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Title: An Efficient Quantum Algorithm for Dynamics of a Spin System Coupled to a Spin Bath

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We present an algorithm for the real-time dynamics of a quantum spin system coupled to a particular type of quantum spin bath. We assume the spins are spin $\frac{1}{2}$. The M spins in the bath are assumed to couple to the N system spins only with couplings of the form $J_{i,j} \sigma^\alpha_i \sigma^\alpha_j$ with $\alpha$$=$$x$,$y$,$z$. Furthermore, the bath spins are assumed to have no interaction with other bath spins. With these assumptions the time development of the N system spins reduces to a sum over 2^M terms that are different real-time dynamics of a Hilbert space of size 2^N. Thus the real-time dynamic algorithm does not require any vectors of size 2^{MN}, as would be required by other real-time quantum dynamic algorithms. We present efficient methods to calculate the quantum purity and von Neumann entropy of the N spin system once the spin bath has been traced out. For $N$$=$$1$ we reproduce the result that the quantum purity decays exponentially if all $\alpha$$=$$x$ while it decays algebraically if $\alpha$$=$$x$ for $M/2$ spins and $\alpha$$=$$y$ for $M/2$ spins [1,2]. For $N$$=$$1$ and $N$$=$$4$ we study the efficiency of both the decoherence and thermalization for this class of quantum spin baths. [1] D.D. Bhaktavatsala Rao, H. Kohler, and F. Sols, New J. Phys. 10, 115017 (2008). [2] Marta Guerra, PhD dissertation, Mississippi State University, 2011.