Lecture: Quantum Computing

Lecture 1 (Part 1) Quantum Computing

Classical vs Quantum Computing, Quantum Circuits, Quantum Gates

classical model = abstract of some real-world thing, which classical and quantum computers and how we call gates.

classical computer: $\text{INPUT} \xrightarrow{\text{LOGIC GATE}} \text{OUTPUT}$

→ simple logic gates = gates that act on simple bits. classical example:

classical example: $\text{INPUT} \xrightarrow{\text{LOGIC GATE}} \text{OUTPUT}$

→ we generally assume that quantum gates are performed by unitary matrices $U^\dagger U = I$

Circuit diagram representation

$$\begin{array}{ccc} \text{INPUT} & \xrightarrow{\text{LOGIC GATE}} & \text{OUTPUT} \\ \text{INPUT} & \xrightarrow{U} & \text{OUTPUT} \end{array}$$

Quantum example 1: a quantum circuit (a unitary) quantum gates can be represented as unitary matrices.

$U \circ U = U^2$

$$\begin{array}{ccc} \text{INPUT} & \xrightarrow{U} & \text{OUTPUT} \\ \text{INPUT} & \xrightarrow{U} & \text{OUTPUT} \end{array}$$

Here the matrix U can be represented as:

$$\begin{array}{ccc} \text{INPUT} & \xrightarrow{U} & \text{OUTPUT} \\ \text{INPUT} & \xrightarrow{U} & \text{OUTPUT} \end{array}$$

$$\begin{array}{ccc} \text{INPUT} & \xrightarrow{U_1} & \text{OUTPUT} \\ \text{INPUT} & \xrightarrow{U_2} & \text{OUTPUT} \end{array}$$

$$\begin{array}{ccc} \text{INPUT} & \xrightarrow{U_1} & \text{OUTPUT} \\ \text{INPUT} & \xrightarrow{U_2} & \text{OUTPUT} \end{array}$$

$|0\rangle \to |0\rangle$

$|1\rangle \to |1\rangle$

$|0\rangle \to \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$

$|1\rangle \to \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$

$|\psi\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$

$|\psi\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$

$|\psi\rangle \to U|\psi\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$

$|\psi\rangle \to U|\psi\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$

$|\psi\rangle \to U|\psi\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$

$|\psi\rangle \to U|\psi\rangle = \begin{pmatrix} 1 \\ 0