Contribution ID: **24** Type: **not specified**

Quantum Computation of nonlinear partial differential equations and Uncertainty Quantification

Thursday, December 15, 2022 11:15 AM (45 minutes)

Nonlinear partial differential equations (PDEs) are crucial to modelling important problems in science but they are computationally expensive and suffer from the curse of dimensionality. Since quantum algorithms have the potential to resolve the curse of dimensionality in certain instances, some quantum algorithms for nonlinear PDEs have been developed. However, they are fundamentally bound either to weak nonlinearities, valid to only short times, or display no quantum advantage. We construct new quantum algorithms–based on level sets –for nonlinear Hamilton-Jacobi and scalar hyperbolic PDEs that can be performed with quantum advantages on various critical numerical parameters, even for computing the physical observables, for arbitrary nonlinearity and are valid globally in time. These PDEs are important for many applications like optimal control, machine learning, semi-classical limit of Schrodinger equations, mean-field games and many more.

Depending on the details of the initial data, it can display up to exponential advantage in both the dimension of the PDE and the error in computing its observables. For general nonlinear PDEs, quantum advantage with respect to M, for computing the ensemble averages of solutions corresponding to M different initial data, is possible in the large M limit.

We will also propose quantum algorithms for uncertainty quantification of partial differential equations with quantum advantage over M.

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