Title: Real-Time Quantum Control with Reinforcement Learning: Integrating QPU and Classical Compute on the DGX Quantum Platform

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Abstract: Tight integration of classical and quantum compute is becoming a necessity as we scale QPUs to many dozens of qubits. The scale of QPUs as well as the improvement in gate and readout fidelities opens the path to fault tolerant computations using quantum error correction with ensembles of qubits. This however requires the real-time decoding of the logical qubit state via the observation of ancilla qubit states, tightly merging classical and quantum compute. In addition to the QEC use case, the multitude of degrees of freedom present in a multi qubit system must be controlled to consistently deliver nominal qubit drive and readout policies resulting in fidelities below the threshold. We showcase results of such a control system based on the Quantum Machines OPX controller, tightly integrated with a NVidia Grace Hopper server to optimize the control of a 5Q Rigetti Quantum Computer. Low-latency communication between the two systems is made possible using the DGX Quantum platform which allows the transfer of data from the pulse-programming language QUA to the GH superchip in under 4us (round trip). We further demonstrate how the DGX Quantum platform can be used to learn optimal policies through reinforcement learning strategies that efficiently explore the parameter space to deliver extremely fast and scalable results.

Related Works:

- **IEEE Quantum Week 2024 Tutorial:**
  https://qce.quantum.ieee.org/2024/program/tutorials-abstracts/#tut13

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- **TechCrunch Article**: https://techcrunch.com/2024/11/02/quantum-machines-and-nvidia-use-machine-learning-to-get-closer-to-an-error-corrected-quantum-computer/

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