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Solving the Time-Dependent Schrödinger Equation for a Harmonic Oscillator and Extracting the Bohm Quantum Potential Using PINNs.

Background: Physics-informed neural networks (PINNs) are numerical methods for solving partial differential equations by embedding physical laws into the learning process. In quantum mechanics, they provide smooth approximations of wavefunctions, enabling the computation of standard observables as well as Bohmian quantities. The quantum harmonic oscillator is a fundamental model with applications in quantum mechanics and plasma physics, particularly for describing confinement and collective oscillations.

Purpose: This work aims to develop a PINNs - based framework for solving the one-dimensional time-dependent Schrödinger equation (TDSE) for the quantum harmonic oscillator and to extract physically relevant quantities, including the ground-state energy and the Bohm quantum potential, from the learned wavefunction.

Methods: A physics-informed neural network is used to represent the real and imaginary parts of the wavefunction through a fully connected architecture. The TDSE is enforced via the loss function together with appropriate initial and boundary conditions corresponding to the harmonic oscillator ground state. Training is carried out using randomly sampled space–time collocation points. Automatic differentiation is employed to evaluate the required derivatives, enabling computation of the ground-state energy from the Hamiltonian expectation value and the Bohm quantum potential from the wavefunction amplitude.

Results: The trained PINNs reproduces the ground-state wavefunction of the quantum harmonic oscillator and yields a ground-state energy consistent with the analytical value $E = 0.5\hbar\omega$. The Bohm quantum potential obtained from the network shows good agreement with the corresponding analytical expression, indicating that the model captures the essential spatial structure of the quantum amplitude.

Conclusions: These results indicate that physics-informed neural networks provide a viable approach for solving the time-dependent Schrödinger equation and for extracting Bohmian quantities. In the context of plasma physics, this framework may be useful for studying quantum confinement effects, effective potentials, and wave-particle interactions in dense plasmas where quantum effects play a role.

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