XGBOOST: A STATE OF THE ART LIBRARY FOR PREDICTING FIRE RESISTANCE

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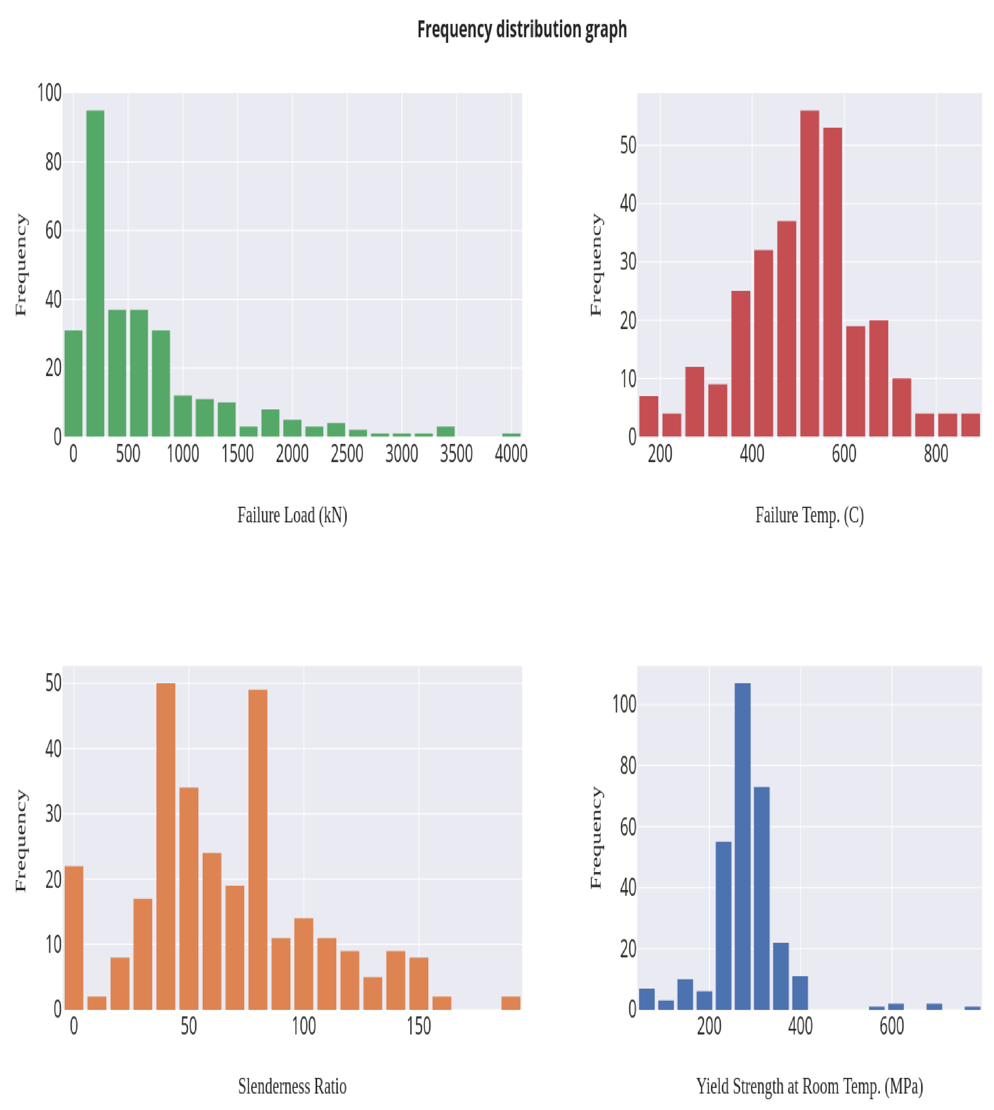
Introduction

In this research, we have investigated the capability of using Gradient Boosted Library, Xgboost, to predict the fire-resistance of structural steel-columns. We have also demonstrated the compared statistical performance metrics between other machine learning libraries, like Multi-layer Perceptron and Deep-Neural Network. We have also explained the machine-learning model architecture by quantifying the sensitivity of the model fire-resistance output with respect to the steel-column specificationâs feature-space by using the SHAP library for generating the partial dependence plots (PDP) and individual conditional expectation (ICE) plots.

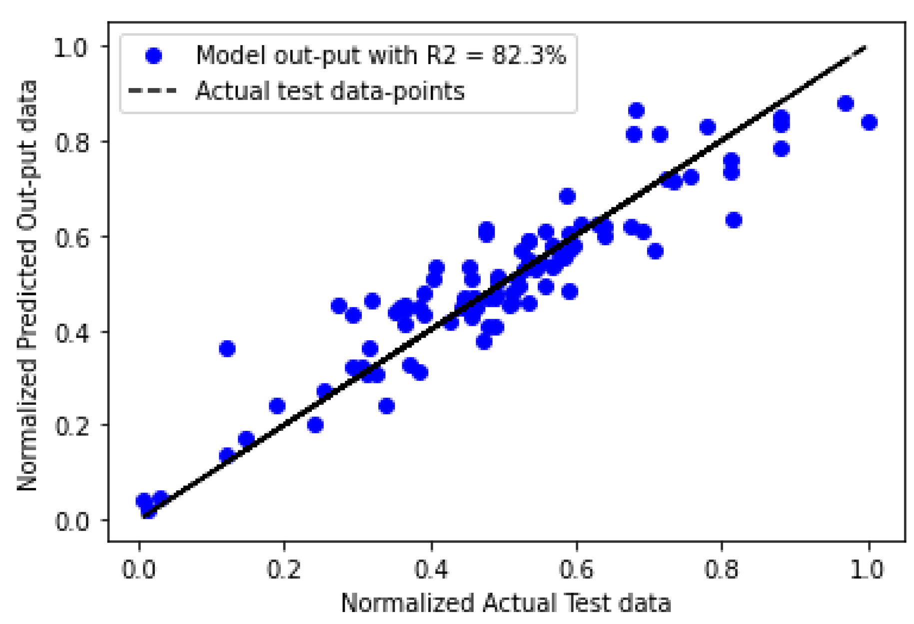
Dataset Feature Space

The distribution of feature space based on 296 experimental data points.

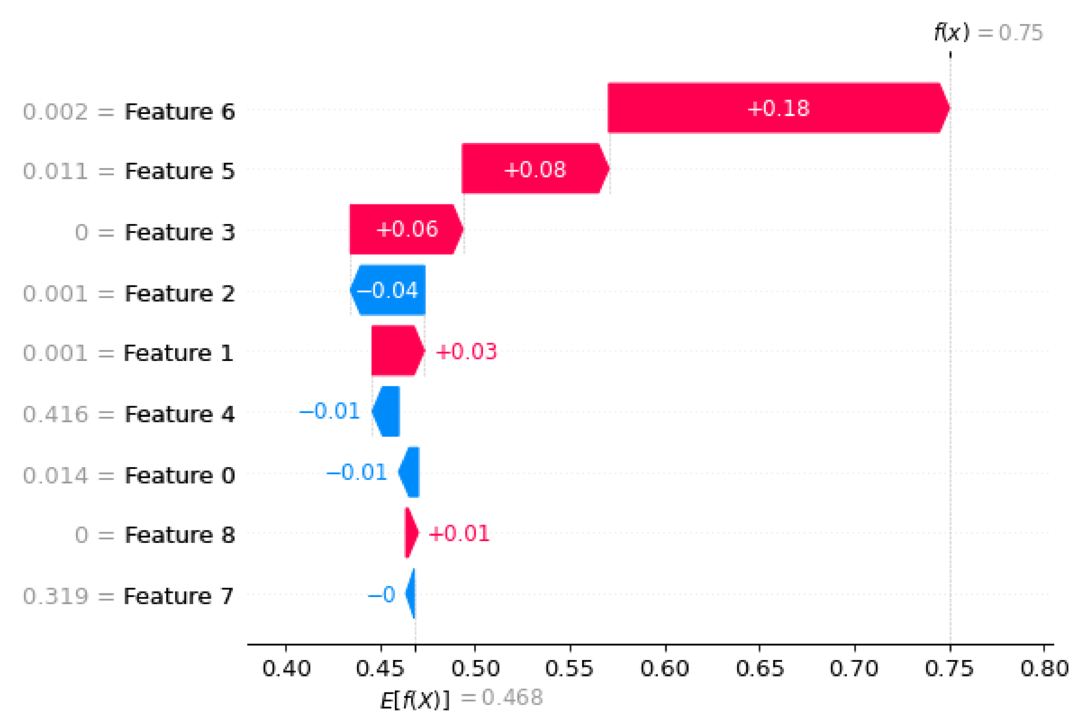


Results

Correlation Plot



SHAP-Waterfall Plot

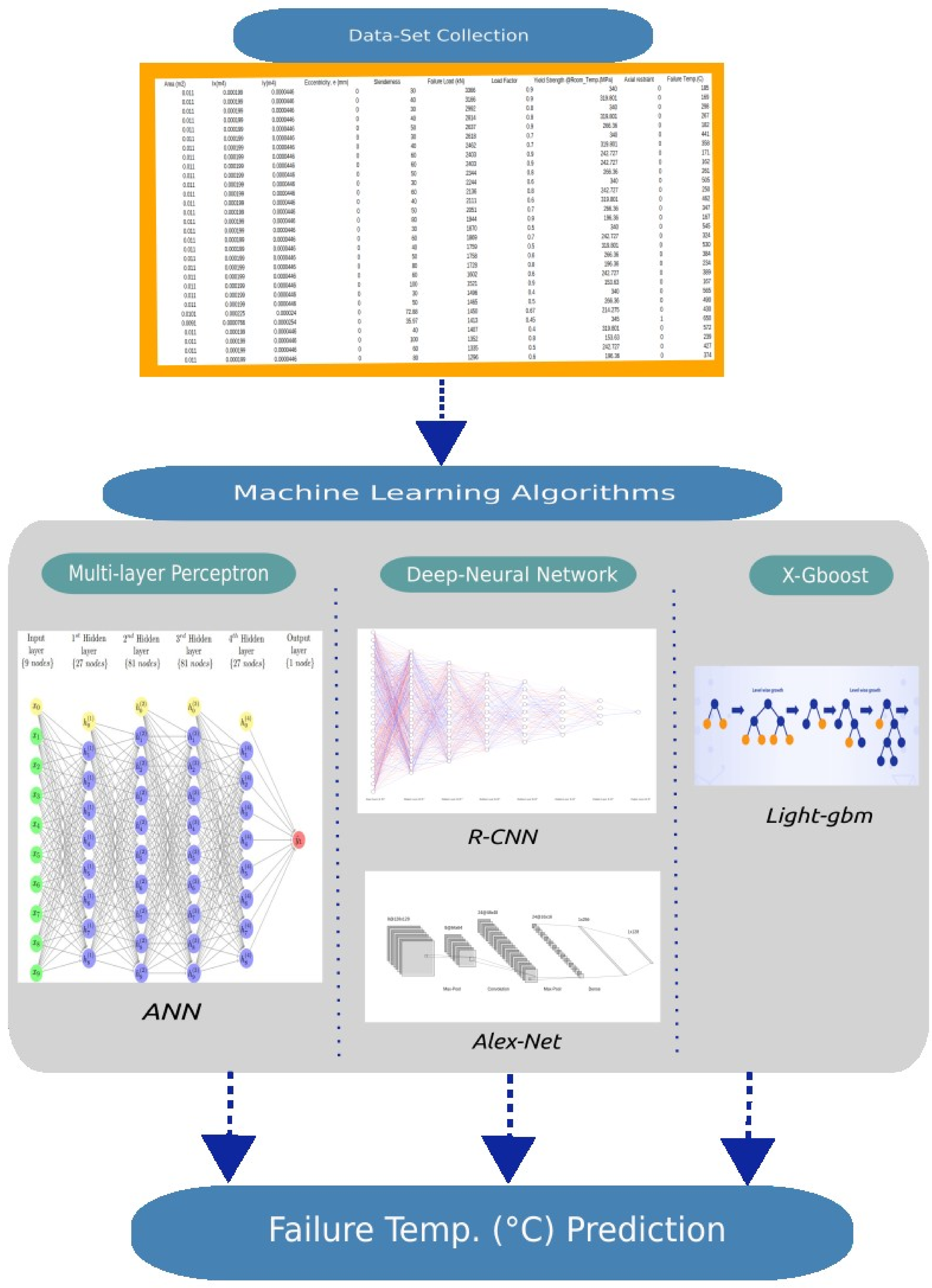


Comparisions

	MAPE	MAE	RMSE	R^2	Train-Test Split	CPU Time (mins.)
MLP	0.162	0.057	0.075	0.7980	80% - 20%	0.23
	0.2563	0.0747	0.1011	0.6459	70% - 30%	0.3458
	276079209597.7	0.1100	0.1535	0.2916	60% - 40%	0.1686
X-boost	0.1352	0.0629	0.0805	0.77	80% - 20%	0.0012
	0.128	0.055	0.073	0.8230	70% - 30%	0.0025
	0.1579	0.0629	0.0841	0.7507	60% - 40%	0.0011
DNN	0.105	48.28	63.02	0.6949	80% - 20%	156.52
	0.0949	45.56	58.93	0.7342	70% - 30%	167
	0.111	51.058	67.167	0.638	60% - 40%	151.54

Table 2: Performance metrics Comparison

Schematic of ML Framework



Conclusions

Analysis on the results generated by the shap plots as well as the partial dependency plots (PDP), the key parameters that governs the fire-resistance capacity are area of cross-section, eccentricity, slenderness ratio, failure load and load-factor. We have also investigated the capability of using Machine learning algorithms like MLP, DNN and X-gboost, and validated the scope of their effectiveness in predicting fire-resistance temperature. In this comparative study, X-gboost prediction outperforms other ML algorithms with an overall accuracy of 82.3%. The fundamental reason behind this out-come, is that X-gboost inherits all the benefits of decision trees and tree ensembles, while making even further improvements over the classic gradient boosting machine by introducing two new tree regularization hyper-parameters γ and λ which are incorporated directly into its target minimising objective function. Combining these with the additional column and row sampling functionality provides a variety of ways to reduce over-fitting. Also, the X-gboost formulation provides a much more elegant way to train models on custom objective functions. Besides, X-gboost formulation improves on this two-stage approach by unifying the generation of tree structure and predicted values. Both the split scoring metric and the predicted values are directly computable from the instance gradient and hessian values, which are connected directly back to the overall training objective. This also removes the need for additional numerical optimizations, which contributes to speed, stability, and scalability.

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References

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