

# Introduction to Quantum Machine Learning

Your Name

Your Institution

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# Outline

# What is Quantum Computing?

- ▶ Quantum computing harnesses quantum mechanics principles to perform computations.
- ▶ Key quantum principles:
  - ▶ Superposition: Quantum bits (qubits) can exist in multiple states simultaneously.
  - ▶ Entanglement: Qubits can become entangled, meaning the state of one qubit depends on the state of another.
  - ▶ Interference: Quantum algorithms use interference to amplify correct solutions.
- ▶ Quantum computers aim to solve problems too complex for classical computers.

# Basic Quantum Concepts

- ▶ **Qubits:** Quantum version of classical bits, can represent both 0 and 1 simultaneously.
- ▶ **Superposition:** A qubit can be in a linear combination of 0 and 1.

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

- ▶ **Entanglement:** A pair of qubits can be entangled, leading to correlations that are not possible in classical systems.

$$|\psi\rangle_{AB} = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$$

# What is Quantum Machine Learning?

- ▶ Quantum machine learning (QML) integrates quantum computing with machine learning algorithms.
- ▶ The goal is to leverage quantum computing's advantages, such as superposition and entanglement, to improve the speed and efficiency of learning algorithms.
- ▶ QML could potentially outperform classical algorithms for specific problems.

# Quantum vs Classical Machine Learning

## ▶ **Classical Machine Learning:**

- ▶ Uses classical bits for computation.
- ▶ Training often requires large datasets and high computational power.

## ▶ **Quantum Machine Learning:**

- ▶ Uses qubits and quantum gates for computation.
- ▶ Quantum parallelism and entanglement offer potential speedups.
- ▶ May require new algorithms designed for quantum data structures.

# Quantum Algorithms for Machine Learning

- ▶ **Quantum Support Vector Machine (QSVM):** A quantum version of the classical SVM that can use quantum algorithms for faster training.
- ▶ **Quantum Neural Networks (QNN):** Quantum-inspired neural networks where quantum circuits represent layers.
- ▶ **Quantum Principal Component Analysis (QPCA):** A quantum algorithm for dimensionality reduction.

# Quantum Support Vector Machine (QSVM)

- ▶ Quantum SVM can solve classification tasks with quantum kernels.
- ▶ The quantum kernel method enables SVMs to process complex data in high-dimensional spaces more efficiently.
- ▶ The algorithm uses quantum entanglement and superposition to potentially speed up kernel matrix computations.

qsvm\_example.png



# Quantum Neural Networks (QNN)

- ▶ Quantum neural networks use quantum circuits to represent the model layers.
- ▶ Quantum gates can replace classical activation functions in neural networks.
- ▶ The quantum model allows for faster training of some models and the representation of complex, high-dimensional data.

# Applications of QML

- ▶ **Quantum Chemistry:** Solving molecular simulations and reactions.
- ▶ **Finance:** Portfolio optimization and fraud detection.
- ▶ **Medical Imaging:** Quantum-enhanced image processing.
- ▶ **Optimization Problems:** Quantum algorithms can solve large-scale optimization problems faster than classical methods.

# Current Challenges in QML

- ▶ **Hardware Limitations:** Current quantum hardware is noisy and has limited qubits.
- ▶ **Quantum Software:** Algorithms need to be designed for noisy quantum computers (NISQ devices).
- ▶ **Data Encoding:** Encoding classical data into quantum states is a complex task.
- ▶ **Scalability:** It's unclear how quantum models will scale to large datasets.

# Conclusion

- ▶ Quantum machine learning is an exciting field that has the potential to revolutionize the way we approach machine learning tasks.
- ▶ It integrates quantum computing principles with machine learning to leverage the power of quantum mechanics for faster and more efficient algorithms.
- ▶ While quantum hardware is still in the early stages, the future of QML holds immense promise, especially for complex problem-solving.

# References

- ▶ **Books:**

- ▶ "Quantum Computing for Computer Scientists" by Noson S. Yanofsky, Mirco A. Mannucci
- ▶ "Quantum Machine Learning" by Peter Wittek

- ▶ **Papers:**

- ▶ "Supervised Learning with Quantum Computers" by J. Biamonte et al.