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Proton and neutron approximate shell model: Exponentially converging reconstruction of many-body states by subspace truncation

High fidelity nuclear structure models are of little use if they cannot be computed on modern hardware. This is still the case for medium to heavy mass nuclei of interest to the nuclear physics community. We address the combinatorial growth of shell model dimensions with a novel method for efficient truncation of the Hilbert space. This work is inspired by the density-matrix renormalization group (DMRG) from condensed matter physics (e.g. see [1]), and related work on factorization of shell model wave functions [2,3].
Our approach constructs a basis by coupling together proton and neutron states obtained by diagonalizing Hamiltonians from each partition of the Hilbert space and approximates the nuclear Hamiltonian by retaining only a fraction of states from each subspace. We will highlight the advantages of this scheme and demonstrate exponential convergence for low-lying eigenstates as we increase the number of sub-space states retained. We will discuss initial efforts to extend the framework to calculate electromagnetic and beta-decay transition rates and the possibility of extrapolating to the untruncated solution.

[1] Karen A. Hallberg (2006) New trends in density matrix renormalization, Advances in Physics, 55:5-6, 477-526, DOI: https://doi.org/10.1080/00018730600766432
[2] T. Papenbrock and D. J. Dean (2003) Factorization of shell-model ground states, Phys. Rev. C 67, 051303(R), DOI: https://doi.org/10.1103/PhysRevC.67.051303
[3] T. Papenbrock, A. Juodagalvis, and D. J. Dean (2004) Solution of large scale nuclear structure problems by wave function factorization, Phys. Rev. C 69, 024312, DOI https://doi.org/10.1103/PhysRevC.69.024312

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