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State Diagrams and Tree Tensor Networks

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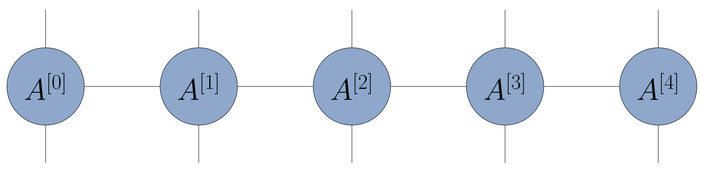
Motivation

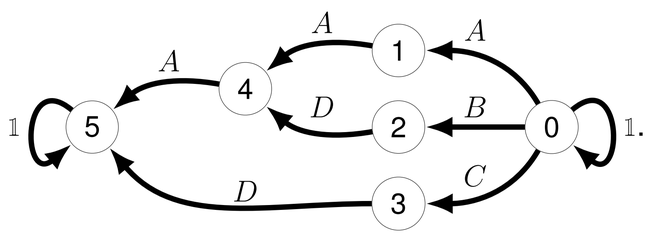
Many relevant Hamiltonians and operators have the following form

$$H = \sum_{i=1}^{K} \bigotimes_{s \in Q} A_i^{[s]},$$

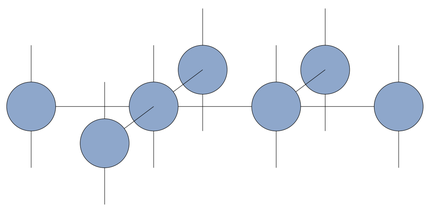
where Q is a set of small quantum systems or sites and the operator $A^{[s]}$ acts on site s.
If Q represents a 1D-chain, we can bring such an operator in matrix product operator form



using cellular automata, e.g.

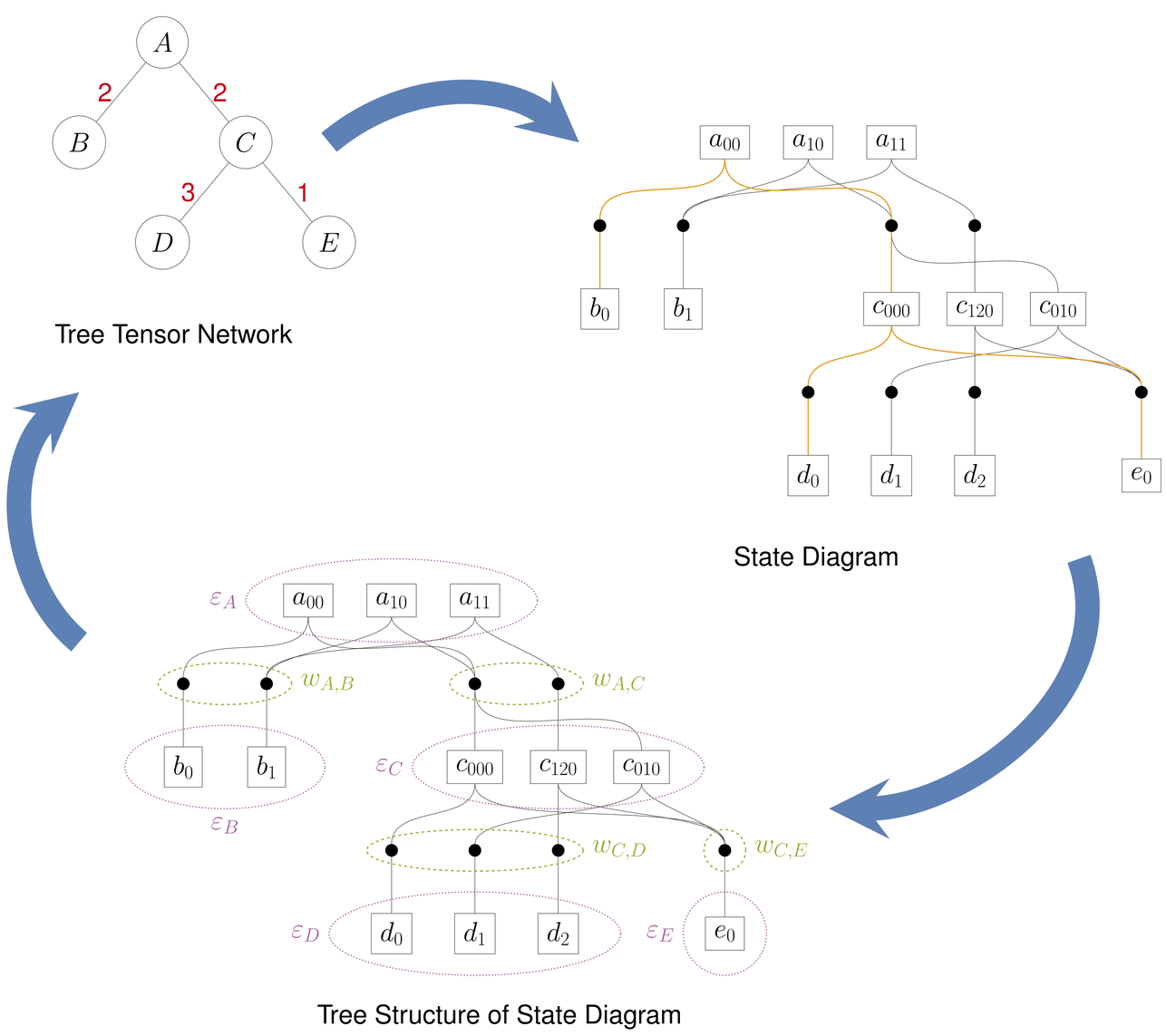


However, if Q or the operator have a tree structure it can be advantageous to use a tree tensor network operator



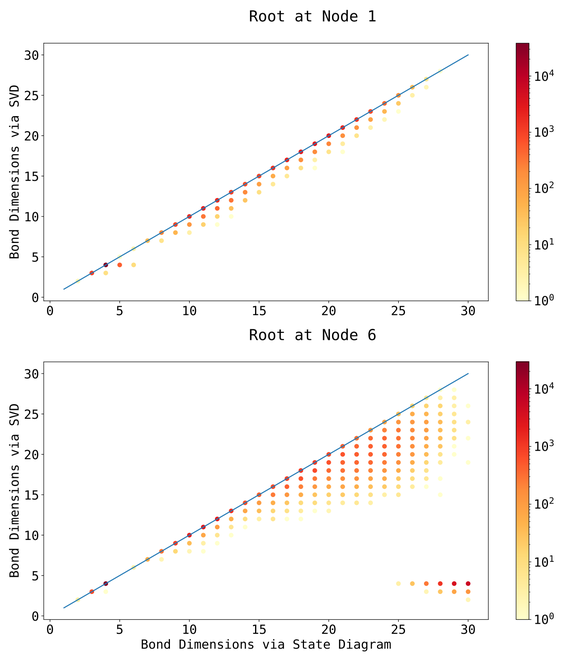
In this case the basic automaton method fails. Therefore we considered state diagrams and developed an algorithm to obtain a state diagram that corresponds to a given operator.

The State Diagram



Tree Structure of State Diagram

Bond Dimensions



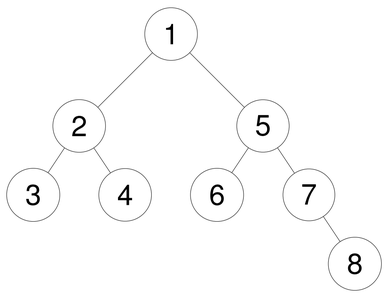
Plots of the tree tensor network operator bond dimension for randomly generated Hamiltonians with 30 terms.

Reference

Richard M. Milbradt, Qunsheng Huang, Christian B. Mendl; *State Diagrams to determine Tree Tensor Network Operators*; arxiv: 2311.13433

Adding State Diagrams

Tree Structure:



Terms:

- $T_1 = \mathbb{1}_1 \otimes Y_2 \otimes X_3 \otimes X_4 \otimes \mathbb{1}_5 \otimes \mathbb{1}_6 \otimes \mathbb{1}_7 \otimes \mathbb{1}_8$
- $T_2 = X_1 \otimes Y_2 \otimes X_3 \otimes X_4 \otimes \mathbb{1}_5 \otimes X_6 \otimes \mathbb{1}_7 \otimes \mathbb{1}_8$

Given the state diagrams of T_1 and T_2, how can we find the state diagram of their sum $T_1 + T_2$ with a low bond dimension?

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