NORTHWEST
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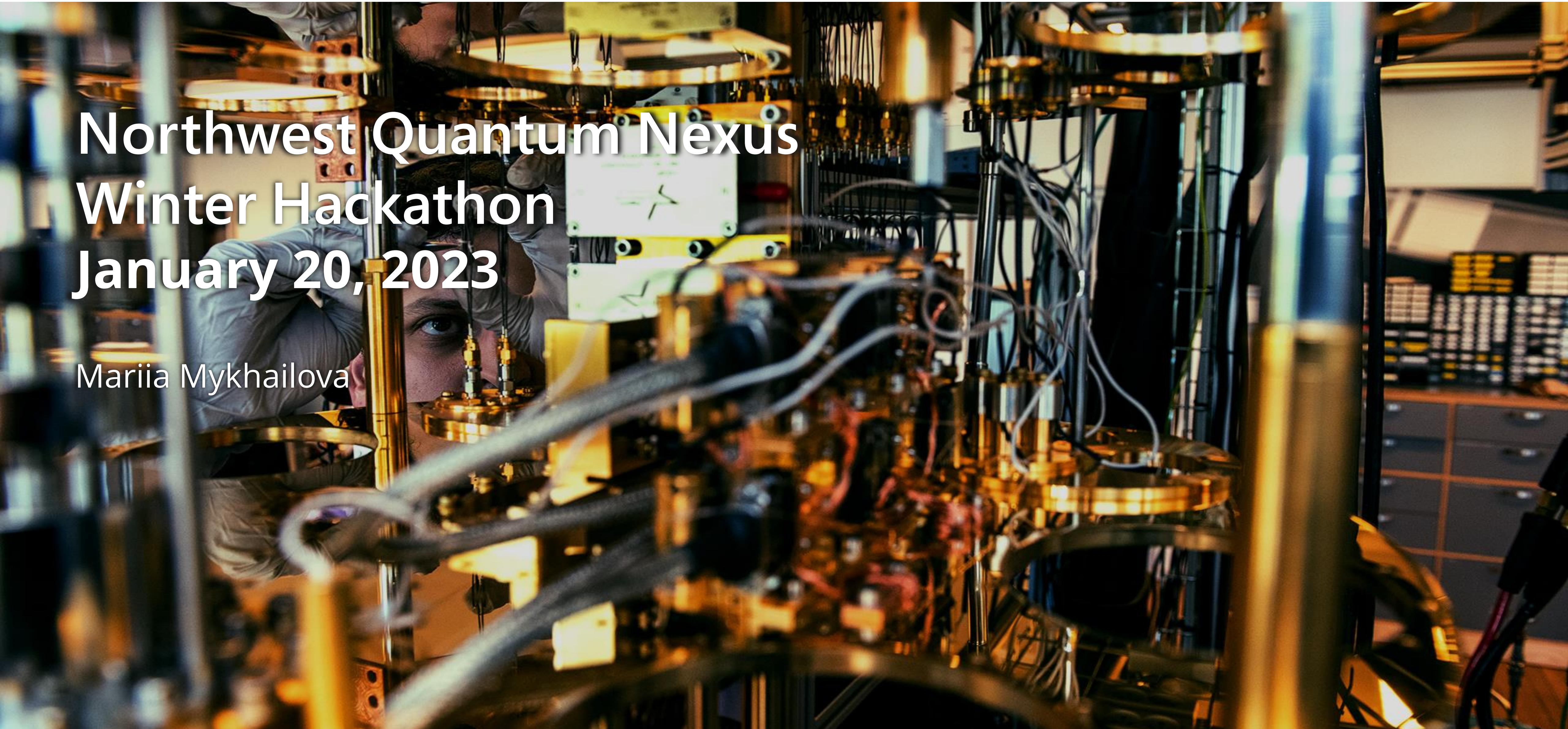


Northwest Quantum Nexus Winter Hackathon
January 20, 2023

Mariia Mykhailova

Challenge Overview

Explore running programs on IonQ quantum hardware!

1. Come up with a problem you'd like to explore using a quantum computer.
2. Implement the solution in a quantum programming language supported by Azure Quantum: Q#, Qiskit, or Cirq.
3. Explore your solution's behavior on the noiseless cloud simulator and then on real ion trap quantum computers provided by IonQ, Harmony and Aria.

Challenge description, resources, and useful links

https://github.com/tcNickolas/NQN-Hack-2023-Challenge

Project submission and judging

Create a GitHub repository and commit all relevant files (description, the project code, resource estimations, results visualizations, etc.)

Submit project to https://aka.ms/NQNHack/ProjectSubmit
by Sunday, January 22nd, 5 pm PST

Judging criteria:

Technical depth (5 points). How complicated is the selected problem? How well is it solved? How does the project use IonQ simulator and hardware to solve the problem?

Creativity (5 points). How original is the problem selection? How creative is the output presentation? Is the solution to the problem displayed using a clever visualization?

Educational value (5 points): Is this project valuable for helping others learn? Did the team write a blog post about the project sharing their learnings with others? Is the project structured as a tutorial?

Hacking tips and tricks

Writing the code

Hybrid quantum-classical jobs and mid-circuit measurements are not supported for this event

Each job should apply some gates, perform measurements, and return the results

You can do any post-processing of the results in the classical host code

Testing and evaluating your project

Make sure to test your work using simulators before running hardware jobs – this step is a part of software development process!

"Local" noiseless simulators (Qiskit Aer simulator or Q# sparse simulator)

Free IonQ noiseless cloud simulator (ionq.simulator target in Azure Quantum)

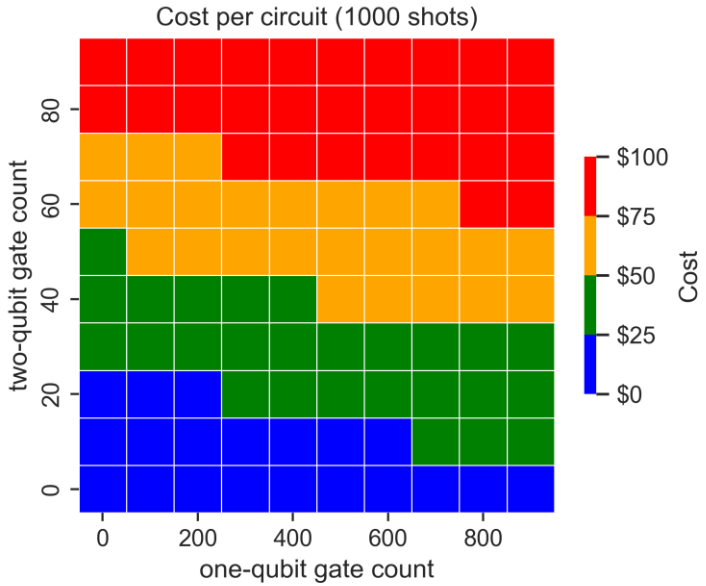
Use resource estimator to evaluate the circuit size to select the QPU

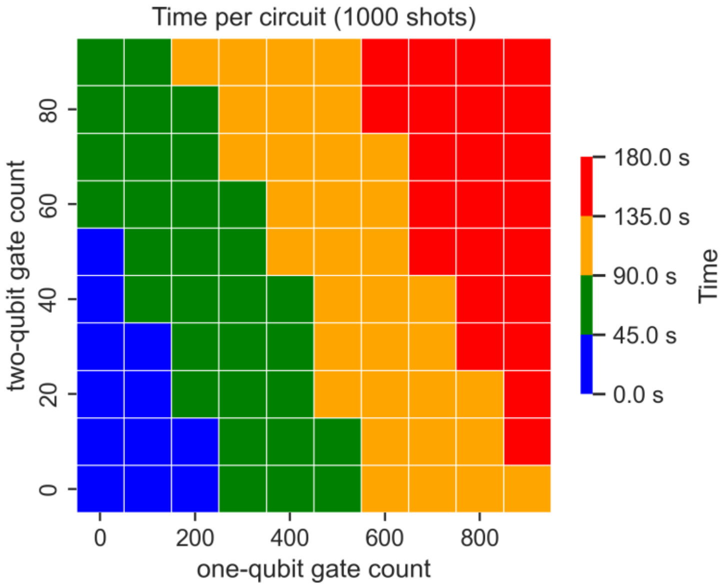
Do not wait with hardware jobs until late Sunday!

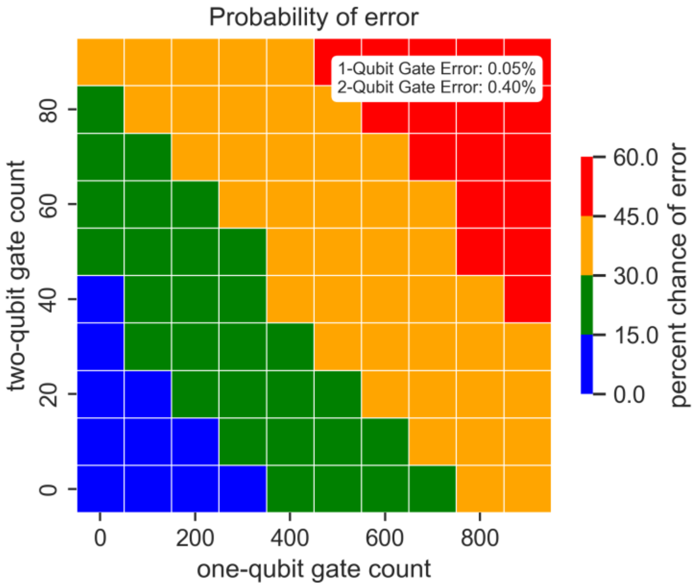
Hardware jobs: plan ahead!

Use cost estimator to budget your $500 credits (per team member) before submitting the jobs to the QPU

You can use the charts below as a rough estimate of runtime, cost, and noise impact







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Example Projects

Example 1. Find bit strings with alternating bits

Search space = all bit strings of length N

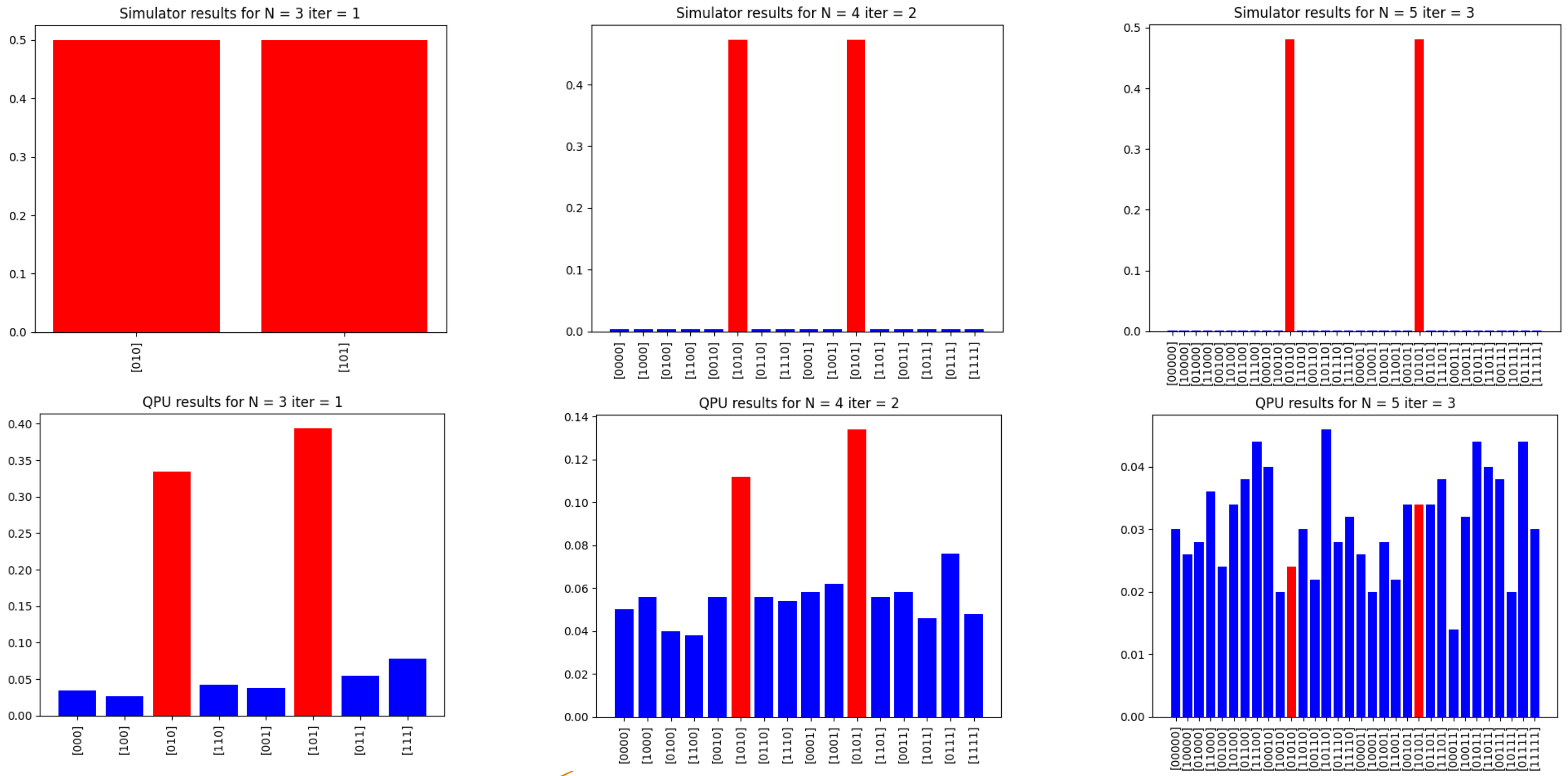
2 solutions: 0101… and 1010…

The oracle for Grover's search checks whether each pair of adjacent bits is different

As the problem size increases, both the width and the depth of the circuit grow

String length N	3	4	5
Optimal number of iterations	1	2	3
Circuit width	3	5	7
Circuit depth	5	38	111

Example 1. Find bit strings with alternating bits



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Example 2. Solve a Sudoku puzzle using Grover's search

Represent the Sudoku puzzle as a vertex coloring problem

Each empty cell corresponds to a vertex labeled 1..4

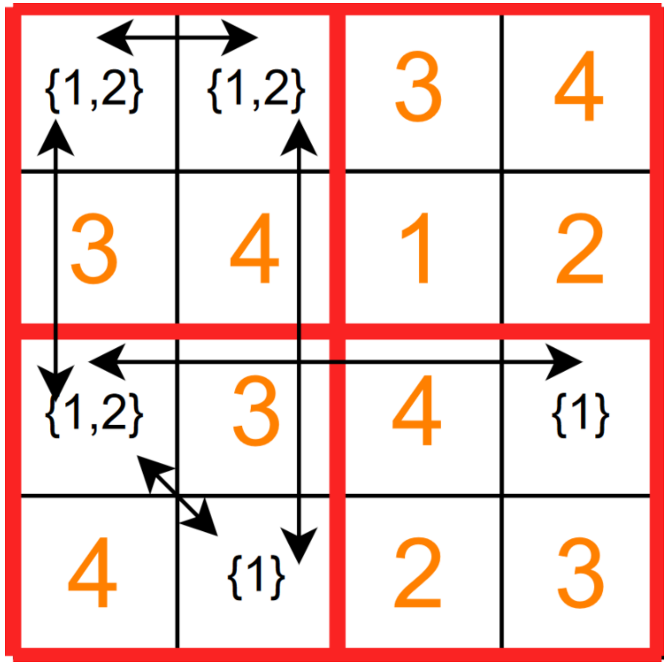
The labels that can be assigned to a vertex are constrained by the digits present in the same row, column, or subgrid

Pairs of empty cells in the same row, column, or subgrid correspond to graph edges and must have different labels

This puzzle translates to a graph with 5 vertices and 5 edges

Each vertex is encoded with 2 qubits regardless of its labels list

5 additional qubits to evaluate constraints and 1 to use as the target for the marking oracle, for a total of 16 qubits



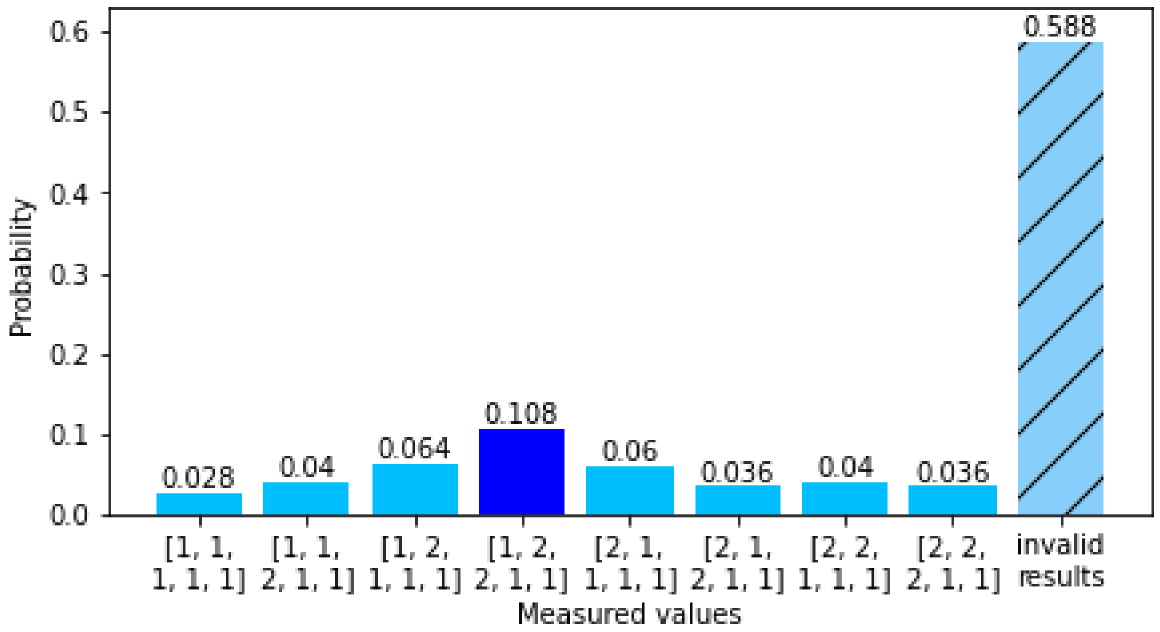
Example 2. Solve a Sudoku puzzle using Grover's search

Results of solving this puzzle instance on IonQ Aria (23 qubits)

Search space size 8 => 2 iterations

Correct result (dark blue) is the most likely one, ~11%

The last column is an aggregate of 208 invalid results (results produced by noise that don't correspond to elements of the search space), each with probability under 3%



Project ideas

Deutsch-Jozsa algorithm

Increasing problem size increases the number of qubits rather than circuit depth

Grover's search

Increasing search space size can increase both the number of qubits and the circuit depth

Quantum arithmetic

How do the results behave when processing numbers of larger size?

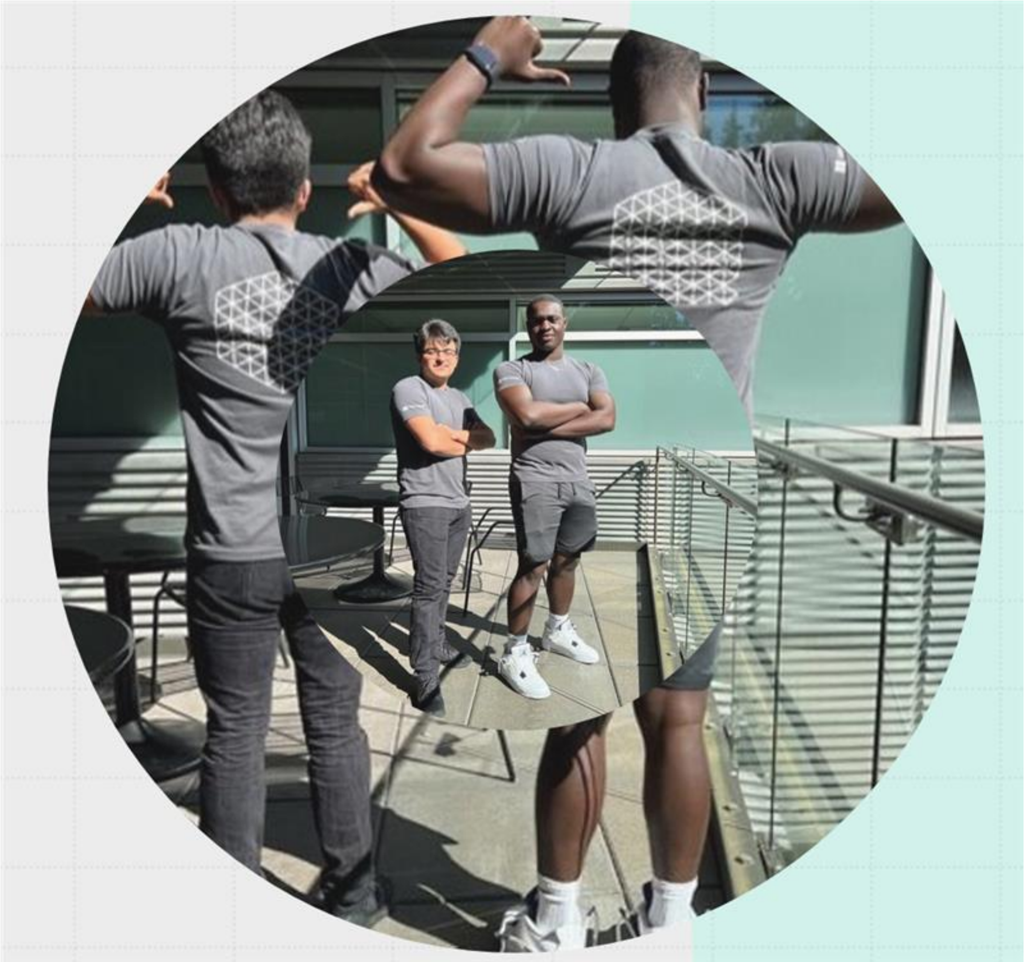
Single-iteration QAOA

Run your first Azure Quantum job and get a t-shirt!

Run your first Azure Quantum job!

Set up your Azure Quantum workspace & run IonQ HelloWorld notebook in any language (use IonQ simulator to save your credits for the Hackathon!)

Show the execution results to any Microsoft SME to get an Azure Quantum t-shirt!



Happy hacking!

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Demo: running quantum programs on Azure Quantum