QUANTUM COMPUTING MACHINE LEARNING TRAINER

MODEL - QUANTUMML100

This Machine Learning with Quantum Computing trainer has been designed with a view to provide practical and experimental knowledge of Quantum Computing Machine learning Technology.

SPECIFICATIONS

EXPERIMENTS

A. Introduction to Quantum Computing and Quantum Physics

1. How is Quantum Computing Different?
2. Introduction to Quantum Physics
3. Quantum Physics Through Photon Polarization
4. DiVincenzo's Criteria for a Quantum Computer

B. Math Foundation Complex Numbers, Probability, Linear Algebra & Logic

5. Boolean Algebra
6. Boolean Variables and Operators
7. Truth Tables
8. Logic Gates
9. Logic Circuits
10. AND Gate
11. OR Gate
12. NOT Gate
13. Multiple Input Gates
14. Equivalent Circuits
15. Universal Gate NAND
16. Exclusive OR
17. XOR for Assignment
18. XOR of Bit Sequences
19. Introduction to Cryptography
20. Cryptography with XOR
21. Shared Secret
22. Importance of Randomness
23. Breaking the Code
24. Introduction to Probability
25. Probability of a Boolean Expression
26. Mutually Exclusive Events
27. Independent Events
28. Manipulating Probabilities With Algebra
29. P (Mutually Exclusive Events)
30. P (Independent Events)
31. Complete Set of MutEx Events

32. P (A OR B)
33. P (Bit Values)
34. Analysis With Venn Diagrams
35. Venn Diagram P (A AND B)
36. Venn Diagram P (A OR B)
37. Venn Diagram P (NOT A)
38. Conditional Probability
39. Introduction to Statistics
40. Random Variables
41. Mapping Random Variables
42. Mean, Average, Expected Value, ...
43. Beyond Mean
44. Standard Deviation
45. Combinations of Random Variables
46. Correlation
47. Analysis of Correlation
48. Introduction to Complex Numbers
49. Imaginary i
50. Addition
51. Subtraction
52. Multiplication by a Real
53. Division by a Real
54. Complex Multiplication
55. Complex Conjugates
56. Squared Magnitude
57. Complex Division
58. Euler's Formula
59. Polar Form
60. Fractional Powers
61. Complex Cube Roots of
62. Square Root of i
63. D Coordinates
64. Matrices
65. Matrix Dimensions
66. Matrix Addition
67. Matrix Subtraction

68. Scalar Multiplication
69. Matrix Multiplication
70. More Multiplications
71. When is Multiplication Possible?
72. Not Commutative
73. Associative and Distributive
74. Dimension of Result
75. Odd Shaped Matrices
76. Outer Product
77. Inner Product
78. Identity Matrix
79. Matrix Inverse
80. Transpose
81. Transpose Examples
82. Transpose of Product
83. Complex Conjugate of Matrices
84. Adjoint
85. Unitary
86. Hermitian
87. Hermitian and Unitary
88. Why Hermitian or Unitary ?
89. Vectors and Transformations
90. Rotation in D
91. Special Directions
92. Eigen Vectors and Eigen Values
93. More Eigen Vectors
94. Computing Eigen Values

C. Quantum Cryptography

95. Photons
96. Photon Polarization
97. Experiments with Photon Polarization
98. No-Cloning Theorem
99. Encoding with XOR
100. Encryption with Single-Use Shared-Secrets
101. Encoding Data in Photon Polarization

102. Making the Protocol Secure
103. Exchanging Polarization Angles
104. Why is the BB protocol secure?
105. Analysis

D. Developing a Math Model for Quantum Physics

106. Modeling Physics with Math
107. Subtractive Probabilities Through Complex Numbers
108. Modeling Superposition Through Matrices
109. Overview of Math Model

E. Quantum Physics of Spin States

110. Introduction to Spin States
111. Basis
112. Column Matrix Representation of Quantum State
113. State Vector
114. Experiments with Spin

F. Modeling Quantum Spin States with Math

115. Analysis of Experiments
116. Dirac Bra-Ket Notation
117. On Random Behavior

G. Reversible and Irreversible State Transformations

118. Irreversible Transformations Measurement
119. Reversible State Transformations

H. Multi-Qubit Systems

120. Analyzing Multi-Qubit Systems

I. Entanglement lecture

121. Entanglement

J. Understanding Superposition and Entanglement with Quantum Simulators

122. Download the Simulator Code
123. Installing Java and Running the Simulators
124. Launching the Superposition Simulator
125. Classical Photon
126. Quantum Photon
127. No Cloning
128. Measurement is Irreversible
129. Deterministic vs Probabilistic
130. Running the Simulator
131. Superposition
132. Measurement and Superposition
133. Two Photon Systems
134. Entanglement
135. Simulating Entanglement
136. Independent Photons
137. Effect of Measurement

K. Quantum Computing Model

138. Quantum Circuits
139. Fanout
140. Uncomputing
141. Reversible Gates
142. Quantum NOT
143. Other Single Qubit Gates
144. CNOT Gate
145. CCNOT Toffoli Gate
146. Universal Gate
147. Fredkin Gate
148. Effects of Superposition and Entanglement on Quantum Gates

L. Quantum Programming with Microsoft Q#

149. Q#, Qiskit, or Cirq?
150. Installing Q#
151. Troubleshooting Q#
152. Q# Simulation Architecture

153. Q# Controller
154. Q# Execution Model
155. Measuring Superposition States
156. Overview of -Qubit Simulation Framework
157. Set Operation
158. Iterative Measurement
159. Verifying Output after Initialization -
160. Verifying Output after Initialization -
161. NOT Operation
162. Superposition
163. SWAP
164. CNOT
165. Significance of Superposition and Entanglement
166. Effect of Superposition on Quantum Gates
167. Toffoli Gate General Configuration
168. Verifying Results
169. Toffoli Configured as NOT
170. Toffoli Configured as AND
171. Toffoli Configured as Fanout

M. IBM Quantum Experience

172. IBM Quantum - Note
173. IBM Quantum Experience

N. Quantum Circuits

174. Quantum Bit String Comparator (QBSC), Midpoint Quantum Comparator (MQC)
175. Quantum Half-Adder, Full-Adder
176. Quantum Half-Substractor, Full-Substractor
177. Quantum Multiplexer, Demultiplexer
178. Quantum Adder Circuits
179. Quantum Multiplier-Accumulator
180. Quantum BCD Priority Encoder, Decoder
181. Quantum Latches, Counters
182. Quantum Barrel Shifter
183. Quantum Increment/Decrement
184. Quantum RAM

185. Quantum ALU
186. Quantum Fourier Transform

O. Basic Quantum Algorithms

187. Conceptual Understanding of Quantum Algorithms
188. Deutsch-Jozsa Algorithm - Phase Kickback
189. Simon's Algorithm - Generalized Born Rule
190. Quantum Communication Superdense Coding
191. Quantum Phase Estimation (Eigen Solver)
192. Quantum Search Grover's Algorithm
193. Quantum Factorization Shor's Algorithm
194. Quantum Teleportation
195. Quantum Counting
196. Hamiltonian Simulation
197. Quantum Walks
198. Quantum Matrix Inversion HHL Algorithm
199. Variational Quantum Eigensolver
200. Quantum Approximate Optimization Algorithm
201. Quantum Least Square Fitting

P. Quantum Photonics Programs

202. Strawberry Fields Quantum Photonics & QuModes
203. (CVQIT) Continuous Variable Quantum Information Theory
204. Fock States, Wigner Function, Photonic Measurements
205. Quantum Teleportation & Gaussian Cloning
206. Boson Sampling Model
207. Time Domain Photonic Circuits
208. Instantaneous Quantum Polynomial

Q. Quantum Programming and Algorithms with IBM Qiskit

209. Qiskit Code Resources
210. What is Qiskit?
211. Installing Python and Qiskit
212. Interactive Python
213. Jupyter Notebooks
214. Spyder Python IDE

215. Variables and Assignment
216. Data Types
217. Operators
218. Type Conversion
219. Strings
220. Lists
221. Dictionaries
222. Loops
223. Decisions
224. Functions
225. Object Oriented Programming
226. Exceptions
227. Modules
228. Quantum Circuits
229. Running a Circuit
230. Circuit Matrix
231. Implementing BB Cryptography
232. Shor's Algorithm
233. Shor's Algorithm - Temporary Fix

R. Machine Learning Foundation

234. Introduction to Machine Learning
235. What is AI?
236. Structure of ML Systems
237. Learning With Models
238. Speed Up Learning
239. Underfit & Overfit
240. Classification
241. Sigmoid Models
242. Regularization
243. Machine Learning Libraries
244. Machine Learning Coding
245. Multi-Layer Network
246. Convolution
247. Recurrent
248. Quantum Machine Learning - Pennylane

249. Quantum Embedding
250. Circuit Ansatz, Hybrid Computation, Quantum Node
251. Variational Circuits, Quantum Gradient, Parameter Shift Rule
252. Quantum Feature Map
253. Barren Plateus, Narrow Gorge Phenomenon
254. Relevance of QNN
255. Optimization & machine learning with TensorFlow
256. Quantum State Learning
257. Pennylane VQE Tutorial

S. Quantum Error Correction

258. Causes of Quantum Error & Quantum Noise (BF, NF, BNF)
259. Physical vs. Logical Qubits & Shor Code
260. Stabilizers & Quantum Noise Model
261. XZZX Surface Coding

T. Quantum Information Theory

262. Types of Entropy and Mutual Information
263. Kullback Leibler Divergence, Quantum Relative Entropy
264. Holevo's Theorem
265. Landauer Principle, Margolus-Levitin Theorem
266. Distance Measures for QIT Trace Distance & Fidelity
267. Uncertainty Principle
268. Solovay–Kitaev Theorem
269. Wehrl Entropy, SSA, Lieb's Theorem
270. Gottesman–Knill theorem, Eastin–Knill theorem
271. Bennet's Laws, Partial Transpose, Entanglement Measures
272. No-Broadcasting Theorem, Superbroadcasting
273. No-Hiding Theorem, No-Communication Theorem
274. No-Teleportation Theorem, No-Deleting Theorem

U. Quantum Communication

275. LOCC, Entanglement Swapping
276. Quantum Channels, Channel Capacity
277. Quantum Repeaters & Entanglement Distillation
278. Quantum Key Distribution

V. Quantum Computer Architecture & Hardware

279. OpenQASM Quantum Assembly
280. Photonics Hardware
281. Ion Trapping Technique
282. Superconducting Quantum Interference Device (SQUID

W. Quantum Machine Learning With Qiskit

283. Quantum Machine Learning with KNN
284. KNN Problem Description
285. Code for Classical KNN
286. Code for Quantum KNN
287. Math for Classical KNN
288. Math Prerequisites for Quantum KNN
289. Math for Quantum KNN
290. Connecting Math and Code for Classical KNN
291. Connecting Math and Code for Quantum KNN
292. Introduction to Classification
293. Support Vector Machines - Separation
294. Support Vector Machines - Overfitting
295. Support Vector Machines - Soft Margins
296. Support Vector Machines - Higher Dimensions and Kernels
297. Support Vector Machines - Multiple Classes
298. Quantum Support Vector Machines
299. Significance of Quantum Machine Learning
300. IBMQ - Quantum Experience
301. Quantum Support Vector Machines (QSVM)
302. Principle Component Analysis (PCA)
303. Variational Quantum Classifiers (VQC)
304. Quantum K-Means Clustering (KMC)
305. Quantum Convolutional Neural Network (CNN)
306. Quantum Optical Neural Network (QONN)
307. (Exercise) Quantum GAN

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