Hackathon Prompt: Use Dynamic Circuits

Background and motivation:

Dynamic circuits are an exciting feature of IBM Quantum hardware that incorporates quantum circuits with real-time classical communication. Different from the static counterpart, dynamic circuits can not only implement a set of basic quantum operations like the Hadamard gate, CNOT gate, or qubit reset but also can implement measurement in the middle of a circuit, store the measurement results to classical bits, evaluate classical expressions on the fly, and determine what quantum operation to do next.
We encourage you to explore what you can do with dynamic circuits in this challenge! Some examples include but are not limited to:

- Find an application using dynamic circuits. *For example: prepare a large GHZ state, generate long-range entanglement, prepare a repetition code, do quantum phase estimation.*
- Demonstrate the improvement of implementation using the dynamic circuit feature. *For example: use dynamic circuit feature to shorten circuit depth or suppress error rate in a real circuit execution.*
- Characterize noise and errors in dynamic circuits. *For example, study how error propagates in dynamic circuits: use a benchmark method to study the fidelities of individual operations and composite operations in dynamic circuits.*
- With deeper understanding of how noise affects dynamic circuits, could you think of ways to suppress noise?

Deeper questions:

In the case of dynamic circuits, the types of error and how error propagates will be more complicated due to the hybrid quantum and classical nature of noise. We challenge you to characterize the noise in dynamic circuits. Tips: there is a suite of noise characterization and verification tools like tomography and randomized benchmarking, which are fairly well understood on static circuits, and extending them to dynamic circuits is an interesting research question to take on.

Suggested resources:

- What are dynamic circuits?
- Dynamic Circuits
- For testing and debugging the quantum circuits locally, qiskit_aer simulators can be useful
- Further reading about dynamic circuits:
  - Exploiting Dynamic Quantum Circuits in a Quantum Algorithm with Superconducting Qubits
  - Efficient Long-Range Entanglement using Dynamics Circuits
  - A randomized benchmarking suite for mid-circuit measurements
  - Randomized Benchmarking Protocol for Dynamic Circuits

Hackathon Prompt: Real-world Applications

Background and motivation:

We've entered a new era of quantum computing - The Quantum Utility era.

Quantum utility is what we get when a quantum computer can perform reliable computations at a scale beyond brute force classical computing methods that provide exact solutions to computational problems. Now, computational scientists and other researchers can tackle these large-scale problems using quantum computers with IBM's 100+ qubits backends accessible to everybody. Entering the era of quantum utility is, in other words, the quantum computers we have today are valuable tools researchers can use to explore meaningful scientific problems. Now it is your turn to tackle and explore issues with this leading-edge computational resource.

This challenge aims to design and build a cloud-based, quantum-powered application that addresses a real-world problem and is accessible to end users. This includes applications of quantum algorithms that can have practical usage and, in theory, be exposed to businesses or individual users on the internet for consumption. Teams should identify a problem that can be solved (though not necessarily more efficiently) with quantum computers.

Your prompt is to create a quantum-powered application that utilizes at least 80 qubits.

Deeper questions:

We encourage contestants to be creative and to leverage their existing quantum knowledge to develop new applications and experiments. To get you started, we offer some suggestions and prompts that may lead to interesting projects.

Some examples include but are not limited to:

- An application involving a Random Number Generator
- An application involving Optimization
- An application involving Chemical Simulation
- An application involving a Quantum Calculator
- An application involving Image Classification
- A game involving a quantum algorithm

Suggested resources:

- Variational algorithm design
- Solve utility-scale quantum optimization problems
- Quantum Computing in Practice playlist