Learning quantum entanglement from incomplete measurements

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Abstract: Entanglement quantification is of paramount importance to fundamental research as well as to many cutting-edge applications. Here, we propose a neural network-based approach for direct estimation of an amount of entanglement from a local informationally incomplete measurement. The network accepts data from various scenarios and performs independently of the measurement device. We demonstrate significantly lower errors of quantum concurrence estimation from heavily undersampled Pauli's measurements compared to quantum tomography.

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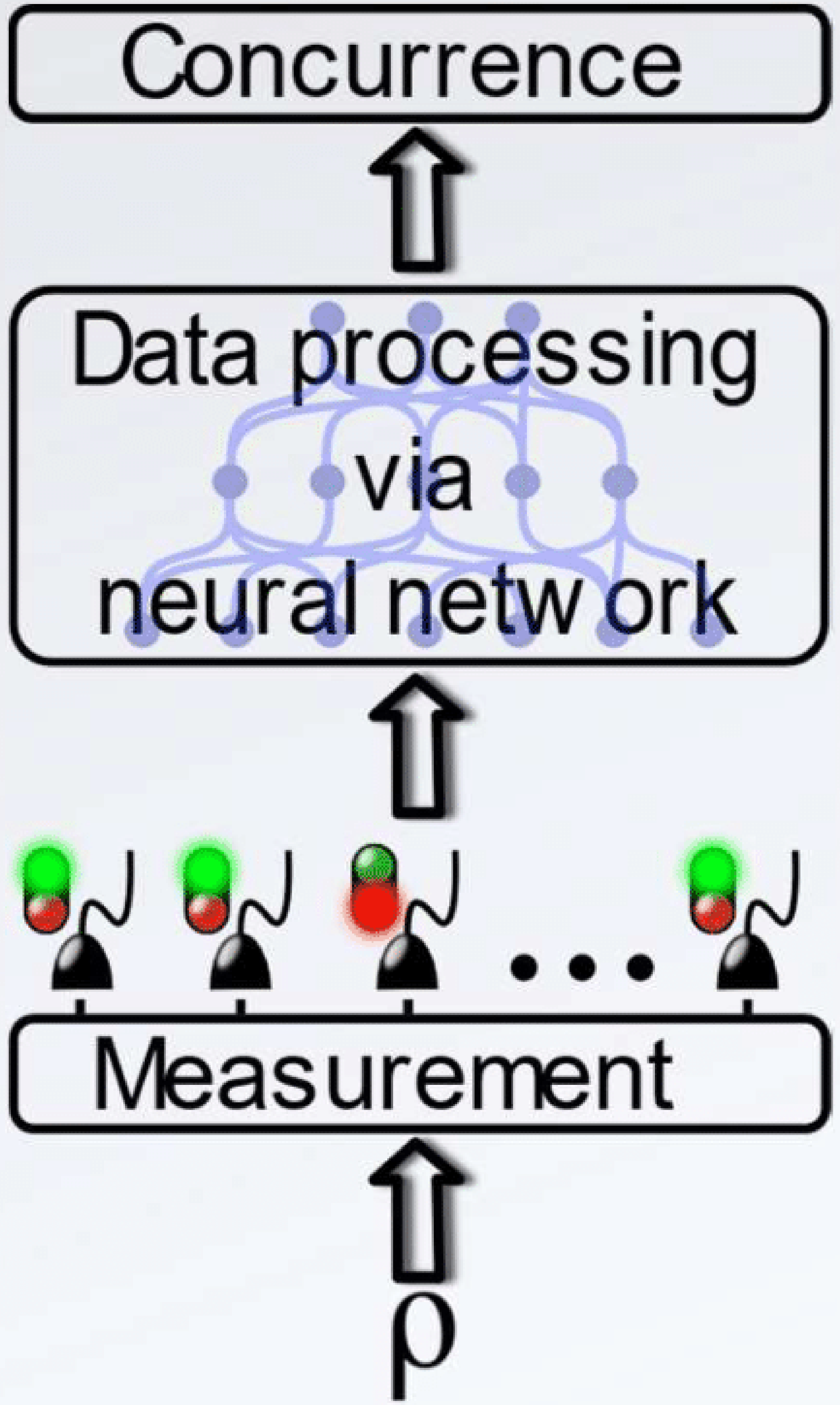
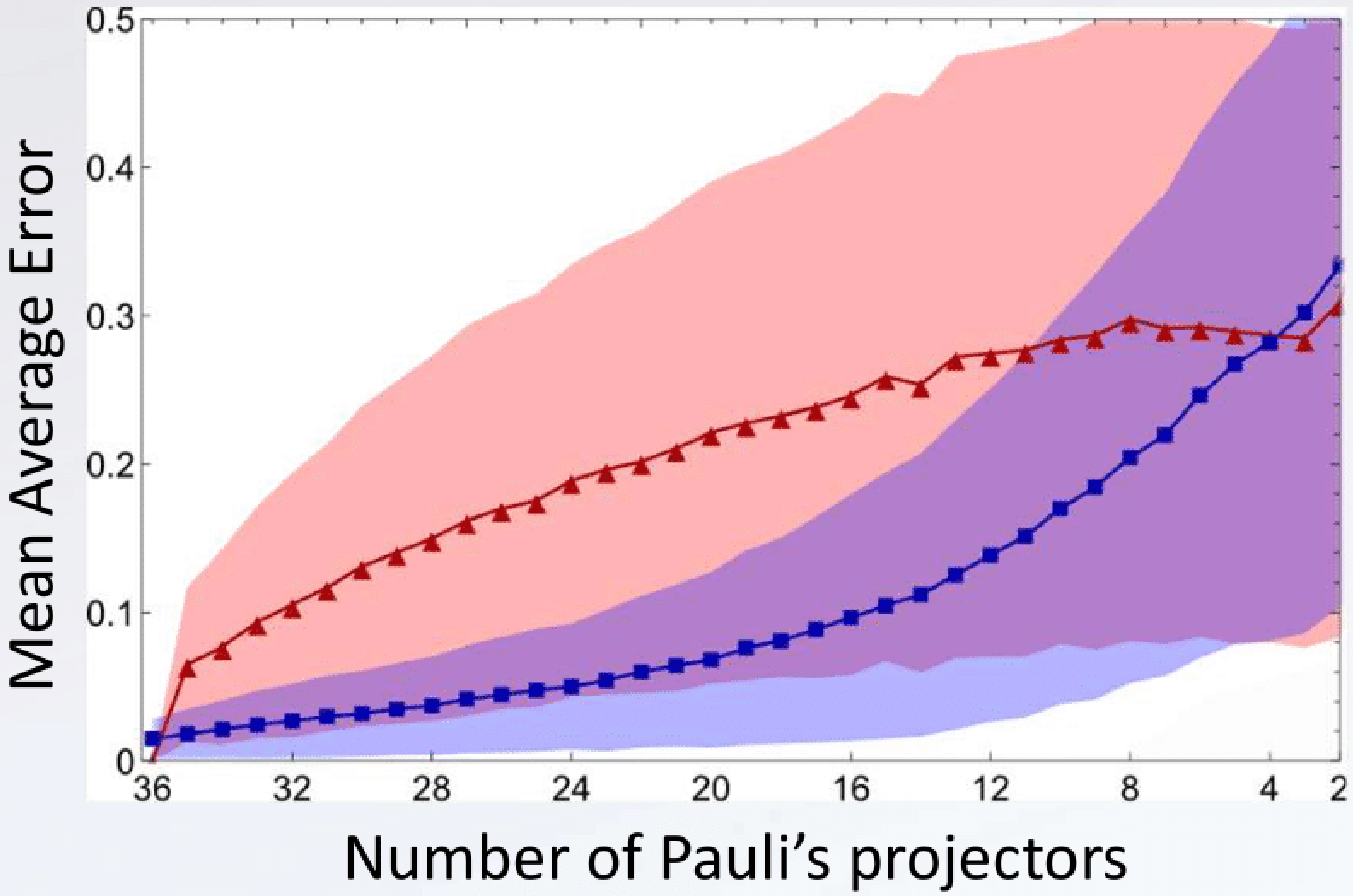
Motivation and our approach

- The knowledge about the quality of the entanglement produced by a source is crucial for the execution of quantum information processing protocols, enhanced quantum metrology, or quantum key distribution.
- Recently, the field of machine learning entered the realm of quantum physics with huge success. From approximations of ground states in many-body quantum hamiltonians to predicting advanced quantum dynamics, deep neural networks paved a new way of understanding quantum systems from incomplete information. Our goal is to construct a develop neural network which will provide estimates of concurrence from informationally incomplete local Pauli's measurement.



Training data set and results

- We build a convolutional neural network (CNN) which predicts the two-qubit entanglement measure concurrence.
- Altogether, CNN has slightly over 100 000 trainable parameters.
- The main advantage of our approach lies in the ability of CNN to accept randomized Pauli's projectors. Meaning, in the training dataset, for every randomly generated density matrix we choose at random which measurement settings are fed to the first layer of the CNN.
- We depicted the comparison of the tomographic MaxLik approach (red triangles) and the CNN approach (blue squares) together with the uncertainty region of 1σ.
- Our CNN approach outperforms significantly the standard tomographic approach.



Verification for a particular noisy quantum state

- To show the power of the CNN approach to estimating concurrence, we depict the average of the estimated values for the two-qubit Werner state $\rho = p\rho_{\psi^-} + \frac{1-p}{4}1$
- The concurrence for the Werner state is a piecewise linear function that takes zero value for p ϵ (0,1/3) and increases linearly up to 1.
- The results are shown for the 18 randomly chosen Pauli's projectors, which is exactly half the number needed for the complete tomography.
- Even with such a heavily undersampled measurement, CNN estimator is still able to correctly recognize patterns in the data hidden to the MaxLik estimator.