Fuel Spray Prediction for Efficient Combustion using AI with Confidence Intervals.

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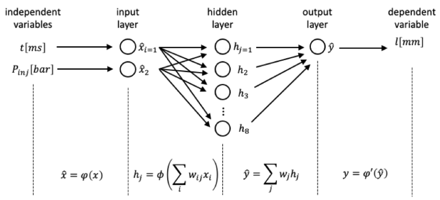
Summary

Neural networks have become important tools for predicting physical phenomena, including spray penetration [1]. This applies also field of internal combustion engine efficiency and optimization [2]. Confidence intervals improve the usefulness of neural network predictions for engineering applications.

Chryssolouris et al. [1] derived confidence intervals for a neural network from fundamental statistics in 1996, but there are difficulties implementing this as a methodology in practice. Trichakis et al. [2] reviewed numerical methods of estimating the confidence intervals with a view to neural network applications (in aquifer management) and adapted the bootstrap method of Efron [3].

The present work extends the state of the art by incorporating uncertainty due to under training alongside uncertainty due to experimental variations. When working with limited available training data, neural networks are intentionally undertrained. Random initialisation effects are quantified along with variations due to uncertainty in input data to create confidence intervals encompassing both aspects.



We introduce Full Range Sampling to enforce an even representation of data from the entire experimental domain. This helps to address the tendency of the bootstrap method to over-estimate uncertainty at the limits of the experimental domain.

Methodology

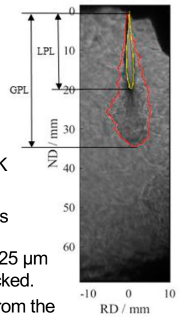
Gas and Liquid penetration data from Honecker (2019) [6]

Injection pressures:
700 bar
1000 bar
1500 bar

Cylinder conditions:
50 bar, 800K

Injector:
310mL / 30 s
at 100 bar
8 holes of 125 µm
5 holes blocked.

Measured from the downward-facing hole.



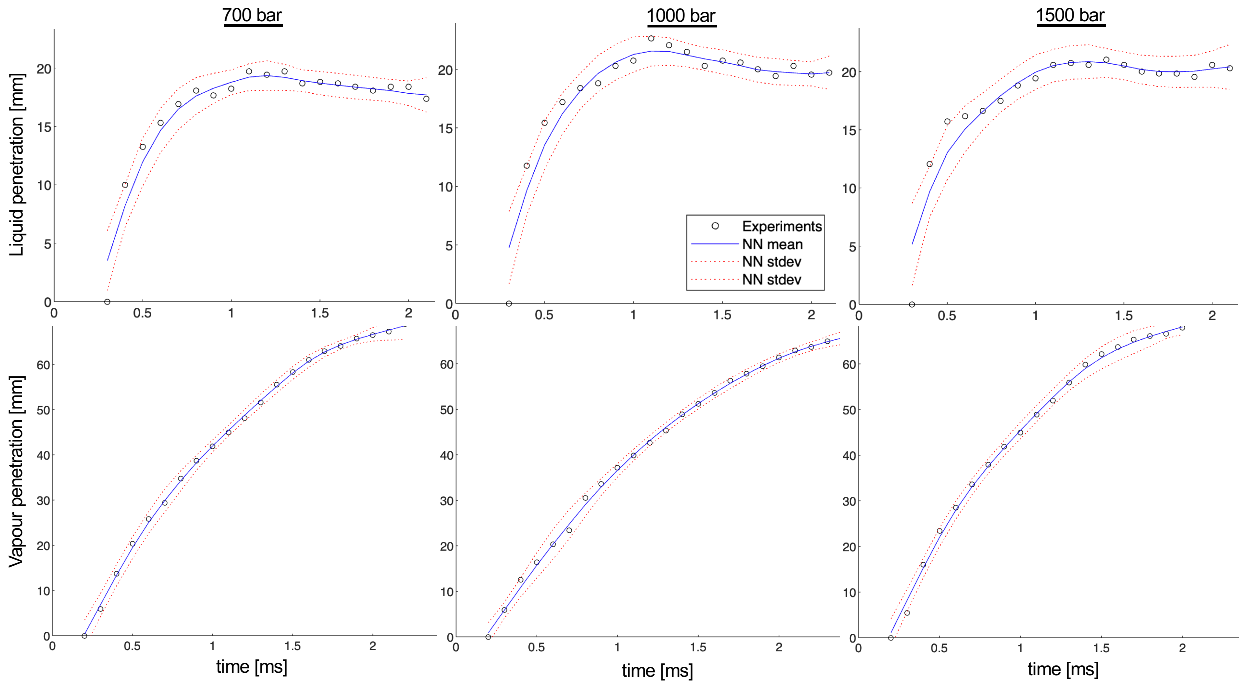
We used 20x repeat measurements to generate 100x randomised complete datasets to train 100x neural networks.

The population of 100 neural networks are all under-trained (because of limited range of experimental data available).

The population mean and standard deviation are used to calculate predictions with confidence intervals, encompassing both experimental uncertainty and model uncertainty.

Results

Mean and standard deviation predictions from a population of 100 neural networks each trained on random combinations of resampled experimental data.



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[2] Koukouvinis, Phoevos, Carlos Rodriguez, Joonsik Hwang, Ioannis Karathanassis, Manolis Gavaises, and Lyle Pickett. "Machine Learning and Transcritical Sprays: A Demonstration Study of Their Potential in ECN Spray-A." International Journal of Engine Research 23, no. 9 (2021): 1556–72.

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