Quantum control landscapes and the design of adaptive feedback control algorithms

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A quantum control landscape is the map between a time-dependent control function and associated values of a quantum control objective functional. Since most quantum control problems cannot be solved analytically, this landscape must generally be traversed numerically or experimentally in order to identify optimal controls. I review our current understanding of the critical point topology and level set structure of control landscapes for finite-dimensional quantum systems, including a classification of extremals and the effects of controllability and environmental decoherence. I show that the vast majority of local optima for observable and gate control problems are saddle points, indicating that local search algorithms will generally be unhindered in their traversal of the control landscape. The dynamics of quantum control gradient flows, which determine the algorithmic complexity of control optimization, are then discussed. Based on these foundations, I describe a generic class of continuation algorithms for the simultaneous control of multiple quantum observables, a control problem that is difficult to solve using conventional stochastic algorithms. I show that the Pareto frontier of quantum multiobservable control landscapes can be analytically characterized, and effectively explored using such algorithms. I conclude with a discussion of open questions and experimental applications.