

Machine Learning assisted Quantum Sensing: Noise Classification and Plaquette Phase Detection

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Abstract: We develop a machine-learning-assisted framework employing quantum probes to detect noise correlations in two-qubit systems and reconstruct plaquette phases in three-level Δ systems using a small set of measurements.

We present a machine-learning-assisted framework for quantum sensing in which a controlled quantum system is used as a probe to extract information about external noise and intrinsic system parameters from limited experimental data. The key idea is to combine coherent control protocols with data-driven analysis, enabling the inference of otherwise inaccessible quantities from simple measurements.

First, we introduce and validate a protocol to classify spatial and temporal correlations of classical noise affecting two ultrastrongly coupled qubits [1]. We consider several classes of Markovian and non-Markovian noise and exploit the sensitivity of STIRAP under a small set of driving conditions [1,2]. The different noise types are discriminated using only final-state observables, without requiring time-resolved measurements. A shallow neural network trained on these few features achieves high classification accuracy, with near-perfect discrimination between Markovian and non-Markovian regimes. The results are shown in Fig. 1 (left). This shows that global properties of the noise can be efficiently inferred from controlled quantum dynamics with minimal experimental resources.

Second, we investigate quantum phase sensing in three-level systems, focusing on triangular (Δ -type) configurations where all levels are mutually coupled. In this setting, a gauge-invariant plaquette phase arises as a physically observable parameter that directly affects the dynamics by breaking the dark-state condition underlying the coherent population transfer of STIRAP. The resulting population dynamics exhibit a highly non-linear dependence on the phase. To address this, we employ supervised machine learning techniques to reconstruct the plaquette phase directly from population measurements. The prediction error is of the order of 0.01 radians. The results are reported if Fig. 1 (right).

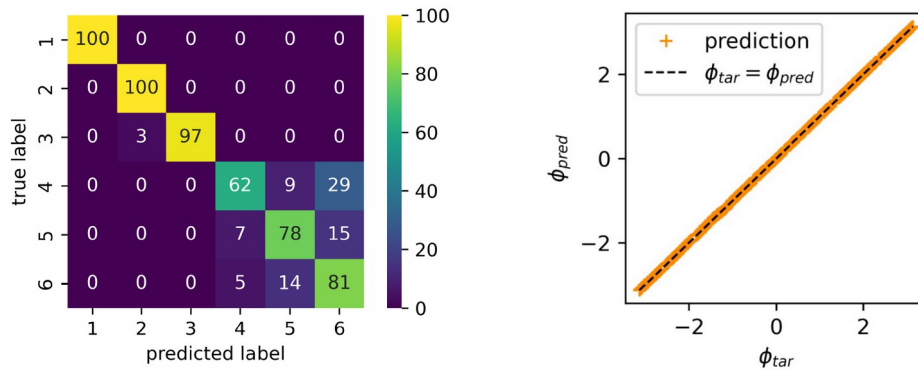


Fig. 1 (Left) Confusion Matrix for the prediction of noise correlations in two ultrastrongly coupled qubits: labels (1,2,3) represent non-Markovian noise, labels (4,5,6) represent Markovian noise; labels (1,4) refer to correlated noise, labels (2,5) to anti-correlated noise, and labels (3,6) to uncorrelated noise. (Right) Predicted vs actual plaquette phase of the three-level Δ system.

Together, these results illustrate a unified approach in which quantum systems act as probes and machine learning provides an efficient tool to extract information from their response. The framework enables the identification of global noise features and the detection of phase parameters using a small set of experimentally accessible observables, offering a flexible and resource-efficient strategy for quantum sensing applications.

References

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