Of ladders and frames: informationally complete measurements for quantum algorithms

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As quantum computing technology matures, developing effective ways to query large quantum registers becomes of critical importance. In recent years, randomized measurement protocols – such as classical shadows – and other informationally complete methods received special attention, thanks to their power and versatility. Notably, shadows allow for a clear separation between the data acquisition phase, which can be carried out without fixing a target observable, and the classical processing and reconstruction stage. In this tutorial, we first review the general theory of informationally complete positive operator valued measurements (POVMs) in finite dimension and discuss their applications to paradigmatic quantum information processing task, such as quantum state discrimination, tomography and operator averaging. We then briefly comment on practical implementations of POVMs on superconducting quantum processors. In the second part, we focus on the link between POVMs and classical shadows through the notion of measurement dual frames. After introducing the key concepts, we present some novel results from the literature on efficient dual frame optimization, and conclude by showcasing some hands-on examples based on the recently released Qiskit POVM toolbox (qiskit-community.github.io/povm-toolbox/).