AI CERTs™

AI+ Quantum™ (5 Days)

Program Detailed Curriculum

AI CERTs™ AI+ Quantum™

Executive Summary

This comprehensive course provides a deep dive into the intersection of Artificial Intelligence (AI) and Quantum Computing, exploring fundamental concepts, advanced techniques, and ethical considerations. Participants will gain insights into Quantum Computing Gates, Circuits, and Algorithms, with a particular focus on their application in AI domains. Through discussions on Quantum Machine Learning and Quantum Deep Learning, attendees will discover how these technologies are reshaping traditional AI methodologies. Ethical implications are carefully examined throughout, alongside an exploration of current trends and future outlooks. Real-world case studies offer practical insights, while a hands-on workshop solidifies understanding, making this course essential for professionals and enthusiasts alike seeking to navigate and contribute to the transformative landscape of AI and Quantum Computing.

Course Prerequisites

- A foundational knowledge of AI concepts, no technical skills are required.
- Willingness to exploring unconventional approaches to problem-solving within the context of AI and Quantum.
- Openness to engage critically with ethical dilemmas and considerations related to AI technology in quantum practices.

Module 1

Overview of Artificial Intelligence (AI) and Quantum Computing

1.1 Artificial Intelligence Refresher

- **Machine Learning Fundamentals:** Introduction to key concepts, algorithms, and applications of machine learning, including supervised, unsupervised, and reinforcement learning.
- **Deep Learning Fundamentals:** Overview of deep learning principles, neural network architectures, and key techniques like backpropagation and convolutional neural networks.

1.2 Quantum Computing Refresher

- **Introduction to Quantum Computing:** Basic concepts of quantum computing, quantum bits (qubits), and the principles that differentiate it from classical computing.
- **Introduction to Qiskit SDK:** Introduction to IBM's Qiskit SDK for quantum computing, including installation, setup, and basic usage for quantum programming.
- **Introductory Tutorial:** Hands-on tutorial for beginners to understand and apply fundamental concepts in quantum computing using Qiskit SDK.

Module 2

Quantum Computing Gates, Circuits, and Algorithms

2.1 Quantum Gates and their Representation

- **Single Qubit Gates:** Introduction to single qubit gates, including Pauli-X, Y, Z, and Hadamard gates, fundamental for manipulating qubit states in quantum computing.
- **Measurement:** Explains the process of measuring qubits, collapsing quantum states into classical outcomes, crucial for interpreting quantum computations.

2.2 Multi Qubit Systems and Multi Qubit Gates

- **Multi-Qubit Systems:** Covers the principles and complexities of multi-qubit systems, including entanglement and superposition, essential for advanced quantum computing operations.
- **Multi-Qubit Gates:** Overview of multi-qubit gates like CNOT, essential for quantum entanglement and implementing complex quantum algorithms in multi-qubit systems.

Module 3

Quantum Algorithms for AI

3.1 Core Quantum Algorithms

- **Deutsche-Jozsa Algorithm:** Introduction to the Deutsch-Jozsa algorithm, demonstrating quantum advantage by solving specific problems faster than classical algorithms.
- **Bernstein-Vazirani Algorithm:** Explains the Bernstein-Vazirani algorithm, which efficiently identifies a hidden string using quantum computing principles, outperforming classical methods.
- **Grover's Algorithm:** Overview of Grover's algorithm for quantum search, providing a quadratic speedup in searching unsorted databases compared to classical algorithms.

3.2 QFT and Variational Quantum Algorithms

- **Quantum Fourier Transform:** Introduction to the Quantum Fourier Transform, a key quantum algorithm for processing periodicity, crucial in many quantum computing applications.
- **Variational Theory:** Covers variational methods in quantum computing, combining classical optimization with quantum states to solve complex optimization problems.
- **Quantum Approximate Optimization Algorithm:** Explains the Quantum Approximate Optimization Algorithm (QAOA), which leverages quantum principles for solving combinatorial optimization problems efficiently.

Module 4

Quantum Machine Learning

4.1 Algorithms for Regression and Classification

- **Introduction to QML:** Overview of Quantum Machine Learning (QML), integrating quantum computing with machine learning to enhance computational capabilities and algorithm performance.
- **Harrow-Hassidim-Lloyd (HHL) Algorithm:** Explains the HHL algorithm for solving linear systems of equations exponentially faster than classical methods using quantum computing.
- **Quantum Classifier Algorithm:** Introduction to quantum classifier algorithms, leveraging quantum principles to improve classification tasks in machine learning applications.

4.2 Algorithms for Dimensionality and Clustering

- **Quantum Support Vector Machines:** Covers Quantum Support Vector Machines (QSVM), enhancing traditional SVMs with quantum computing to increase efficiency and classification performance.
- **Quantum k-Nearest Neighbors:** Overview of Quantum k-Nearest Neighbors (QkNN), improving the classical k-NN algorithm with quantum speedup for faster data classification.
- **Other Resources:** Lists additional materials and references for further learning and exploration of quantum computing and quantum machine learning topics.

Module 5

Quantum Deep Learning

5.1 Algorithms for Neural Networks – Part I

- **Quantum Neural Networks (QNNs):** Introduction to Quantum Neural Networks (QNNs), combining quantum computing with neural networks to enhance machine learning capabilities and efficiency.
- **Quantum Convolutional Neural Networks (QCNNs):** Overview of Quantum Convolutional Neural Networks (QCNNs), leveraging quantum computing for improved image processing and pattern recognition in neural networks.
- **Quantum Generative Adversarial Networks (QGANs):** Explains Quantum Generative Adversarial Networks (QGANs), utilizing quantum mechanics to enhance generative models for creating and distinguishing data samples.

5.2 Algorithms for Neural Networks – Part II

- **Quantum Recurrent Neural Networks (QRNNs):** Covers Quantum Recurrent Neural Networks (QRNNs), integrating quantum computing with RNNs to improve processing of sequential and time-series data.
- **Quantum Variational Autoencoders (QVAEs):** Introduction to Quantum Variational Autoencoders (QVAEs), enhancing traditional VAEs with quantum computing for more efficient data encoding and generation.

Module 6

Ethical Considerations

6.1 Ethics for Artificial Intelligence

- **Risks, Challenges, and Ethics:** Examines potential risks, challenges, and ethical considerations in quantum computing, emphasizing responsible development and deployment.
- **Framework and Guidelines:** Outlines frameworks and guidelines for ethical and secure quantum computing practices, ensuring adherence to standards and best practices.

6.2 Ethics for Quantum Computing

- **Current Scenario:** Discusses the current state of quantum computing, highlighting ongoing developments, challenges, and real-world applications.
- **Guidelines:** Presents detailed guidelines for implementing quantum computing solutions, focusing on security, ethics, and practical considerations.
- **Considerations:** Explores key considerations in quantum computing, including technical, ethical, and regulatory aspects to ensure responsible usage and development.

Module 7

Trends and Outlook

7.1 Current Trends and Tools

- **Current Trends:** Overview of current trends in quantum computing, highlighting latest advancements, research focus areas, and emerging applications.
- **Quantum Tools:** Explores various quantum computing tools and software, essential for developing and running quantum algorithms and applications.

7.2 Future Outlook and Investment

- **Future Predictions:** Discusses future predictions for quantum computing, including potential breakthroughs, market growth, and transformative impacts on various industries.
- **Funding and Investments:** Examines the landscape of funding and investments in quantum computing, identifying key players, investment trends, and economic implications.

Module 8

Use Cases & Case Studies

8.1 Quantum Use Cases

- **Use Cases:** Illustrates diverse applications of quantum computing, spanning cryptography, drug discovery, optimization, and machine learning, showcasing its transformative potential.

8.2 QML Case Studies

- **IBM:** Highlights IBM's quantum computing initiatives, including Qiskit development, quantum cloud services, and collaborations, contributing significantly to quantum advancements.
- **Quantinuum:** Spotlights Quantinuum's role in advancing quantum computing through strategic partnerships, quantum software development, and fostering innovation in quantum technologies.
- **Rigetti:** Examines Rigetti's contributions to the quantum computing ecosystem, encompassing quantum hardware development, quantum software platforms, and quantum education initiatives.

Module 9

Workshop

9.1 Project – I: QSVM for Iris Dataset

- Utilizes QSVM to classify Iris dataset, demonstrating quantum machine learning capabilities in pattern recognition and classification tasks.

9.2 Project – II: VQC/QNN on Iris Dataset

- Explores VQC/QNN applications on Iris dataset, showcasing quantum variational circuitsand neural networks for data analysis and classification.

9.3 Bonus: IBM Quantum Computers

- Provides insights into IBM Quantum Computers, exploring their architecture, capabilities, and opportunities for experimentation and development in quantum computing.