quantum computing in abstract

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QUANTUM RESOURCES FOR COMPUTING

SUPERPOSITION	ENTANGLEMENT	INTERFERENCE
quantum objects can be in two states at once. You won't know the state until you make a measurement	Is a quantum correlation between objects where the state of one quantum object depends on the state of the other	Two quantum objects can interact with each other or and either cancel each other out or amplify one another.

These three weird quantum properties enable the design of quantum algorithms which can compute in ways classical computers cannot, making quantum computers more powerful for solving certain types of problems

QUANTUM BITS: QUBITS

"How quantum computers compute"

BIT to QUBIT

BIT	QUBIT
0	$\|0\rangle$
1	$\|1\rangle$

$|\ \rangle$ is a ket and it indicates that we're talking about quantum states.

Example:

50-50 superposition of 0 and 1:

$|\psi\rangle = \sqrt{0.5}\,|0\rangle + \sqrt{0.5}\,|1\rangle$

$\alpha = \sqrt{0.5} = |\alpha|^2 = 0.5$

$\beta = \sqrt{0.5} = |\beta|^2 = 0.5$

75-25 superposition of 0 and 1:

$|\psi\rangle = \sqrt{.75}\,|0\rangle + \sqrt{.25}\,|1\rangle$

$\alpha = \sqrt{.75} = |\alpha|^2 = 0{,}75$

$\beta = \sqrt{.25} = |\beta|^2 = 0{,}25$

QUANTUM SUPERPOSITION

"Quantum objects can be in two states at once."

Superposition

Superposition: a qubit can be $|0\rangle$ and $|1\rangle$ at the same time

This is how we show it: $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$

Measurement

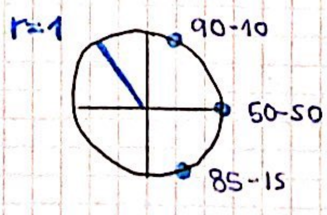
Measurement: collapses the quantum state of the qubit $|\psi\rangle$ to either $|0\rangle$ or $|1\rangle$

probability of me. $|0\rangle$: $|\alpha|^2$

probability of me. $|1\rangle$: $|\beta|^2$

$$|\alpha|^2 + |\beta|^2 = 1$$

There are continuous set of superposition state



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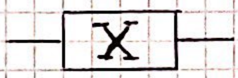
QUANTUM GATES: SINGLE-QUBITS

X-GATE

* X (or σ^x): bit-flip

$X|0\rangle \rightarrow |1\rangle$

$X|1\rangle \rightarrow |0\rangle$



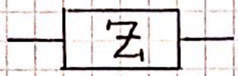
in	out
$\|0\rangle$	$\|1\rangle$
$\|1\rangle$	$\|0\rangle$

Z-GATE

* Z (or σ^z): phase gate

$Z|0\rangle \rightarrow |0\rangle$

$Z|1\rangle \rightarrow -|1\rangle$



in	out
$\|0\rangle$	$\|0\rangle$
$\|1\rangle$	$-\|1\rangle$

HADAMARD

* creates a 50-50 superposition from $|0\rangle$ and $|1\rangle$

$H|0\rangle = \sqrt{.5}\,|0\rangle + \sqrt{.5}\,|1\rangle$

$H|1\rangle = \sqrt{.5}\,|0\rangle - \sqrt{.5}\,|1\rangle$

in	out
$\|0\rangle$	$\frac{\|0\rangle+\|1\rangle}{\sqrt{2}}$
$\|1\rangle$	$\frac{\|0\rangle+\sqrt{1}}{\sqrt{2}}$

QUANTUM GATES applied to superposition

Quantum gates apply to each state of the superposition

* separately
* In parallel

$X|\psi\rangle = X(\alpha|0\rangle + \beta|1\rangle)$

$= \alpha(X|0\rangle) + \beta(X|1\rangle)$

$= \alpha|1\rangle + \beta|0\rangle$

What is the difference between a coin flip and quantum superposition

COIN FLIP

1 coin flip: 50% H 50% T

2 coin flip: 50% H 50% T

SUPERPOSITION

1. Had. Gate $\xrightarrow{\text{measu.}}$ 50% 0, 50% 1
2. Had. Gate $\xrightarrow{\text{measu.}}$ 100% 0

The states involved in quantum superposition can cancel or amplify

Why are Q.C. FASTER

# of Qubit	# of superposition states
1	2 $\|0\rangle, \|1\rangle$
2	4 ($\|00\rangle, \|01\rangle, \|10\rangle, \|11\rangle$)
3	8 ...

* n qubits $\rightarrow 2^n$ superposition states
  - Each operation acts on all the elements of the superposition

QUANTUM SUPREMACY

A programmable quantum device can solve a problem that no classical computer can solve in any feasible amount of time.

TWO QUBITS

Let's say we have two qubits: A and B

$|00\rangle$ or $|0\rangle|0\rangle$: qubit A $\rightarrow |0\rangle$
qubit B $\rightarrow |0\rangle$

$|01\rangle$ or $|0\rangle|1\rangle$: qubit A $\rightarrow |0\rangle$
qubit B $\rightarrow |1\rangle$

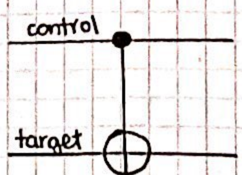
$|10\rangle$ or $|1\rangle|0\rangle$: qubit A $\rightarrow |1\rangle$
qubit B $\rightarrow |0\rangle$

$|11\rangle$ or $|1\rangle|1\rangle$: qubit A $\rightarrow |1\rangle$
qubit B $\rightarrow |1\rangle$

QUANTUM GATES: two qubit

* CNOT gate (controlled NOT)
  - If the control qubit is 0, does nothing
  - If the control qubit is 1, flip the target qubit

in		out	
c	t	c	t
$\|0\rangle$	$\|0\rangle$	$\|0\rangle$	$\|0\rangle$
$\|0\rangle$	$\|1\rangle$	$\|0\rangle$	$\|1\rangle$
$\|1\rangle$	$\|0\rangle$	$\|1\rangle$	$\|1\rangle$
$\|1\rangle$	$\|1\rangle$	$\|1\rangle$	$\|0\rangle$



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QUANTUM ENTANGLEMENT

Quantum correlation between two qubits where the state of one qubit depends on the other qubit

Entanglement

Entangled state: $|\psi\rangle = \sqrt{0.5}\,|00\rangle + \sqrt{0.5}\,|11\rangle$

if we measure $|\psi\rangle$

* we get $|00\rangle$ with 50% probability
* we get $|11\rangle$ with 50% probability

What if we only measure qubit A?

- If qubit A is 0 → the quantum state of qubit B is immediately set to $|0\rangle$
- If qubit A is 1 → q.s. qubit B → $|1\rangle$

APPLICATIONS OF ENTANGLEMENT

- Quantum teleportation
- Quantum cryptography
- Superdense coding
- Quantum speedups

Q.TELEPORTATION

Transferring information or matter from one point to another without physically moving things!

HOW TO CREATE ENT.