From Point A to Point B with a Quantum Computer

Shelby Kimmel

Collaborators:
- Stacey Jeffery – CWI Amsterdam
- Alvaro Piedrafita – CWI Amsterdam

"Quantum Algorithm for Path-Edge Sampling", Proceedings of 18th Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC 2023), **10.4230/LIPIcs.TQC.2023.5**

Getting from A to B is important!

Image: Google maps

Getting from A to B is important!

LinkedIn Social Network

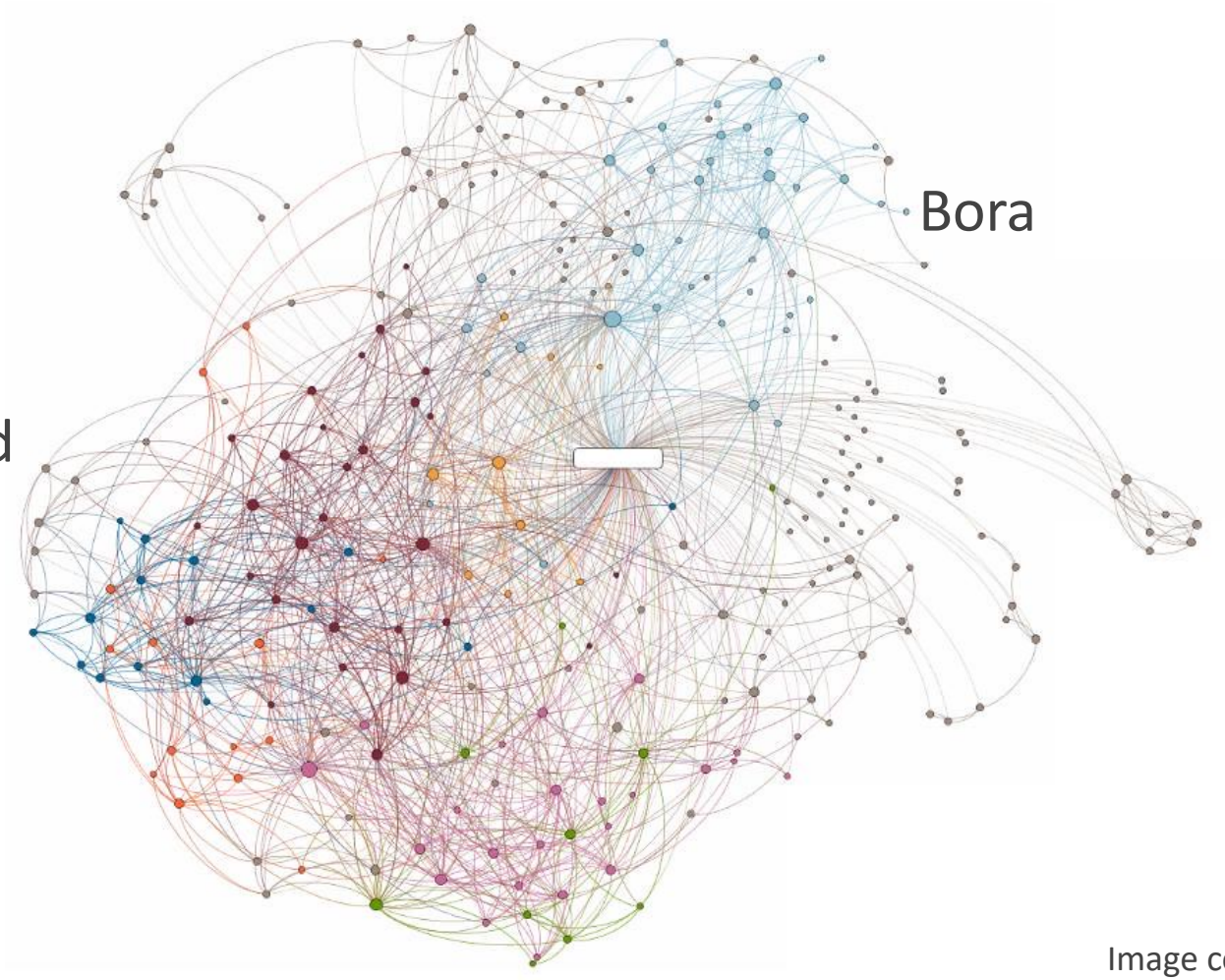


Image courtesy Brewbooks

Getting from A to B is important!

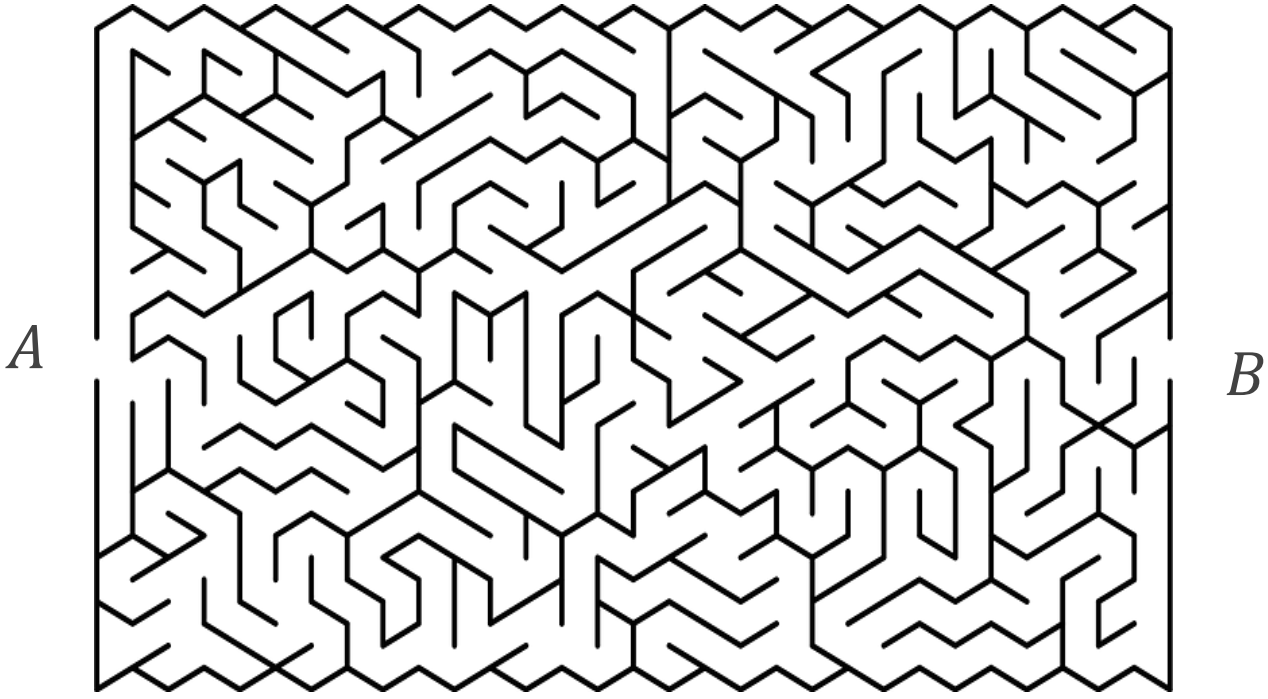
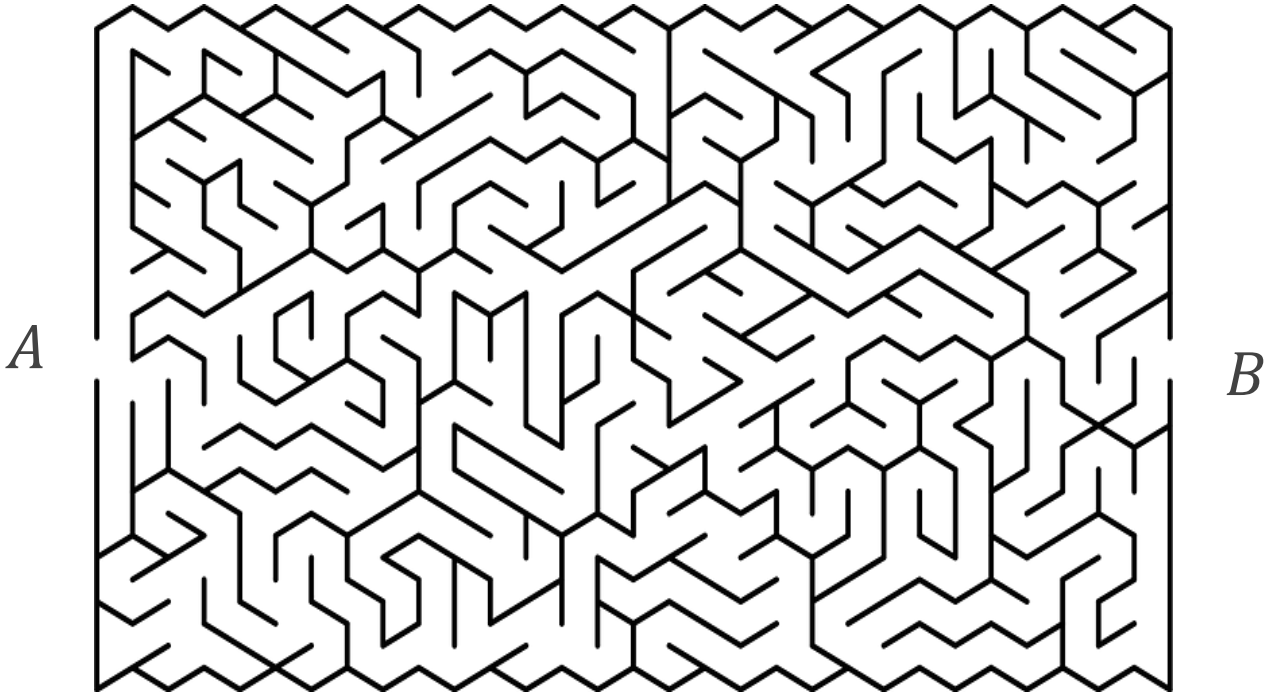


Image: https://publicdomainvectors.org

Getting from A to B is important!

Goal: find the sequence of steps to get from A to B



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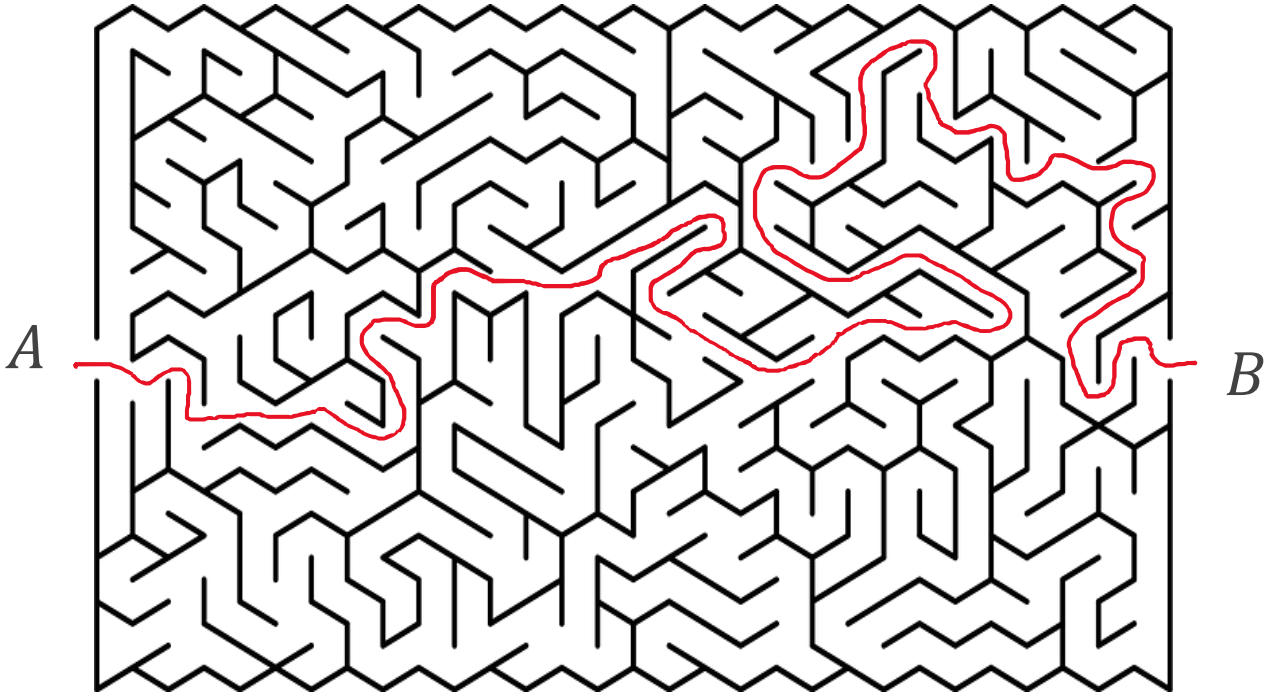
Getting from A to B is important!

Goal: find the sequence of steps (edges) to get from A to B



Quantum Computers Solve (some) Problems Faster

Quantum computers manipulate very small particles, which obey laws of quantum mechanics, to solve problems

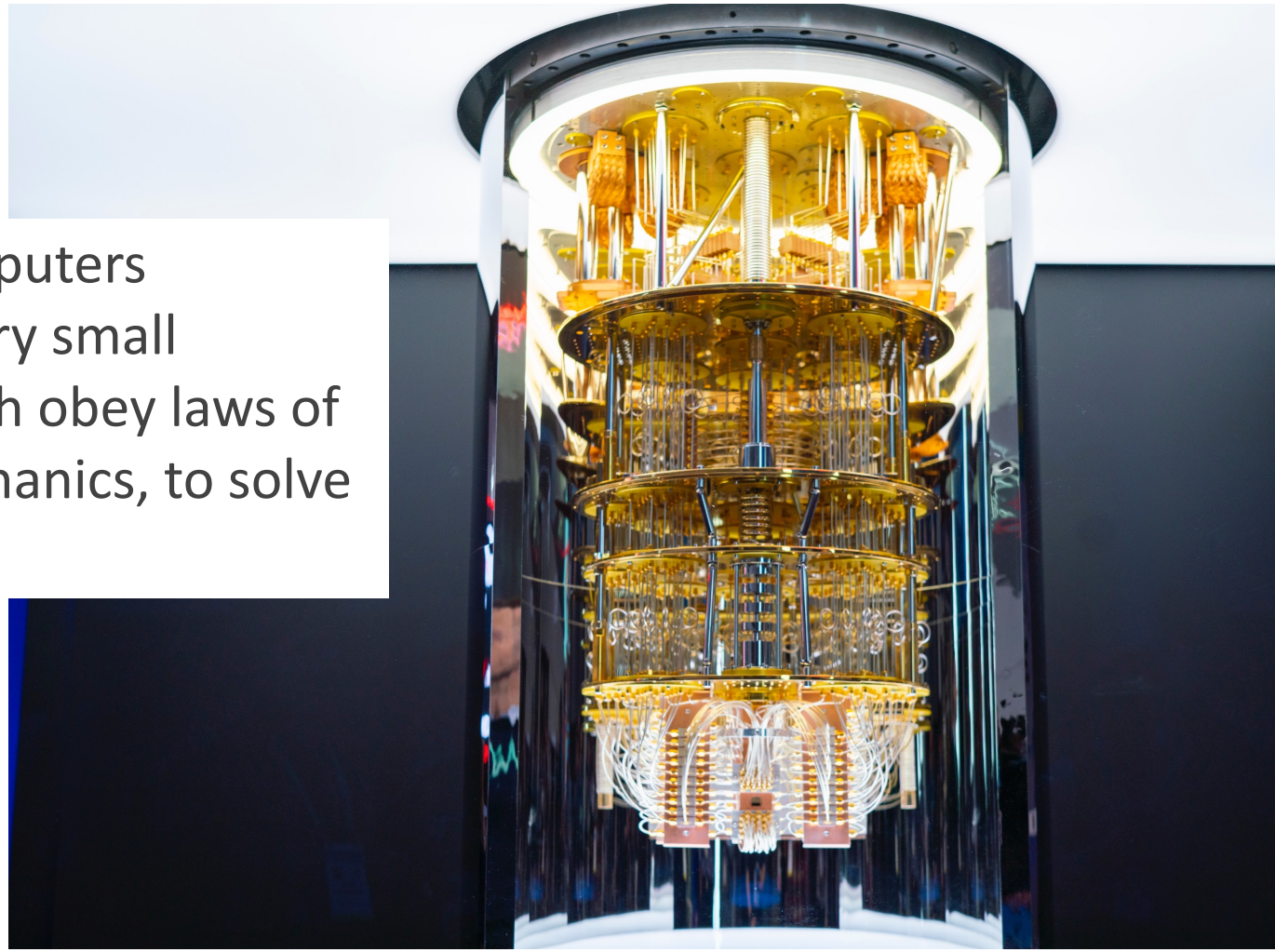


Image: IBM

How fast can a quantum computer find a path?

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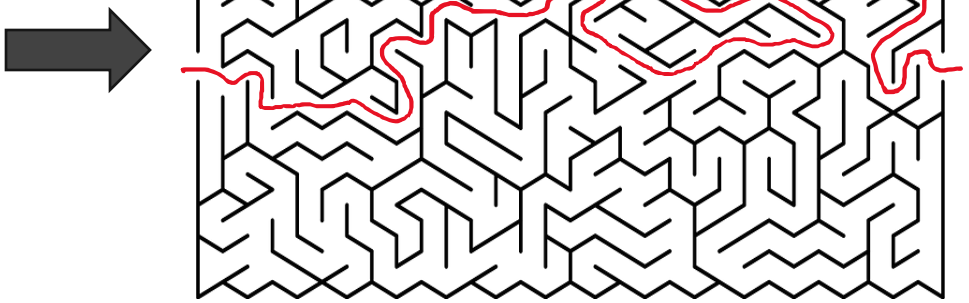

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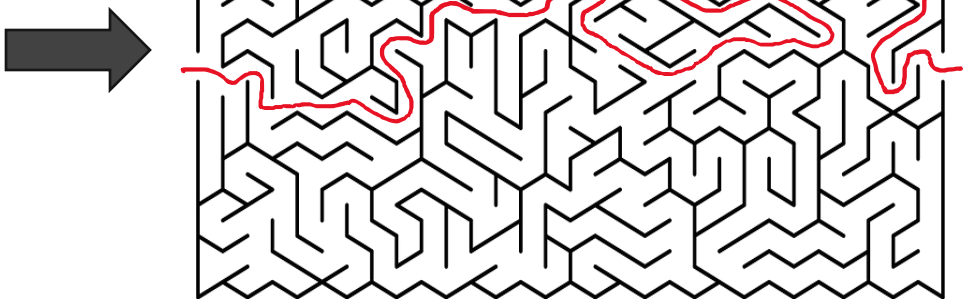

Faster than with a regular computer!

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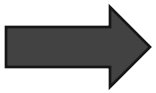

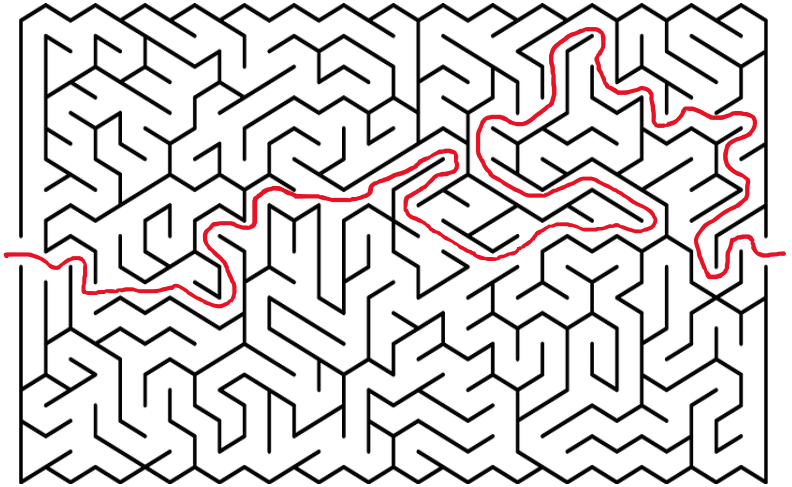

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Faster than with a regular computer!

Already known in prior work (Durr, 2006) – but we improve for short paths.

What can we learn about quantum computers by studying path finding?

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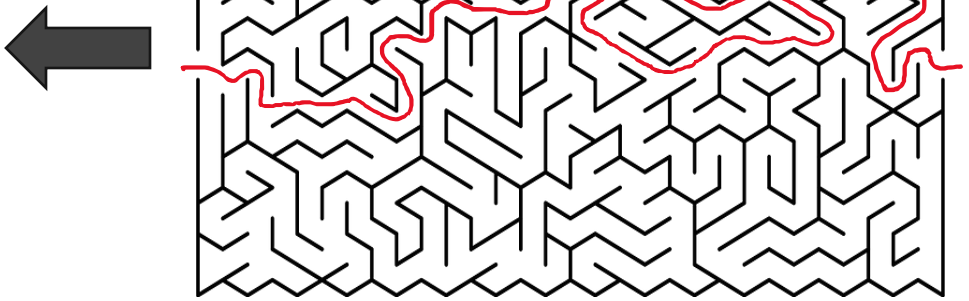

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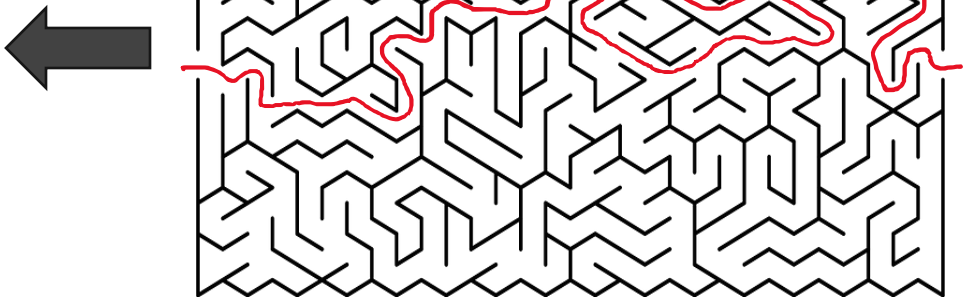
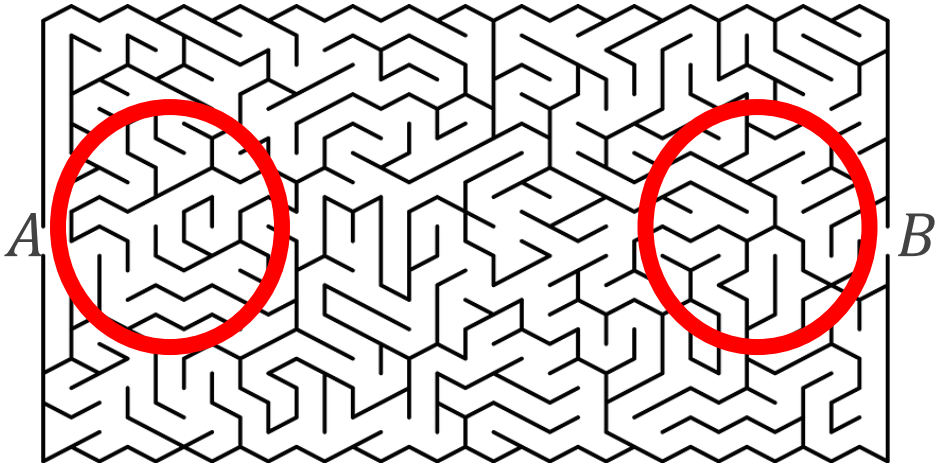


Quantum computers are weird!

How does a quantum computer find a single path?



What I would expect:

Initially find path steps that are close to the entrance and exit

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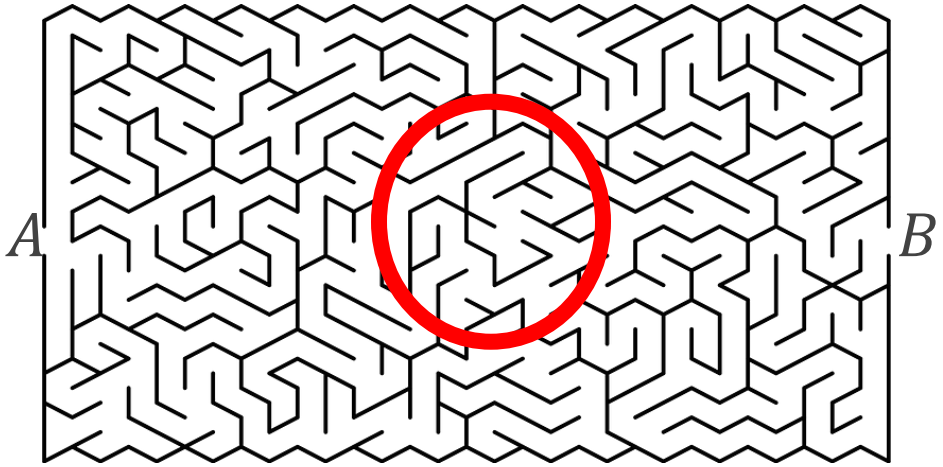

What our algorithm does: Finds edges in the middle first

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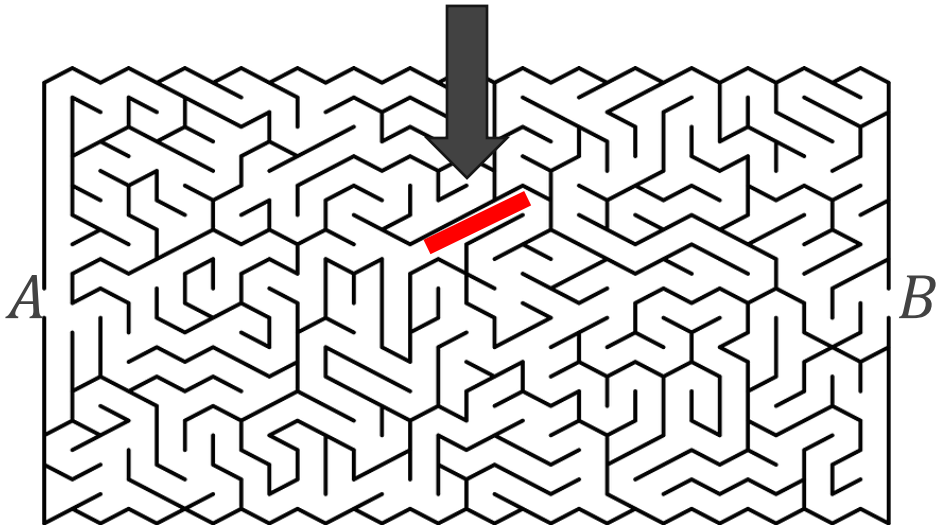
Output of first iteration of our algorithm



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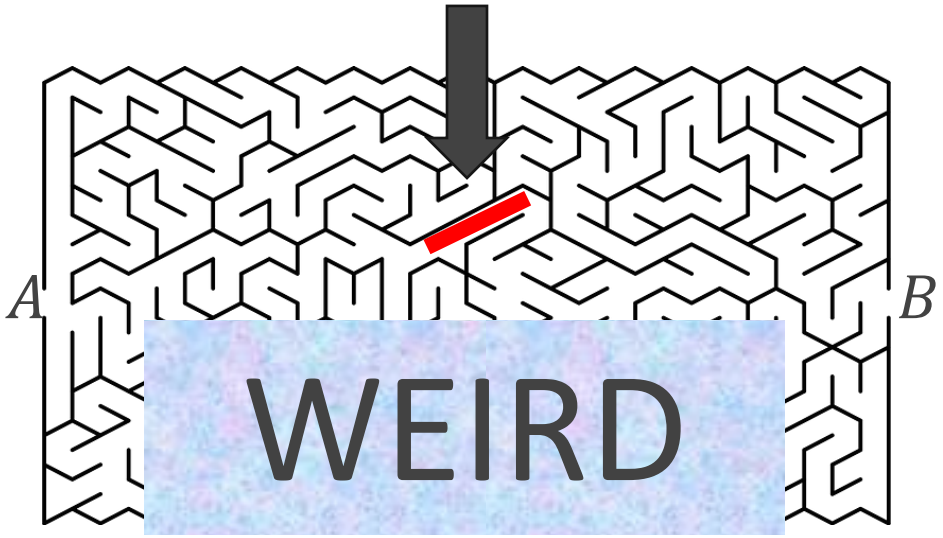

WEIRD

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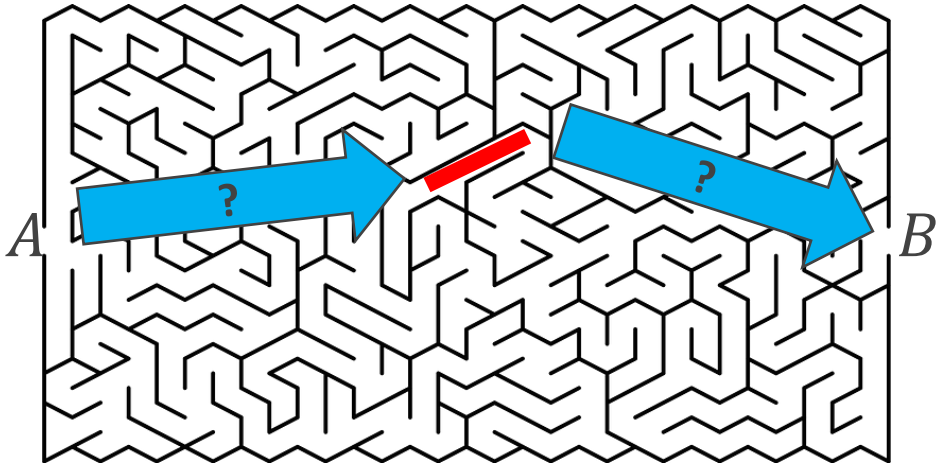

What our algorithm does:

- Finds edge in the middle
- Break problem up into two smaller subproblems

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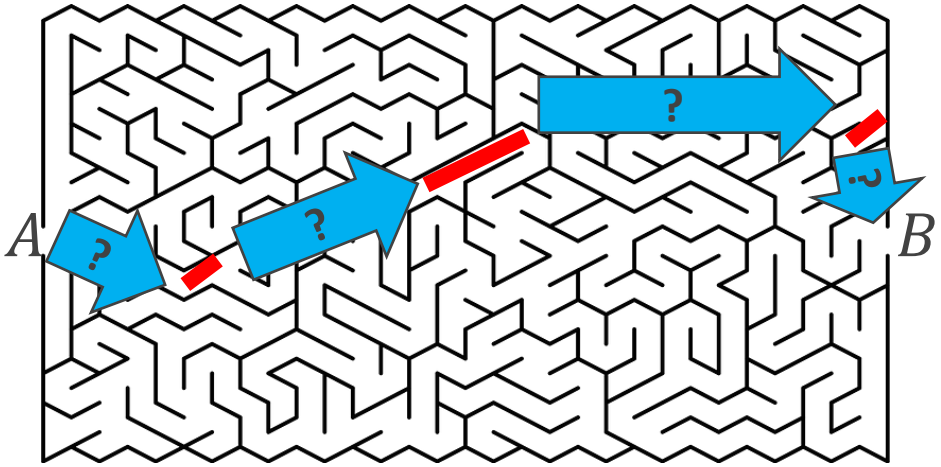

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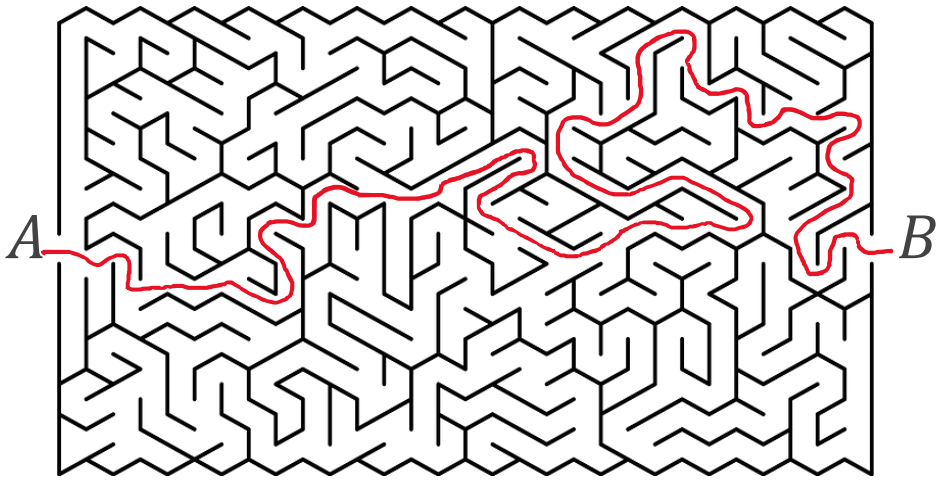

What our algorithm does:

- Finds edge in the middle
- Break problem up into two smaller subproblems
- Continue…divide and conquer

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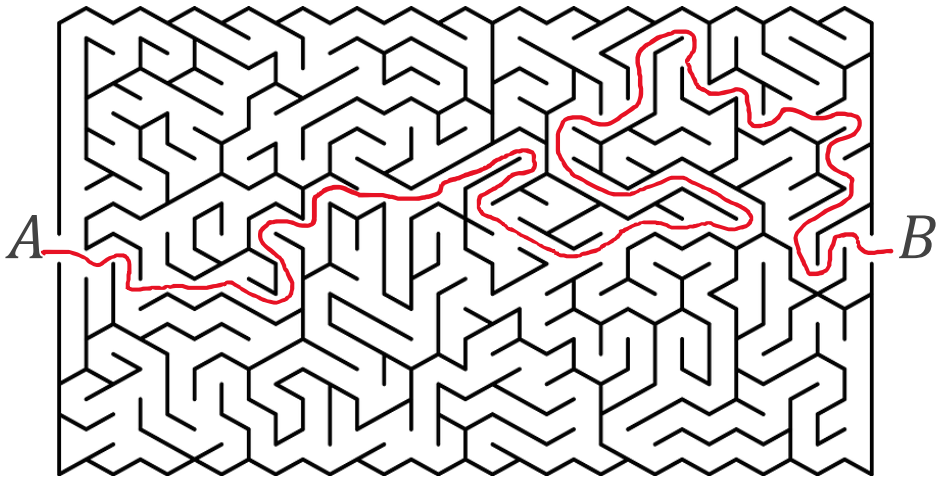

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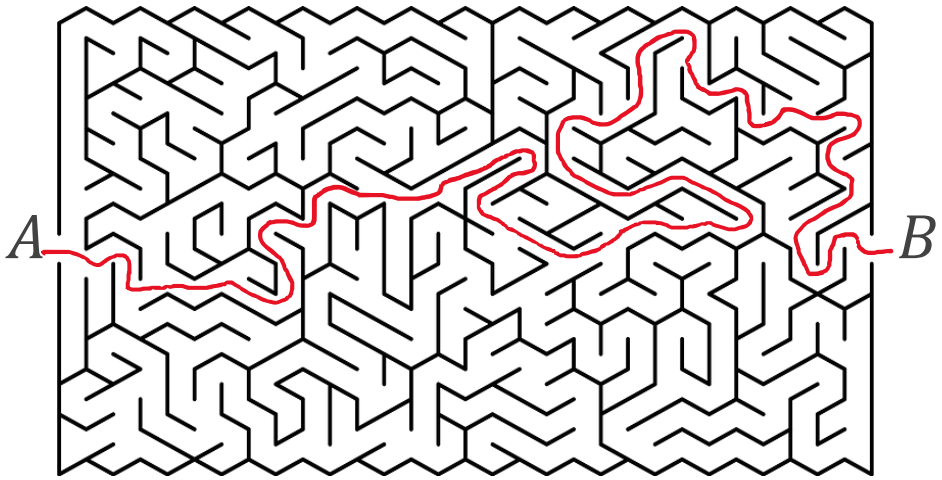

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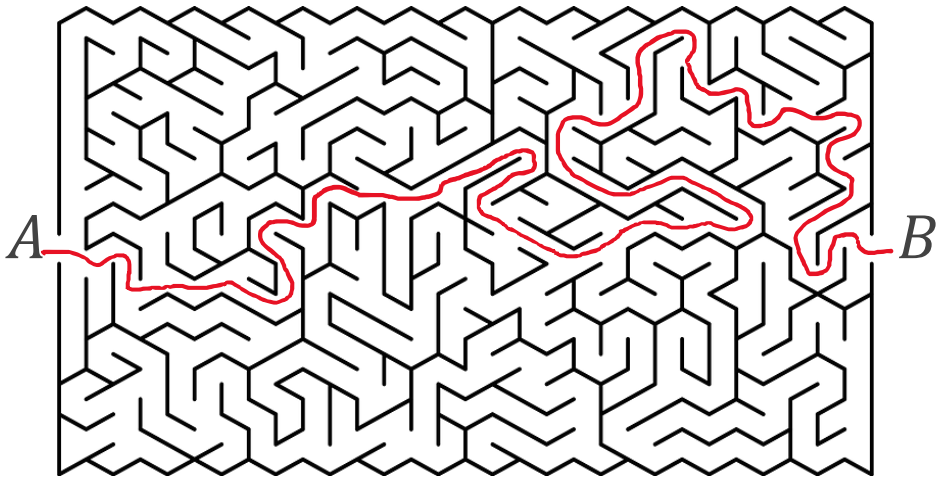

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*Durr et al. 2006

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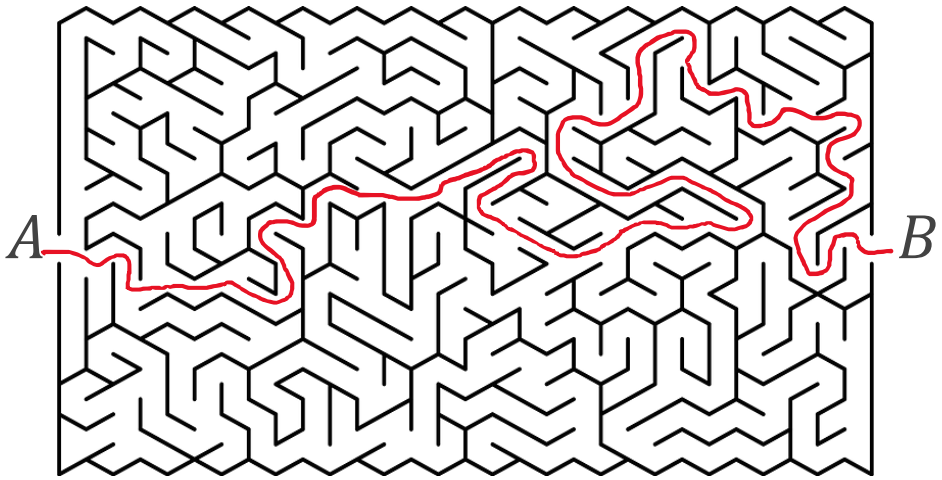

- For length L path, n-vertex graph, algorithm uses $\tilde{O}\left(nL^{1+o(1)}\right)$ time
- Faster than existing quantum algorithm* for $L = O\left(n^{1/2}\right)$
- Model: query access to adjacency matrix of complete n-vertex graph

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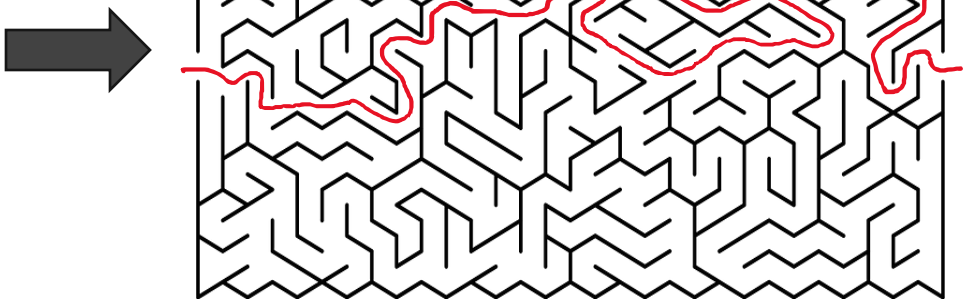

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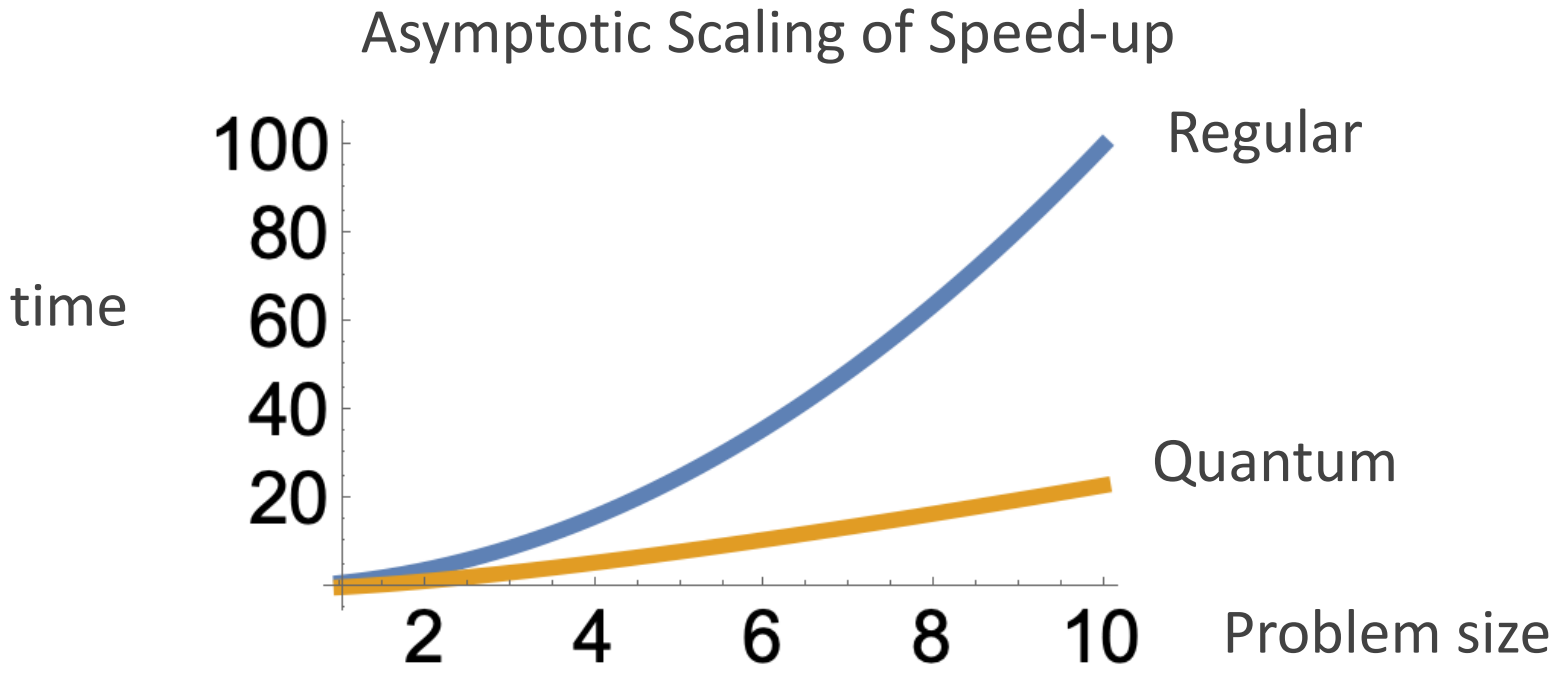
Quantum vs Classical

For an n vertex graph and short path,
Regular: $\Omega(n^2)$ time to find a path
Quantum: $\tilde{O}\ (n)$ time to find a path



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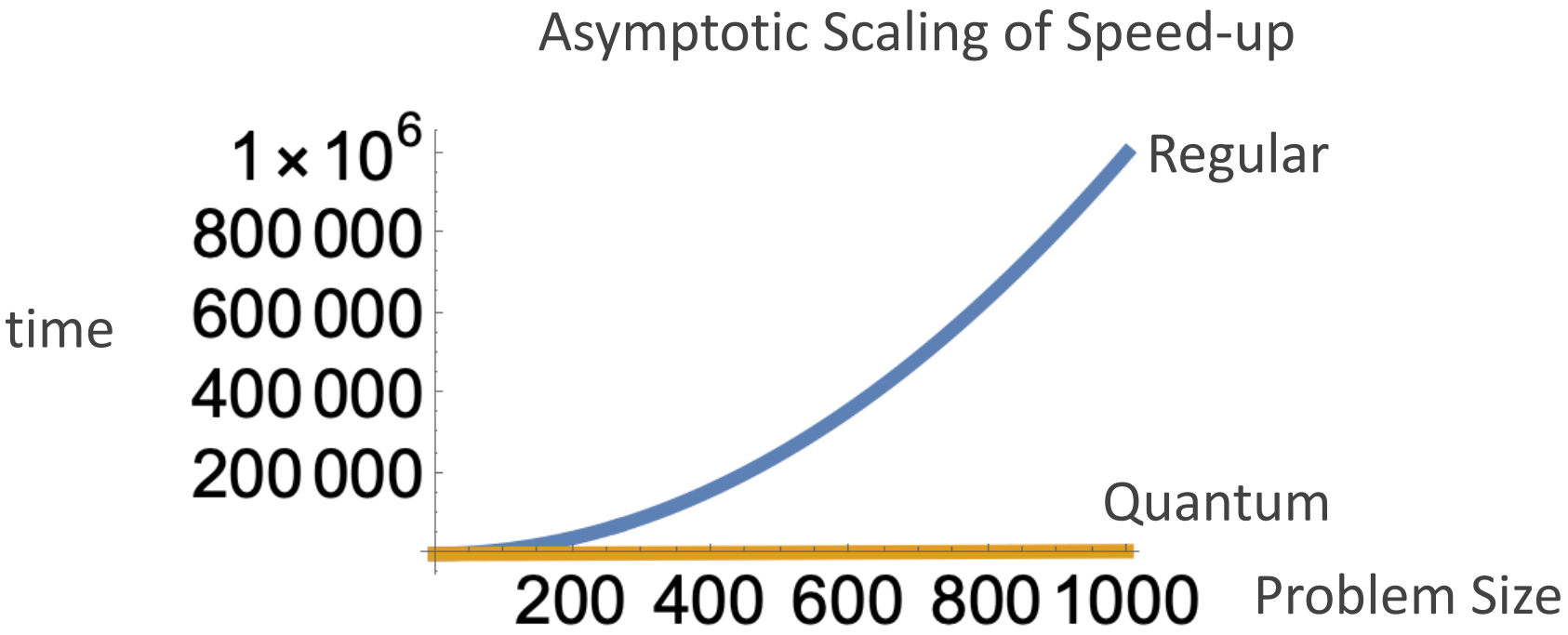

ARO

To conclude and to question

- Quantum computers can find paths faster than regular computers
- Quantum computers are weird
- Our algorithm outperforms existing quantum algorithm* for finding short paths, but not for finding long paths. Can we improve?
- Why are quantum computers weird?

Our work: “Quantum Algorithm for Path-Edge Sampling”, Proceedings of 18th Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC 2023), **10.4230/LIPIcs.TQC.2023.5**

*Dürr, Christoph, et al. "Quantum query complexity of some graph problems." *SIAM Journal on Computing* 35.6 (2006): 1310-1328.