Partial Isolation and Risk-Sensitive Decoherence Time Criteria for Quantum Harmonic Oscillator Memory Systems

Igor G. Vladimirov[1] and Ian R. Petersen[2]

[1,2]*Australian National University, School of Engineering, Canberra, Australia*

This talk is concerned with open quantum harmonic oscillators with position-momentum system variables, whose internal dynamics and interaction with the environment are governed by linear quantum stochastic differential equations. We consider a partially isolated subsystem, which is not directly affected by the external fields and can be employed as a Heisenberg picture quantum memory in the framework of a recent approach [1,2,3] exploiting the system ability to approximately retain initial conditions over a decoherence time horizon. The quantum memory decoherence time was previously described in terms of a fidelity threshold on a weighted mean-square deviation of the system variables from their initial values. We extend this approach to a risk-sensitive setting with quadratic-exponential measures of deviation from the initial subsystem variables. This leads to guaranteed upper bounds on the worst-case mean-square deviation in the presence of quantum statistical uncertainty described in terms of relative entropy [4] of the actual system-field state from its nominal model. We also discuss the maximization of the resulting decoherence time in the high-fidelity and low-uncertainty limits over the energy parameters of a coherent feedback interconnection of such systems to improve its robust memory performance.

References

[1] I.G.Vladimirov, and I.R.Petersen, Decoherence time in quantum harmonic oscillators as quantum memory systems, 2024 Australian and New Zealand Control Conference (ANZCC), Gold Coast, Australia, 1-2 February 2024, pp. 211-216.

[2] I.G.Vladimirov, and I.R.Petersen, Decoherence time control by interconnection for finite-level quantum memory systems, European Journal of Control **80**, **Part A**, 101054 (2024).

[3] I.G.Vladimirov, and I.R.Petersen, Optimization of partially isolated quantum harmonic oscillator memory systems by mean square decoherence time criteria, 2025 Australian and New Zealand Control Conference (ANZCC), Gold Coast, Australia, 30-31 January 2025, pp. 64-69.

[4] M.Ohya, and D.Petz, Quantum Entropy and Its Use, Springer-Verlag, Berlin, 1993.