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Local basis truncation for Quantum Field Theories

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While perturbative methods have led to significant insights into fundamental interactions,non-perturbative phenomena remain poorly understood—particularly in regimes where Monte Carlo (MC) techniques suffer from the sign problem, such as in dense nuclear matter and real-time dynamics in Quantum Chromodynamics (QCD). Tensor Network (TN) methods, which are not affected by the sign problem,therefore offer a suitable extension to existing techniques.
To apply TN techniques to gauge theories, we use the Hamiltonian Lattice Gauge Theory (HLGT) framework, with the dressed-site formalism to enforce Gauss's law, allowing for an efficient and gauge-invariant representation of the local Hilbert space. Building on this, we present a general-purpose library for constructing HLGTs with non-simple finite and compact Lie groups in any dimension, supporting flexible choices of background charge.

Even with this efficient encoding, the local Hilbert space can still be large. To address this, we propose an effective description of the target theory. Using cluster mean-field techniques, we estimate the reduced density matrix and project the theory onto the relevant subspace. We demonstrate this approach in purely bosonic quantum field theories, such as the sine-Gordon model in (1+1)D and the φ^4 model in (1+1)D and (1+2)D, where it is particularly effective in symmetry-broken phases and allows for accurate determination of critical exponents.
This development improves the scalability of TN simulations in higher dimensions of theories with bosonic degrees of freedom and can also be applied to quantum computation and quantum simulation.

Secondary track

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