Open student project: Truncated gradient for quantum circuit optimization (thesis or guided research)

Project description

Consider a so-called brickwall quantum circuit and a unitary reference U expressed as an matrix product operator (MPO) as visualized in Fig. 1. Our overall goal is to optimize the quantum gates within the quantum circuit such that the overall quantum circuit approximates the reference U well.

If we denote the set of quantum gates by $\{V_i\}$ and the quantum circuit by $W(\{V_i\})$, the overlap of the quantum circuit and the reference is given by

$$\mathcal{F} = \mathrm{Tr}\left(W(\{V_i\})U^\dagger\right) \tag{1}$$

and gives a good measure for the optimization. Eq. (1) can be visualized as a tensor network contraction as shown in Fig. 1.

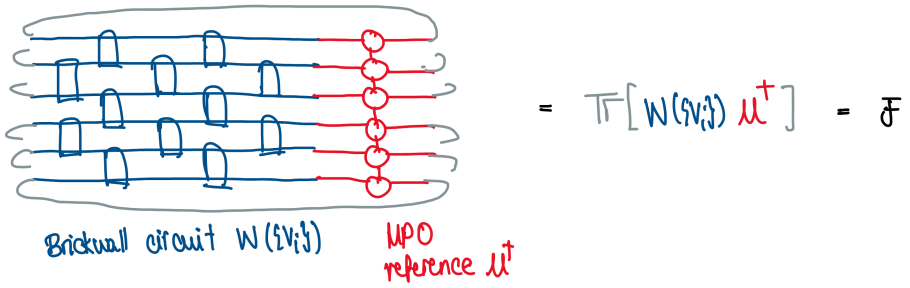

Figure 1: A quantum circuit (blue) and an MPO (red) are contracted to obtain their overlap.

For gradient-based optimization, the derivatives $\frac{\partial \mathcal{F}}{\partial V_i}$ with respect to each gate V_i are required. This can be obtained by "cutting out" V_i and contracting the remaining tensor network [1], see Fig. 2. As this has to be done for each

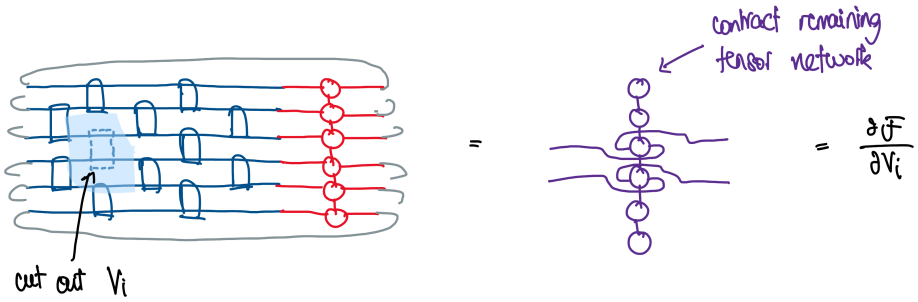

Figure 2: Derivative with respect to a specific quantum gate.

quantum gate, it is reasonable to store certain intermediate contracted tensors to memory for re-usage. We have developed an algorithm to identify these intermediate tensors and to build the overall gradient in a systematic way. **Within this project, you are asked to implement this algorithm. This involves concepts from tensor networks, quantum computing and basic graph theory.** The resulting implementation might be used in ongoing research projects. The project start is flexible.

Application

If you are interested, please send your application containing a current transcript of records, some information about your educational background (field of study, experience in tensor networks or quantum computing) and the type of project you would like to do (thesis or guided research) to isabel.le@tum.de.

[1] Ayse Kotil et al. "Riemannian quantum circuit optimization for Hamiltonian simulation". In: *Journal of Physics A: Mathematical and Theoretical* 57.13 (2024), p. 135303.