Quantum AI mini Seminar series

Quantum Fundamentals

- Quantum Power
  - One chip checks many paths at once (parallel thinking)
  - Classical = tries one at a time
- Why Quantum for AI
  - AI has huge spaces to search (like hyperparameters or paths)
  - Quantum explores more options faster
- Still mysterious
  - It works—but no one fully knows why (just how nature works)

Classical Bits vs. Qubits

- Classical Bits
  - Just 0 or 1 (clear cut)
  - Always gives same answer if you run again
- Qubits
  - Can be 0 and 1 at same time → *superposition*
  - Has 3D spin (on Bloch sphere)
  - Once you measure it → *collapses* to 0 or 1
  - Example: like flipping a coin but it spins until you look
- Entanglement
  - Qubits can be linked → affect each other even if far apart
  - Example: twin dice — roll one and the other "knows"
  - Used for quantum communication + more powerful circuits

Superposition & Entanglement in AI

- Superposition
  - Try many answers at once
  - Saves time → better for huge AI tasks
- Entanglement
  - Helps connect data, qubits can share info
  - Good for graphs, high-dimensional data
- Example:
  - Bell State = two entangled qubits
  - Collapse = final measured state (what's left after you "look")

Quantum Gates (Tools)

- Pauli-X → flips 0 ↔ 1 (like NOT gate)
- Z Gate → changes phase (used in logic)
- Hadamard (H) → puts qubit into superposition
- CNOT → makes entanglement
- Important: All quantum gates are reversible

- Dirac Notation: |0⟩ (called "ket") and ⟨0| (called "bra")

Simulation & Circuits

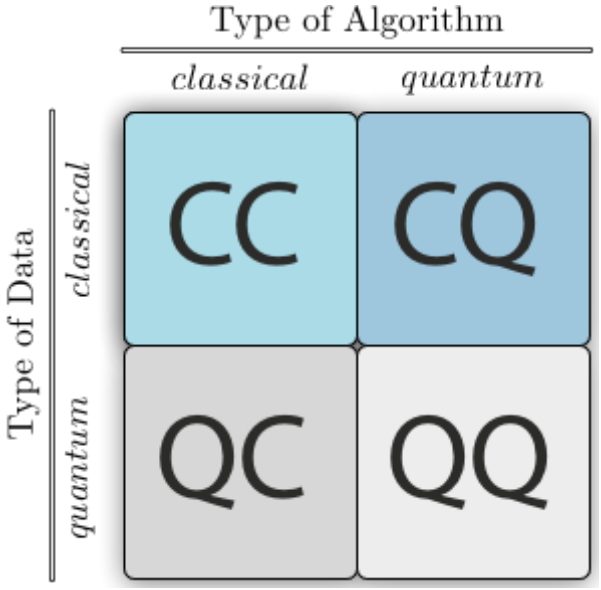
- Classical computers
  - Good for testing small circuits
  - Slow for full-scale quantum tasks
- Quantum deployment
  - Needs proper circuits (depends on the task)
  - Some setups can take hours to run

Applications in AI

- Hyperparameter Search
  - Use Grover's Algorithm → faster search
- Optimization
  - Find best path or choice (ex: robot with water tank in a forest)
- Real Companies
  - ProteinQure → finds new drugs
  - D-Wave → supply chain optimization
  - CQC → improves NLP
  - Toshiba → secure networks

Quantum Algorithms for AI

- Grover's Algorithm
  - Speeds up search (ex: finding needle in haystack)
  - Used in tuning AI models
- QFT (Quantum Fourier Transform)
  - Turns complex wave into simple one
  - Used in AI for pattern detection & optimization



- QAOA
    - Solves graph problems (like scheduling or routing)
    - Good for logistics + planning
- VQE
    - Mix of quantum + classical
    - Used to optimize parameters (like weights in ML)
    - Loop: set guess → measure → adjust → repeat
- QSVM
    - Quantum version of SVM (classifier)
- Quantum Walks
    - Move through a graph faster
    - Good for ranking nodes, pathfinding

Data in Quantum

- Amplitude Encoding
    - Vector stored in amplitude
- Angle Encoding
    - Vector turned into angle on Bloch sphere
- Quantum Feature Maps
    - Turns normal data into quantum data for AI

Quantum Clustering

- Basic
    - Uses qubit distances to group data
- Dynamic
    - Clusters change over time → better for live data
- Limited Basis
    - Uses fewer states → saves qubits/resources

Challenges

- Noise: outside energy messes up qubits
- Decoherence: qubits lose info fast
- Qubit Limits: we don’t have enough powerful ones yet
- Quantum Error Correction: hard but needed

Real-World Example: Maldives Disaster

- Scenario: Typhoon hits main island
- Goal: Send supplies from nearby islands
- Tools Used:
    - Quantum Walk (to explore map)
    - Encoded data: demand, supply, distance
    - Used coin + shift operators + Grover's to find best path

Quantum Graph Neural Networks (QGNNs)

- What is GNN
    - A model that learns from nodes and connections (like social networks)
- Quantum Part
    - Use qubits to store node info
    - Circuits process all graph paths at once (superposition)
    - Helps with graph tasks like pathfinding and node ranking

Tools & Learning

- Languages
    - Python + Qiskit (IBM tool)
- Resources
    - IBM courses with certs
    - Projects you can build