QUANTUM SEARCH AND IT'S BREADTH OF APPLICATIONS

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OVERVIEW

- Search Algorithm
- Classical VS Quantum
- Grover’s Search Algorithm
- Quantum Partial Search
- Applications of Quantum Search
- Conclusion
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SEARCH ALGORITHM

- The search problem can be described informally as finding an item possessing a specific property, in a given set of N items.
- A search algorithm is one that retrieves the desired information or path from a specific search space, where instances can be categorical or continuous.
- The time complexity and space complexity of an algorithm determine its efficiency.

CLASSICAL VS QUANTUM

Leider, A., Siddiqui, S., Sabol, D.A. and Tappert, C.C., 2019, October. Quantum computer search algorithms: Can we outperform the classical search algorithms?.

- While classical computers only perform operations by manipulating binary bits with the values 0 and 1, quantum bits can represent data in multiple states.

- The property of inheriting multiple states at the same time (superposition) provides quantum computers with enormous power over classical computers.

- The algorithms designed on quantum computers to solve search queries can yield result significantly faster than the classical algorithms.

Suppose there are N items in a database.The task is to search for an item in the given database.

Classically, searching an unsorted database requires a linear search, which is O(N) in time. But in the case of quantum search, it takes O(√ N) to find the item from the database.

CLASSICAL SEARCH	QUANTUM SEARCH
Sequentially try all N possibilities	Simultaneously try all possibilities
Average search steps : N/2	Average search steps : N^(½)

GROVER’S ALGORITHM

Giri, P.R. and Korepin, V.E., 2017. A review on quantum search algorithms
Jozsa, R., 1999. Searching in Grover's algorithm

- **One of the most important quantum search algorithm.**
- **Proposed by Lov Grover in 1996**.
- Quantum algorithm for searching an unsorted database with *N* entries in $O(\sqrt{N})$ time and using $O(\log N)$ storage space
- This algorithm can speed up an unstructured search problem quadratically.
- Grover's algorithm is probabilistic.

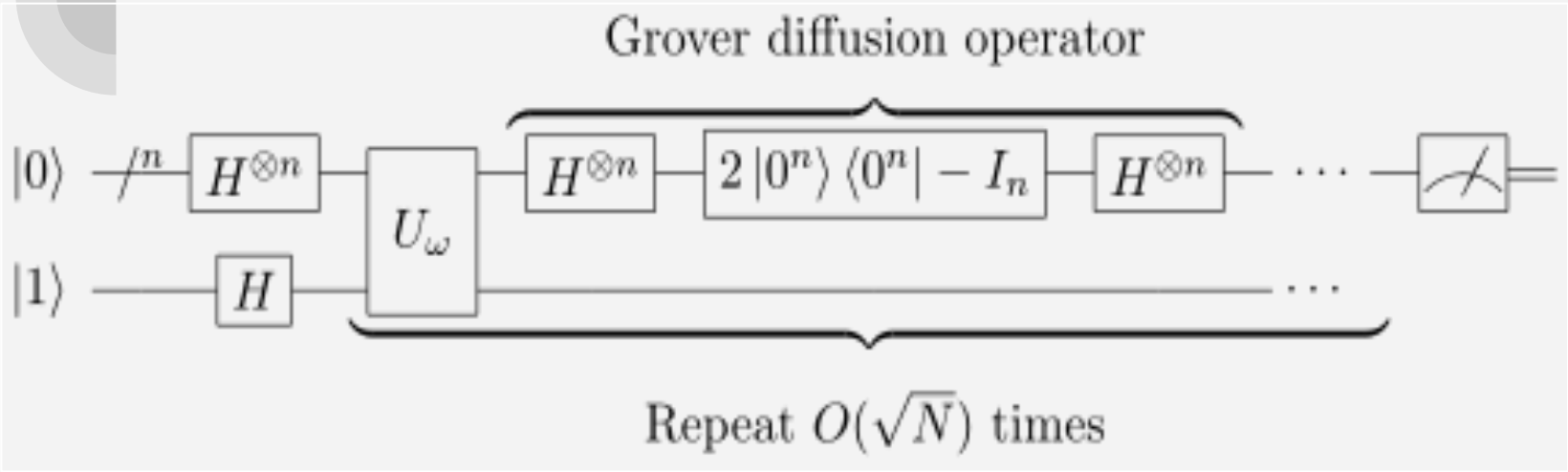

FIG 1 : Quantum circuit of Grover's algorithm

QUANTUM PARTIAL SEARCH

Korepin, V.E. and Grover, L.K., 2006. Simple algorithm for partial quantum search

- A variant of Grover's algorithm.
- Does not find the exact location of the desired item. It basically divides the search space into chunks or blocks and yields the address of the block which might contain the desired item.
- The Grover's algorithm yields the answer in $\sqrt{N}$ steps whereas the partial algorithm would yield result faster by a numerical factor that depends on the number of blocks K.

APPLICATIONS OF QUANTUM SEARCH

- Ambainis, A., 2005. Quantum search algorithms
- Viamontes, G.F., Markov, I.L. and Hayes, J.P., 2005. Is quantum search practical?.

1. NP-complete problems

Classically, the only option to solve NP-complete problem is as exhaustive search problems. But quantum search provides a square-root speedup in this case

2. Quantum counting

The counting problem is to find the number of items in a set that satisfy the given query. Its quantum solution is based on the fact that the iterative evolution in Grover search is periodic.

3. Element distinctness

Element distinctness problem is to find distinct x, y such that f (x)= f (y), for an unknown function f that can be accessed only by an oracle. An optimal O(N^⅔) quantum algorithm is used for this problem.

4. Spatial search

A search problem in which the items in a database are distributed across distinct physical locations and there is a restriction that one can only move from one location to its neighbours while searching for the target item. Its quantum solution replaces the global Grover diffusion operator by a local quantum walk.

5. Distributed search.

A straightforward distributed implementation of the quantum search algorithm solves the set intersection problem or the appointment problem. When A and B have respective data strings x, y ∈ {0, N}^N , and they want to find an index i such that xi = yi = 1, only O(√ N log N) qubits of communication is necessary.

CONCLUSION

- We have analysed various research papers and learnt about Grover's search algorithm and Quantum Partial Search.
- We have successfully implemented Grover's search algorithm.
- We have studied about various applications of quantum search algorithms
- Research into quantum algorithms is picking up momentum. Researchers are trying to develop new algorithms as well as apply the known algorithms to new problem areas.

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THANK YOU