Jinguo Liu (刘金国)

Postdoc fellow in Harvard university

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"朝正确的方向努力，而不是去摘下垂的果实。"

Education

Nanjing Institute of Technology *Nanjing*

B.S. in Software Engineering *2008–2012*

I was a pioneer of the open-source software movement in my institute. Deeply impressed by the beautiful computation framework in the book "Quantum Computation and Quantum Information" by Michael A. Nielsen, I was eager to learn more about quantum computing.

Nanjing University *Nanjing*

Ph.D. Theoretical Physics *2012–2017*

Advised under Prof. Qianghua Wang, I built up my interest in algorithms for solving quantum many-body systems. I mastered tensor networks algorithms and renormalization group theories and became a geek in simulating quantum many-body systems. Most of my works are about designing new algorithms to solve problems in physics, like the multi-channel Kondo problem and fractional topological excitation. In the last year as a doctoral candidate, I won the first prize in the ZTE fantastic algorithm challenge, which reflects my solid algorithmic background in matrix computation and combinatorial optimization.

Skills

Programming Julia, Python, Fortran

Language Chinese, English

Knowledge Tensor Networks, Differential Programming, Quantum computing, Computational complexity, Condensed matter physics, Combinatorial optimization, High performance computing

Experience

Institute of Physics (IOP), Chinese Academy of Sciences (CAS) *Beijing*

Postdoc *2017–2019*

I became a postdoc in Lei-Wang's group, one of the smartest people I knew. Besides providing valuable advice about research, Lei also provides opportunities for me to give lectures and talks at international conferences and summer schools. At that time, my research interest is automatic differentiation and quantum algorithms.

QuEra Computing Inc. *Waterloo*

Consultant *2020.01-2020.07*

Due to the COVID, I was trapped in Waterloo - a wild place where you can see wild animals on the streets. QuEra kindly offered me a full-time consultant job. I worked on stochastic optimizers for variational quantum algorithms and classical benchmarking quantum approximation optimization algorithm (QAOA).

Harvard university *Boston*

Postdoc *2020.08-*

QuEra also sponsored my Postdoc in Mikhail Lukin's group. Working at Harvard is a unique experience for me. While my skills helped experimentalists and theorists in Misha's group, I learned more exciting stuff from people around me every day.

- I developed generic tensor networks (tensor networks with generic element types) to understand the solution space properties of the maximum independent set problem. I learned their approach to analyzing hardness from the solution space geometry: the overlap gap property and adiabatic gap analysis.
- I mapped the maximum independent set problem on a general graph to the one with restricted geometry of diagonal-coupled unit-disk grid graph that Rydberg atom arrays can implement (has been patented). I learned how to reduce many other hard problems to the maximum independent set problem.
- I improved SLM hologram computation for generating arbitrary optical traps (will be patented). I learned how Fourier optics plays a role in the Rydberg atom experiment works in turn.

Honors & Awards

2007	**First prize**, Physics Olympiad	*JiangSu, China*
2016	**Academic Excellence Scholarship**, Nanjing University	*NanJing*
2017	**First prize (out of 8000 teams, 100,000 RMB award)**, ZTE Fantastic Algorithm Challenge	*Xi An, China*

Open Source Contributions

Yao.jl

ONE OF THE MAIN DEVELOPERS

`Yao.jl` is the most popular quantum circuit simulation framework in the Julia community. The Yao repository has 650+ Github stars, and the paper has 50+ citations. It is fast, generic, GPU accelerated, and differentiable.

OMEinsum.jl and OMEinsumContractionOrders.jl

MENTOR OF OMEINSUM.JL, MAIN DEVELOPER OF OMEINSUMCONTRACTIONORDERS.JL

`OMEinsum.jl` is a generic, differentiable einsum library with GPU support. It was developed by Andreas Peter (mentor under me) on the Google Summer of Code (GSoC) project about differential programming tensor networks. This project is a successful one and now its Github repo has 100+ stars. `OMEinsumContractionOrders.jl` is its extension for contraction order optimization that many state-of-the-art algorithms implemented in it.

GenericTensorNetworks.jl

MAIN DEVELOPER

`GenericTensorNetworks.jl` is a package using generic tensor network contraction for solving graph properties. It comes together with the paper: *"Computing solution space properties by generic programming tensor networks"* (see section "Selected Publications").

Selected Presentations

The FOR 1807 Winter School on Numerical Methods for Strongly Correlated Quantum Systems — *Marburg*

LECTURER — *2018*

Lecture: "Deep learning and quantum many body systems".

March Meeting — *Boston*

SPEAKER — *2019*

Talk: "Differentiale Quantum Circuits and Generative Modeling"

Juliacon — *Baltimore*

SPEAKER — *2019*

Talk: "Differential Programming Tensor Networks"

Deep Learning and Quantum Programming: A Spring School — *Dongguan*

LECTURER — *2019*

Lectures on the quantum computing part, one of the main organizers of "happy fatty night" (coding party for resolving student's issues).

Selected Publications

Maximum independent sets: from unit disk graphs to arbitrary connectivity — *Unpublished*

JINGUO LIU, MIN-THI NGUYEN, SHENGTAO WANG ET AL AND HANNES PICHLER — *2022*

Recent progress in variational quantum algorithms shows the great potential of using Rydberg atom arrays to find maximum independent sets of diagonal-coupled unit-disk grid graphs. We propose a mapping scheme that maps the problem of finding an MIS of a general graph G to that on a diagonal-coupled unit-disk grid graph to make these quantum algorithms be useful in a more general setup. Given a general graph, the proposed mapping scheme only introduces an overhead that is proportional to the pathwidth of that graph. We show this mapping scheme is optimal, otherwise, there is an algorithm for finding maximum independent sets of a general graph that runs in sub-exponential time to the problem size, i.e. better than any existing algorithms. Understanding its value to quantum algorithms, we patented it.

Computing solution space properties by generic programming tensor networks — *Unpublished*

JINGUO LIU, XUN GAO, SHENGTAO WANG, MIDELYN CAIN AND MIKHAIL LUKIN — *2022*

We introduce a tensor network algorithm to compute various solution space properties of a class of combinatorial optimization problems on graphs that can be rephrased as satisfiability problems of constraints over local sets of vertices, including the independent set problem, the maximum cut problem, the vertex coloring problem, the maximal clique problem, the dominating set problem, and the satisfiability problem, among others. We look at the independent set problem as an example, and show how to compute the size of the maximum independent set, count the number of independent sets of a given size, and enumerate/sample the independent sets of a given size. By using generic programming techniques, the same simple-to-implement framework can be used to compute all of these properties. Our algorithm utilizes recent advances in tensor network contraction techniques to achieve high performance, including methods to quickly find a near-optimal contraction order and slicing. To demonstrate how our versatile tool helps to understand these hard problems, we apply it to a few examples, including computing the entropy constant for several hardcore gases on disordered lattices, studying the Overlap Gap Property on unit disk graphs and regular graphs, and analyzing the performance of quantum and classical optimization algorithms for the independent set problem.

Tropical tensor network for ground states of spin glasses — *Phys. Rev. Lett. 126, 090506*

JINGUO LIU, LEI WANG AND PAN ZHANG — *2021*

Yao.jl: Extensible, Efficient Framework for Quantum Algorithm Design — *Quantum*

XIUZHE LUO, JINGUO LIU, PAN ZHANG AND LEI WANG — *2020*