An Efficient Unstructured Search Algorithm for NISQ Era Quantum Computers

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An Introduction

Goal: run any **coveted QC algorithm** on actual quantum H/W to benchmark **QC** as **a solution to hard problems** (surpassing the classical approach)

Till very recently, nobody has been able to show Grover's search on real hardware with N as low as 16.

Solution: A description of a family of algorithms especially constructed for NISQ computers promising much better results at currently available qubit counts and circuit depths and the consequences of having a hardware able to running them.

The method: Challenge the widely accepted assumptions

Deferred Measurement Principle

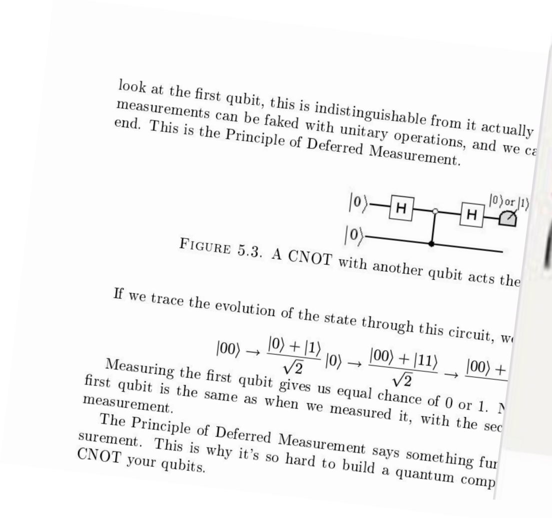

look at the first qubit, this is indistinguishable from it actually
measurements can be faked with unitary operations, and we ca
end. This is the Principle of Deferred Measurement.

FIGURE 5.3. A CNOT with another qubit acts the

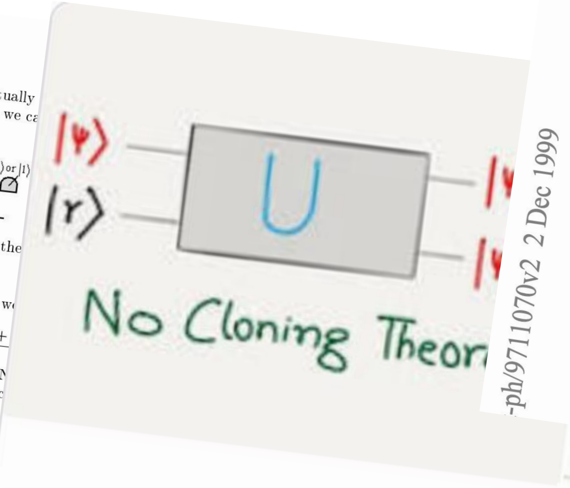
If we trace the evolution of the state through this circuit, w

$$|00\rangle \to \frac{|0\rangle + |1\rangle}{\sqrt{2}} |0\rangle \to \frac{|00\rangle + |11\rangle}{\sqrt{2}} \to |00\rangle + $$

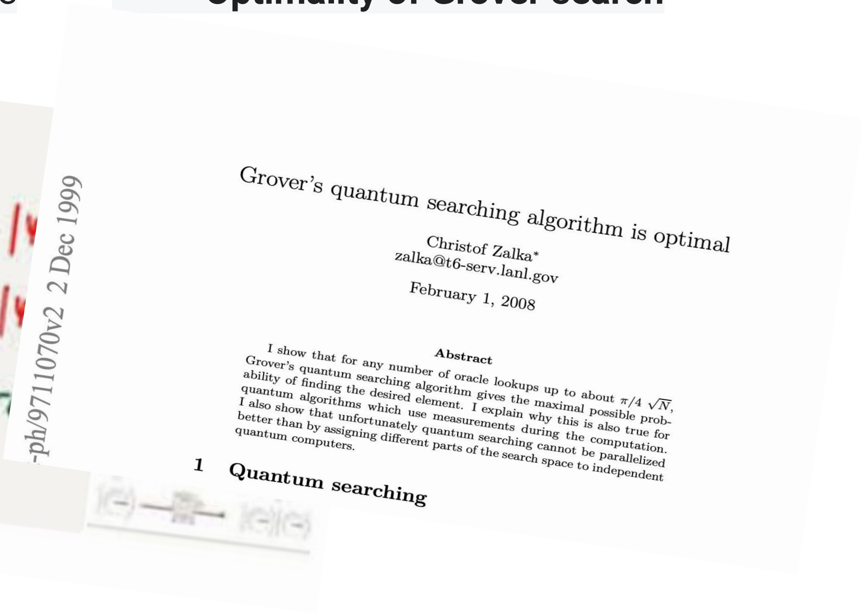
Measuring the first qubit gives us equal chance of 0 or 1. N
first qubit is the same as when we measured it, with the sec
measurement.

The Principle of Deferred Measurement says something fur
surement. This is why it's so hard to build a quantum comp
CNOT your qubits.

No Cloning Principle



Optimality of Grover search


-ph/9711070v2 2 Dec 1999

Grover's quantum searching algorithm is optimal

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February 1, 2008

Abstract

I show that for any number of oracle lookups up to about $\pi/4\sqrt{N}$, Grover's quantum searching algorithm gives the maximal possible probability of finding the desired element. I explain why this is also true for quantum algorithms which use measurements during the computation. I also show that unfortunately quantum searching cannot be parallelized better than by assigning different parts of the search space to independent quantum computers.

1 Quantum searching

The work

The theoretical result, dropping log log term from the scaling of a version of an unstructured search exploiting subspaces of the search space enabled:

- **Usage of measurement to enhance the implementation (CCX in 4.5 CX average)**
- **Efficient branching on qubit measurement result**
- **Partial uncompute to shorten the circuit depth to 20-odd gates for a single iteration of 4-qubit unstructured search (down from 140+)**

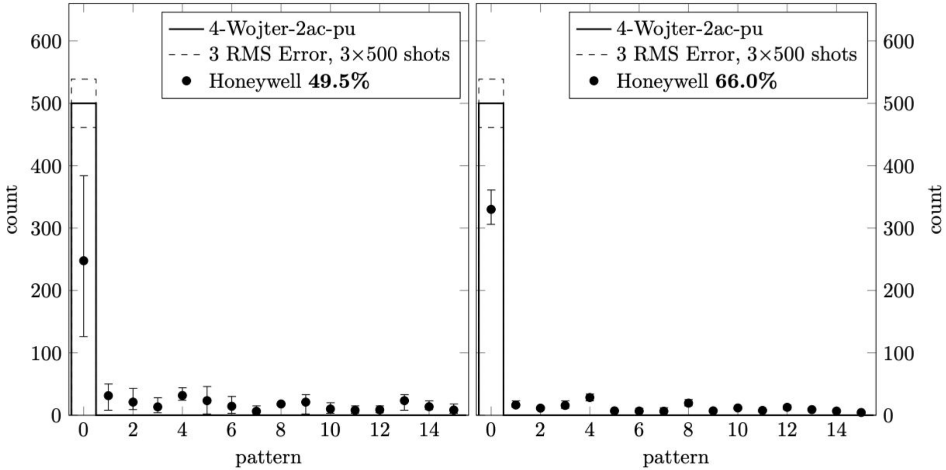
- **9 patent applications (one already accepted), 3 research papers, 2 invited conference talks**

Introducing Structure to Expedite Quantum Search arXiv:2006.05828

The Results

- World best result for unstructured search on superconducting qubits hardware: 3-qubit search 56% success probability, IBM Q 4-qubit search, 24.5% probability of success, IBM Q-Vigo, almost surpassing classical result

- Absolute world best results for unstructured search in 3-, 4-, 5-, 6-qubit spaces
  Ion-trapped qubits, Honeywell System Model H0, impossible for any classical algorithm
  (4-qubit search success probability is 66%)
  https://arxiv.org/pdf/2010.03841.pdf



4-qubit Wojter with 2 ancilla qubits and partial uncompute: session 1 (left), session 2 (right).

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The Summary

BEIT's **hardware-agnostic algorithms** and their proprietary, IP protected **hardware-aware implementations** minimize the number of 2-qubit gates, shortening quantum circuits so they can be executed on actual quantum computing hardware with high success probabilities.

These **results**, obtained **on actual NISQ hardware**, surpass any possible classical approach now and **guarantee scalability** into the future of larger quantum computers.