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Lockheed Martin Quantum Machine Learning

Cooperative Research and Development Agreement Final Report

CRADA Number: FRA 2018-0005

Fermilab Technical Contact: Gabriel Perdue

Summary Report

13 July 2021

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In accordance with Requirements set forth in Article X of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

CRADA number: FRA 2018-0005

CRADA Title: Lockheed Martin Quantum Machine Learning

Parties to the Agreement: Lockheed Martin Corporation and Fermi Research Alliance, LLC

Sponsoring DOE Program Office(s): DOE Office of Science

DOE Funding Commitment Table:

(a)	*(b)*	*(c)*
	Total Project Hours	Total Project Cost
Total Labor	1.2 FTE	**$238,375.31**

Abstract of CRADA work:

The primary goal of this collaboration is to produce an algorithm for applying a class of machine learning solutions to real world problems to be executed on a quantum annealer. FRA will utilize this algorithm to produce at least one scientific publication based on data filtering using machine learning algorithms on a quantum computer. LM's primary goal is to leverage current quantum machine learning algorithmic expertise and apply it to cosmological data.

Summary of Research Results:

Our research was primarily focused on utilizing a quantum machine learning algorithm for scientific data analysis. This is a difficult task – current research suggests it will be difficult to find quantum advantage in quantum machine learning on “classical” data for fully quantum algorithms, although there will be data-dependent special cases. There is the possibility though that hybrid quantum-classical approaches may offer speed-ups or performance improvements.

For example, it may be possible to "outsource" a subroutine in hybrid classifier to the quantum processor where the processor may have a scaling advantage. Our goal was to test whether a general machine learning algorithm with this approach might show preliminary indications of a scaling advantage. We chose to use a quantum annealer because there are some circumstances under which we might expect the quantum annealer may provide a computational speed-up for certain algorithm classes, and we wanted to understand the mechanics of utilizing modern hardware and the process for efficiently encoding image data from an astrophysics problem for use by this algorithm.

We produced a paper based on this investigation, available online at https://arxiv.org/abs/1911.06259. Our primary finding was that the annealing hardware available at the time through D-Wave Systems was too noisy to offer any evidence of scaling advantage for algorithmic speed-up. We did find some evidence that there was a performance advantage in terms of absolute classification accuracy for very small datasets.

Both parties executed on their expertise – the Fermilab astrophysics team was able to present and encode a compelling domain science problem, and the Lockheed Martin team brought their considerable experience with quantum annealers to bear to get the best possible performance from the quantum hardware.

Also, it should be noted this collaboration led directly to the participation by Lockheed Martin in Fermilab's successful bid for a DOE National Quantum Center. Lockheed Martin was one the most high-profile industry partners in the consortium and their expertise was invaluable throughout the proposal and award process.

Related Reports, Publications, and Presentations:

The primary research paper produced was "Restricted Boltzman Machines for galaxy morphology classification with a quantum annealer", by J. Caldeira et al, https://arxiv.org/abs/1911.06259. J. Caldeira presented a poster summary of the work at D-Wave's user's conference in September, 2019 (https://qubitsna2019.eventzilla.net/web/event?eventid=2138748422). The poster is not available from the website but we can supply a copy on demand. Additionally, the study was cited in discussed in the paper "Quantum Machine Learning in High Energy Physics", by W. Guan et al, doi 10.1088/2632-2153/abc17d.

Subject Inventions listing:

None

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