

Theme: *Compute the mean electrical axis of the heart on IBM quantum hardware.*

Make the heart axis prediction using the DWave Quantum Annealers

By AXIS Team

Adiabatic Linear Regression

- *Adiabatic Quantum Linear Regression* by Prasanna Date and Thomas Potok.

Ref: Date, P., Potok, T. Adiabatic quantum linear regression. Sci Rep 11, 21905 (2021).

<https://doi.org/10.1038/s41598-021-01445-6>

- Linear Regression can be formulated as an optimization problem where the Euclidean error function $E(w)$ is minimized.

$$\min_{w \in \mathbb{R}^{d+1}} E(w) = ||Xw - Y||^2.$$

Adiabatic Linear Regression

- Formulate the Euclidean error minimization as a QUBO (Quadratic Unconstrained Binary Optimization) problem that could be submitted to the DWave Quantum Annealers.

$$\min_{w \in \mathbb{R}^{d+1}} E(w) = w^T X^T X w - 2w^T X^T Y + Y^T Y.$$

Adiabatic Linear Regression: Code Implementation

```
import QALinearRegression

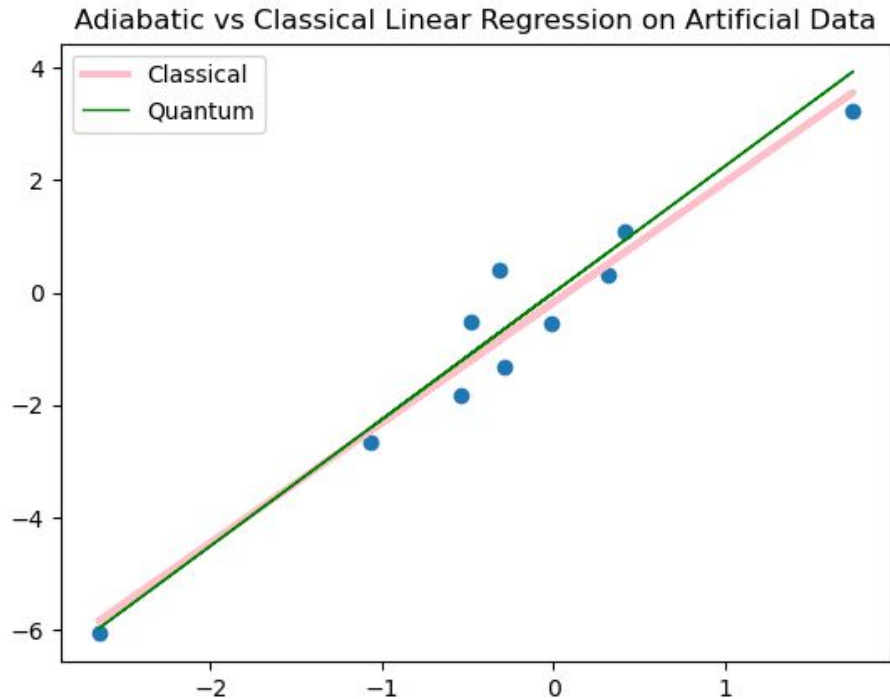
quantum_lin_regression = QALinearRegression()
quantum_lin_regression.train(x_train, y_train)
quantum_lin_regression.predict(x_test)
```



1. Construct the QUBO matrix with the model's coefficients
2. Constructs the objective function to be submitted to the Quantum Annealer
3. Optimizes the Euclidean error function on a Quantum Annealer (Simulated Annealing was tested only.)
4. Returns the set of optimized coefficients for the linear model that is used to make predictions.

Test on Artificial Data

- Classical Framework: Python Scikit Learn (pink line)
- Quantum: DWave Ocean SDK, Quantum Annealing (green line)

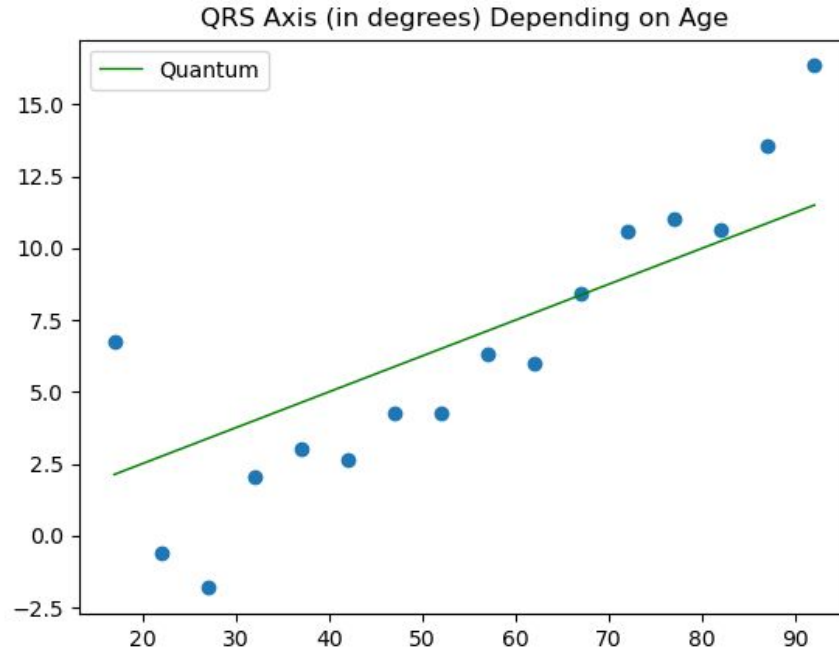


Adiabatic Linear Regression on Medical Data

1. Medical data has been taken from *A 12-lead electrocardiogram database for arrhythmia research covering more than 10,000 patients* Jianwei Zheng et. al.
<https://figshare.com/collections/ChapmanECG/4560497>
2. The ECG records in the database have been prepared in a similar way as described in *Combined Effects of Age and Comorbidities on ECG parameters in a Large Non-Selected Populations*.
Ref. Giovanardi, P.; Vernia, C.; Tincani, E.; Giberti, C.; Silipo, F.; Fabbo, A. *Combined Effects of Age and Comorbidities on Electrocardiographic Parameters in a Large Non-Selected Population*. *J. Clin. Med.* 2022, 11, 3737. <https://doi.org/10.3390/jcm11133737>
3. From each ECG record, patient's age and QRS axis has been collected.
 - a. All patients were divided into age groups (15-19, 20-24, 25-29, etc. years old)
 - b. The QRS data has been averaged within each age group.

Adiabatic Linear Regression on Medical Data

Trained Quantum Linear Regression
on the Medical Data.



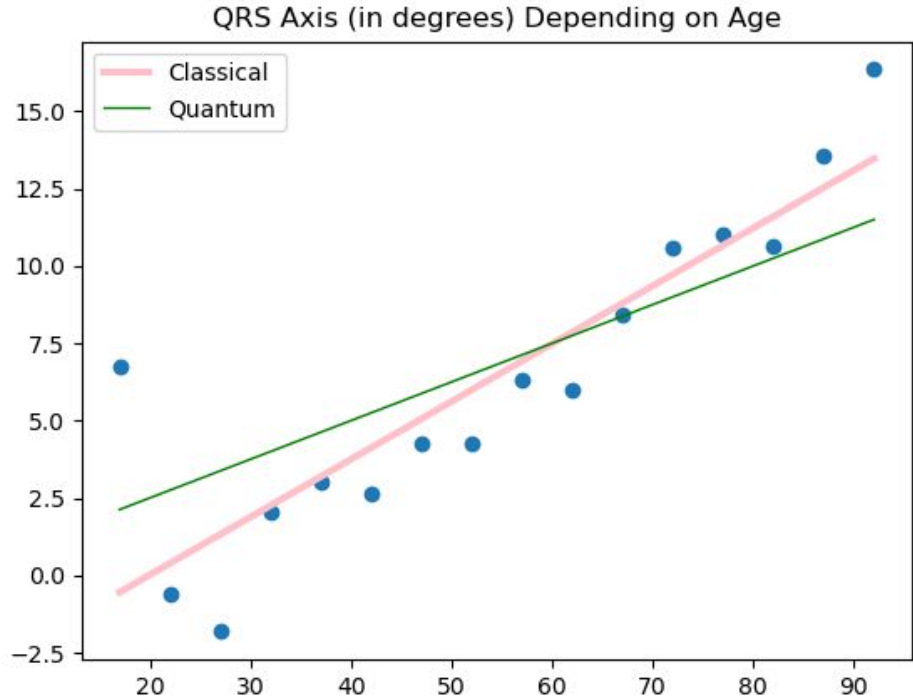
Adiabatic Linear Regression on Medical Data

Compare to the Python Scikit Learn
Linear Regression

The Quantum Linear Regression
encorporates ML metrics as well

The model was evaluated on
*Electrocardiography (ECG) Signals
Database* available on Kaggle.

MAE: 29.3.
MSE: 10277.6
RMSE: 101.4
 R^2 : 0.045



Thank You!