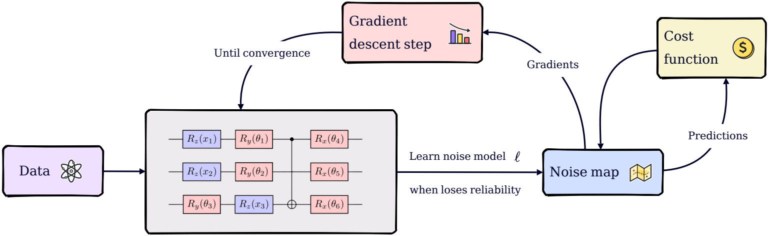
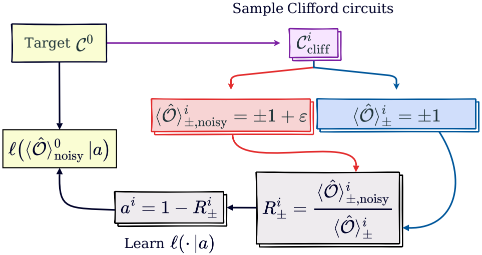
RTQEM pipeline

We define a Real-Time Quantum Error Mitigation (RTQEM) procedure.



1. consider a Variational Quantum Algorithm trained with gradient descent;
2. learn the noise map ℓ every time is needed over the procedure;
3. use ℓ to clean up both predictions and gradients.

We use the Importance Clifford Sampling (ICS) procedure to learn the noise map ℓ.

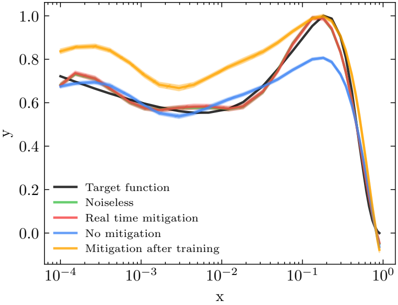


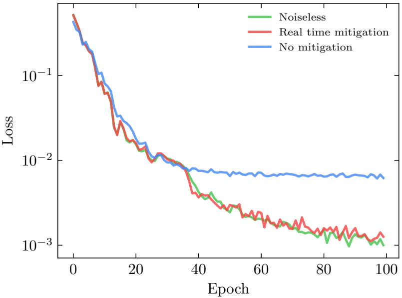
1. sample a training set of Clifford circuits on top of a target $\mathcal{C}^0$;
2. process them so that their expectation values on Pauli strings is $+1$ or -1;
3. QEM parameters (a, σ_a) are computed comparing exact values with noisy ones;
4. build ℓ following the Phenomenological-Error-Model Inspired (PEMI) protocol:

$$\ell\big(\langle\hat{\mathcal{O}}\rangle|a,\sigma_a\big) = \frac{1-a}{[(1-a)^2+\sigma_a^2]}\langle\hat{\mathcal{O}}\rangle_{\rm noisy}$$

One dimensional HEP target: the u-quark PDF

Parameter	N_{train}	N_{params}	N_{shots}	$\mathrm{MSE}^{\mathrm{rtqem}}_{\mathrm{best}}$	$\mathrm{MSE}^{\mathrm{unmit}}_{\mathrm{best}}$	Noise
Value	30	16	10^4	$1.1 \cdot 10^{-3}$	$6.1 \cdot 10^{-3}$	local Pauli



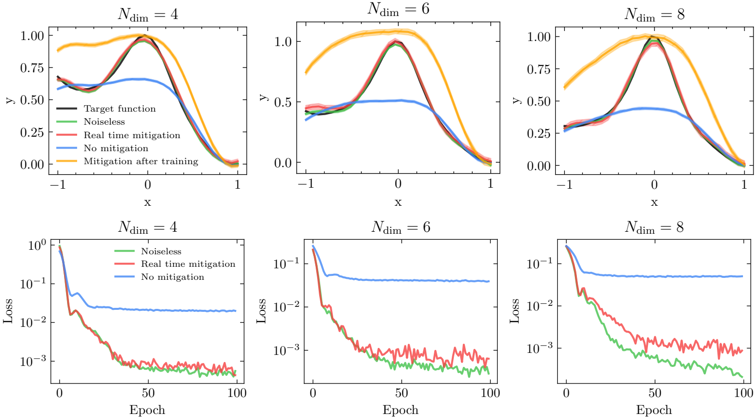


1. thanks to the RTQEM procedure, we reach a good minimum of the cost function;
2. the QEM is not effective is applied to a corrupted scenario (orange curve).

Multidimensional target

We tackle a multi-dimensional target computing predictions as expected value of a $Z^{\otimes N_{\text{dim}}}$ after executing an N_{dim} circuit.

Job ID	N_{train}	N_{params}	N_{shots}	$\text{MSE}^{\text{rtqem}}_{\text{best}}$	$\text{MSE}^{\text{unmit}}_{\text{best}}$	Noise
$N_{\text{dim}} = 4$	30	48	10^4	$4.4 \cdot 10^{-4}$	$1.9 \cdot 10^{-2}$	local Pauli
$N_{\text{dim}} = 6$	30	72	10^4	$4.1 \cdot 10^{-4}$	$3.8 \cdot 10^{-2}$	local Pauli
$N_{\text{dim}} = 8$	30	96	10^4	$5.6 \cdot 10^{-4}$	$4.8 \cdot 10^{-2}$	local Pauli



RTQEM on a superconducting qubit