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Hiking Over Quantum Control Landscapes

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Seeking the best control over a posed quantum dynamic objective entails climbing over the associated control landscape, which is defined as the quantum mechanical observable as a function of the controls. The topology and general structure of quantum control landscapes as input output maps dictate the final attainable yield, the efficiency of the search for an effective control, the possible existence of multiple dynamically equivalent controls, and the robustness of any viable control solution. Normal optimization problems in virtually any area of engineering and science typically have landscape topologies that remain a mystery. Quantum mechanics appears out to be quite special in that the topology of quantum control landscapes can be established generically based on minimal physical assumptions. Various features of these landscapes will be discussed and illustrated for circumstances where the controls are either an external field or the time independent portions of the Hamiltonian; the latter circumstance corresponds to subjecting the material or molecules to systematic variation and hence viewed in the context of being controls. Both theoretical and experimental findings on control landscapes and their consequences will be discussed, including issues of robustness to noise, search algorithm efficiency, existence of multiple control solutions, prospects for identifying reduced sets of control variables, simultaneous control of multiple quantum systems (optimal dynamic discrimination (ODD)), and mechanism analysis.