Characterizing and Filtering out Device Noise for Quantum Optimization Algorithms

Optimization in Quantum Computing
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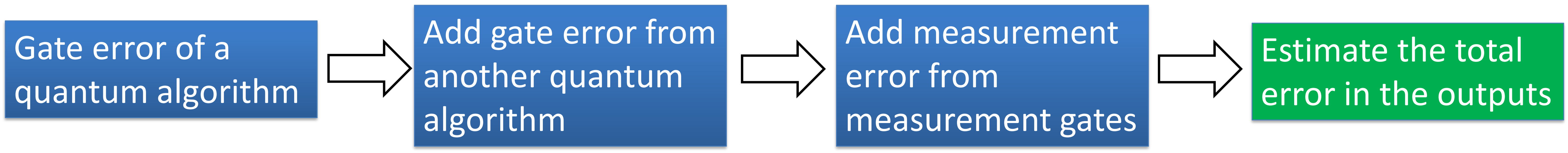
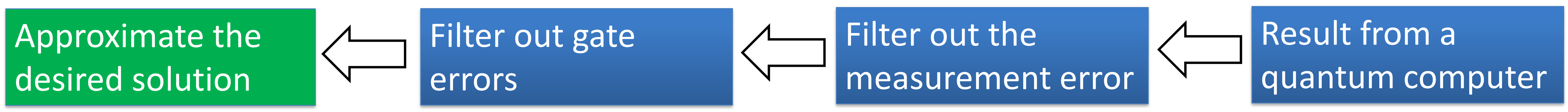
Research Objective:

- Error propagation and filtering models for optimization algorithms.



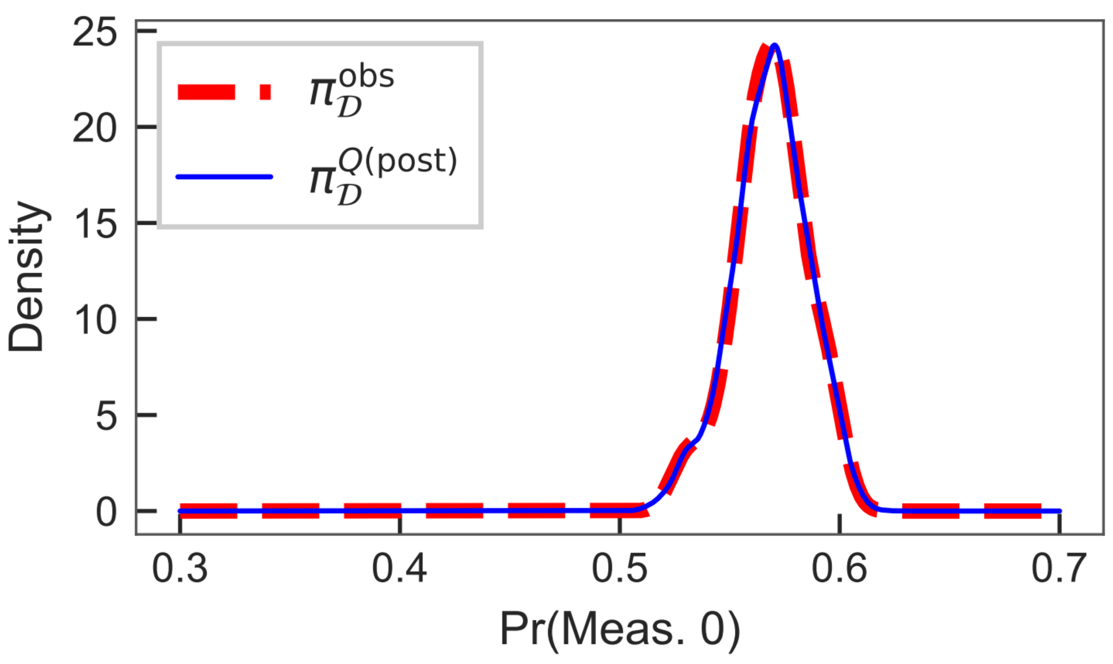
Error Propagation (forward model)

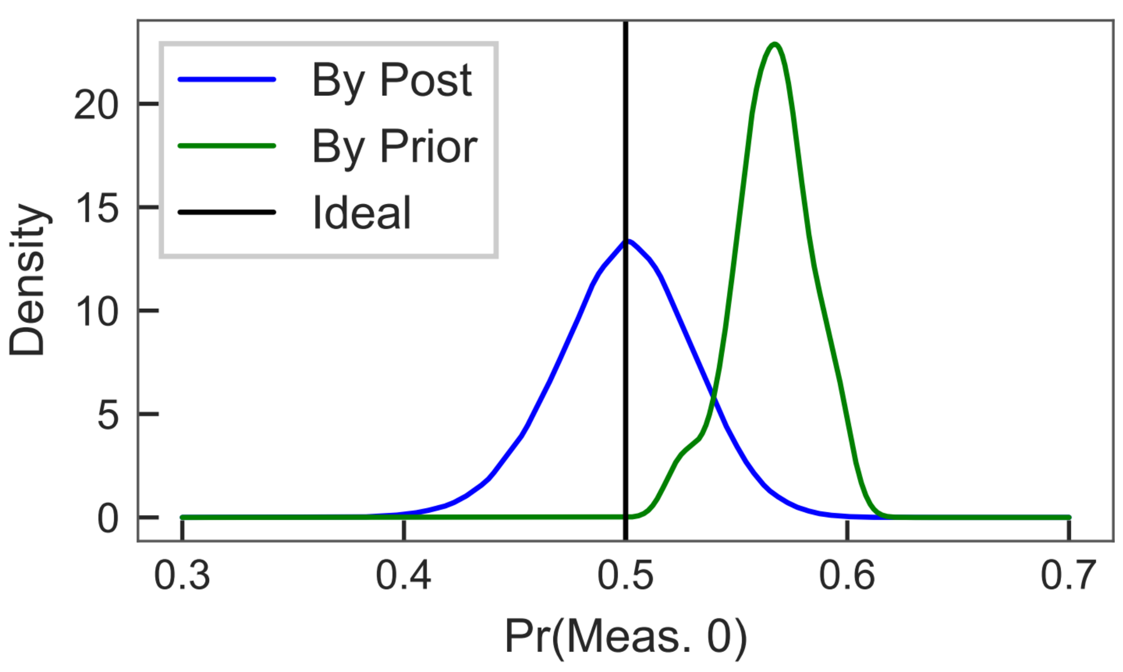


Error Filtering (inverse problem)

Recent Accomplishments

Source or Method	Pr(Meas. 0) after 200 NOT Gates	Entangled 3-Qubit State Tomography Fidelity	2-Qubit Grover's Search Solution Prob.	Correct Solutions Prob. of 4-Qubit QAOA
Ideal/Simulator	1	1	1	0.8930
Raw Data	0.6377	0.6974	0.6727	0.5784
Qiskit	N/A	0.8863	0.7097	0.5968
QDT	N/A	N/A	0.7107	0.6400
Consistent Bayesian	1.0000	0.9443	0.9128	0.6975





- We use the *consistent Bayesian method* [1] to capture the **fluctuations** of quantum hardware error parameters, such as gate error rates and readout error rates.
- Inference for gate errors uses the following error propagation model.

$$\tilde{p}(x) = \sum_{s\in\{0,1\}^n} \left[(1-\epsilon)^{|s|}\right]^m \hat{p}(s)(-1)^{s.x}$$

- Law of total probability is considered to predict readout errors.
- Posterior distributions of error parameters can perfectly simulate the noise in data (figure in the upper left) and denoise the training data (figure in the lower left).
- Our approach has better performance than two existing methods in several experiments conducted on IBM's quantum computer (table above and more in [2]).

Looking Forward

- Develop a correlated readout error model using the polynomial number of parameters.
- Expand gate error model to a more complicated situation.
- Build up a description of hardware errors from an integrated quantum circuit perspective.

[1] T. Butler, J. Jakeman, and T. Wildey. Combining push-forward measures and bayes' rule to construct consistent solutions to stochastic inverse problems. SIAM Journal on Scientific Computing, 40(2):A984–A1011, January 2018. DOI: 10.1137/16m1087229.
[2] Zheng, M., Li, A., Terlaky, T., & Yang, X. (2020). A bayesian approach for characterizing and mitigating gate and measurement errors. arXiv preprint arXiv:2010.09188.