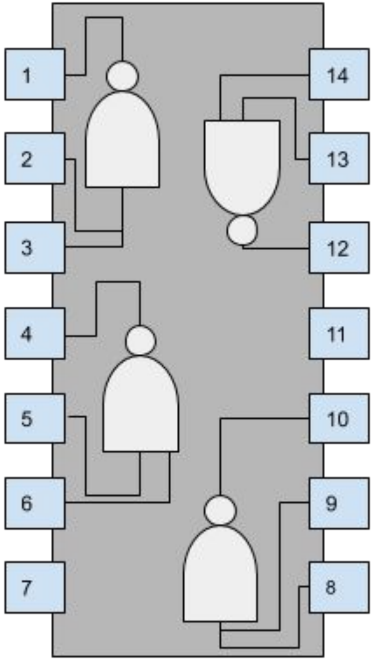
Quantum Computing

Hardwarenahe Systemprogrammierung

Trier University

What is a classical computer

- CPU
- Transistors
- Use Logic gates and bits
- 7 to 14 nm
- Size limit
- Quantum tunneling

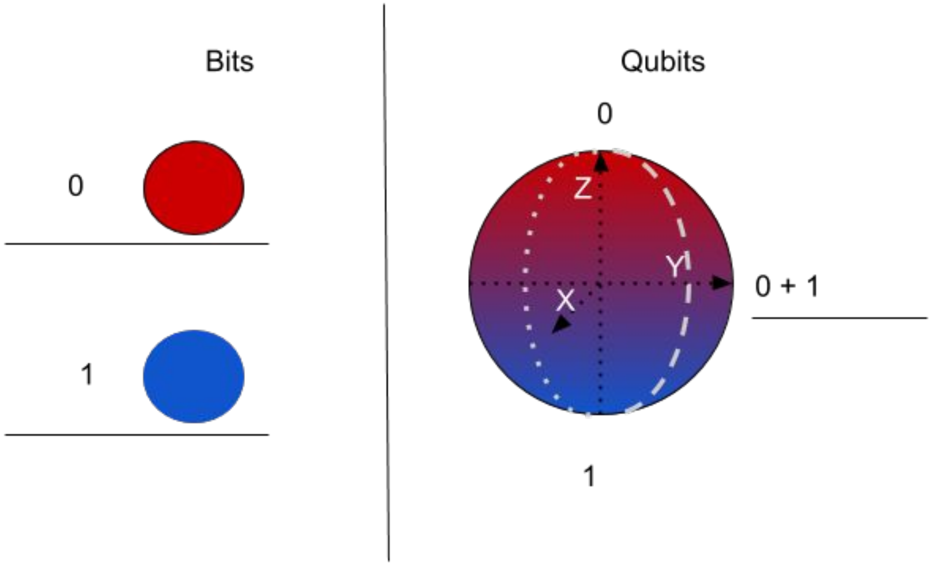


Quantum Computers

Components

- Qubits
- Gain in speed
- Quantum Gates
- Reversible
- Blocsphere

Blocsphere



Mathematical representation

Classical bit

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix} \qquad \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

Qubit

$$\begin{bmatrix} \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} \end{bmatrix} \qquad \begin{bmatrix} \frac{1}{2} \\ \frac{\sqrt{3}}{2} \end{bmatrix} \qquad \begin{bmatrix} -1 \\ 0 \end{bmatrix}$$

Braket notation (Hilbert Space)

$$|2 >= \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \qquad |1 >= \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

Quantum Gates

- **Hadamard Gate** & Superposition

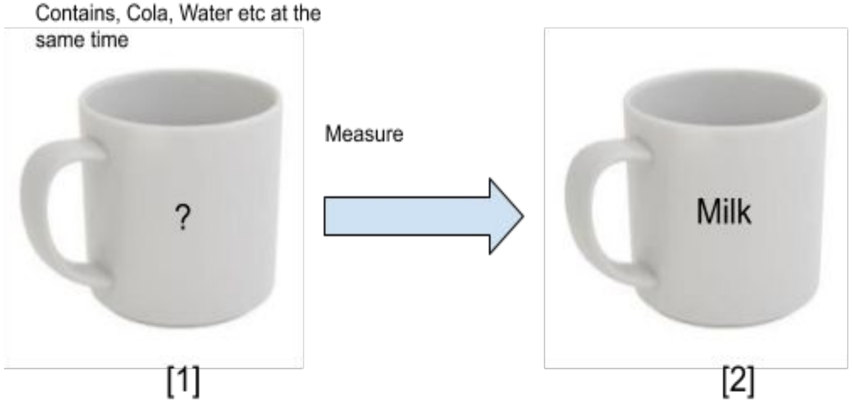
$$H = \frac{1}{\sqrt(2)}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$$

- **Pauli X Y and Z gates**

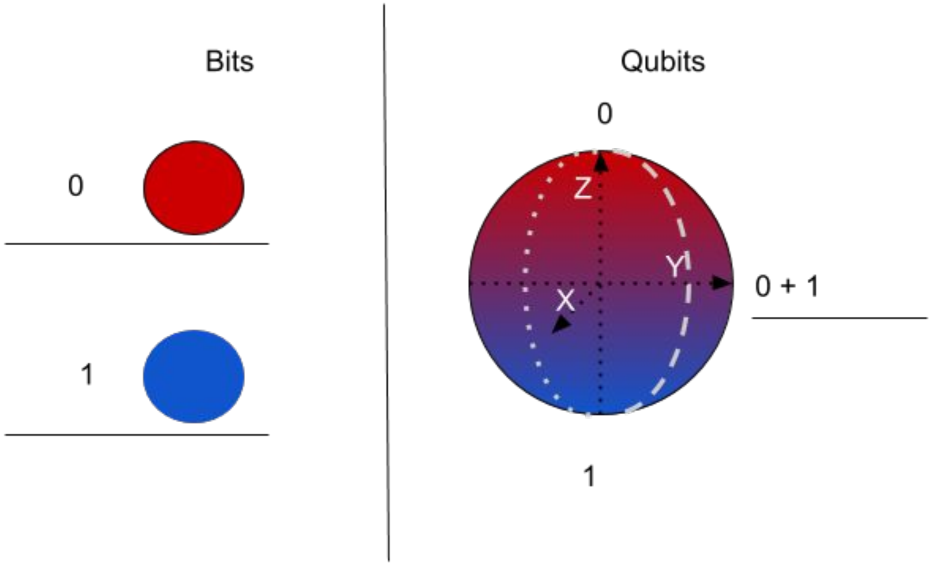
$$X = \begin{bmatrix}0 & 1\\1 & 0\end{bmatrix} \qquad Y = \begin{bmatrix}0 & -i\\i & 0\end{bmatrix} \qquad Z = \begin{bmatrix}1 & 0\\0 & -1\end{bmatrix}$$

- **Controlled not gate**

- **Measure**

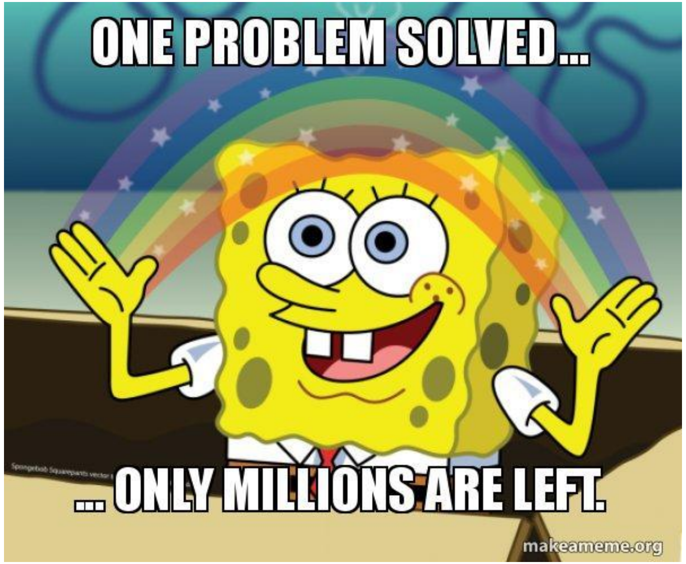


Blocsphere

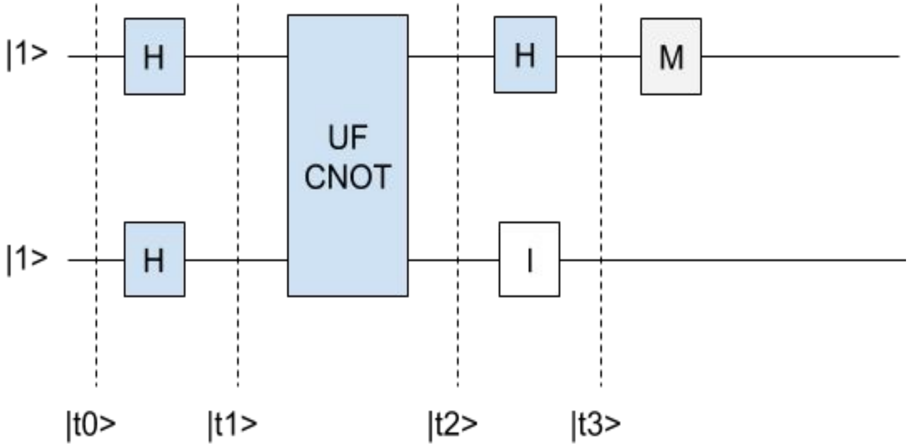


Quantum Algorithm

- Deutsch's Problem
  - Not a real problem
  - f constant or balanced
  - 1 Qubit
- Deutsch-Jozsa Algorithm



Deutsch-Jozsa Algorithm



Input:

$$|t_0 >= |11 >$$

Both Bits pass a Hadamard gate

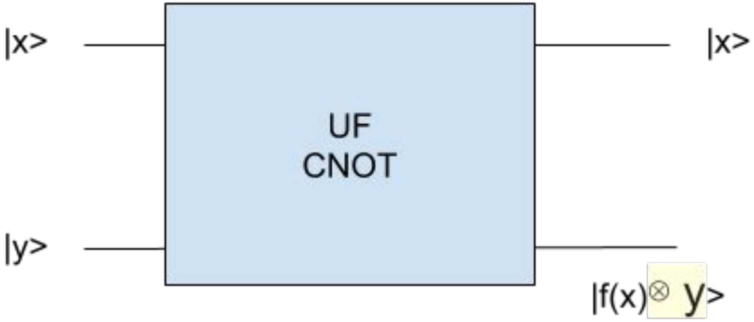
- Results in a Superposition

$$|t_1 >= (\frac{|0_1 > -|1_1 >}{\sqrt{2}})(\frac{|0_2 > -|1_2 >}{\sqrt{2}})$$

$$t_{1b} = \frac{1}{2}(|0_1 0_2 > -|1_1 0_2 > -|0_1 1_2 > +|1_1 1_2 >)$$

UF & CNOT

$$t_{1b} = \frac{1}{2}(|0_1 0_2 > -|1_1 0_2 > -|0_1 1_2 > +|1_1 1_2 >)$$



$$t_2 = \frac{1}{2}(|0_1 f(0)_2 > -|1_1 f(1)_2 > -|0_1 f'(0)_2 > +|1_1 f'(1)_2 >)$$

If $f(0) = f(1)$ and factor:

$$\frac{1}{2}(|0_1 > -|1_1 >)(|f(0)_2 > -|f'(0)_2 >$$

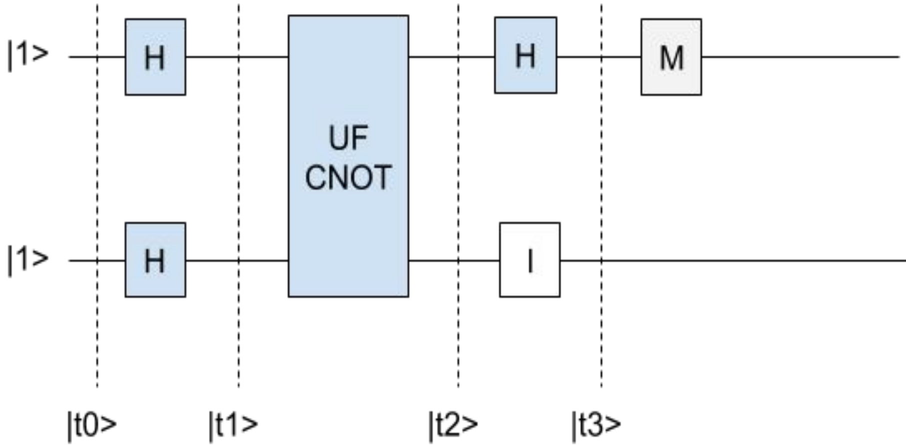
If $f(0)$= $f'(1)$and factor:

$$\frac{1}{2}(|0_1 > +|1_1 >)(f(0)_2 - f'(0)_2$$

Applying the Hadamard Gate

$$f(0) = f(1)\ |1_1 > (|f(0)_2) > -|f'(0)_2 >$$

$$f(0) = f^(1) = |0_1 > (|f(0)_2 > -|f'(0)_2)$$



Measure 1 f is constant

Measure 0 f is balanced

Current State

- Google 23 October 2019 Quantum Supremacy
  - IBM
- Quantum computers won’t replace classical computers
  - Cooling
  - Price
- Quantum in the cloud
- For scientists

Final Words