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Predicting the success rates of quantum circuits with artificial neural networks

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Abstract:

Current quantum computers are noisy and error-prone. As devices grow in size, we need scalable methods for predicting the performance of a given device. In this work, we explore the potential of neural networks to play this role. We demonstrate a convolutional neural network's ability to predict circuit success rates under both simulated and experimental error models; in each case outperforming non-neural network models that are based on per gate error rates. We also experimentally investigate how a convolutional network's ability to predict success rates varies as a function of dataset size and measurement accuracy, achieving noticeable improvements in performance on simulated data as measurement precision increases. Finally, we present proof-of-concept work detailing a convolutional neural network's ability to handle non-Markovian noise on wide circuits (greater than 25 qubits), a regime in which traditional techniques become inaccurate and highly expensive.

Simulated Results

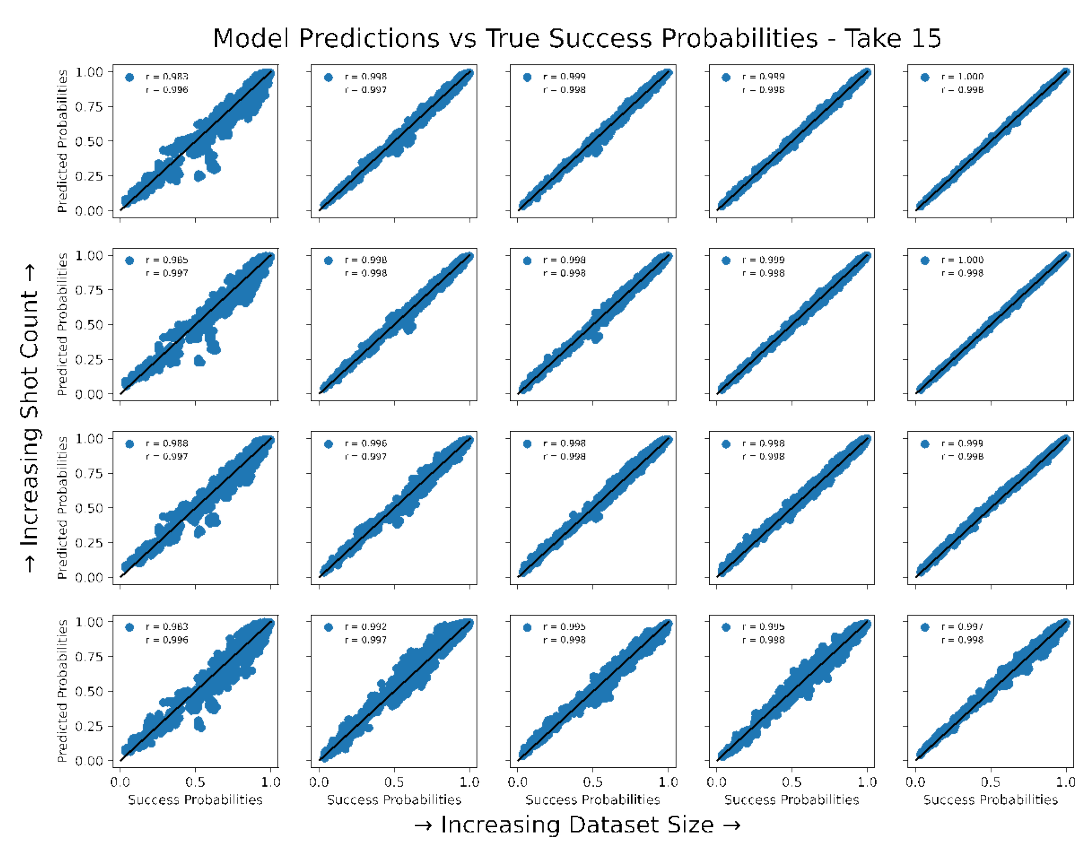

Fig. 1 – CNN predictions versus true success probabilities for networks trained on increasingly large training sets and with increasingly more precise data. The circuits were simulated under a biased stochastic noise model. Error rates model predictions are included as a benchmark.

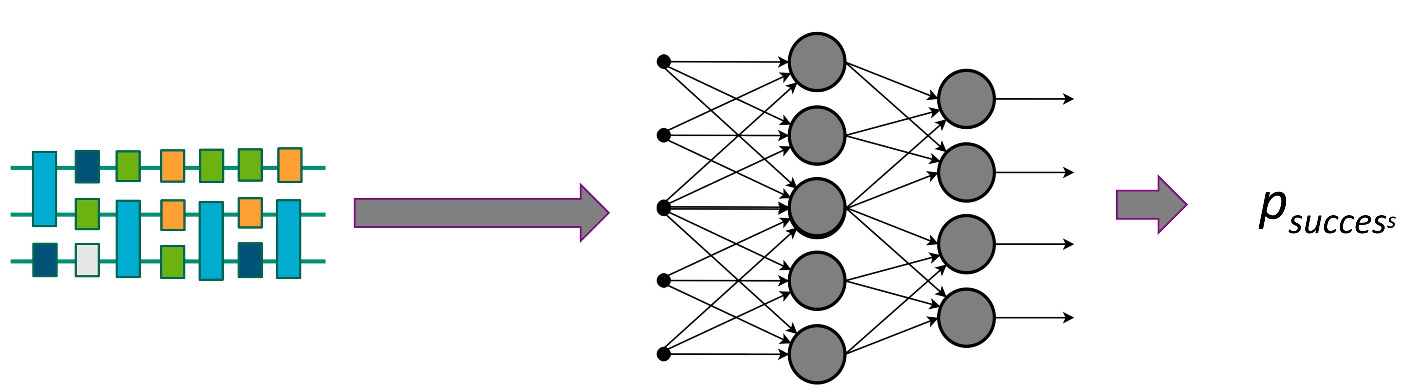

Fig. 2 - Neural networks are trained on circuits encoded as 2D images and used as a device proxy to predict circuit success rates.

Motivation

- Can machine learning help us understand the capabilities of a quantum device?
- Develop a scalable and expressive predictor of circuit performance.

Non-Markovian Results

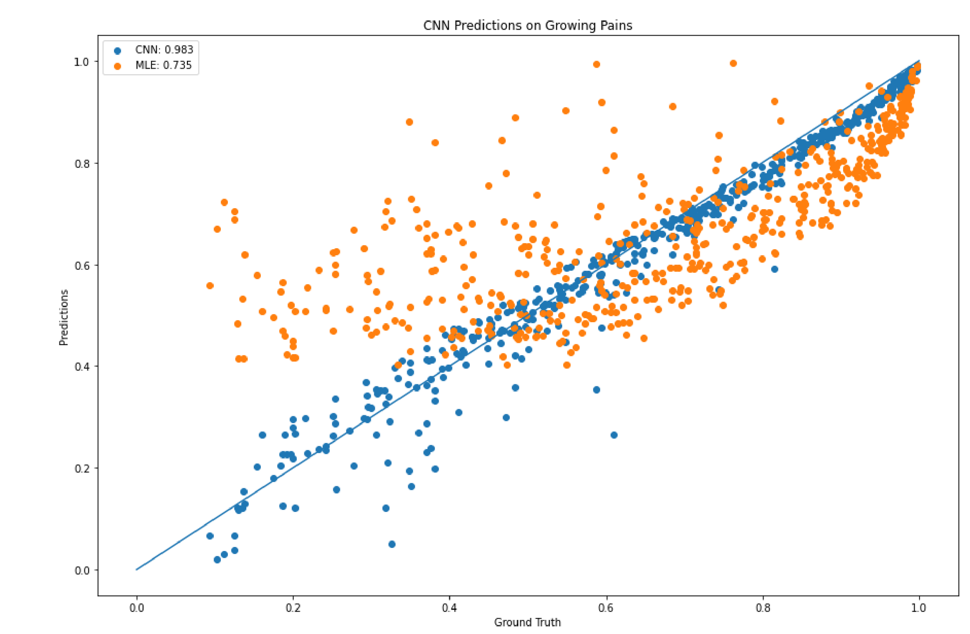

Fig. 3 – CNN trained to predict success probabilities for circuits simulated under a noise model where gate errors increase with depth.

IBMQ Ourense Results

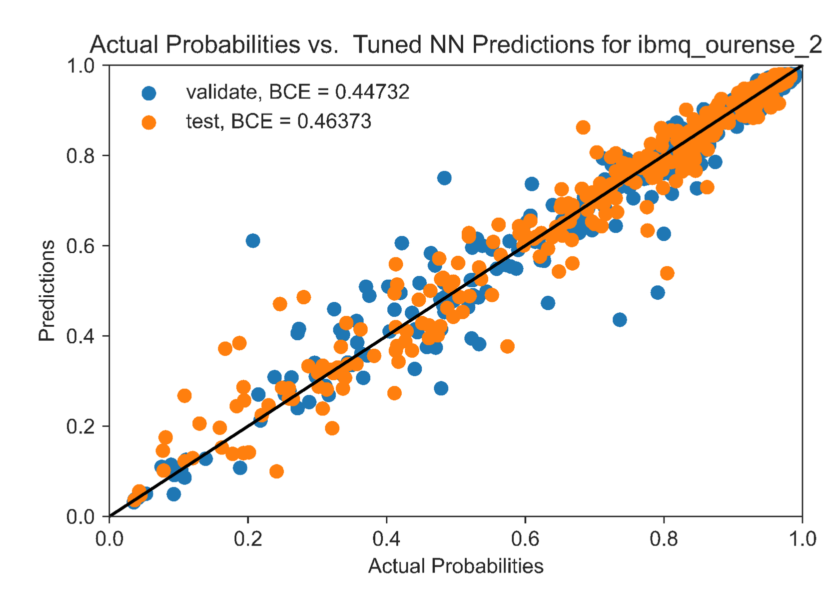

Fig. 4 - A CNN's predictions of circuit success probabilities plotted against true success probabilities for five qubit random mirror circuits run on the IBMQ Ourense device. The poor performance of the comparison error rates model suggests the presence of non-Markovian noise; noise which the CNN is able to better handle than the error rates model.

Data

Simulated Data

- Random Clifford mirror RB circuits
- 1-5 qubits wide
- 10 to 3082 layers deep
- Biased stochastic noise at 100, 1000, 10000, and infinite shots
- 5 sets of 100, 300, 500, 1000, 16600 circuits

Non-Markovian

- Random Clifford mirror RB circuits
- 1-25 qubits wide
- 7 to 1423 layers deep
- Three non-Markovian noise models with infinite precision
- 5000 total circuits

IBMQ Ourense

- Random Clifford mirror circuits
- 1-5 qubits wide
- 3 to 515 layers deep
- 1024 shots per circuit

Conclusions

Simulated Data

- Handle biased stochastic noise well,
- Improve as dataset size and quality increase,
- Learn increasingly useful features,
- And outperform error rates models.

Non-Markovian

- Outperform error rates models,
- Scale well.

Experimental

- Outperform error rates models,
- Needs additional work.

Citations

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