AI

Quantum circuit simulation

Combinatorial optimization

Einsum is all you need

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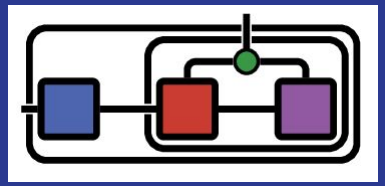
OMEinsum.jl

Andreas Peter & GiggleLiu

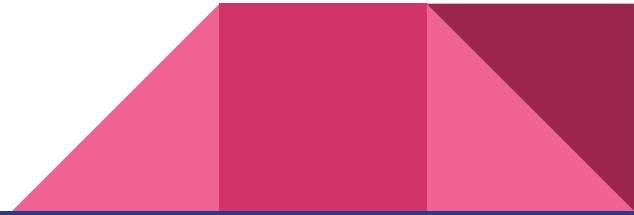
Google summer of code (2019)



You will know

- What is Einsum, by examples.
- Features in OMEinsum and OMEinsumContractionOrders.
- What is Einsum contraction order, and why it matters.

Required background knowledge: basic linear algebra



Get your hands dirty!

Quick Start (requires Julia REPL)

```
# press `]` to enter Pkg mode

pkg> add OMEinsum, OMEinsumContractionOrders

julia> using OMEinsum, OMEinsumContractionOrders
```

Julia's tensor ecosystems

Note 1: TensorKit does not support CUDA yet, although TensorOperations supports it.

Note 2: ITensorsGPU is not registered yet.

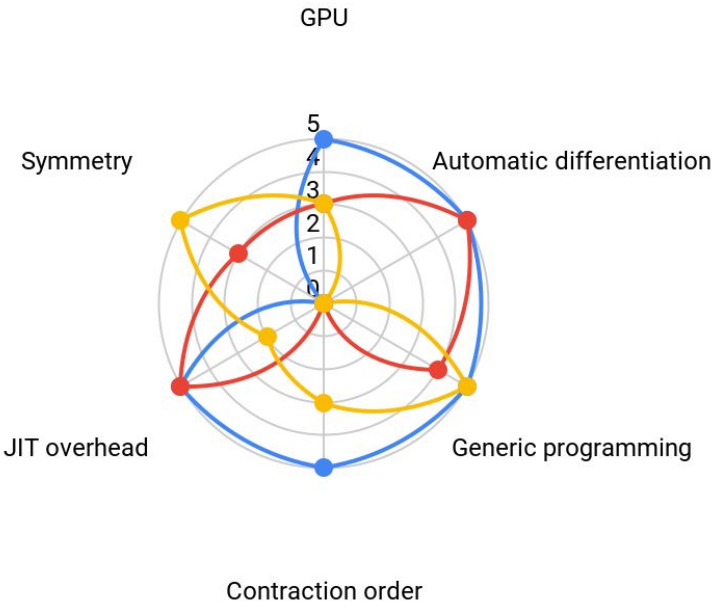
Note 3: The contraction order optimizer in TensorOperations is similar to NCon, this is slow for large scale tensor networks.

Note 4: ITensors only supports Abelian quantum numbers.

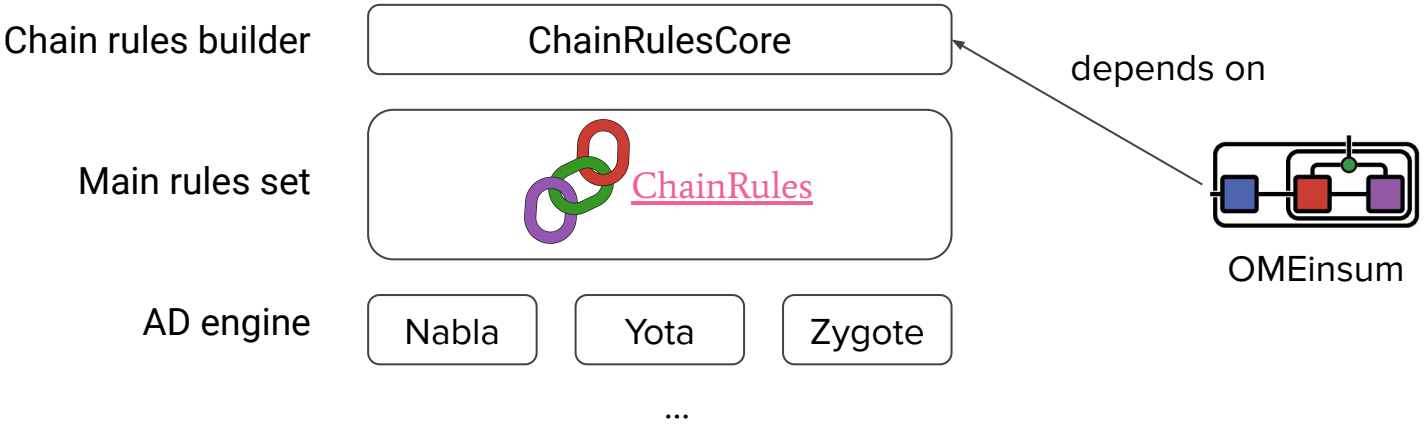
Note 5: The reason why ITensors has score 4 in generic programming is because some of its design pattern does not take different number types into consideration.

- OMEinsum + OMEinsumContractionOrders
- ITensors + ITensorsGPU
- TensorOperations + TensorKit

Only tensor networks are supported.



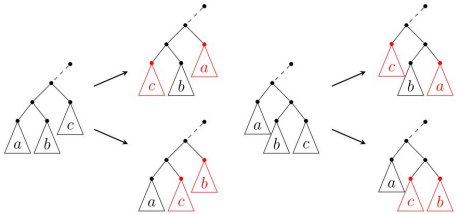
Automatic differentiation



OMEinsumContractionOrders.jl

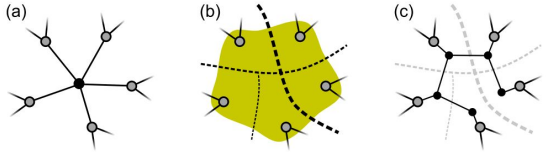
Finding optimal einsum contraction orders

TreeSA



Kalachev, G., Panteleev, P., & Yung, M.-H. *Recursive Multi-Tensor Contraction for XEB Verification of Quantum Circuits*. arXiv: 2108.05665

KaHyParBipartite



Gray, Johnnie, and Stefanos Kourtis. *Hyper-optimized tensor network contraction.* Quantum 5 (2021): 410.

GreedyMethod, fast but not optimal

SABipartite, a replacement of KaHyParBipartite when KaHyPar can not be installed

Einsum is useful

All use GPU

Papers motivating OMEinsum

- Liao, Hai-Jun, et al. "Differentiable programming tensor networks." Physical Review X 9.3 (2019): 031041.
- Feng Pan, Pan Zhang. *Simulating the Sycamore quantum supremacy circuits*. arXiv: 2103.03074
- Feng Pan, Keyang Chen, Pan Zhan. *Solving the sampling problem of the Sycamore quantum supremacy circuits.* arXiv:2111.03011

Papers using OMEinsum

- Xun Gao, Marcin Kalinowski, Chi-Ning Chou, Mikhail D. Lukin, Boaz Barak, Soonwon Choi. *Limitations of Linear Cross-Entropy as a Measure for Quantum Advantage.* arXiv:2112.01657.
- Jin-Guo Liu, Lei Wang, Pan Zhang. *Tropical Tensor Network for Ground States of Spin Glasses.* arXiv:2008.06888
- Jinguo Liu, Shengtao Wang, et al and Xun Gao. *Computing Properties of Independent Sets by Generic Programming Tensor Networks.* not published yet

Autodiff

Contraction order

Generic programming

Summary - We talked about OMEinsum.jl

- Einsum notation
  - Its representation power
  - Estimate time complexity
  - Contraction order matters
- Features
  - GPU
  - Automatic differentiation
  - Contraction order optimization
  - Generic programming

Open source events

国内:开源软件供应链点亮计划

Abroad: Google Summer of Code

Discussion

Github issue

Julia slack (@GiggleLiu)