Normal quantum channels

Alejandro Contreras Reynoso, Thomas Gorin
Universidad De Guadalajara, Guadalajara , Mexico

We study general normally (Gaussian) distributed random unitary transformations acting on finite-dimensional quantum systems. These distributions can be understood in terms of a diffusive random walk in a compact Lie group, formally underpinned by the concept of infinite divisibility for probability distributions [1,2]. These normal distributions are completely defined by a diffusion matrix A and a drift vector b . We call a quantum channel “normal” if it is generated by such normally distributed operations. We show that there is a surjective correspondence between the normal distributions and the Lindblad-divisible quantum channels [3], i.e. quantum channels which can be generated by a Lindblad master equation. We study the one-qubit case and then consider normal quantum channels with correlations for two qubits. In the one-qubit case, we show that different normal distributions can generate the same quantum channel (Fig. 1). In the two-qubit case we use the normal distributions for modeling correlated quantum errors. We propose two models for two qubit errors Λ2 and Λc that use linear correlations modeled by the parameter m and correlations from the diffusion matrix A that use the correlations coefficient ρ respectively. We compare our proposed models with the two qubit correlated Pauli error ΛcP from the literature [4,5] on an entanglement distillation protocol and found that the distillation is more effective for the normal channels as seen in figures 2. We expect our work to find applications in the tomography and modeling of one- and two-qubit errors in current quantum computer platforms, as well as in imperfect communication channels, where it is conceivable that subsequently transmitted qubits are subject to correlated errors.

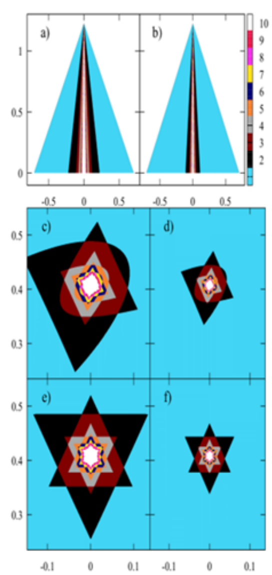

Fig.1: Plot of how many possible normal distributions can generate the same quantum normal channel. The plot is done on the space of the parameters of the diffusion matrix A restricting them to two dimensions with the vector $\vec{b}$ fixed. In other words a point the chosen normal channel and the color how many normal distributions can generate it.

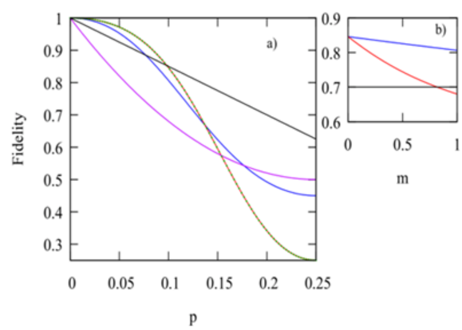

Fig.2: Left: This figure shows the fidelity of a state after the distillation for different error rates p and correlations m. The error channels used are: blue Λc (m = 1), red Λc(m = 0), purple ΛcP (m = 1), green dotted line ΛcP(m = 0). In black the fidelity when no distillation is done is shown. Right: Fidelity as a function of the correlation m when p=0.1. The red and blue lines show are the fidelity when distillation is done. The red line use ΛcP and the blue ΛcP as errors. The black line is when no distillation is done.

References

[1] K. R. Parthasarathy, Theory of Probability and its Applications, IX, 248 (1964).
[2] D. I. Nikolayev, T. I. Savyolova, Textures and Microstructures, 29, (1995).
[3] D. Davalos et al., Quantum, 3, 144 (2019).
[4] C. Macchiavello, G. M. Palma, Phys. Rev. A, 65, 050301 (2002).
[5] F. Caruso et al., Rev. Mod. Phys., 86, 1203 (2014).