Quantum Machine Learning for Earth Observation

Authors: Soronzonbold Otgonbaatar, Mihai Datcu

Affiliation: German Aerospace Center (DLR)

Conference: Phi-week 2020

DLR

Quantum Machine Learning for Earth Observation

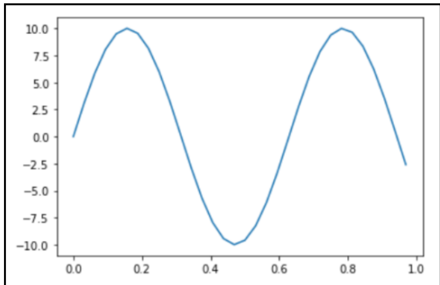
Our objectives are to employ the current methodologies and achievements made in emergent Quantum Computing to real-world problems; in particular, to enlarge and to broaden **Earth Observation** methodologies using by using a **D-Wave quantum annealer** and a **gate-based quantum computer**.

1. D-Wave quantum annealer and Gate-based quantum computers are made a huge progress in terms of theoretical research and development;
2. Such computers are well-suited to certain type of hard-problems (e.g., Boltzmann Sampling and Quantum Sensing), which, otherwise, are ill-suited on conventional computers;
3. Well-suited and real-world problems for a D-Wave quantum annealer and a Gate-based quantum computer to be found is an ongoing research;

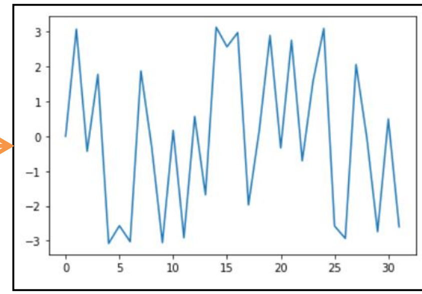
Therefore, we are exploring real-world problems in Earth Observation which are well-suited (e.g., speeding up algorithms, finding global minimum of optimization, or sampling) on a quantum computer over a conventional computer. The quantum computer might prove relevant even if we are not intended to exhibit advantages over a conventional computer.

Quantum Annealer for Residues Connection in InSAR

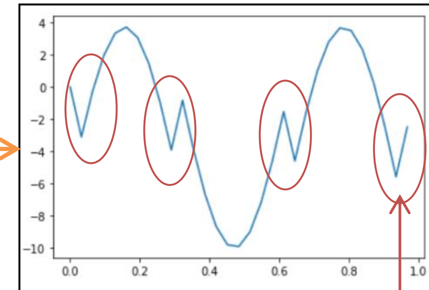
1D Signal



1D Wrapped Signal



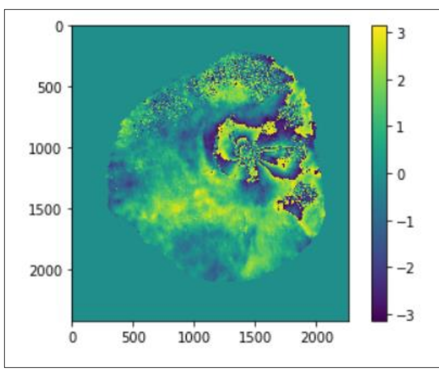
1D Unwrapped Signal



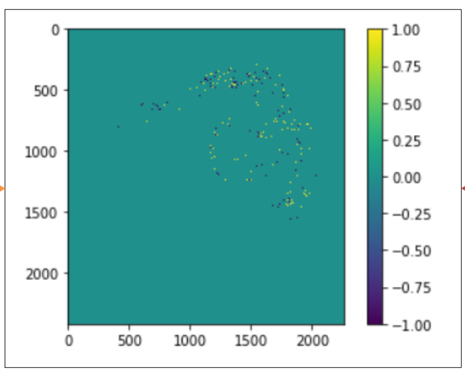
Not a same result after unwrapping the wrapped signal.

Due to noise in signal

2D Signal



Noise in 2D Signal



The Noise can be visualized easily on 2D signal.

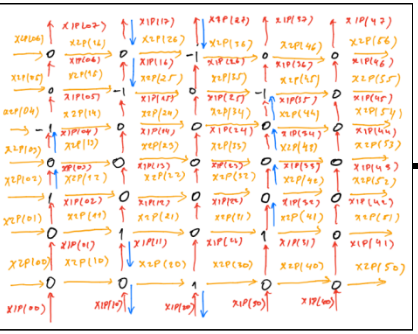
Quantum Annealer for Residues Connection in InSAR

Noise in 2D signal is named after Residues, and the residues must be avoided or connected; So,

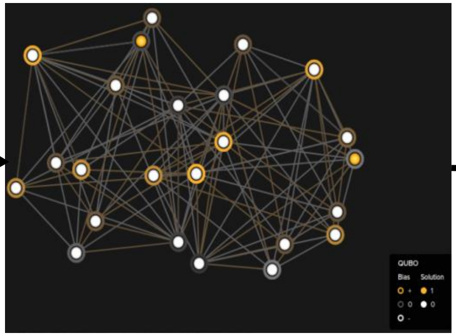
1. Residues can be formulated as a Network Flow (NF) connection problem (Fig. 1);
2. The NF connection problem can be written as quadratic binary optimization problem (QUBO) which have many local solution valleys.
3. Quantum Annealer (QA) promises to solve a QUBO problem efficiently (e.g., finding a global solution) than a classical computer.

Therefore, we formulate the NF problem as a QUBO problem and solve it on the QA. The QA might prove relevant even if we are not intended to increase computational speed and implement whole phase unwrapping procedure, but we aimed to formulate QUBO and embed into the QA.

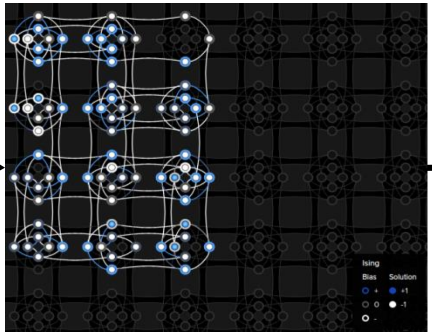
Fig. 1: Noise in 2D Signal



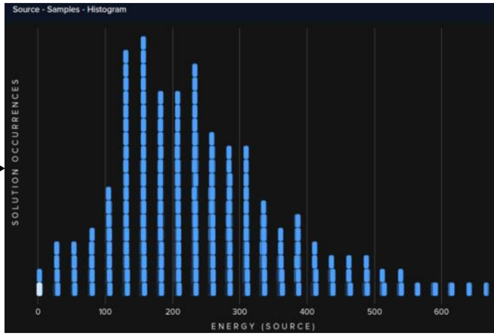
Noise in 2D Signal



Embedding in the QA



Solution in the QA



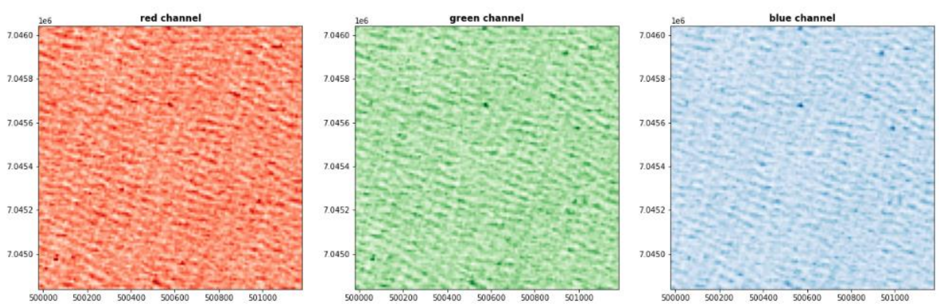
Gate-Based Quantum Image Classification

Number of physical bits (qubits) of Gate-based quantum computer is fewer (~100) than one of the QA (~2000);

1. Qubits of our quantum computer in our study are 17;
2. Hence, EuroSAT image must be reduced in dimension (4x4) by preserving its feature information;
3. And gate-based quantum computer has trainable parameters. Such a quantum computer is called a parametrized quantum circuit (PQC).

Therefore, we can feed dimensionally reduced images into a PQC and classify them by using parameters of a PQC.

EuroSAT Image Dataset

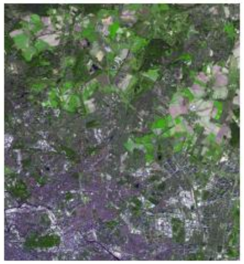


Size of 64x64, 3 Bands, 2 Labels.

Classification result

Quantum: Validation accuracy: **0.9970** Validation Loss: **0.0386**

Classical: Validation accuracy: **0.9994** Validation Loss: **0.0078**



(a) A case of Berlin with several labels.

Fig. 1: The classical deep Learning and PQC are shown for classification of Berlin. The *white* color denotes a **Residential class,** and the *Black* color denotes **a Annual Crop** class. The visual image shows that the quantum classification is better for detecting the vegetation even among building areas than a classical neural network.

(b) The Classical result.

(c) The quantum result.

Conclusion

In this work, we investigated and tested the capabilities of a novel quantum annealing optimization and classification quantum algorithm for real-world problems; in particular, Earth Observation. We proposed a way to formulate a QUBO problem and run the quantum annealer for residue connection and a parametrized quantum circuit for classifying real-world dataset of the Earth observation, EuroSAT.

References

[1] E. Farhi, J. Goldstone, S. Gutmann, "*A Quantum Approximate Optimization Algorithm*", [quant-ph/1411.4028].

[2] M. Costantini, "*A novel phase unwrapping method based on network programing*," IEEE Transactions on Geoscience and Remote Sensing, vol. 36, pp. 813-821, 1998.

[3] E. Farhi, H. Neven, "*Classification with Quantum Neural Networks on Near Term Processors*", [quant-ph/arXiv:1802.06002].

[4] P. Helber, B. Bischke, A. Dengel, D. Borth, "*Eurosat: A novel dataset and deep learning benchmark for land use and land cover classification*", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2019.

Thank you for watching!