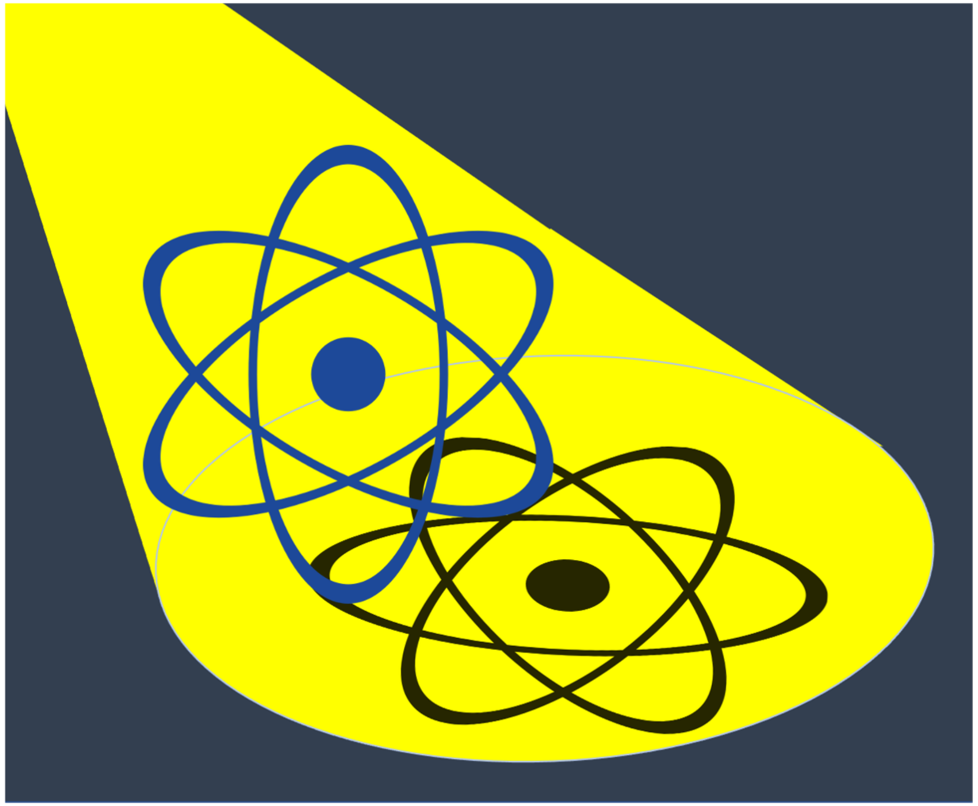
Learning ground state properties from few measurement



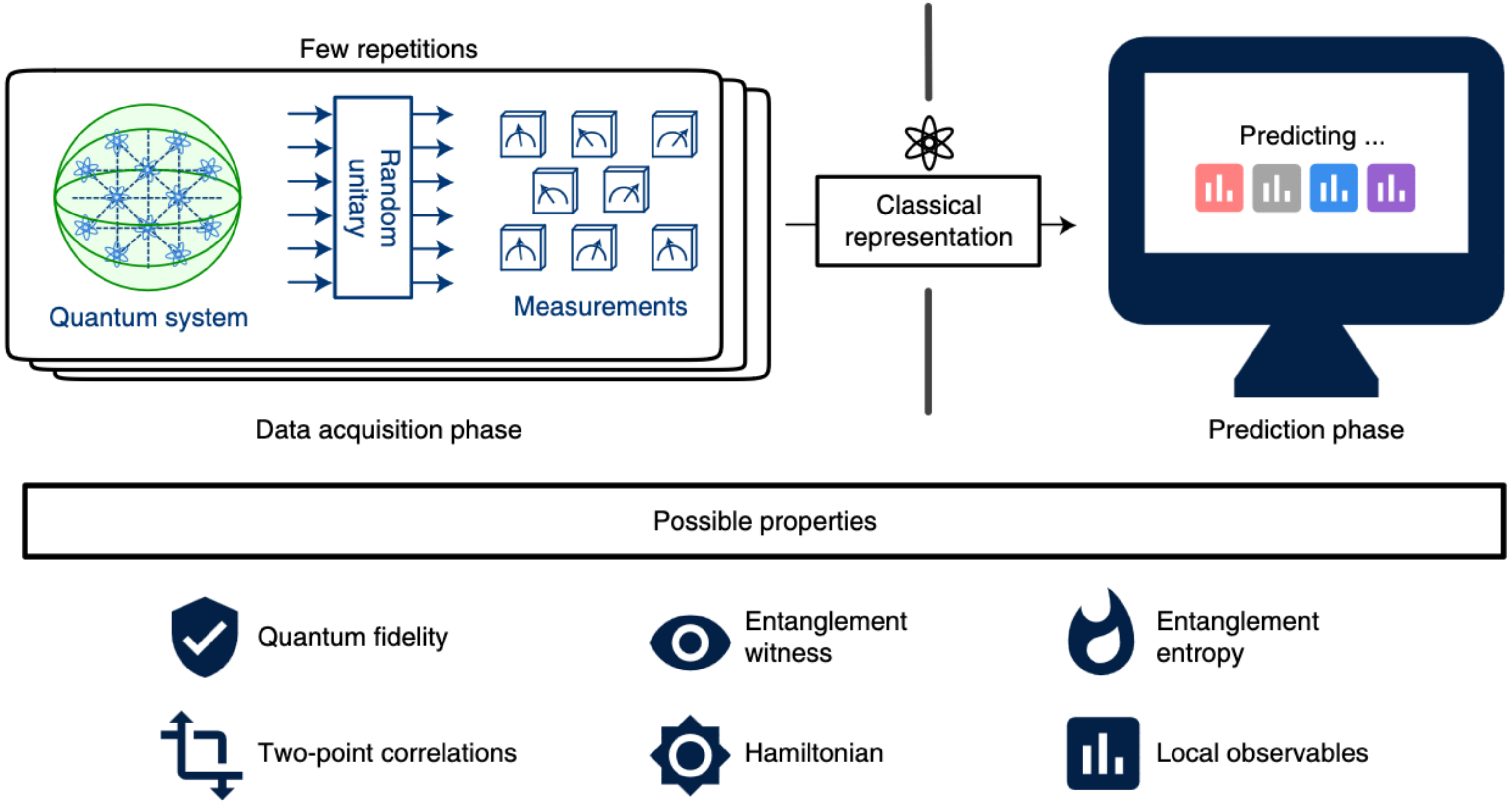
Oriel Kiss
29th May 2024

Physics application of AI
UNIGE

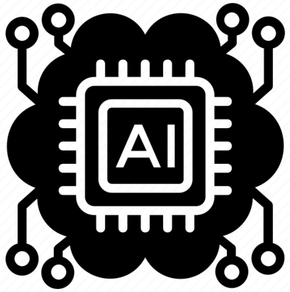
// Classical shadows formalism

- extract information from quantum states with few measurements (optimal protocol).
- generalize to new configurations.

State preparation (here DMRG)



Generalize to different configurations



Huang, HY., Kueng, R. & Preskill, J. *Nat. Phys.* **16**, 1050–1057 (2020)

// The Pipeline

Network

2d XXZ Hamiltonian with transverse field

$$H = \sum_{\langle i,j \rangle} J_{ij}^X (X_i X_j + Y_i Y_j) + J_{ij}^Z Z_i Z_j + \sum_i h_i Z_i$$

$$J_{ij}^X, J_{ij}^Z \sim \mathcal{U}(0,1) \quad h_i \sim \mathcal{U}(-2,2)$$

Target: correlators

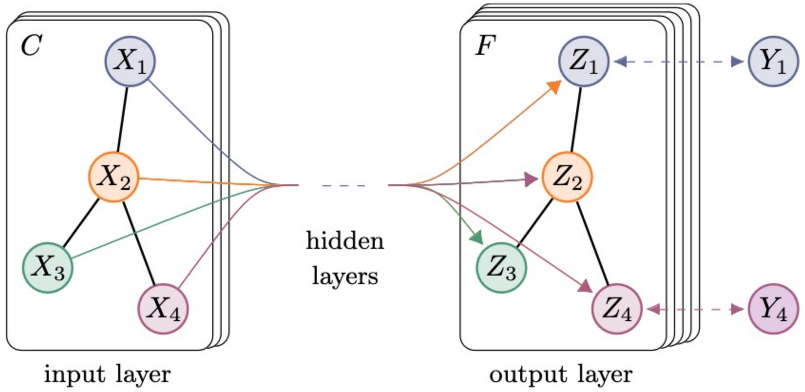
$$C_{ij} = \frac{1}{3} \langle X_i X_j + Y_i Y_j + Z_i Z_j \rangle$$

Loss function: MSE

Optimizer: ADAM

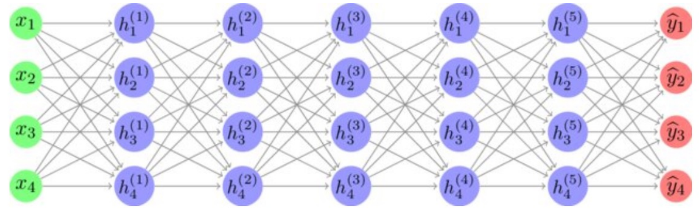
Input (graphs):
Coupling (edges), External field (vertices)

GCNN
(with message passing)



(a) Graph Convolutional Network

MLP
(constant width)

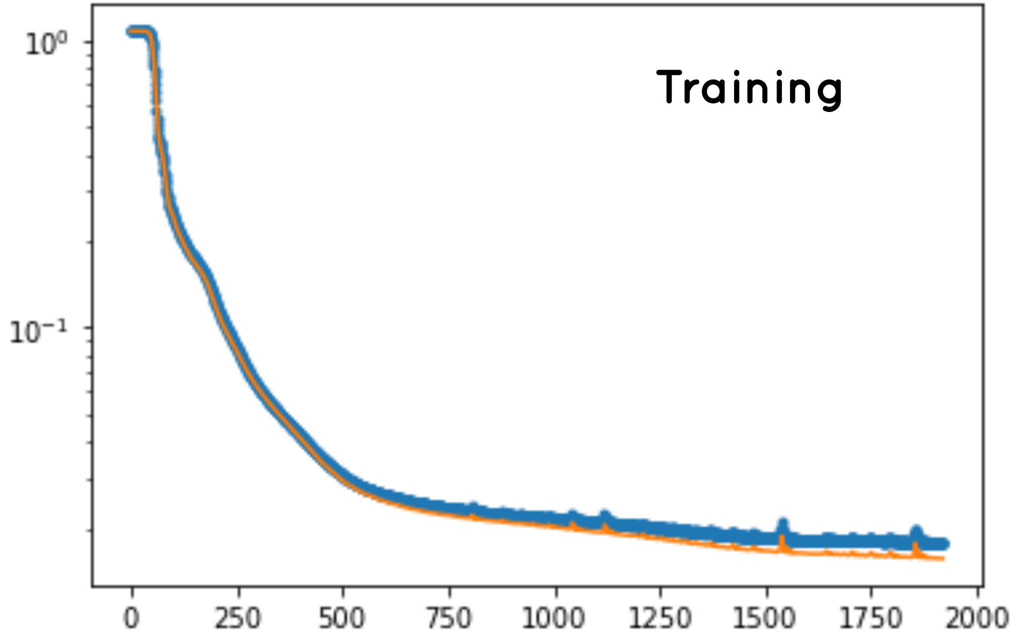


Symmetrisation + Normalization $\hat{c}_{ij}(\rho) = (ZZ^T)_{ij}.$

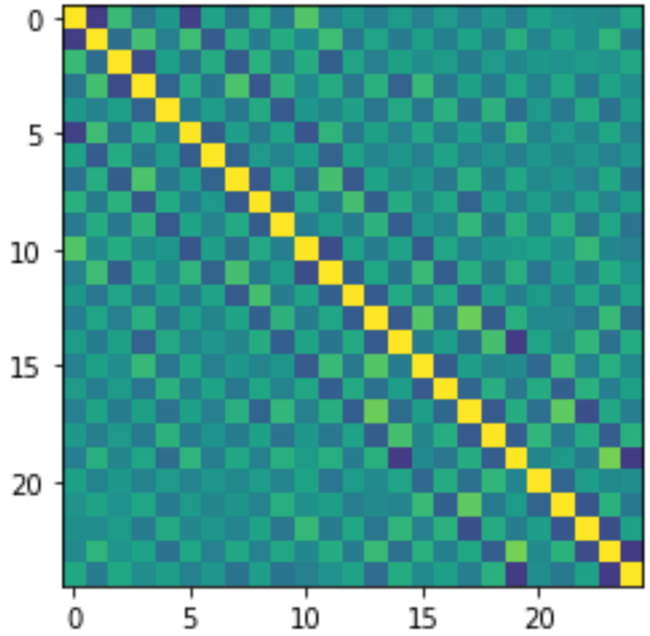
Kipf and Welling, at ICLR 2017
Tran, Lewis, Huang, Kofler, Kueng, Hochreiter and Lehner, at Neurips ML4PS22

// Results

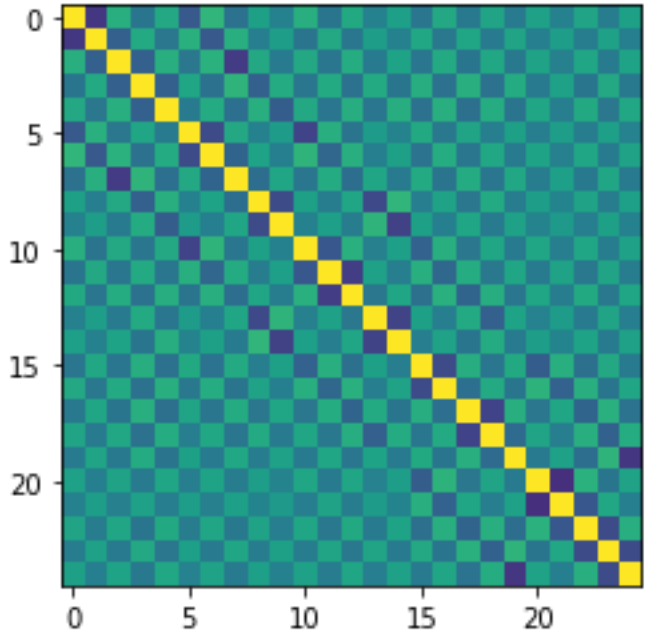
- 5x5 spin-lattice
- no measurement error (i.e. no shadows, for now)
- DMRG initial state
- 300 training points



Test data



Prediction



// Next Steps

- Study the effect of noise on the training data (finite measurements).
- Study the scaling with the system size.
- Study the scaling with the number of training data.
- Learn non-linear properties (e.g. entropies).
- Study more exotic topologies (Kagome lattice, frustrated systems, ...).