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Nana Liu: Efficient quantum simulation of partial differential equations

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What kinds of scientific computing problems are suited to be solved on a quantum device with quantum advantage? It turns out that by transforming a partial differential equation (PDE) into a higher-dimensional space, it can be transformed into a system of Schrodinger's equations, which is the natural dynamics of quantum devices. This new method – called Schrodingerisation – thus allows one to simulate, in a simple way, any general linear partial differential equation and system of linear ordinary differential equations via quantum simulation.

Schrodingerisation can also be applied to problems in linear algebra by transforming iterative methods in linear algebra into evolution of ordinary differential equations, like the Jacobi method and the power method. This allows us to directly use quantum simulation to solve the linear system of equations and find maximum eigenvectors and eigenvalues of a given matrix.

This method can be adapted to also solve boundary value problems like quantum dynamics with artificial boundary conditions, and also physical boundary conditions and interface conditions.

I'll also explore ways in which quantum algorithms can be used to efficiently simulate not just linear PDEs but also certain classes of nonlinear PDEs, like nonlinear Hamilton-Jacobi equations and scalar hyperbolic equations, which are useful in many areas like optimal control and machine learning. PDEs with uncertainties can also be tackled more efficiently with quantum algorithms.