Survey of Machine Learning Methods for Antineutrino-Based Reactor Burnup Time Prediction

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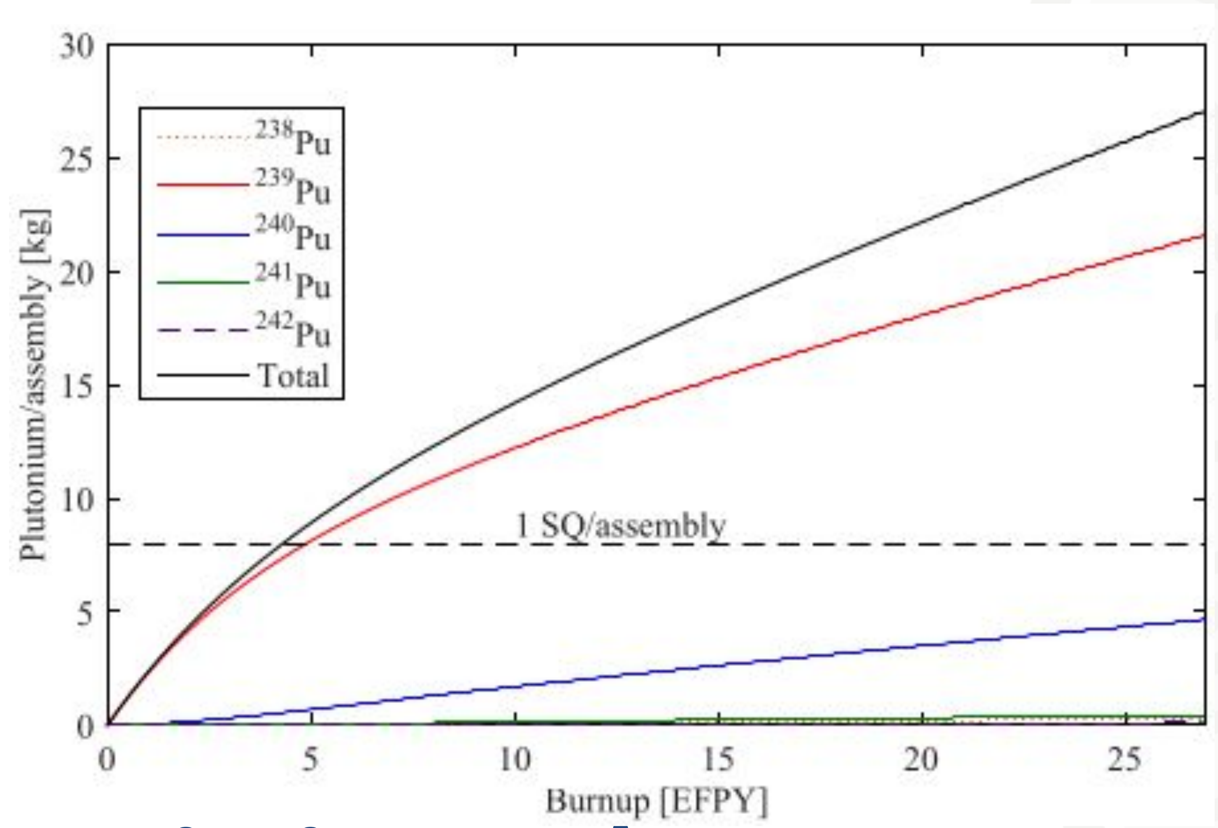
Introduction and Motivation

- As a reactor generates power via fissions in the core, it also breeds plutonium, which can be removed by foreign actors for use in nuclear weapons proliferation
- For this reason it is important to be able to verify the time that the reactor has been running, in order to account for expected reactor inventory



Mission Relevance

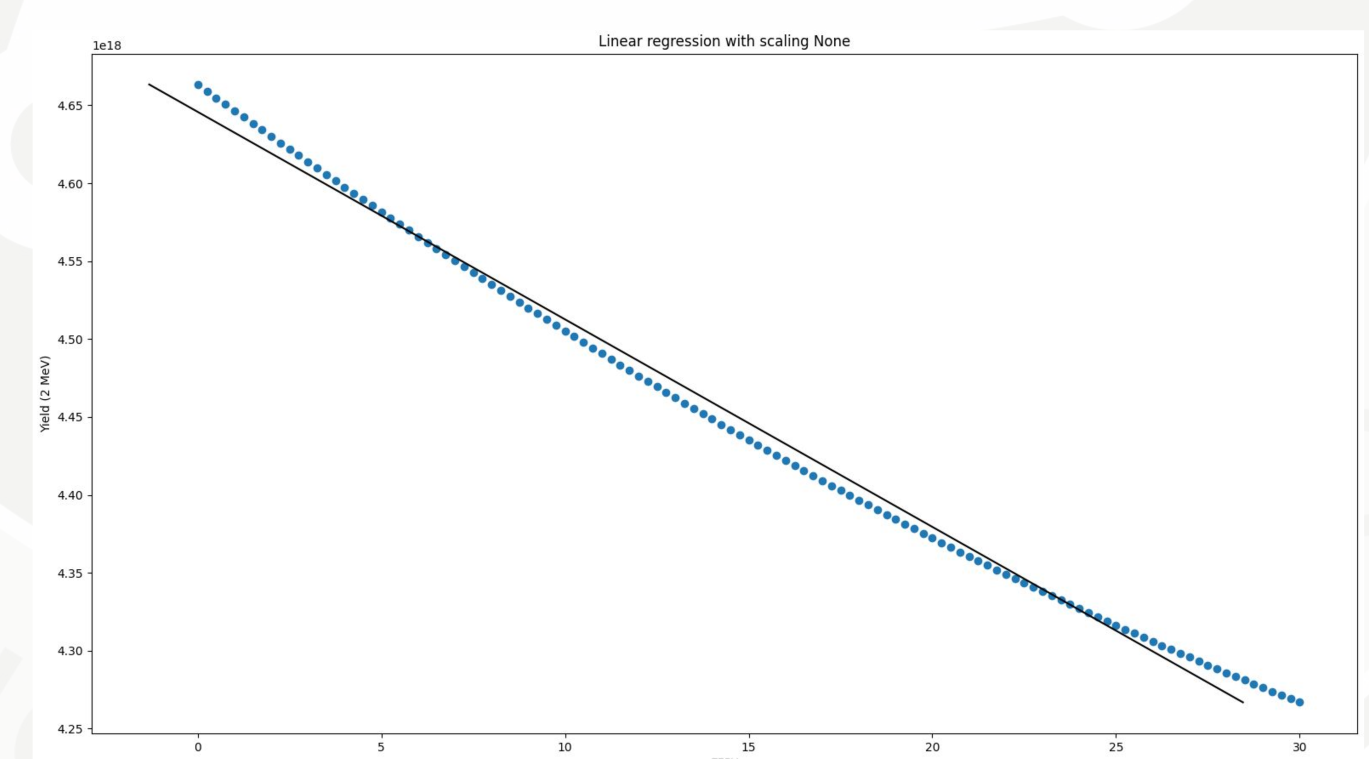
- This work seeks to improve methods of international Non-Proliferation Treaty (NPT) verification by the IAEA
- Response to the 1994 North Korean crisis could have been aided by such technology

Technical Approach

- This work is performed on AFR-100 isotopic fission rates generated from REBUS/MCC simulations by Christopher Stewart
- The models operate on antineutrino yields from the reactor and do not include detector
- The investigated methods for predicting burnup time in Effective Full-Power Years (EFPY) are:
  - Regression (linear and polynomial)
  - Support Vector Regression (SVR)
  - Neural Network (with mean-squared error loss)

Results

- Currently, the linear regression is performing the best, by measure of the difference between the actual and algorithm-predicted values.



- Currently, the results of the SVR and neural network are not demonstrably optimized. The current performance of these methods are shown in Table 1

Table 1

True EFPY	Linear Regression Prediction (and deviation)	Linear SVR (scaled) Prediction (and deviation)	Neural Network Prediction (and deviation)
13.5	13.500 (2.300e-07)	13.534 (-0.034)	13.461 (0.038)
19	19.000 (1.122e-07)	18.941 (0.058)	18.994 (0.005)
8.75	8.749 (5.569e-07)	8.634 (0.115)	8.730 (0.019)
25.25	25.249 (6.408e-07)	24.718 (0.531)	25.240 (0.009)
29.25	29.250 (4.484e-07)	28.223 (1.026)	29.243 (0.006)

- These results represent one given run, as the neural network and SVM will predict slightly different values for every run due to the random nature of the training process
- The linear regression however, predicts the exact same values every time

Conclusion

- Currently, without definitively optimized models, the linear regression predicts the closest to the correct estimates for reactor burnup time, demonstrating the effectiveness of simple models over complex ones for tasks with a simple mathematical relationship

Next Steps

- Verify optimization of hyperparameters for the neural network and SVR
- Test polynomial regression and nonlinear kernels for the SVR

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