Tensor E-graphs for Lattice QCD Nuclear Correlation Function Calculations

Nabil Humphrey,[a] William Detmold,[b,c] Ross D. Young[a] and James M. Zanotti[a]

[a] *CSSM, Department of Physics, The University of Adelaide, Adelaide, SA 5005, Australia.*

[b] *Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*

[c] *The NSF AI Institute for Artificial Intelligence and Fundamental Interactions*

The naïve computational cost required to calculate the correlation functions of nuclei in lattice QCD grows factorially in the number of quarks, making large nuclei inaccessible to *ab initio* study. An extensive programme of work [1, 2, 3] has explored techniques to reduce this scaling dependence.
Equality graphs (e-graphs) have emerged in a number of fields such as automated theorem proving [4], program optimisation [5], and deep learning [6] as a tool that efficiently computes all possible 'rewrites' of a given expression and further extracts the 'most optimal' rewrite according to a given criterion.
Tensor e-graphs are an e-graph variant that optimise the numerical evaluation of a set of tensor expressions. Tensor e-graph optimisation is applied to the tensor expressions of a selection of lattice QCD interpolating operators for nuclei, and benchmarks of numerical performance are presented.

[1] W. Detmold and K. Orginos, Phys. Rev. D 87, 114512 (2013).

[2] T. Doi and M. G. Endres, Computer Physics Communications 184, 117 (2013).

[3] J. Günther, B. C. Tóth, and L. Varnhorst, Phys. Rev. D 87, 094513 (2013).

[4] D. Detlefs, G. Nelson, and J. B. Saxe, J. ACM 52, 365–473 (2005).

[5] M. Willsey *et al.*, Proceedings of the ACM on Programming Languages 5, 1–29 (2021).

[6] Z. Jia *et al.*, *Taso: Optimizing deep learning computation with automatic generation of graph substitutions*, SOSP '19, p. 47–62, New York, NY, USA, 2019, Association for Computing Machinery.