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QUnfold: Quantum Annealing for Distributions Unfolding in High-Energy Physics

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In High-Energy Physics (HEP) experiments, each measurement apparatus exhibit a unique signature in terms of detection efficiency, resolution, and geometric acceptance. The overall effect is that the distribution of each observable measured in a given physical process could be smeared and biased. Unfolding is the statistical technique employed to correct for this distortion and restore the original distribution. This process is essential to make effective comparisons between the outcomes obtained from different experiments and the theoretical predictions.

The emerging technology of Quantum Computing represents an enticing opportunity to enhance the unfolding performance and potentially yield more accurate results.

This work introduces QUnfold, a simple Python module designed to address the unfolding challenge by harnessing the capabilities of quantum annealing. In particular, the regularized log-likelihood minimization formulation of the unfolding problem is translated to a Quantum Unconstrained Binary Optimization (QUBO) problem, solvable by using quantum annealing systems. The algorithm is validated on a simulated sample of particles collisions data generated combining the Madgraph Monte Carlo event generator and the Delphes simulation software to model the detector response. A variety of fundamental kinematic distributions are unfolded and the results are compared with conventional unfolding algorithms commonly adopted in precision measurements at the Large Hadron Collider (LHC) at CERN.

The implementation of the quantum unfolding model relies on the D-Wave Ocean software and the algorithm is run by heuristic classical solvers as well as the physical D-Wave Advantage quantum annealer boasting 5000+ qubits.

Significance

References

GitHub repo: https://github.com/JustWhit3/QUnfold

Experiment context, if any

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