Violation of Bell Inequalities on Quantum Computers

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• New type of inequalities for graph states

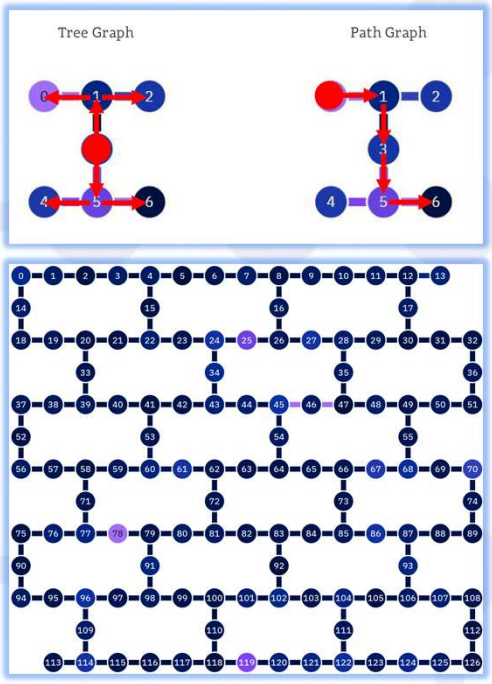

Fig. 1.: Examples of the graphs used in the experiments (top) and the ibm_brisbane computer's architecture (bottom)

• Error mitigation

T-REx mitigation formalism was used to enhance the results. It is provided by IBM in their qiskit library.

While performing the experiments in 2023, T-REx required an enormous amount of time, so just a few runs were made (and only for small systems).

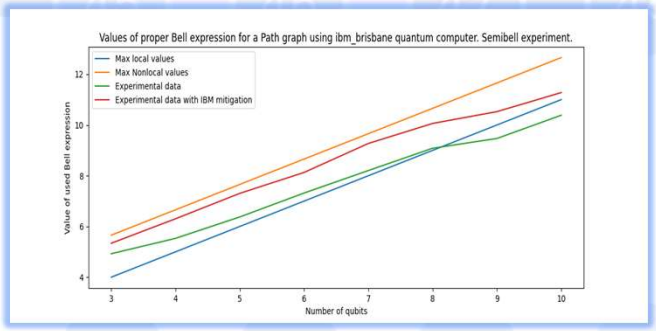

Fig. 2.: Unmitigated (green) and mitigated (red) Bell expression value achieved on ibm_brisbane. Experiment was considered successful if the result exceeded the bottom blue line (the non-Locality threshold). The orange line shows the ideal, theoretical results.

• Results and discussion

Only a few states for some computers exhibited non-locality. The results strongly depended on the type of graph state used and which computer had been chosen.

It was proven that one can perform certain classes of Bell experiments on computers consisting of even up to 100 qubits – though the original Bell inequality violation first described in 1964 is still hardly achievable on the biggest systems available in 2023 (but it is really simply done on smaller devices!)

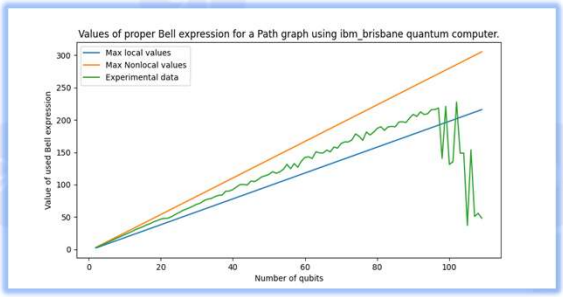

Fig. 3.: The results for Path Graph state encoded into ibm_brisbane. Colour-coded as in Fig. 2.

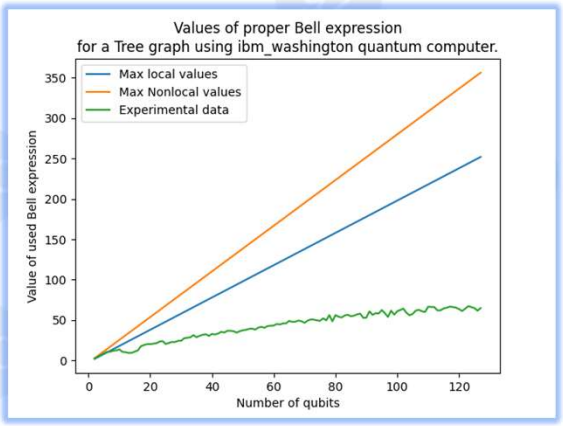

Fig. 4.: The results for Path Graph state encoded into ibm_washington. Colour-coded as in Fig. 2.

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