Quantum process tomography with guaranteed precision

D.O. Norkin[1,2,*], A.A. Bozhedarov[1,3], E.O. Kiktenko[1,2,4], A.K. Fedorov[1,2]

[1] *Russian Quantum Center*
[2] *Moscow Institute of Physics and Technology*
[3] *Skolkovo Institute of Science and Technology*
[4] *Steklov Mathematical Institute of Russian Academy of Sciences*
*E-mail: nordmtr@gmail.com

Tomography of quantum states and processes is an important part of current experiments, as it is used to verify that the actual prepared state ρ is close to the target one. However, a reliable tomography scheme should not only provide a point estimate $\hat{\rho}$, but also confidence regions – justified error bars for this estimate:

$$\mathbb{P}\left(\|\rho - \hat{\rho}\| < \delta\right) \geq \mathrm{CL}, \tag{1}$$

First attempts were made by Sugiyama et al. [?]. We improve their results and propose an algorithm for constructing such regions, using a bootstrapping technique. With the help of the main bootstrap assumption (here $\hat{\rho}_B^{(k)}$ are samples generated from $\hat{\rho}$):

$$\mathbb{P}\left(\|\rho - \hat{\rho}\| < \delta\right) \approx \mathbb{P}\left(\|\hat{\rho} - \hat{\rho}_B^{(k)}\| < \delta\right), \tag{2}$$

it is then straightforward to estimate confidence regions (1). The constructed regions have the shape of a ball and thus can be simplified to one-dimensional confidence intervals. This not only allows for fast computation, but also for efficient estimation of the difference between the prepared and target states. Using Choi-Jamiolkowski isomorphism:

$$C_{\mathcal{E}} := (\mathbf{1} \otimes \mathcal{E}) \left[\sum_{i,j} |i\rangle \otimes |i\rangle \langle j| \otimes \langle j|\right] = \sum_{i,j} |i\rangle \langle j| \otimes \mathcal{E}\left[|i\rangle \langle j|\right] \tag{3}$$

between quantum states and quantum channels [?] we generalize this procedure and apply it to quantum process tomography, which is performed by an iterative algorithm described in [?]. We provide several examples (Fig. 1, 2) to demonstrate the applicability of the proposed scheme in experiments.

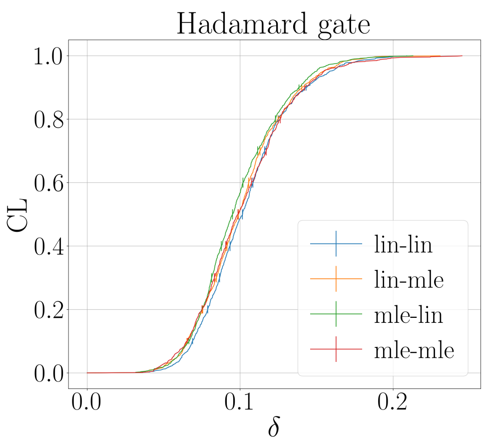

Figure 1: Confidence interval

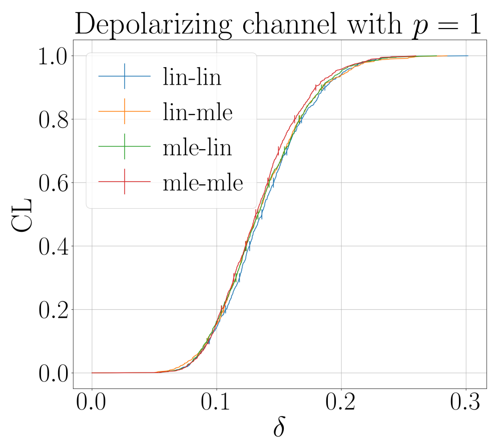

Figure 2: Fully depolarizing channel CI

References

[1] *Takanori Sugiyama, Peter S. Turner, and Mio Murao.*, Precision-guaranteed quantum tomography. Phys. Rev. Lett., 111:160406, Oct 2013.

[2] *Min Jiang, Shunlong Luo, and Shuangshuang Fu*, Channel-state duality. Phys. Rev. A, 87:022310, Feb 2013..

[3] *George C. Knee, Eliot Bolduc, Jonathan Leach, and Erik M. Gauger.*, Quantum process tomography via completely positive and trace-preserving projection. Phys. Rev. A, 98:062336, Dec 2018. 3rd.