Tutorial Sheet-4

PHN-640 QUANTUM COMPUTING SPRING 2024

1. Construct a 2×2 matrix ψ_c and use the classical variational method, to find the minimum eigenvalue of the following matrices.

   $(i)\ H_1 = \begin{bmatrix} 1 & 0.2 \\ 0.1 & 2 \end{bmatrix} \qquad (ii)\ H_2 = \begin{bmatrix} 2 & 0.1 \\ 0.3 & -2 \end{bmatrix} \qquad (iii)\ H_3 = \begin{bmatrix} 4 & -0.1 \\ 0.2 & 2 \end{bmatrix}$

2. Using the minimization rule of the classical variational method, construct a 3×3 matrix ψ_c to find the minimum eigenvalue of a matrix H.

$$H = \begin{bmatrix} 1 & 0.1 & 0 \\ 0.3 & 4 & 0.2 \\ 0 & 0.1 & 3 \end{bmatrix}$$

   (a) Use ψ_c in terms of a single parameter c.

   (b) Use $\psi_{(c_1,c_2)}$ in terms of two parameters c_1 and c_2.

3. Define a circuit $\texttt{qc} = \texttt{QuantumCircuit}(\texttt{n}, \texttt{n}-1)$ to find the phase ϕ of your choice.

   (a) Apply Hadamard gate to all counting qubits and X gate to the nth qubit.

   (b) Apply the unitary gate controlled by the counting qubit q in a for loop of range $(n-1)$ and defined by a diagonal matrix

$$U = \begin{bmatrix} 1, & 1, & 1, & \exp(2\pi\phi\imath 2^q) \end{bmatrix}$$

   (c) Apply the inverse QFT and simulate qc for 1000 value of shots.

   (d) Plot the histogram of counts for $n = 10$.

   (e) Convert the most frequent count to an integer a and print $\phi = a/2^{n-1}$.

4. Define a quantum circuit with 4 qubits first register and 1 qubit (u) second register.

   (a) Apply Hadamard gate to all qubits of first register and X gate to secound register's qubit.

   (b) Apply $cp(\pi/3)$ gate for 2^n times where $n = \{3, 2, 1, 0\}$ between qubits of the first register and second register's qubit.

   (c) Repeat step 3(c) and plot the histogram.

   (d) Print the calculated value of phase and error w.r.t. actual value.

5. Define an array for the number of shots as $S = [\texttt{500}, \texttt{1000}, \texttt{2000}, \texttt{4000}, \texttt{6000}]$.

   (a) Repeat $Q.No.3$ for each value of S taking $n = 4$ and $\phi = \pi/4$.

   (b) Calculate the error each time and store it in an array named `Error`.

   (c) Plot `Error` vs S.

6. Repeat $Q.No.3$ for $n = [3, 4, 5, 6, 7]$ and $\phi = 2\pi/5$. Calculate the error each time and store it in an array named `Error`. Plot `Error` vs n.

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