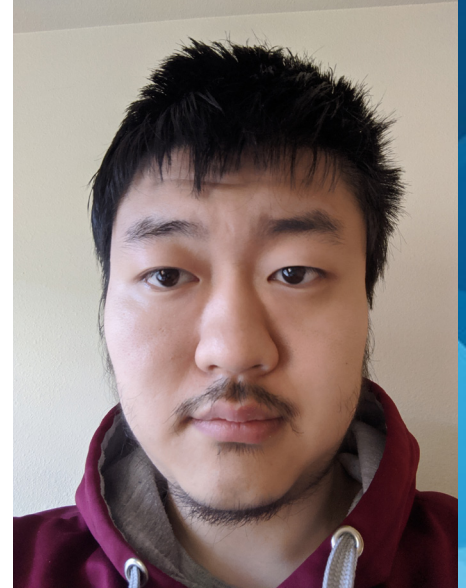




Dissertation Defense

Fang Zhang

A Parallel Tensor Network Contraction Algorithm and Its Applications in Quantum Computation



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ABSTRACT: Tensors are a natural generalization of matrices, and tensor networks are a natural generalization of matrix products. Despite the simple definition of tensor networks, they are versatile enough to represent many different kinds of “products” that arise in various theoretical and practical problems. In particular, the powerful computational model of quantum computation can be defined almost entirely in terms of matrix products and tensor products, both of which are special cases of tensor networks. As such, (classical) algorithms for evaluating tensor networks have profound importance in the study of quantum computation.

In this thesis, we design and implement a parallel algorithm for tensor network contraction. In addition to finding efficient contraction orders for a tensor network, we also dynamically slice it into multiple sub-tasks with lower space and time costs, in order to evaluate the tensor network in parallel. We refer to such an evaluation strategy as a contraction scheme for the tensor network. In addition, we introduce a local optimization procedure that improves the efficiency of the contraction schemes we find.

We also investigate the applications of our parallel tensor network contraction algorithm in quantum computation. The most ready application is the simulation of random quantum supremacy circuits, where we benchmark our algorithm to demonstrate its advantage over other similar tensor network based simulators. Other applications we found include evaluating the energy function of a Quantum Approximate Optimization Algorithm (QAOA), and simulating surface codes under a realistic error model with crosstalk.

Chairs: Profs. John Hayes and Yaoyun Shi