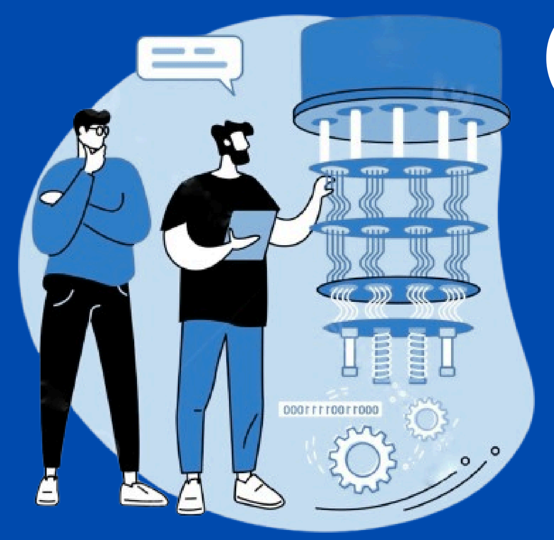

# Qubit Manipulation in Quantum Circuits - Solving Grover's Algorithm for 2 and 3-Qubit Systems

Exploring Quantum Circuit Dynamics through Grover's Search Algorithm in 2 and 3-Qubit Architectures.


Topic : Quantum Computing Concepts & Qubit Manipulation || *Project by Kalash Sanjay Kothari & Purbadri Ray Chaudhuri*

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## 1. SCOPE OF OUR RESEARCH

Qubit ------> the fundamental unit of quantum information

------> can exist in a linear superposition of both 0 & 1

------> the Dirac notation : $|\psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle$

*This Poster...*

- Explores the fundamentals of quantum computing through the manipulation of qubits
- Focuses on essential quantum gates: Pauli$(\mathrm{X}, \mathrm{Y}, \mathrm{Z})$, Hadamard, Rotation $(R_x, R_y, R_z)$ and CNOT
- Examines Grover's Algorithm as a case study for efficient unstructured search using amplitude amplification
- Introduces circuit knitting techniques to overcome hardware limitations in current quantum systems
- Bridges theoretical concepts and practical implementations of quantum algorithms
- Highlights the importance of qubit manipulation in designing and executing effective quantum circuits

## 2. QUANTUM GATES

- Quantum gates are unitary operations that transform qubit states

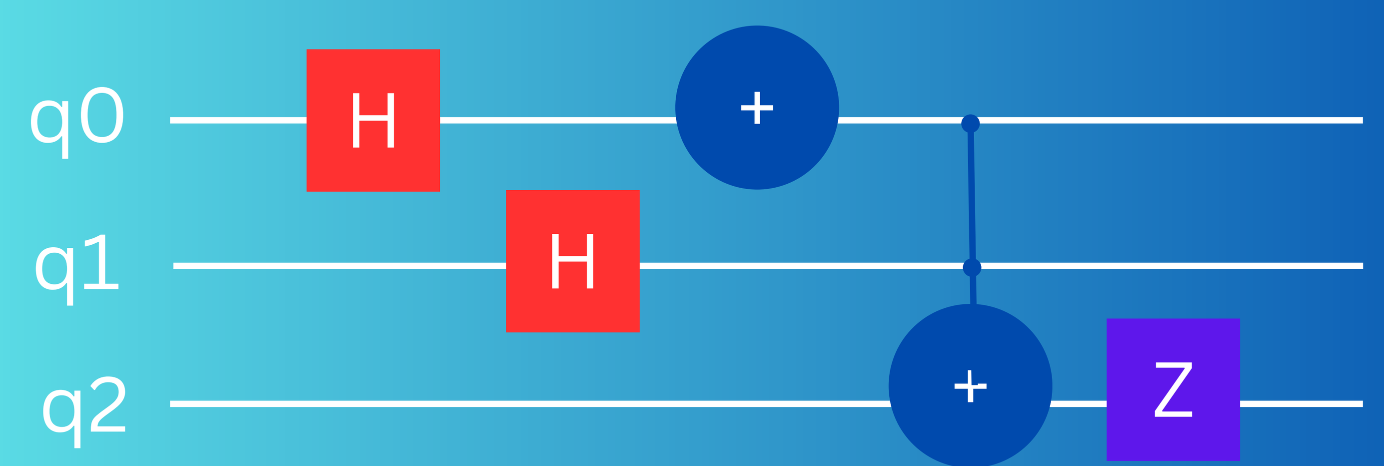


*fig. 1 A general Quantum circuit lookup with different gates*

- Common gates include: Hadamard (H) (Creates superposition), Pauli-X (Bit flip), Phase (S, T) and Rotation $(R_x, R_y, R_z)$ (Phase and orientation control)

## 4. CIRCUIT KNITTING : CUTTING & RECONNECTING QUANTUM CIRCUITS

- Cutting: Large Grover circuits are divided into smaller subcircuits that can run on limited-qubit NISQ hardware
- Knitting: Outputs from these subcircuits are classically combined to emulate the behavior of the full quantum circuit
- Application: Although not needed for 2–3 qubit cases, this approach allows simulation of larger Grover circuits by preserving algorithm flow under current hardware limitations

*real world applications......*

- Cryptanalysis: Speeds up brute-force key searches
- Database Search: Locates target items in unsorted data without sorting or indexing

## 5. CONCLUSION

- Implemented Grover's Algorithm on 2- and 3-qubit systems, showcasing effective qubit manipulation using key quantum gates
- Highlighted circuit knitting as a scalable workaround for hardware limits, enabling larger quantum circuit simulations
- Connected theory to real-world applications, emphasizing the role of precise qubit control in search, cryptanalysis and optimization tasks

## 6. REFERENCES


- Grover, L. K. (1996). A fast quantum mechanical algorithm for database search
- Qiskit Textbook. Learn Quantum Computation using Qiskit. Retrieved from : https://qiskit.org/learn


## 3. GROVER'S ALGORITHM

Our Work

Research Paper

Code

- Objective: Solve for the marked input $\mathrm{x}^*$ where $\mathrm{f}(\mathrm{x}^*) = 1$ , using only $\mathbb{O}(\sqrt{\mathbb{N}})$ oracle queries (compared to $\mathbb{O}(\mathbb{N})$ in classical search)
- Step 1: Initialize all qubits in a uniform superposition using Hadamard gates
- Step 2: Apply the oracle, which flips the phase of the correct (marked) solution
- Step 3: Apply the diffusion operator to amplify the amplitude of the marked state
- Step 4: Repeat steps 2 and 3 approximately π/4√N times to maximize the probability of measuring the correct state

### Geometric Interpretation

- The process performs a rotation in Hilbert space toward the marked state with each iteration

## RESULTS...

*for 2-Qubit system...*

- Create superposition, flip marked state's amplitude with oracle, amplify via diffusion, then measure to find the target state.

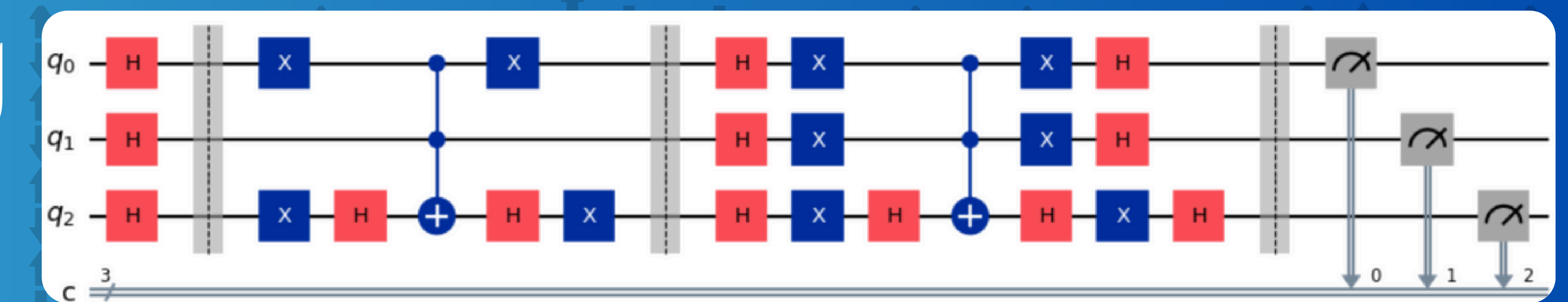


*fig. 2 Above shown is the circuit build up for test case |010> of grover's algorithm*

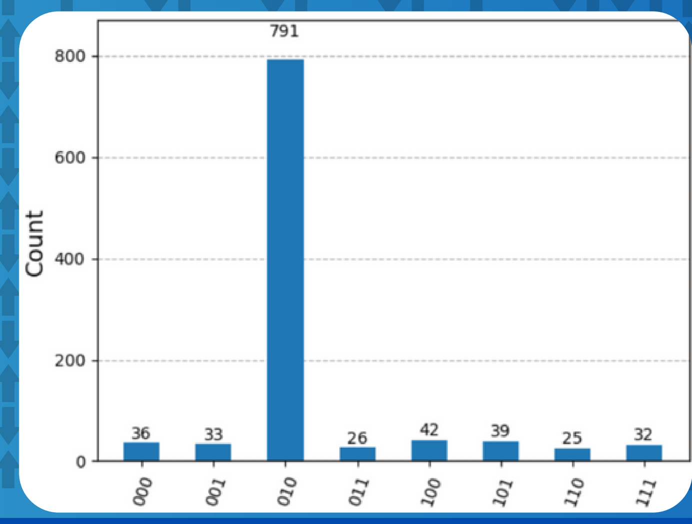


*fig. 3 succesful simulator run of Grover's algorithm on state |010>*

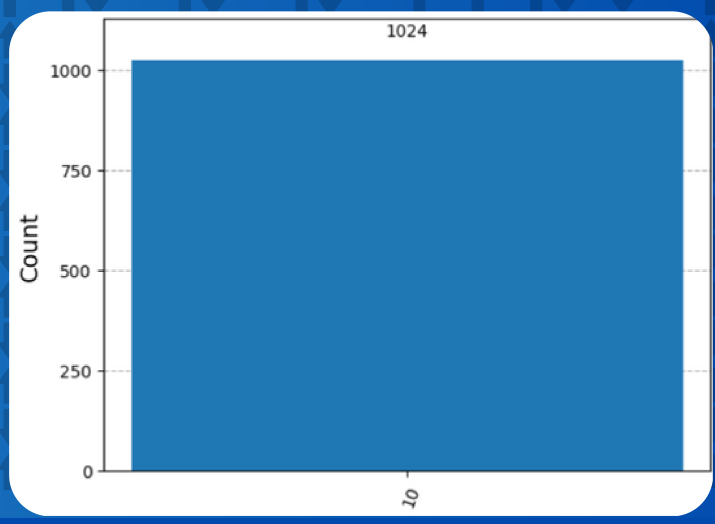


*fig. 4 succesful simulator run of Grover's algorithm on state |10>*