

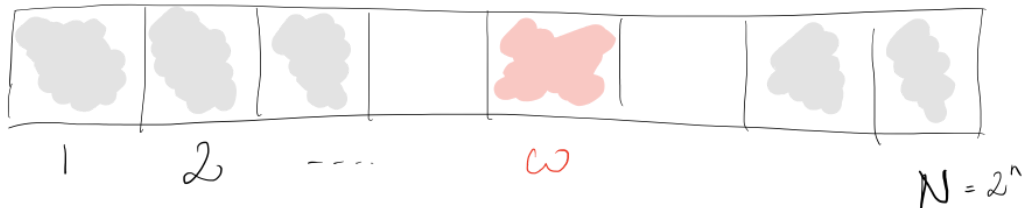
# Grover's Search Algorithm on a Quantum Computer (Solving a Sudoku Problem using Grover's Algorithm)

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## Abstract

Grover's Algorithm is a Quantum Algorithm which conducts a search on an unsorted dataset with  $N$  entries in  $O(\sqrt{N})$  time and  $O(\log N)$  storage space [1]. Classically, performing a linear search on an unsorted dataset takes  $O(N)$  time in the worst-case scenario. Whereas, Grover's Algorithm implemented on a Quantum Computer provides a quadratic speed up to the same problem.

Suppose we are given a large list of  $N$  items. Among these items there is one item that we wish to locate; we will call this one the winner ( $w$ ). Let us say all items in the list are gray except the winner ( $w$ ), which is pink.



To find the pink box -- the marked item -- using classical computation, we would have to check on average  $N/2$  of these boxes, and in the worst case, all  $N$  of them. On a quantum computer, however, we can find the marked item in roughly  $\sqrt{N}$  steps with Grover's amplitude amplification trick. A quadratic speedup is indeed a substantial time-saver for finding marked items in long lists [2].

## Aim

The aim of this project is to implement Grover's algorithm in a search space of 4 qubits. The project would start by discussing the basic concepts of qubits in a Quantum Computer and lead to an analysis of Grover's Search Algorithm on a real Quantum Computer (IBM). In addition to the implementation of the quantum algorithm, the project

would discuss the computational complexity of Grover's Algorithm and would conclude by comparing the theoretical and real-life execution results of the algorithm [3, 4]. The algorithm would also be applied to solve a Sudoku problem.

### Topics to Discuss in the Project

Quantum Computers, Qubits, Grover's Algorithm, Computational Complexity, Oracle, Amplitude, Theoretical Results, Execution Results.

### Outcome

A detailed analysis of the implementation on Grover's Algorithm for unsorted search on a programmable IBM Quantum Computer with the help of available Quantum Gates and Quantum Oracles. Explore the application of Grover's Algorithm in solving a Sudoku problem.

### Tools to be Used

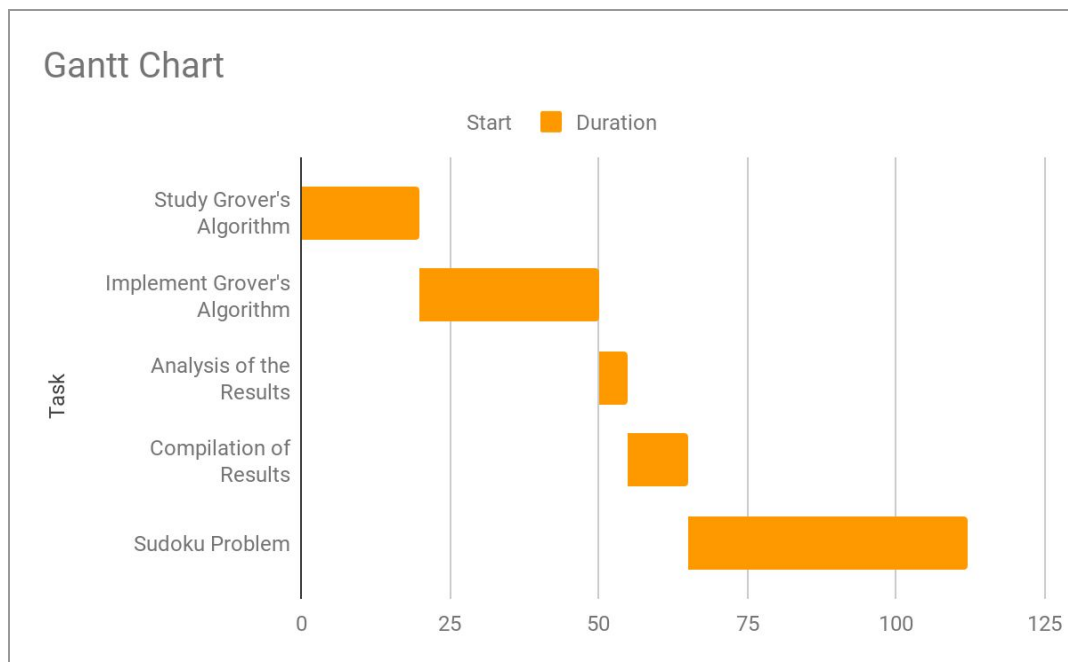
**Software Requirements:** Python, IBM Qiskit, Jupyter Notebook

**Hardware Requirements:** IBM Quantum Computer (minimum 5 qubits)

**Operating System:** Linux

### Execution Timeline

- **September 2020** - Study Grover's Algorithm
- **October 2020** - Implement Grover's Algorithm with Qiskit SDK
- **November 2020** - Analysis and Compilation of the results
- **December 2020** - Solve Sudoku Problem



## References

1. Grover LK. A fast quantum mechanical algorithm for database search. In Proceedings of the twenty-eighth annual ACM symposium on Theory of computing 1996 Jul 1 (pp. 212-219).
2. <https://qiskit.org/textbook/ch-algorithms/grover.html>
3. Figgatt C, Maslov D, Landsman KA, Linke NM, Debnath S, Monroe C. Complete 3-Qubit Grover search on a programmable quantum computer. Nature communications. 2017 Dec 4;8(1):1-9.
4. Strömberg P, Blomkvist Karlsson V. 4-qubit Grover's algorithm implemented for the ibmqx5 architecture.