Quantum Machine Learning for Solar Panel Fault Detection

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PROGRAM: IRES UCY

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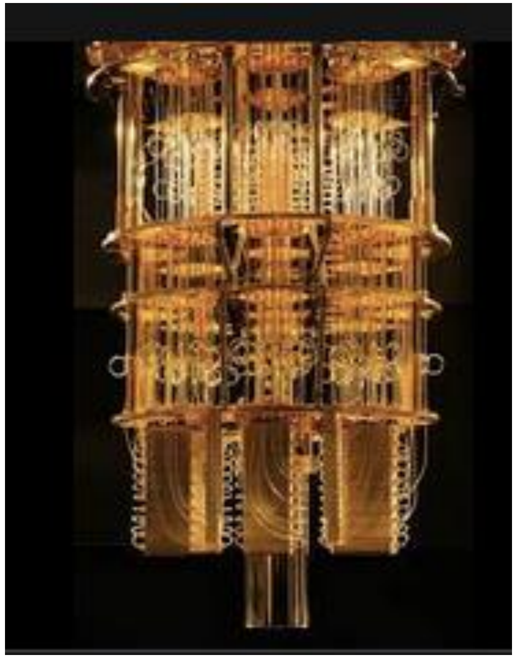
Presentation Agenda

- Problem statement
- Pre-training
- Previous work
- Proposed solution
- Algorithms/circuits
- Challenges of QML vs. CML
- Results
- Conclusions
- Next steps
- Reflection
- References

Problem Statement

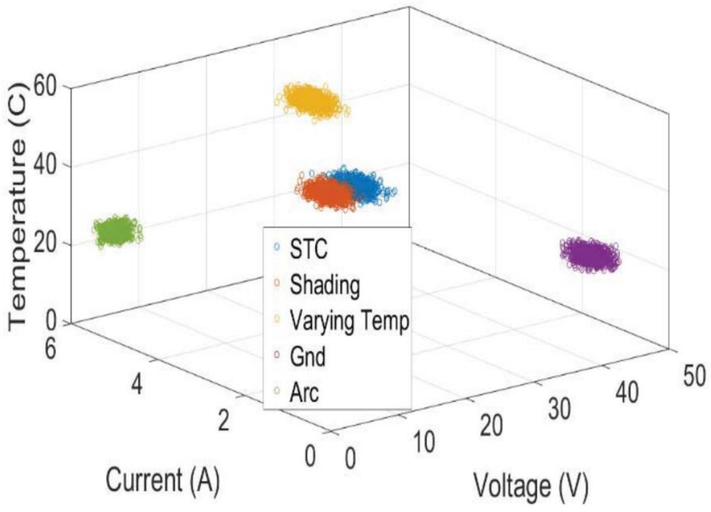
- Fault detection for photovoltaic arrays
  - Faults lead to efficiency issues in arrays
  - Machine learning can identify PV faults
  - Arrays can be reconfigured
- Quantum ML
  - New paradigm in computing
  - Applications in ML
  - Research into QML for this problem can be expanded on



From https://www.neowin.net/news/quantum-supremacy-might-not-have-been-achieved-by-google-and-sycamore-after-all-says-ibm/

Pre-Training

- General ML training in Python and Matlab
- Introduction to PV faults
- Focused training in three ML models
  - Logistic Regression
  - Support Vector Machines
  - Neural Networks
- Quantum ML training



From [1]

Previous Work

- *Machine Learning for Solar Array Monitoring, Optimization, and Control* [1]
- *Quantum Machine learning using Quantum Simulators* [2]
- *Solar Array Fault Detection Using Neural Networks* [3]
- *Quantum Neural Network Parameter Estimation for Photovoltaic Fault Detection* [4]

Proposed Solution

- Implement quantum and classical models
- Test using specifically labeled fault data
  - Short circuit vs. standard test conditions
- Compare quantum vs. classical

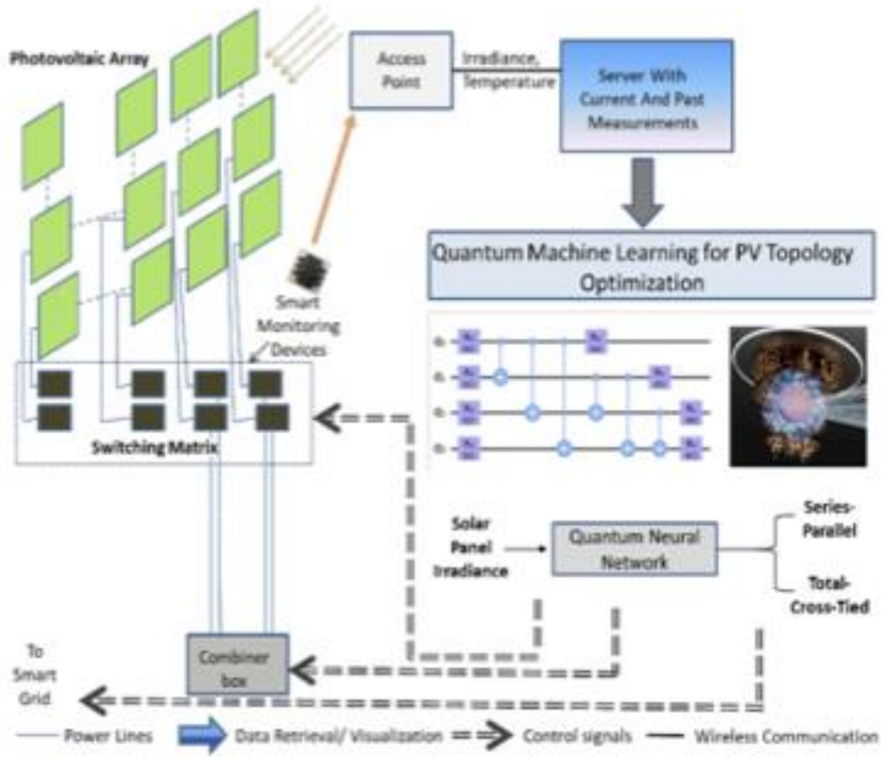


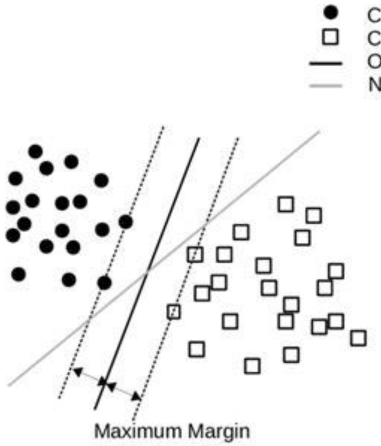
Figure from [4]

Circuits/Algorithms

- Classical Algorithms
  - Logistic Regression
  - Support Vector Machine
  - Neural Network

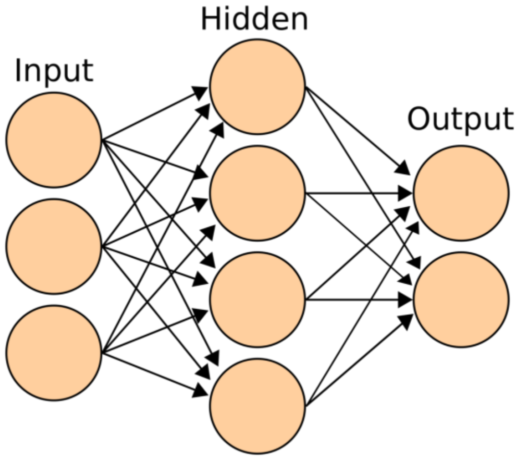
$$Sigmoid(x) = \frac{1}{1 + e^{-\theta x}}$$

$$K(x, x') = e^{-\gamma||x - x'||} \quad \gamma = \frac{1}{n\, features * \sigma^2}$$



From https://www.researchgate.net/figure/Support-Vector-Machine-example_fig4_313851520

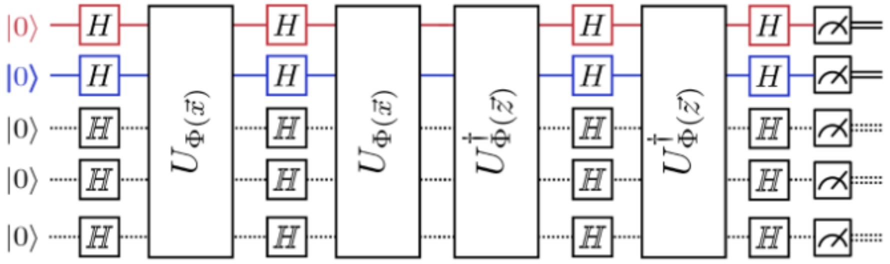
$$f(x) = \begin{cases} 0, if\ x < 0 \\ x, if\ x \geq 0 \end{cases}$$



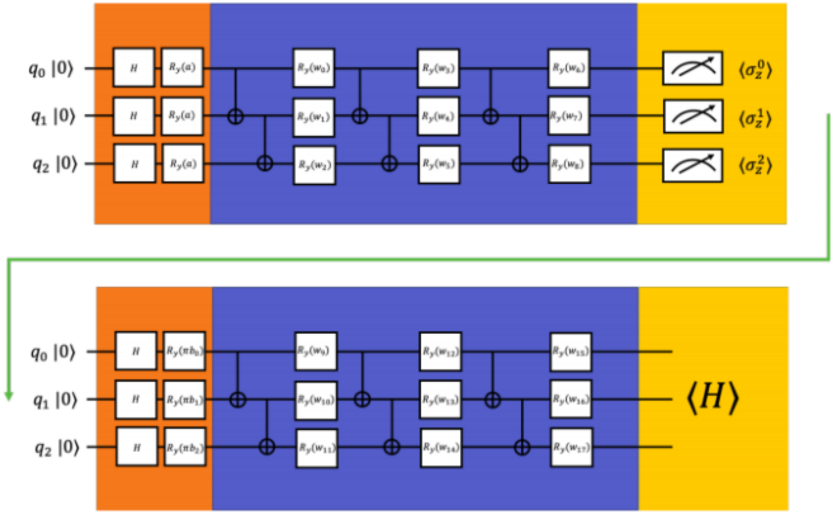
From https://www.sitepoint.com/keras-digit-recognition-tutorial/

Circuits/Algorithms

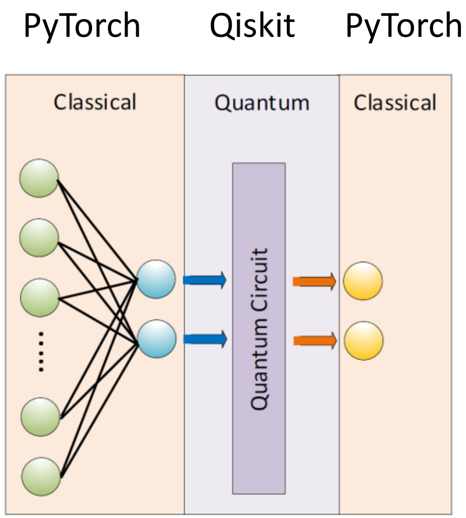
- Quantum Algorithms/Circuits
  - QSVM
  - QNN



From https://medium.com/mit-6-s089-intro-to-quantum-computing/quantum-support-vector-machine-qsvm-134eff6c9d3b



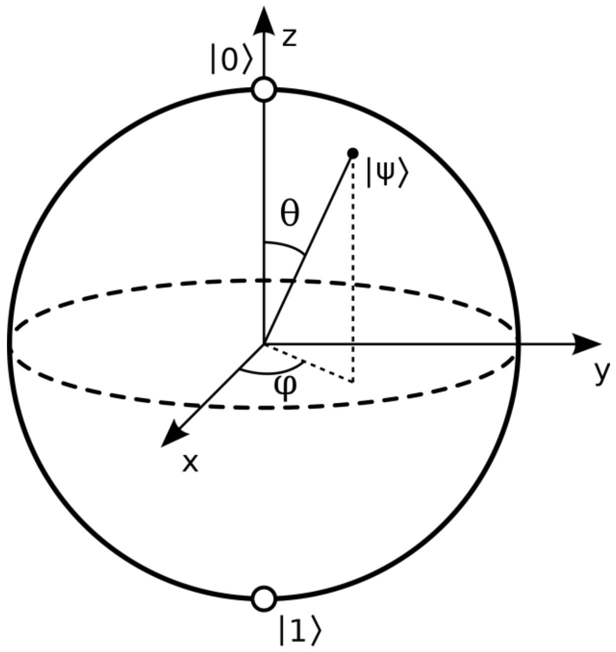
From https://medium.com/qiskit/implement-a-hybrid-quantum-classical-neural-network-with-qiskit-7f732ed3b42a



From [4]

Challenges of QML vs. CML

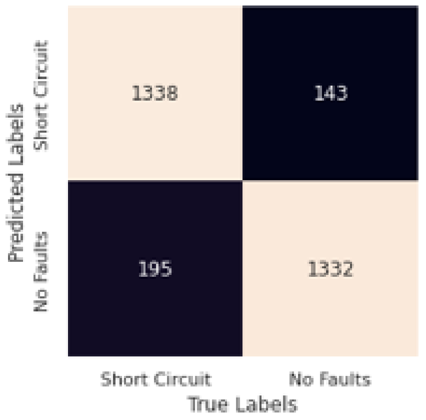
- Simulating Quantum is slow
- More hyperparameters
  - Shots
  - Types of Simulators
  - # of qbits
  - Learning rate
- Quantum is confusing



From https://en.wikipedia.org/wiki/Bloch_sphere

Results

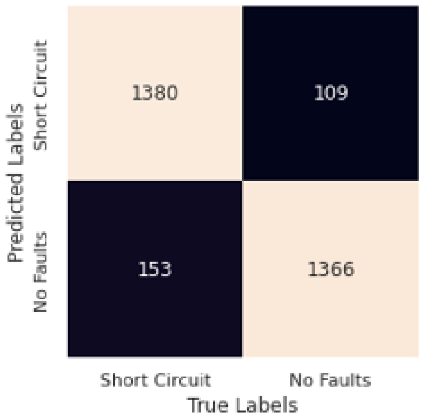
Logistic Regression



Accuracy: 88.76%

Hyperparameters:
Saga solver, l1 penalty

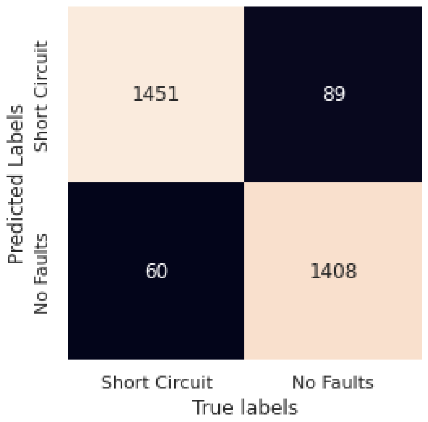
SVM



Accuracy: 91.29%

Hyperparameters:
RBF kernel

Neural Network

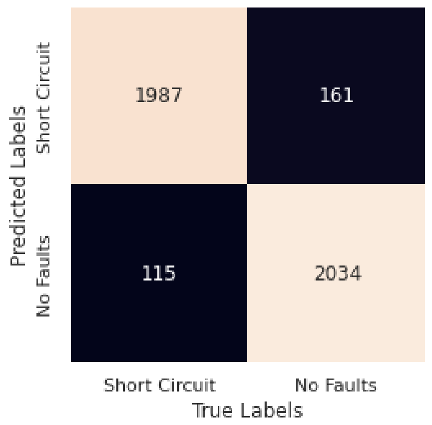


Accuracy: 95%

Hyperparameters:
Two hidden layers, 300 nodes each, relu activation, adam solver

Results

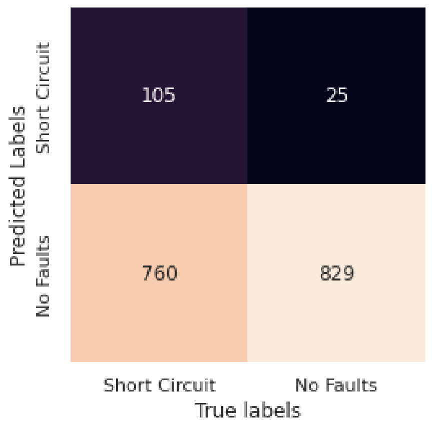
QSVM



Accuracy: 94%

Hyperparameters: 2 qbits, 1024 shots, state vector simulator

QNN



Accuracy: 50-60%

Hyperparameters: 2 qbits, 2 hidden layers, 256 shots, .03 learning rate, Sigmoid activation function, QASM simulator

Conclusions

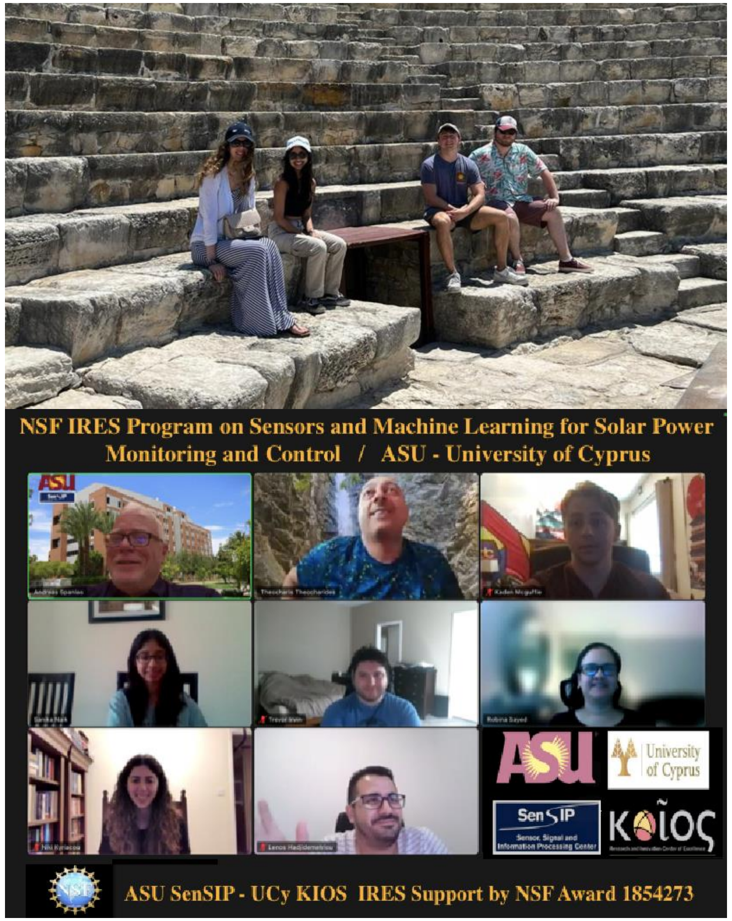
- Achieved good results on the QSVM within the simulator
- Results achieved were superior to the classical model
- The Quantum Neural Network performed poorly
    - Tests in similar quantum research yielded results ~90%
- Inconsistent results warrant further examination

Next Steps

- Attempt further tests with QNN
- Monte Carlo simulations
- Tests on actual quantum computers
- Work with a real, organic solar data set

Reflection

- Introduced to many new subjects
  - Quantum
  - Machine Learning
  - Cybersecurity at Ucy
- Learned much about the research process
  - Presenting findings
  - Writing IEEE style papers
  - Deliverables
- Had a fun and enriching cultural experience
- Satisfied, but want to iron out bugs



References

[1] Rao, Sunil, et al. "Machine learning for solar array monitoring, optimization, and control." *Synthesis Lectures on Power Electronics* 7.1 (2020): 1-91.

[2] Uehara, Glen S. "Quantum Machine learning using Quantum Simulators.“

[3] Rao, Sunil, Andreas Spanias, and Cihan Tepedelenlioglu. "Solar array fault detection using neural networks." *2019 IEEE International Conference on Industrial Cyber Physical Systems (ICPS)*. IEEE, 2019.

[4] Uehara, Glen, et al. "Quantum Neural Network Parameter Estimation for Photovoltaic Fault Detection." *2021 12th International Conference on Information, Intelligence, Systems & Applications (IISA)*. IEEE, 2021.