QMIND

Quantum Generative Adversarial Networks

Cameron Estabrooks, Jacob Ewaniuk, Adam Grace, Spencer Hill, Joshua Otten

April 2nd, 2021

Problem/Motivation for the Work

What makes Quantum GANs Useful?

Figure 1

What are GANs?

Why explore Quantum GANs?

Figure 2

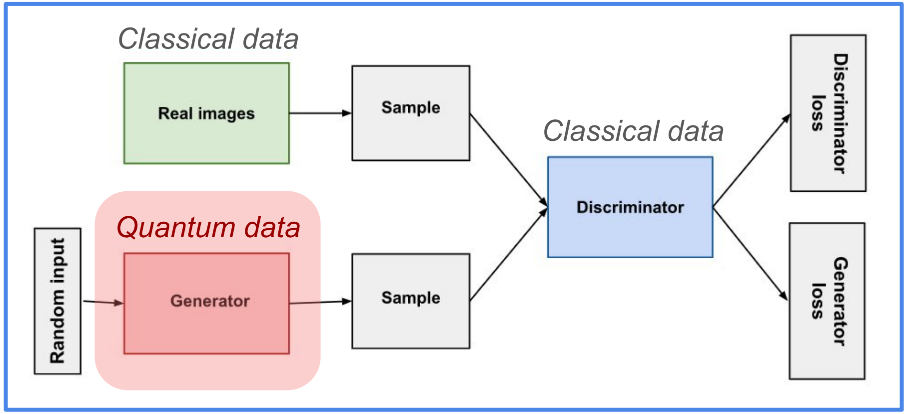


Figure 3

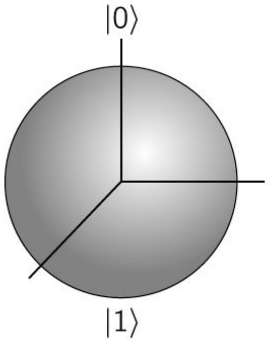
Ideas of Quantum Computing

Classical Computing

$$\text{bit} \in \{0, 1\}$$

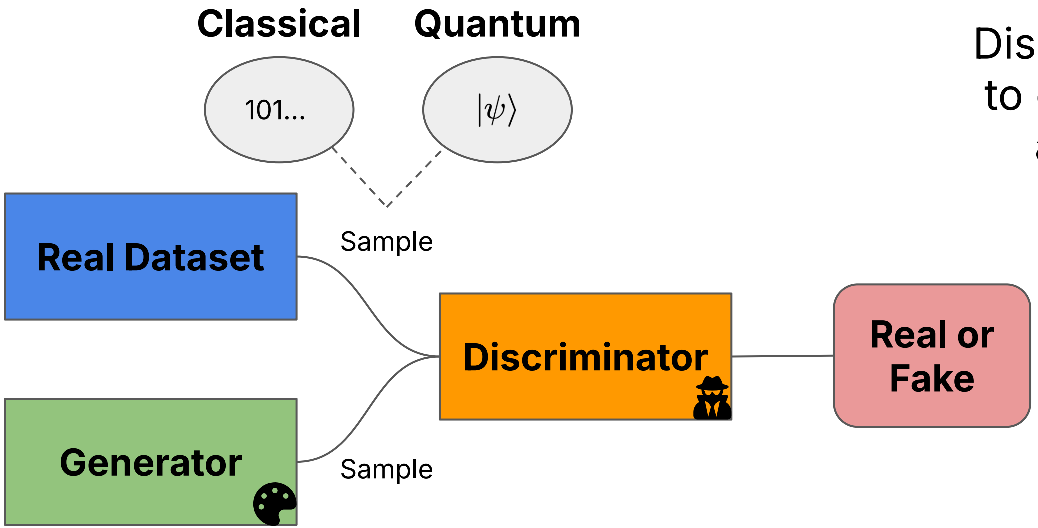
Quantum Computing

$$|\psi\rangle = \alpha |0\rangle + \beta |1\rangle$$



Generative Adversarial Network Architecture

Mapping GANs to the Quantum Domain



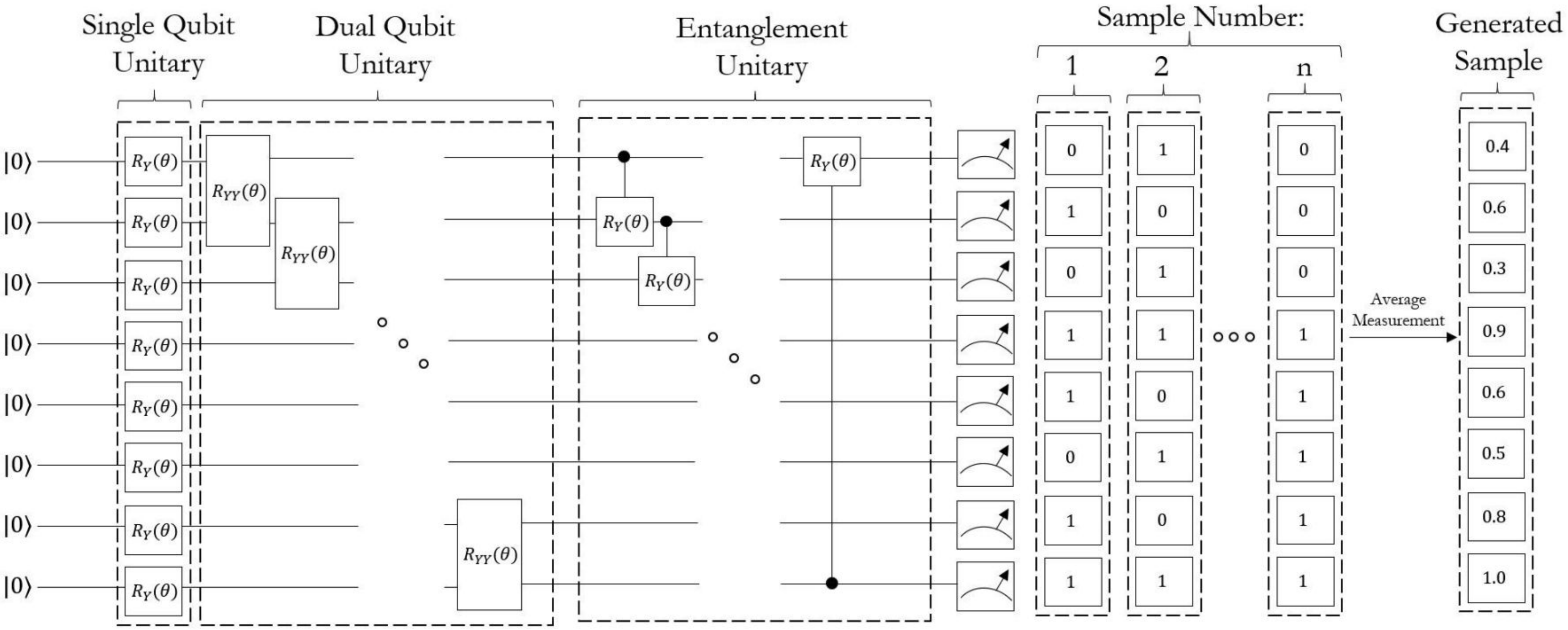
Discriminator is trained to choose what is real and what is fake!

$$\min_{G} \max_{D} \mathrm{E}_{\mathbf{x}\sim p_{\text{data}}}[\log D(\mathbf{x})] + \mathrm{E}_{\mathbf{z}\sim p(\mathbf{z})}[\log(1 - D(G(\mathbf{z})))]$$

Generator is trained to produce data that the discriminator thinks is real!

Quantum GAN Architecture

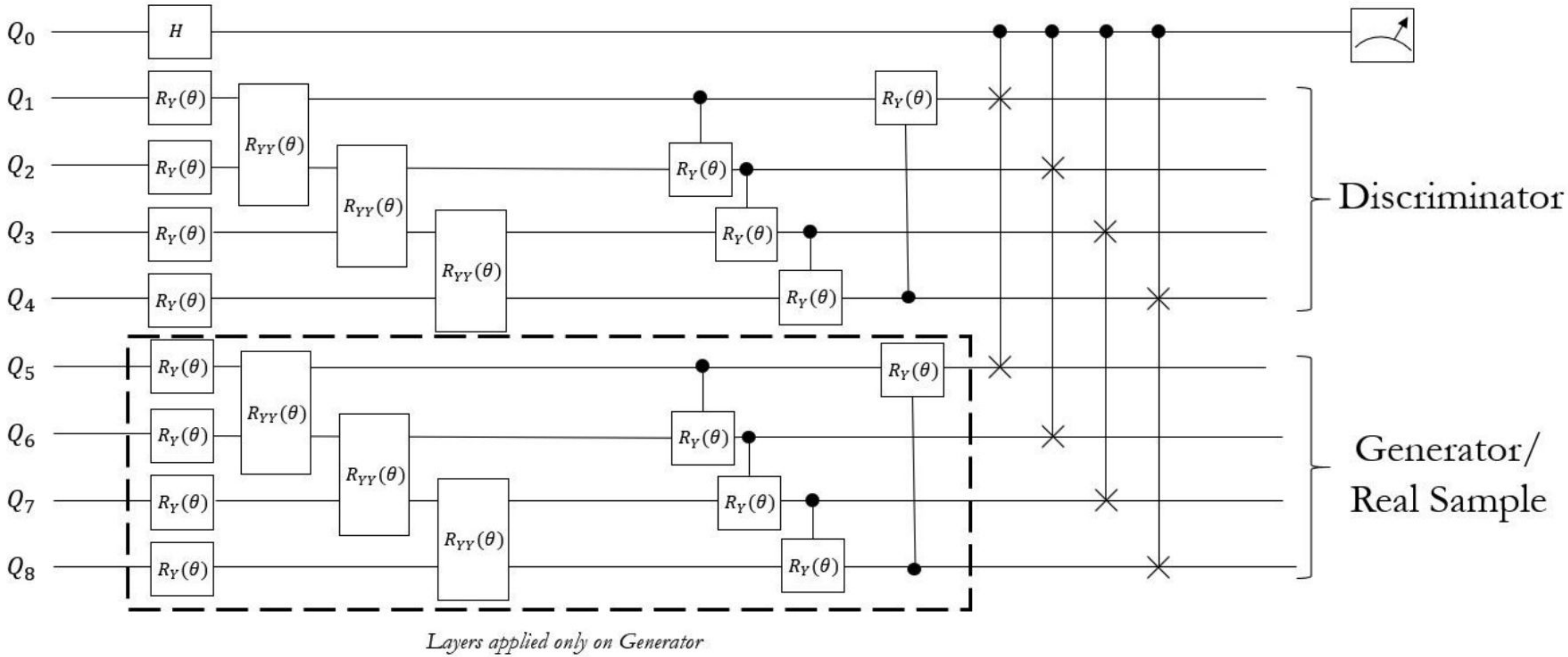
Building the GAN as a Quantum Circuit



S. A. Stein et al., 2021, arXiv:2010.09036v2 [quant-ph].

Quantum GAN Architecture

Building the GAN as a Quantum Circuit

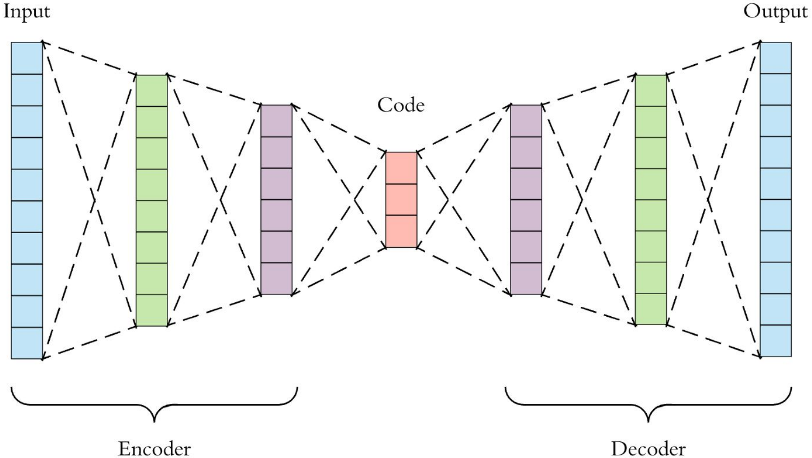


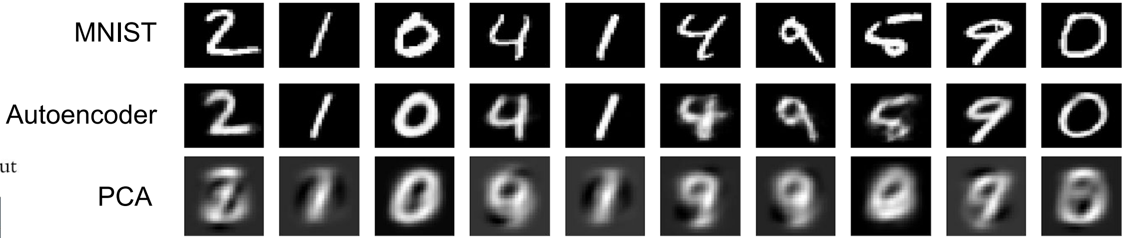
S. A. Stein et al., 2021, arXiv:2010.09036v2 [quant-ph].

Integration of AutoEncoder (vs. PCA)

Dimensionality Reduction for Quantum Embedding

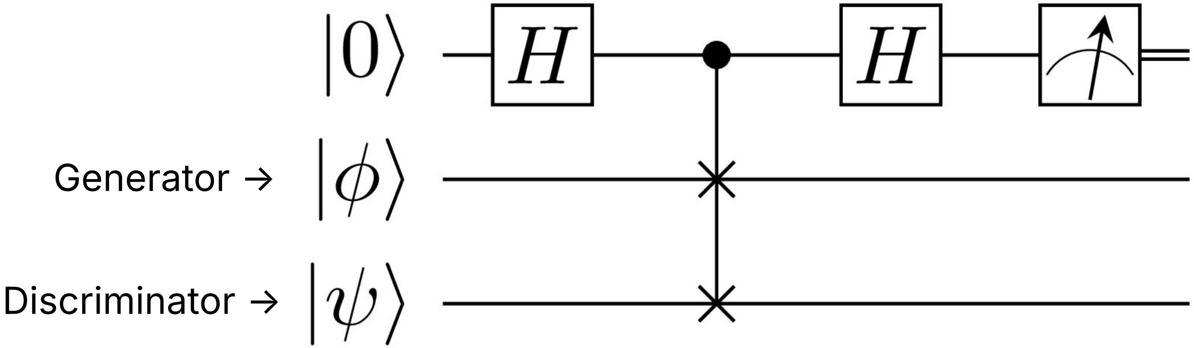
- Simple autoencoder neural network, reduces dimensionality from 784 to 4
- Also tried PCA reducing to the same amount of dimensions





Fidelity-Based Training

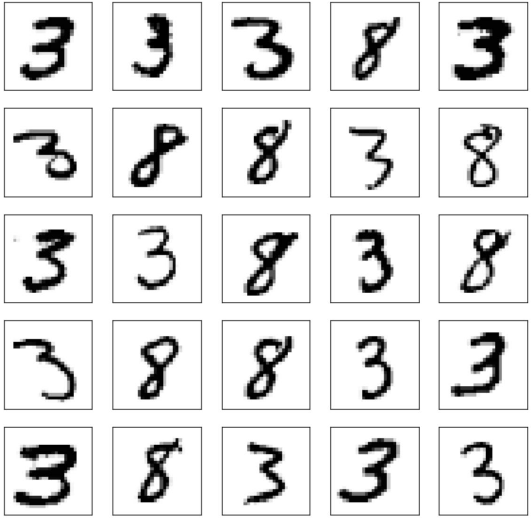
Parameter-Shift Gradient Computation

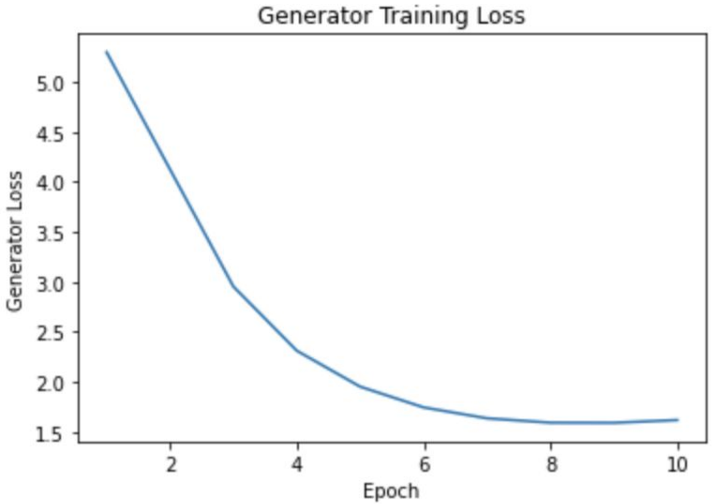


$$P = \frac{1}{2} - \frac{1}{2}|\langle\psi|\phi\rangle|^2$$

$$\frac{\delta f}{\delta\theta} = \frac{1}{2}(f(\theta + \frac{\pi}{2}) - f(\theta - \frac{\pi}{2}))$$

Training Results

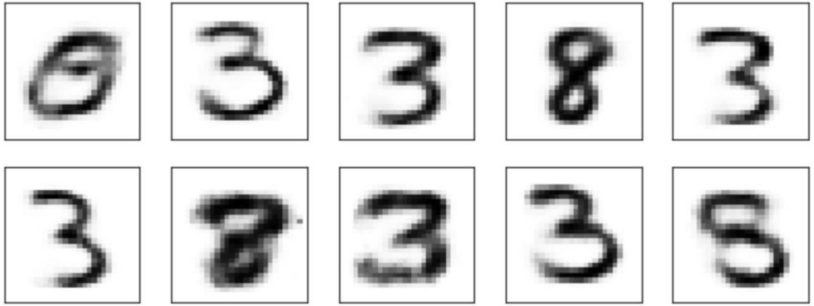




Comparison to Classical GAN

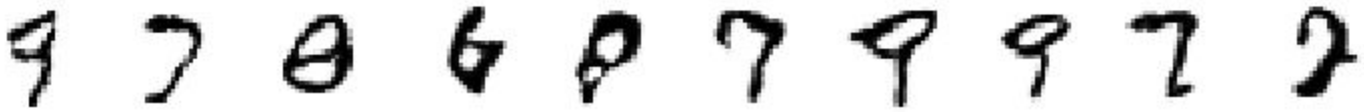
Architecture Complexity and Results

Us - Variational Autoencoder



QuGAN (2021) - PCA Encoding

Simple Classical GAN



Future Work

Where do we go from here?

Improved Embedding Methods

Utilize the exponential storage capabilities of Quantum Computing through different information qubitization methods, namely amplitude embedding

Higher Qubit Count

Quantum computing is in its infancy, and available numbers of qubits continues to grow. This architecture is theoretically scalable to any number of qubits, which improve the quality of the generated images

Beyond MNIST

Quantum GANs can be applied to problems more challenging than MNIST, including atom simulation and quantum information encoding. These are the true meaningful applications of QGANs

Any Questions For Us?

Thanks for listening to our presentation,
we hope you enjoyed it!