Localisation, quantum phase transitions and graph theory for adiabatic quantum computing

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In the context of adiabatic quantum computation (AQC), it has been argued that first order quantum phase transitions (QPTs) due to localisation phenomena will always cause adiabatic quantum computation (AQC) to fail by exponentially decreasing the minimal spectral gap of the Hamiltonian along the annealing path [1]. However this notion has been subject to some debate in the community [2], since more recent findings suggest the existence of methods to avoid this by carefully designing the involved Hamiltonians. It remains a challenge to formulate a comprehensive theory on the effect of the various parameters and the conditions under which QPTs make the AQC algorithm fail. In this work we investigate the conditions under which localisation causes first order QPTs. As a consequence of this analysis and using methods from spectral graph theory, we here examine both analytically and numerically the role of the connectivity of the driver Hamiltonian in the mitigation of such effects in different AQC algorithms and show that in the limiting case of full connectivity, first order QPTs due to localisation are avoided entirely.

References

[1] B. Altshuler, H. Krovi, J. Roland, Proceedings of the National Academy of Sciences, Vol. 107 No. 28 (2010)
[2] V. Choi, Proceedings of the National Academy of Sciences, Vol. 108 No. 7 (2011)
[3] M. H. S. Amin, V. Choi, Phys. Rev. A 80, 062326 (2009)

Figures

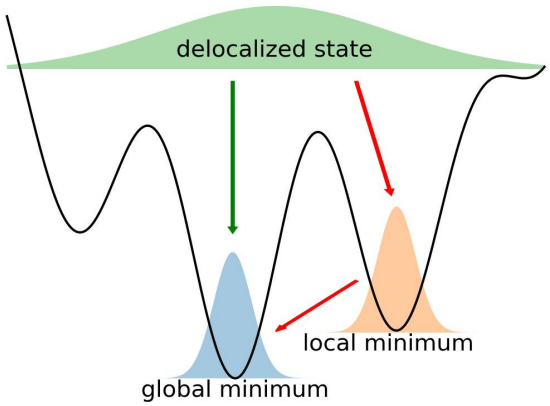

Figure 1: Illustration of the ground state transitioning from a delocalised to a localised state in the global minimum directly (green arrows); the ground state transitioning to a localised state in a local minimum with subsequent localised-localised transition to the global minimum (red arrows)

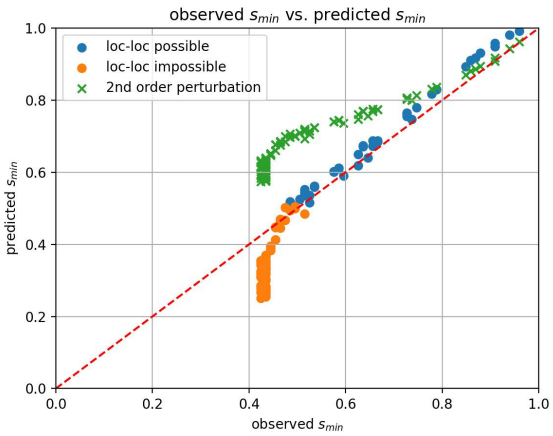

Figure 2: Predicted over observed location of the minimal gap along the annealing path on a toy model with localised-localised transition (blue dots) and without localised-localised transition (orange dots) using our conductance bound; same predictions using perturbation theory from [3]