AI-based Advanced Control Methods for Next Generation Combustion Engines

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Background

The internal combustion engine faces increasing societal and governmental pressure to improve both efficiency and engine out emissions. Currently, research continues in improving traditional combustion methods (diesel) as well as exploring new highly efficient combustion strategies such as homogeneous charge compression ignition (HCCI). However, predicting the exact value of engine out emissions is still a challenge for engine researchers due to the complexity the of combustion and emission formation. Experimental testing on a Cummins diesel engine (Figure 1) and an electromagnetic valve single cylinder engine in HCCI combustion mode (Figure 2) were used to collect performance and emission data.

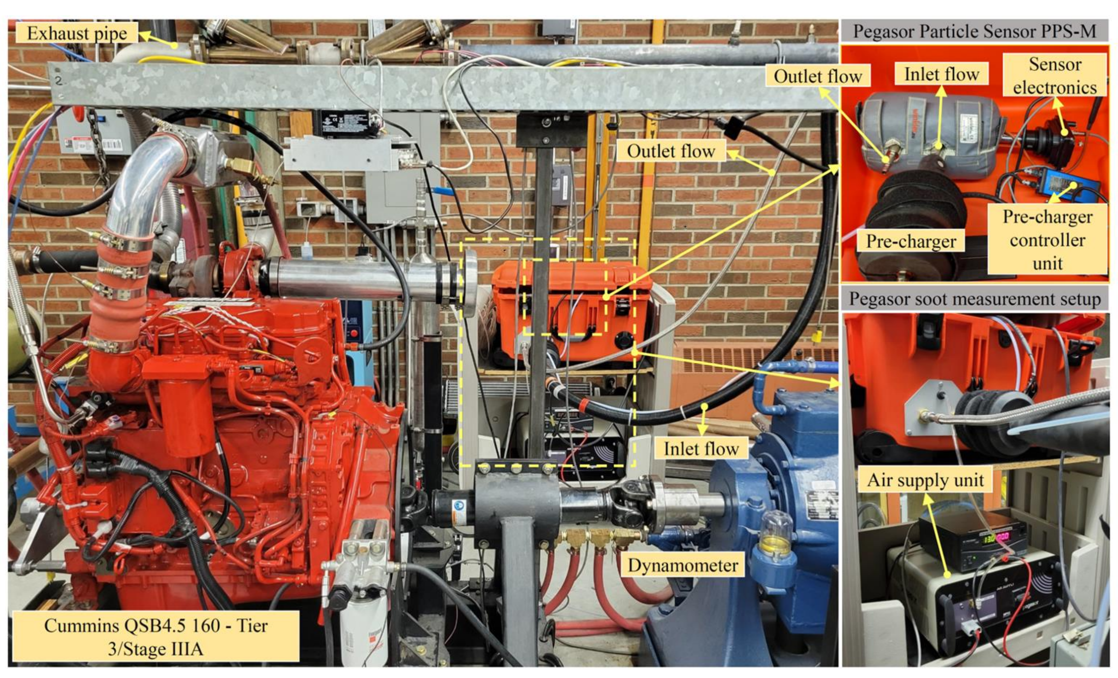

Figure 1: Diesel experimental setup

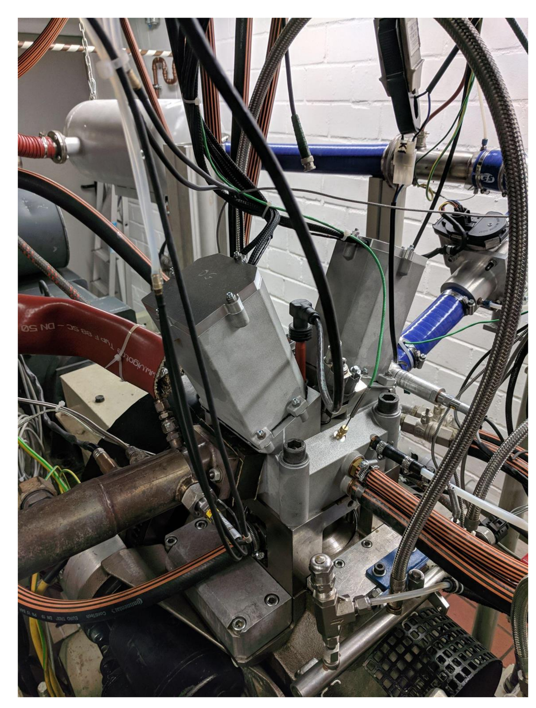

Figure 2: HCCI experimental setup

Methodology

Grey-box modeling approaches are used to combine the advantages of the physical understanding of the process with AI-based data-driven methods. Grey-box can be either a simple physical model (0D or 1D) to generate features cannot be measured in real-time (Figure 3- **Method I**) or using measured features chosen using a physical understanding of the process (Figure 4- **Method II**).

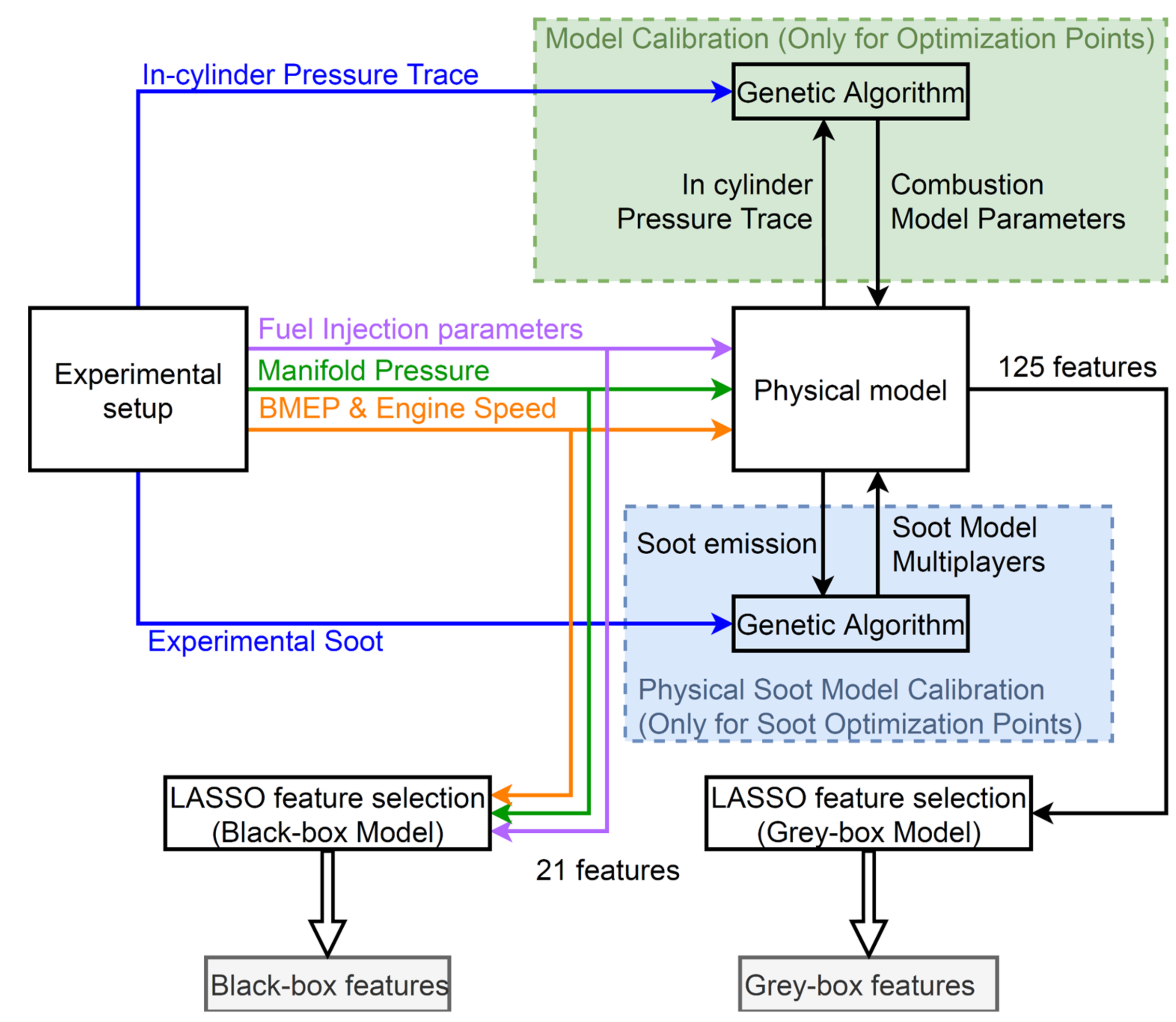

Figure 3: Diesel soot emission modeling process using grey-box techniques

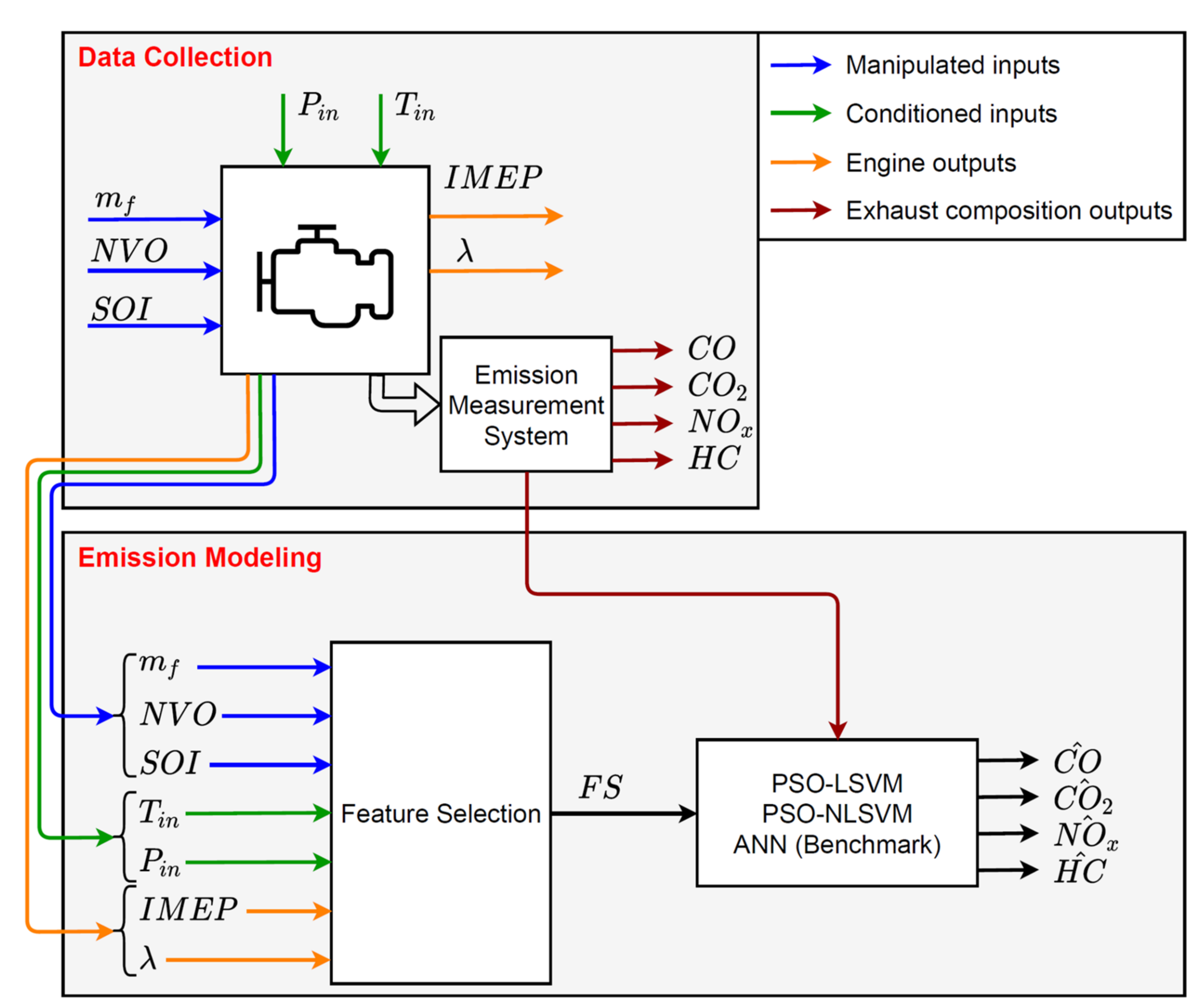

Figure 4: HCCI emission modeling process using grey-box techniques

Results

Different Machine Learning (ML) methods were used in grey-box modeling frameworks for emissions prediction. Figure 5 shows the difference in model performance for soot prediction on the diesel engine in **method I** framework. The physical-based model not only requires high computational resources to run, but also fails to predict emissions accurately. Figure 6 shows the HCCI emissions prediction performance for unburnt hydrocarbon (HC) and carbon monoxide (CO) emissions. This figure shows effect of physical-based features in emission modeling based on **Method II**. Different ML methods can be used in these frameworks such as Support Vector Machine (Linear or Nonlinear), Artificial Neural Network (ANN) and Bayesian Neural Network (BNN).

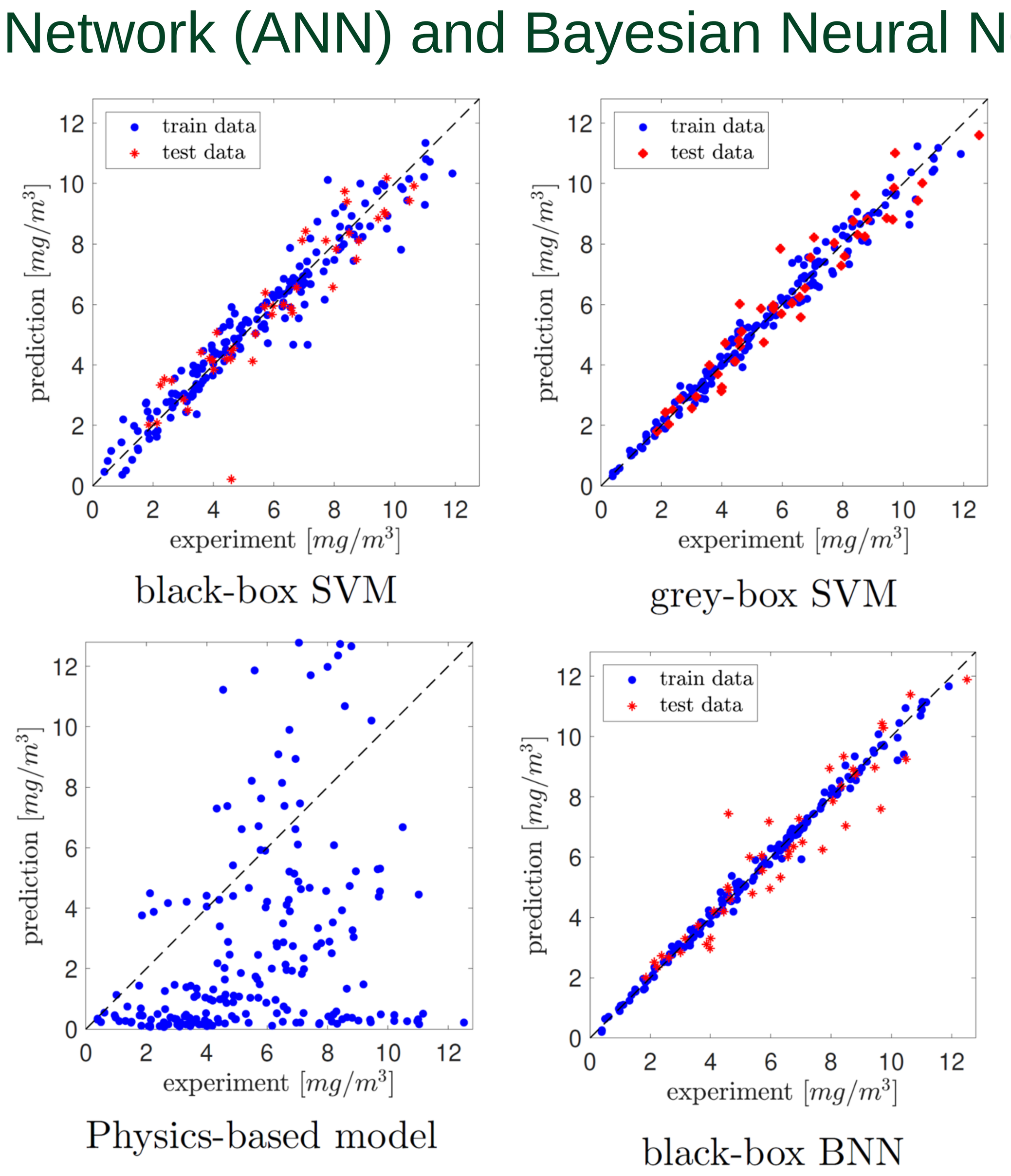

Figure 5: Diesel soot model (method I)

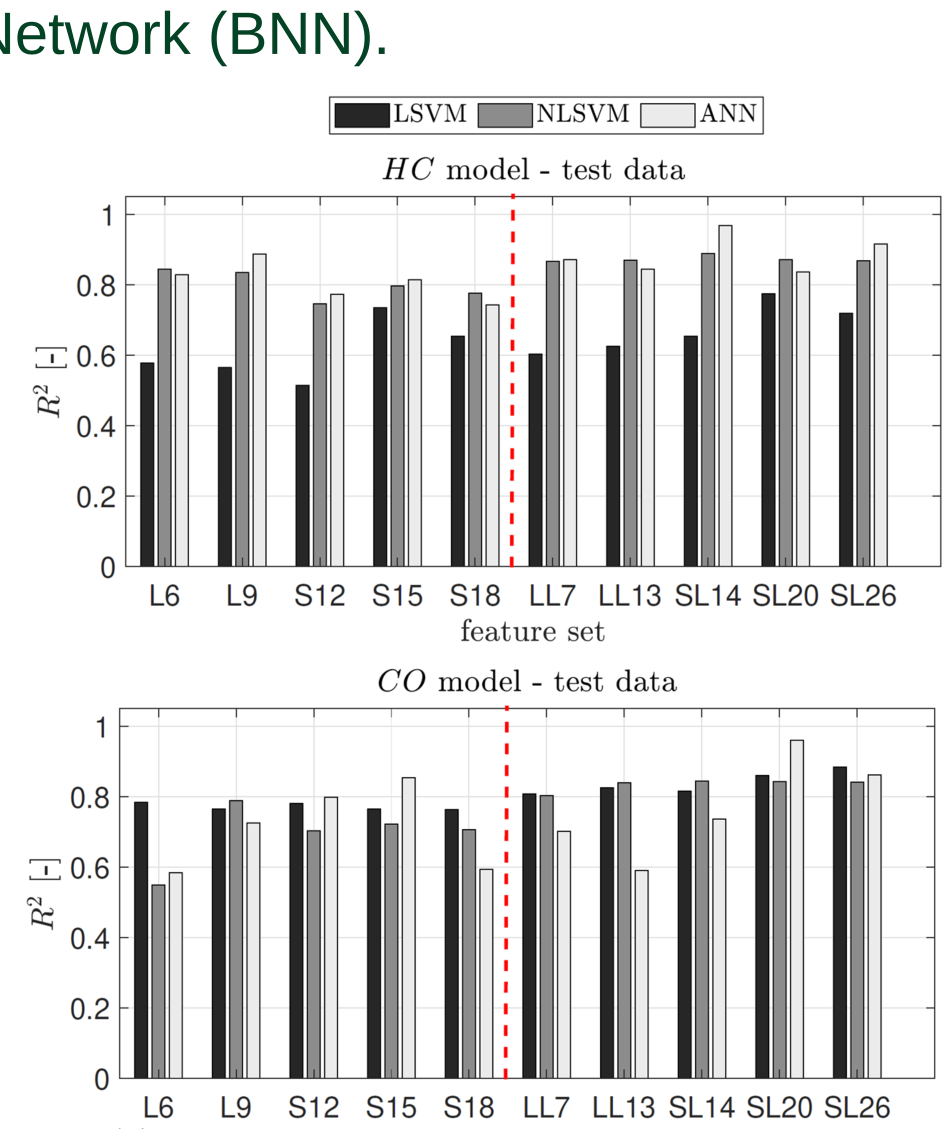

Figure 6: HCCI HC and CO model (method II)

PARTNERS

Reference

[1] Shahpouri, S.; Norouzi, A.; Hayduk, C.; Rezaei, R.; Shahbakhti, M.; Koch, C.R. Soot emission modeling of a compression ignition engine using machine learning. IFAC-PapersOnLine 2021. Modeling, Estimation and Control Conference (MECC 2021).

[2] Gordon, D.; Norouzi, A.; Blomeyer, G; Bedei, J; Aliramezani, M; Andert, J; Koch, C.R. Support Vector Machine Based Emissions Modeling using Particle Swarm Optimization for Homogeneous Charge Compression Ignition Engine. International Journal of Engine Research 2021. (under review).

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