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Quantum State Smoothing[1]

HOWARD WISEMAN, Centre for Quantum Dynamics, Griffith University

Under noisy observations, one can estimate the state of the measured system, if its a priori statistics are given. In the continuous time situation, three different types of estimation can be distinguished: filtering, which is estimating of the state at time t from earlier records; retro-filtering, which is estimating it from later records; and smoothing, which is estimating it from both earlier and later records. Of the three, smoothing allows the greatest precision. Smoothing has been well developed in classical systems, but its application to quantum systems is very recent. Previous works have used the term "quantum smoothing" to mean estimating classical parameters, [Tsang, Phys. Rev. Lett 102, 250403 (2009); Yonezawa et al., Science 337, 1514-1517 (2012)]. This is essentially classical smoothing in which the noisy observation of the classical parameters is mediated by a quantum system. Here we introduce quantum state smoothing, where the state of a partially observed open quantum system itself is smoothed. We achieve this by applying classical smoothing to a hypothetical unobserved noisy measurement record that induces (in part) the stochastic dynamics ("quantum trajectories") of the system. Using the formalism of linear quantum trajectories, we simulate quantum state smoothing for a qubit, and quantify how well it works. Our investigations shed new light on the nature of open quantum systems and the applicability of classical concepts. Applications to continuous measurement of solid-state qubits will be presented.

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