Fast and reliable quantum state tomography

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Quantum computing, communication, and sensing technologies rely on precise knowledge of quantum states, that cannot be directly measured. Quantum state tomography (QST) reconstructs these states from indirect measurements by minimizing the statistical discrepancy between experimentally observed data and predictions from quantum theory. This optimization problem is nonlinear and subject to physical constraints on the states. We present a Julia implementation that efficiently and robustly minimizes this statistical distance while enforcing the physical constraints. Our work provides a practical, extensible toolkit for QST and a comparative guide to choosing optimizer based on accuracy, speed, and robustness. Our approach minimizes a residual between predicted and measured statistics and supports both least-squares and log-likelihood formulations. Physical constraints are enforced through Cholesky parameterization or projection methods. We benchmark on simulated data several optimization strategies, like projected Gauss-Newton, L-BFGS, and trust-region solvers. The benchmarks evaluate reconstruction accuracy, scaling with the number of qubits, convergence speed, and stability, offering practical guidance for selecting optimizer in QST applications.

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