Characterization of Gasoline Fuel Spray Dynamics in IC Engines using AI

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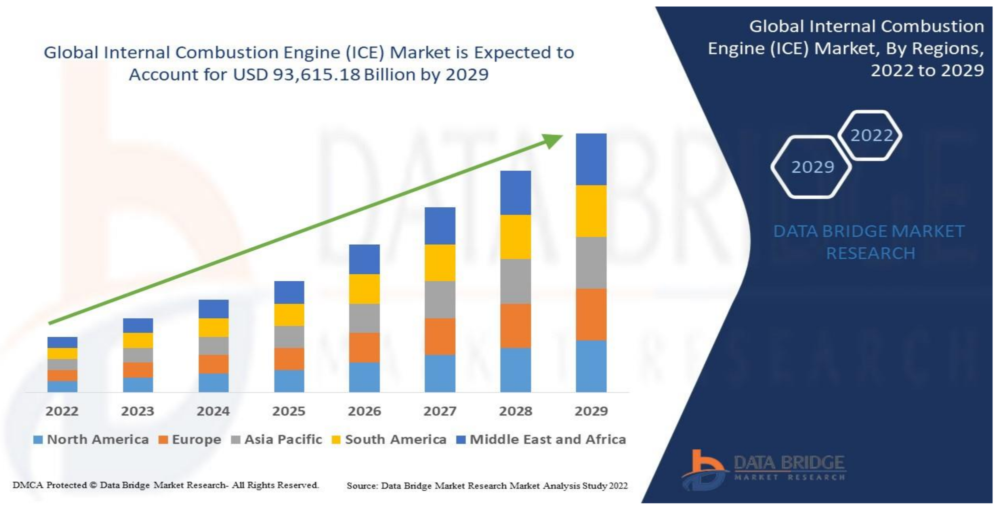
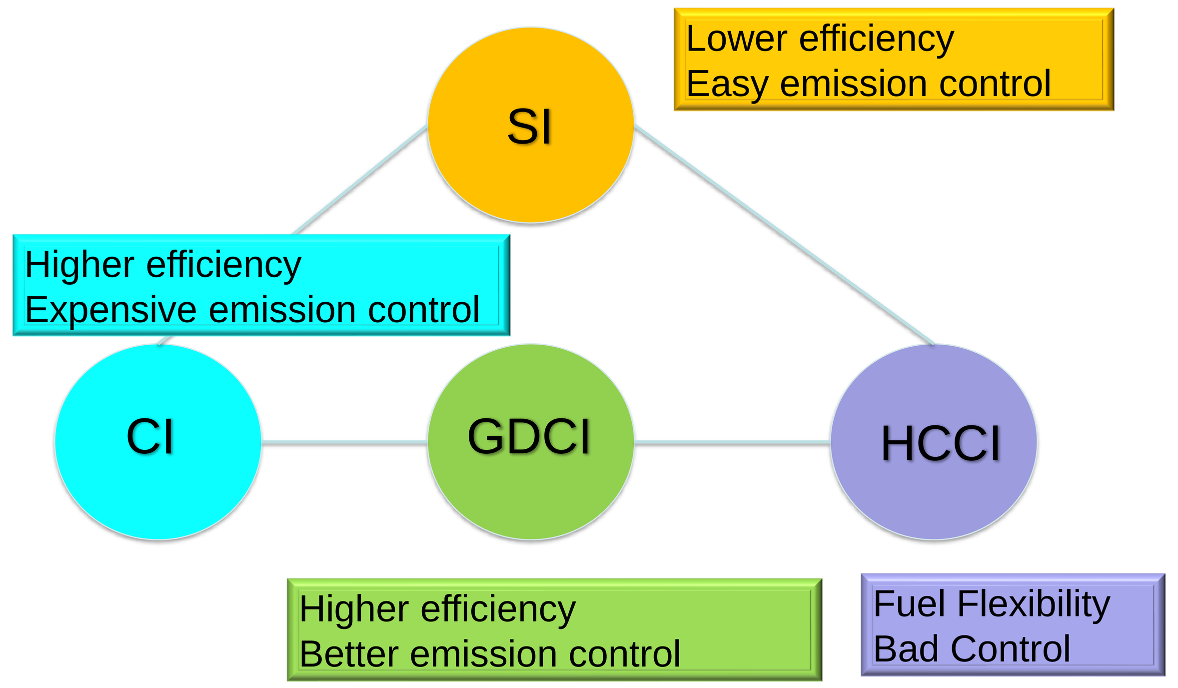
Introduction

- The increase in energy demand and stringent measures on automotive vehicle emissions has led researches to find ways to optimise engine performance.

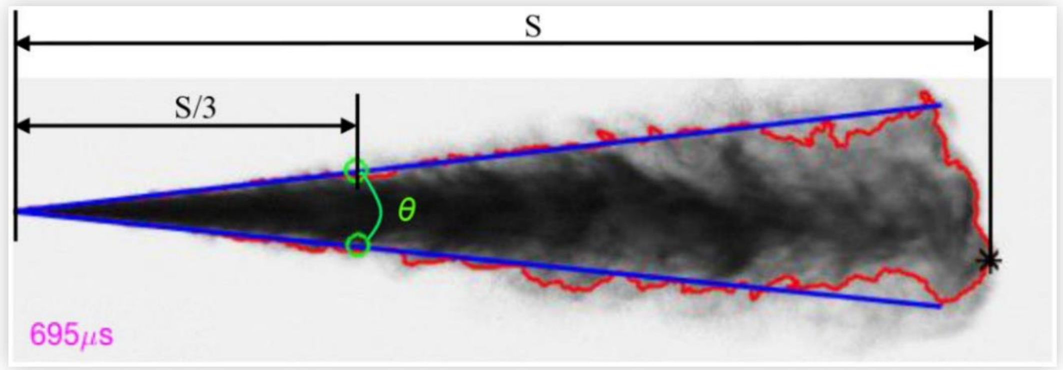


- Gasoline Direct Injection (GDI) in CI engines have shown significant amount of reduction in NO_x and soot when compared to conventional diesel fuel.



- The combustion efficiency, emissions, and combustion stability are highly related to fuel-air mixing in the cylinder.

- Numerous experimental and computational research have generated fuel spray data that can be used to create a machine learning model for predicting spray characteristics.



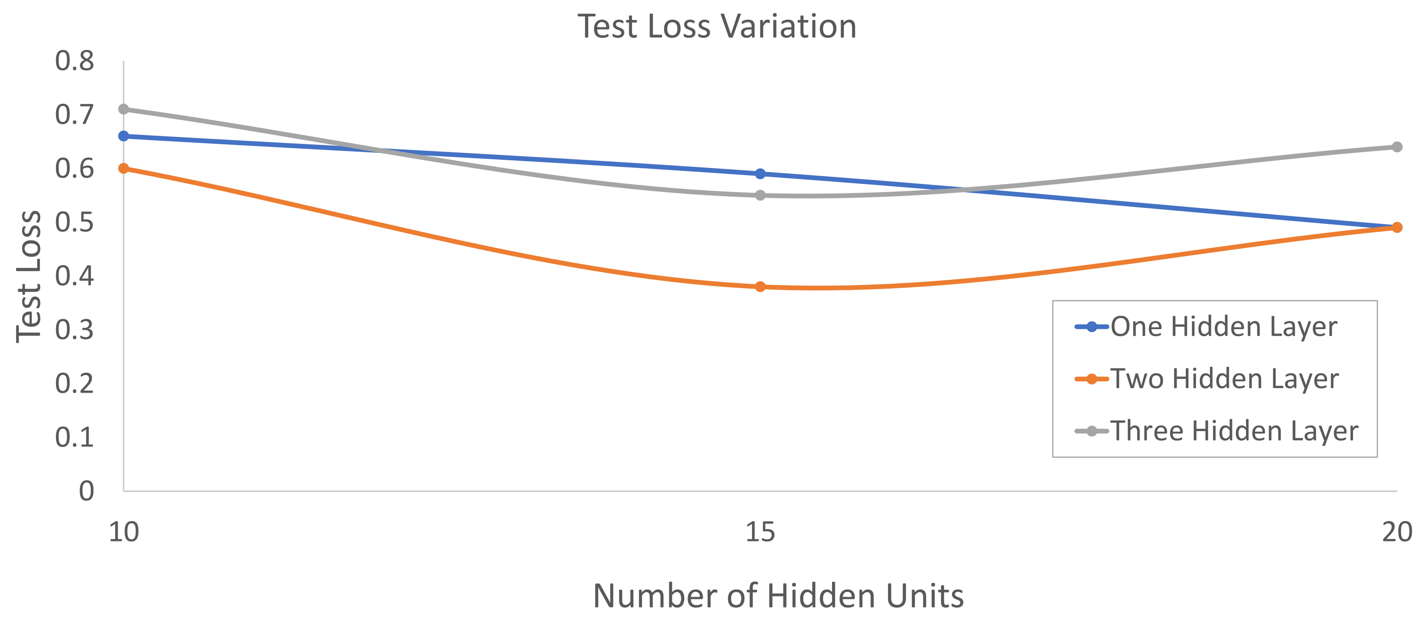
Methodology

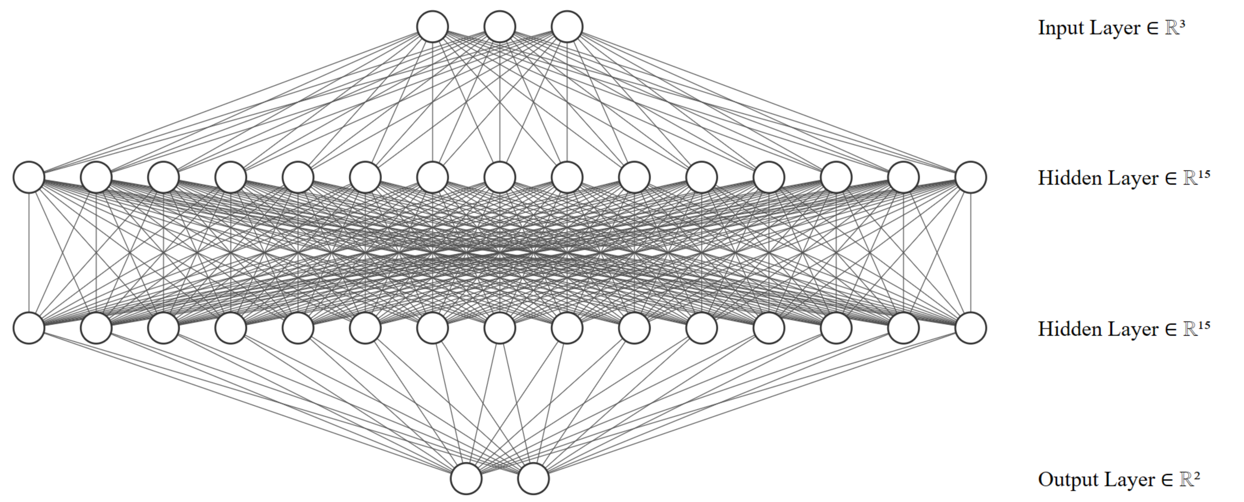
- Fuel spray data consisting of 4170 samples was used for training a fully connected neural network with data split of 70-15-15 for training, validation and testing.

- The fuel injection pressure (300-1500 bar), chamber pressure (1-20 bar) and time are used as scaled input features to the model.

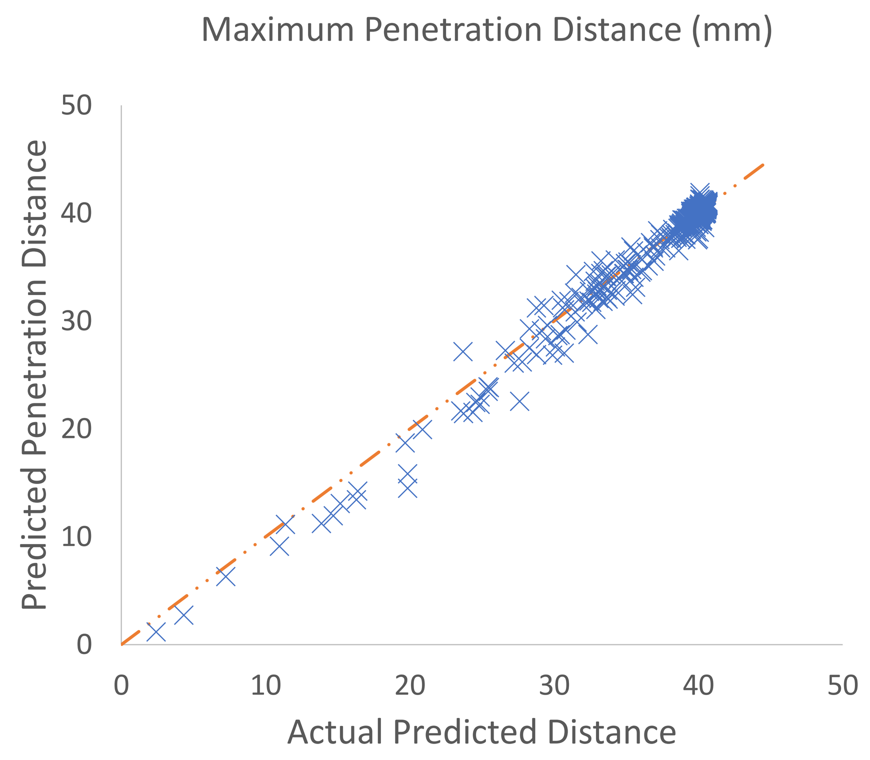
Input Features			Output Features	
Injection Pressure (bar)	Chamber Pressure (bar)	Time (ms)	Spray Angle (degrees)	Maximum Penetration (mm)
300	10	0	0	0
600	5	0.014484	0	0.0792
1200	10	0.02897	0	0.2124
300	1	0.043455	0	0.35664
900	20	0.057941	0	0.65911
1500	10	0.072426	0.49199	0.96536
300	1	0.086911	0.50169	1.3395

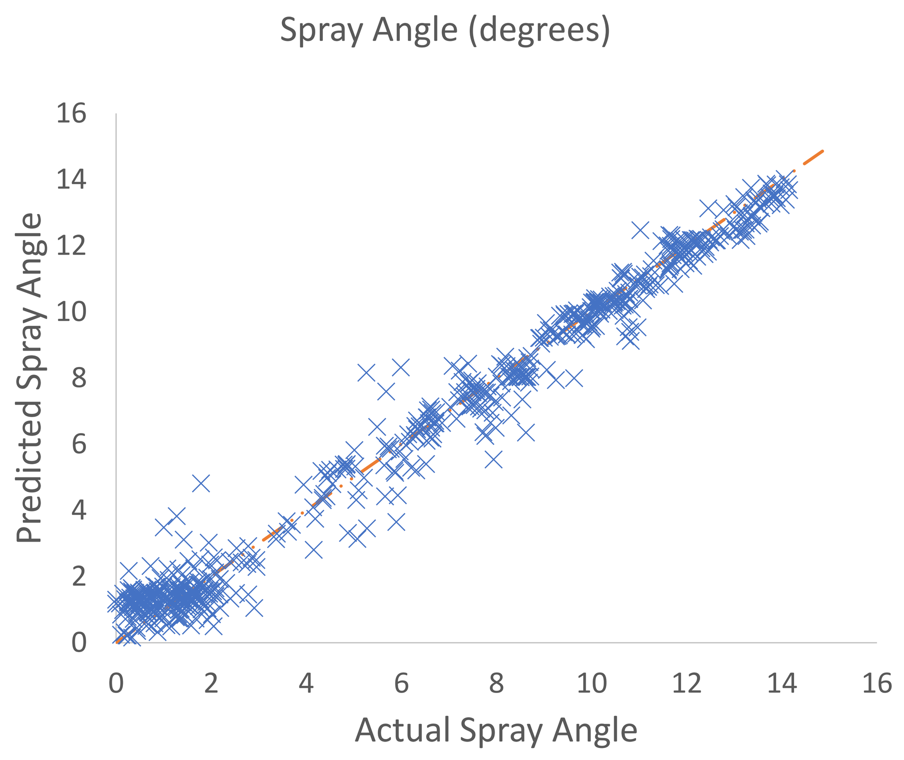
- The training was carried out using neural networks of varying architectures to obtain the best fit.





Results





Epochs	Training Loss	Validation Loss	Test Loss
500	0.046	0.052	0.057
1000	0.024	0.031	0.038
1500	0.015	0.019	0.065

Summary

- The neural network model has effectively learned the fuel spray characteristics from the provided training data and is performing quite well on the test data with a test loss as low as 0.038.

- The model is capable of estimating the spray angle and maximum penetration distance for any given combination of injection pressures and chamber pressure within the range of experimental conditions.

- The obtained results exhibit satisfactory agreement with the experimental data, indicating that the maximum penetration distance and spray angle are significantly influenced by chamber pressure, while their dependence on fuel injection pressure is relatively weak.

Ongoing Work

- Recurrent Neural Network (RNN) for time-series modeling of the data, aimed at obtaining the evolution of fuel spray characteristics over time.

- Enhancing the efficiency of the model by incorporating spray images as input features. Additionally, we can generate spray images as outputs for a given set of input data.

- Extending the ML model to alternative fuels like hydrogen/hydrogen blends.