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Predicting circuit success rates with artificial neural networks

QPL

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Introduction

- Question:

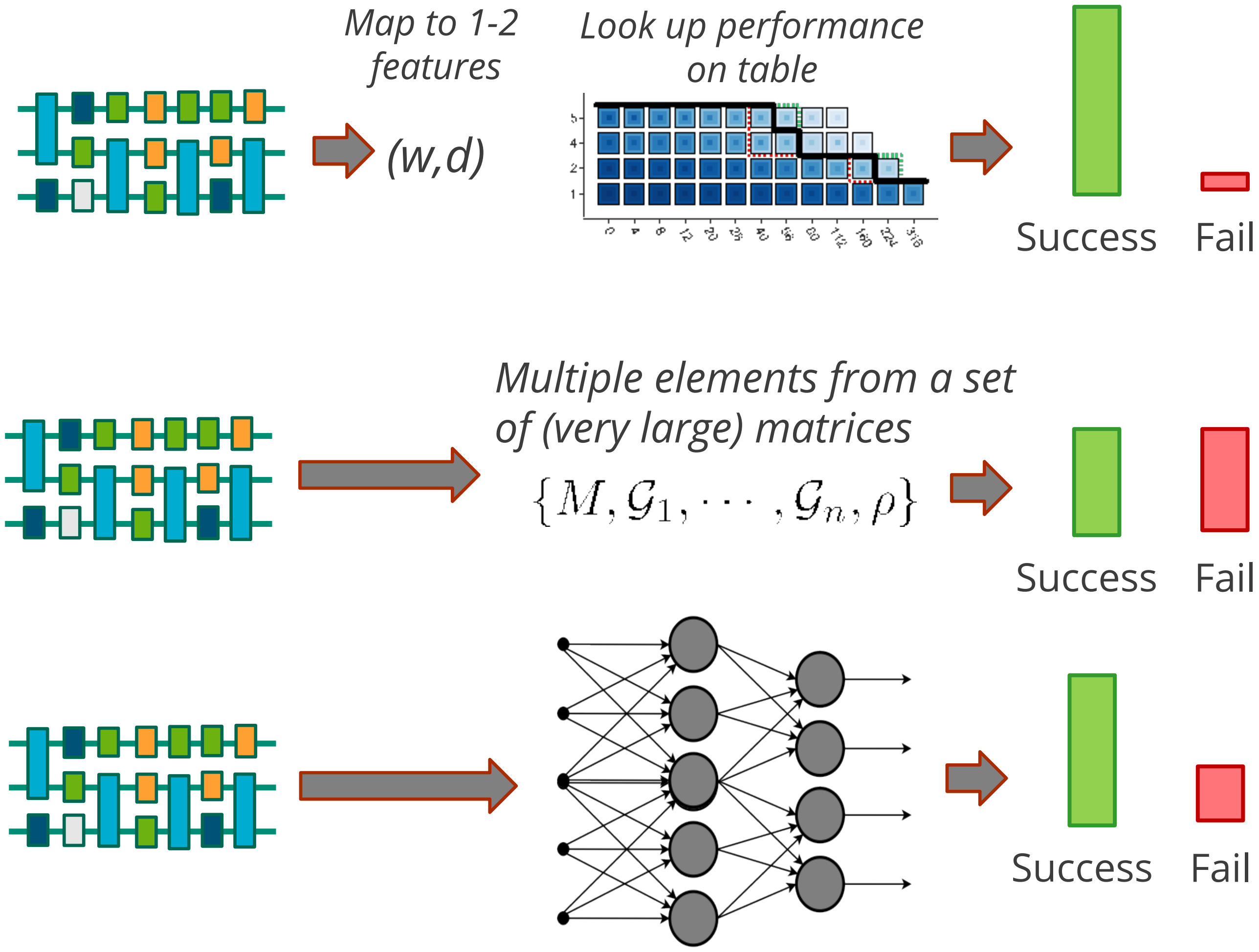
Can we use machine learning to understand the capabilities of a quantum device?

- Our approach:

Train neural networks on classically simulable circuits to predict the fidelity of generic circuits

Background – Other Approaches

- Current quantum computers are noisy and error prone
- Phenomenological models[1]
  - Built on benchmarking tools
  - Rely on human extracted features
  - Poor performance
- Quantum process models[2]
  - Informed by "tomography"
  - Depend on circuit structure
  - Specious assumptions
  - Hard to scale
- Neural Networks
  - Extract their own features
  - Rely on no assumptions
  - Potentially scalable

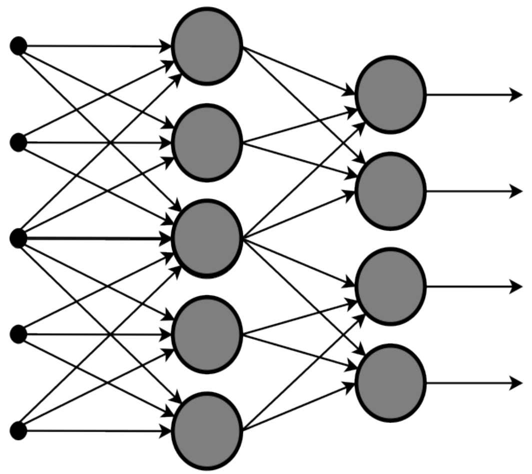


[1]*Characterizing Quantum Gates via Randomized Benchmarking*, Magesan et al, arXiv:1109.6887

[2]*Gate Set Tomography*, Nielsen et al, arXiv:2009.07301

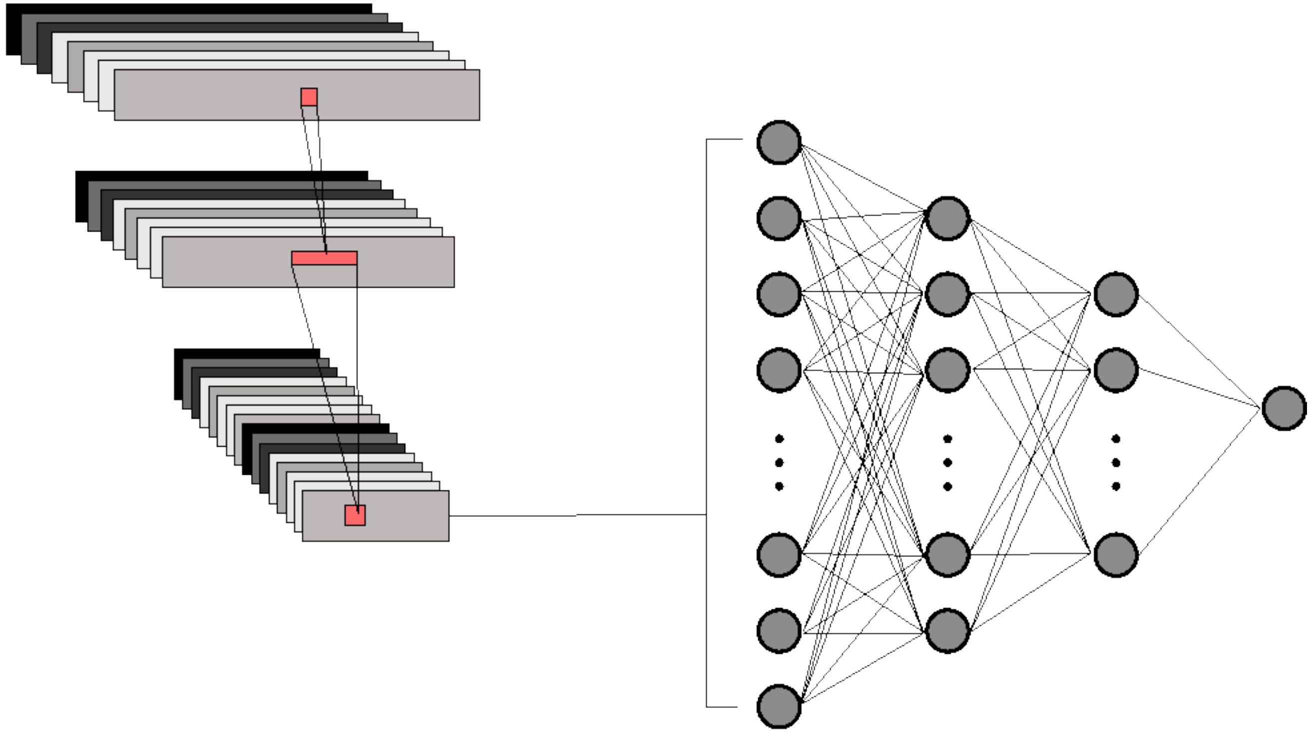
Background – Neural Networks

- Basic structure
  - Layers of “neurons”
  - “Neurons” perform different operations
  - Previous layer feeds into the next layer
- Universal approximation theorem
  - Capable of learning “most” “reasonable” functions
- Convolutional Neural Networks
  - Process images
  - Learns weights for convolutional filters
  - Extracts useful features
- Multilayer Perceptron
  - “Vanilla” (deep) neural network
  - Dot products and activation functions



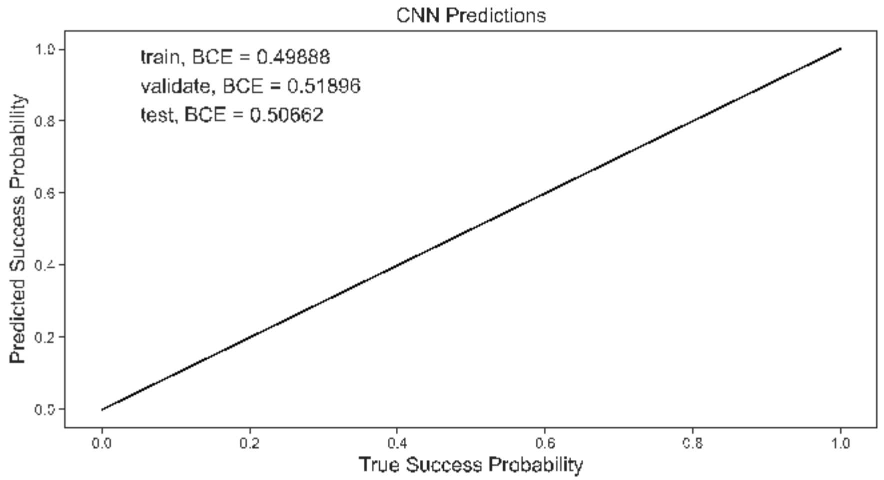
Our Approach

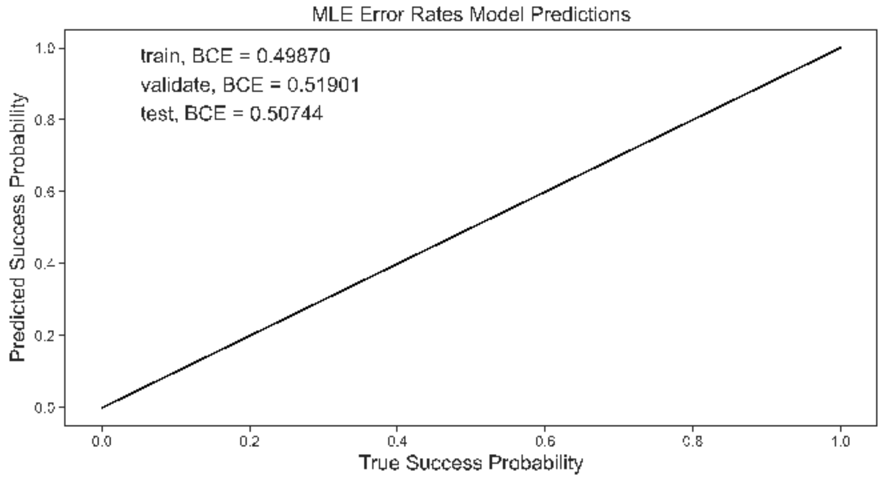
- Encode circuits as images
- Feed images into convolutional layers
- Extracted features are input into a deep multilayer perceptron
- Predict success probability with a softmax function



Preliminary Results – Simulated Data

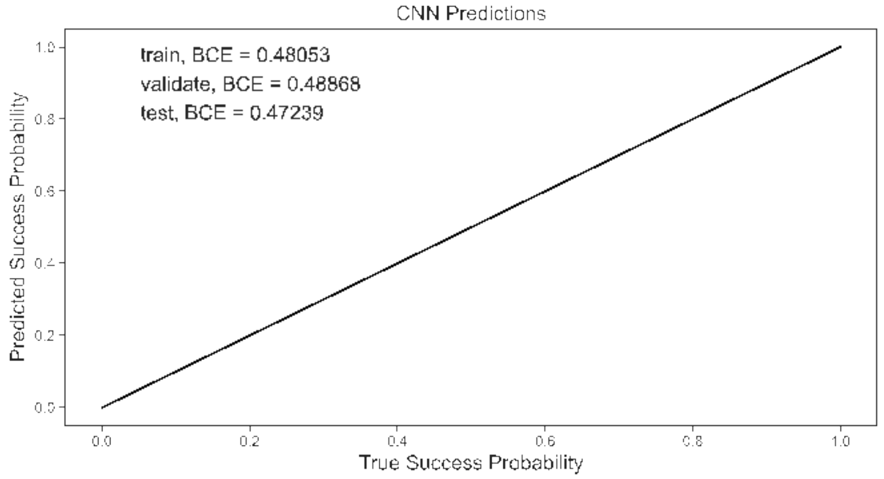
- Biased stochastic error model
- Mirror Clifford Circuits
- Neural networks provided with stabilizer information
- Outperforms models based on per gate error rates estimated from the data

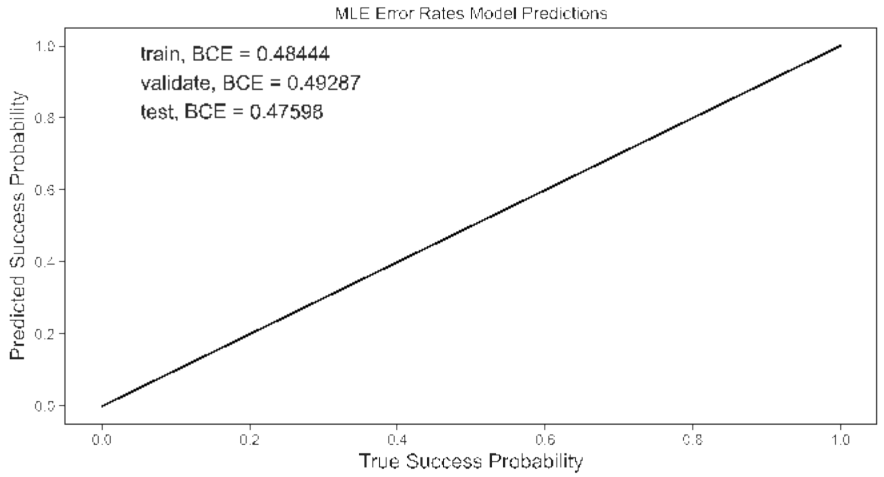




Preliminary Results – Experimental Data

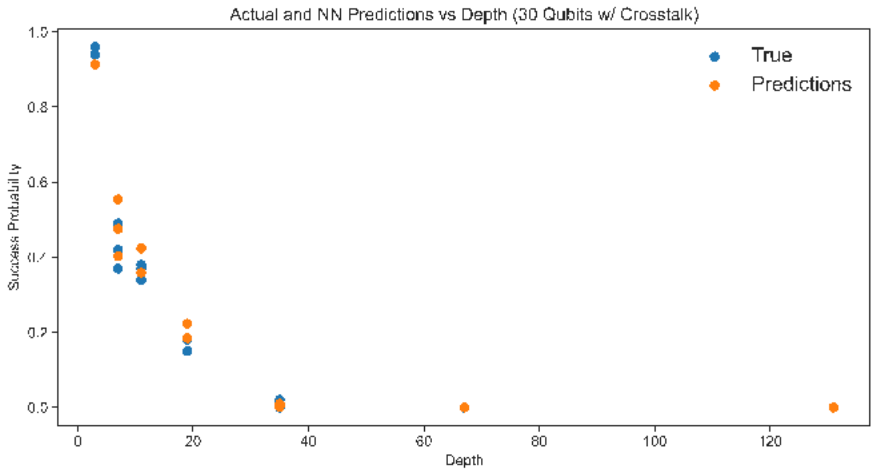
- Run on IBMQ Ourense
- Mirror Clifford Circuits
- Neural Networks not provided with stabilizer information
- Worse performance than on simulated data
  - Still beats MLE model

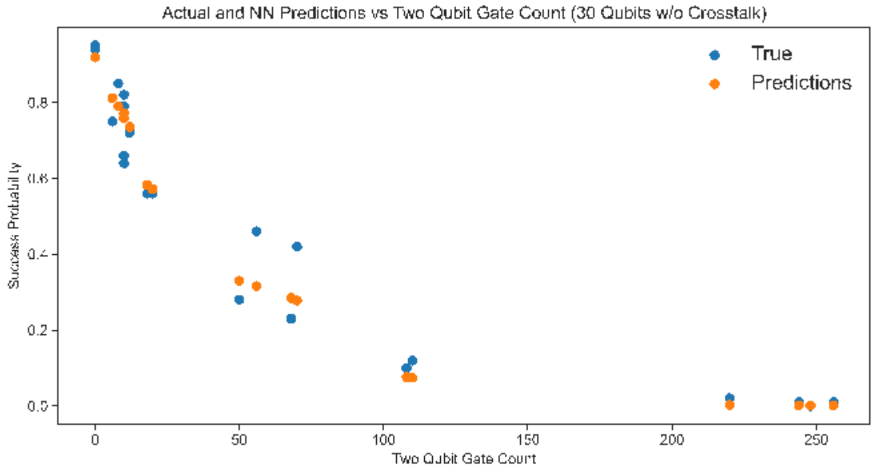




Scalability

- How scalable is this neural network approach?
- Local depolarization errors
  - Crosstalk free
  - 2Q gate crosstalk
- Deep multilayer perceptron learns useful information
  - Up to 30 qubits
  - Given circuit depth and two qubit gate count
- CNN feature extraction is scalable, but hasn't been performed





Conclusions and Future Work

- Proof of concept
  - CNNs on simulated and experimental data
  - Scalability with human extracted features

- Future work
  - Tune network architecture
  - Different types of networks
  - Try more complicated error models
  - Analyze wider circuits with CNNs

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