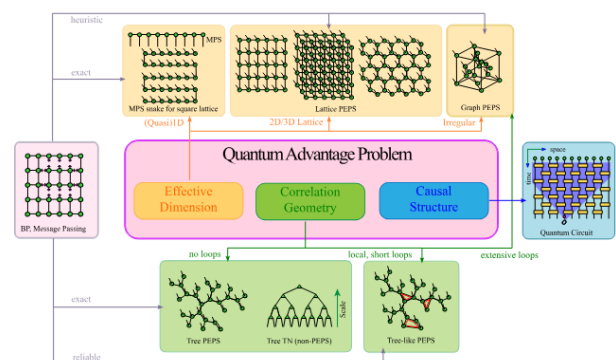


Figure 2: A basic decision tree for selecting an appropriate tensor network method for a quantum advantage experiment