

End-to-End Variational Quantum Sensing with Weighted Graph States

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Entangled quantum states can improve the precision of parameter estimation beyond classical limits, but realizing this advantage in practice requires protocols that remain effective under realistic noise, hardware constraints, and finite measurement data. Here, we study an end-to-end quantum sensing protocol in which weighted graph states are used as metrological resource states for single-parameter phase estimation. The protocol combines weighted graph state preparation with neural-network-based Bayesian parameter estimation from sampled measurement data. The neural network is trained to output an approximate posterior distribution over a discrete phase grid, from which phase estimates are obtained using the mean posterior estimator. This allows the classical estimator to learn the effective likelihood structure generated by the quantum sensor, including distortions induced by noisy state preparation. We benchmark the weighted graph state protocol against a GHZ parity protocol under dephasing and study the scaling behaviour of the protocol with increasing system size. Our results indicate that weighted graph states, when paired with Bayesian neural-network estimation, can provide a robust finite-data sensing strategy in regimes where ideal GHZ coherence is degraded by noise. This suggests that weighted graph state resources may offer a useful platform for robust, practical end-to-end quantum sensing.

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