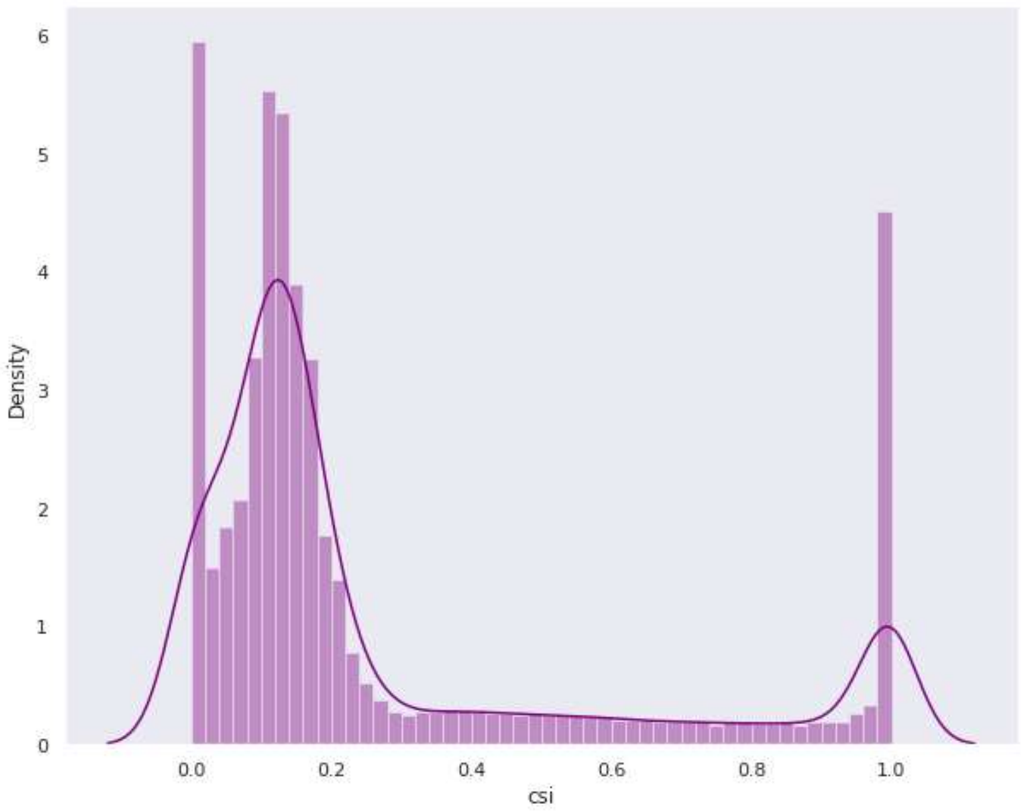
Biotechnology AI-ML Case Study

In biotechnology, the mixture fraction (CSI) is a critical parameter in the design and optimization of combustion processes used in various applications such as biomass and waste-to-energy conversion, pharmaceutical manufacturing, and bioreactor systems. In biotechnology, the combustion process is typically used for waste management, energy generation, and sterilization. The optimization of the combustion process is essential to achieve high efficiency and low emissions. The mixture fraction (CSI) plays a critical role in optimizing the combustion process in biotechnology. By controlling the mixture fraction, it is possible to achieve efficient and complete combustion, leading to reduced emissions and increased energy production.

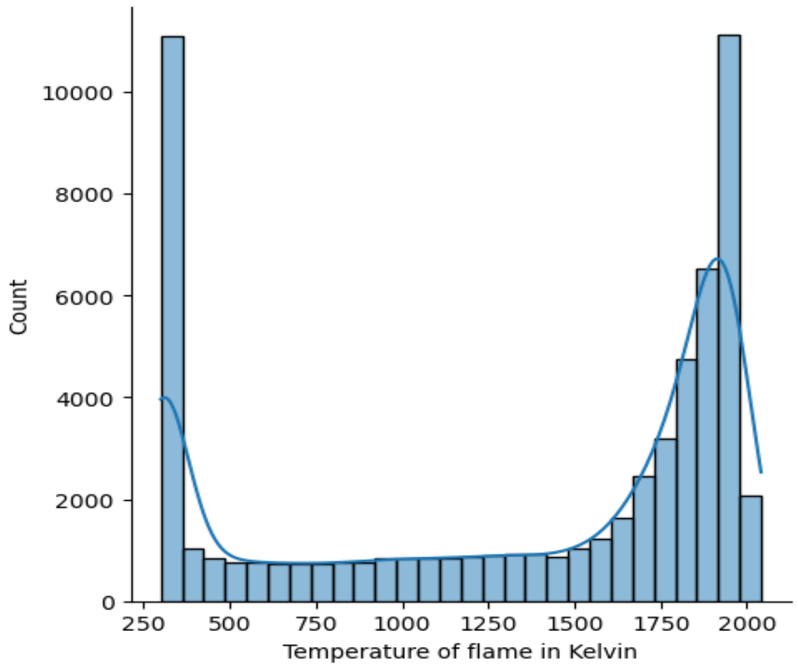
The objective is to identify the relationship between the strains and strain rates in a material testing scenario, where 1000 different strain rates are randomly chosen in the range between 15 1/s and 120 1/s. The goal is to use Auto-ML techniques to predict the strains corresponding to different strain rates accurately. This problem is crucial for material scientists and engineers as it can enable them to optimize the design and performance of materials for various applications



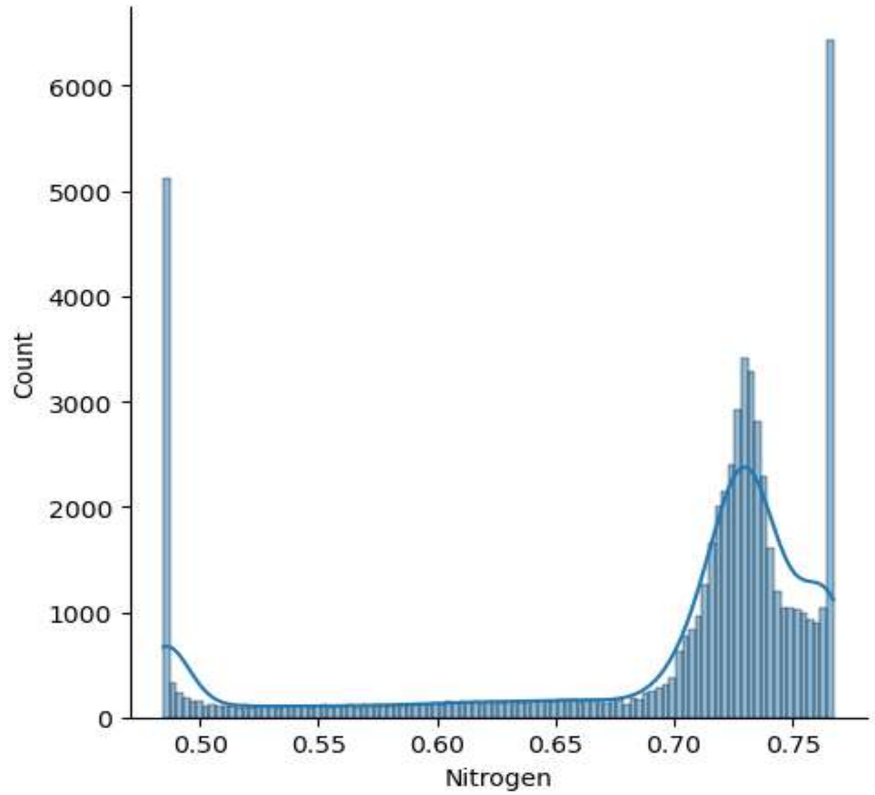
Mixture fraction (CSI) is a parameter used to describe the local fuel/air ratio in a combustion process. It is defined as the ratio of the mass of fuel to the sum of the mass of fuel and air at a given point in a combustion system.

The mixture fraction is an important parameter in combustion engineering, as it directly affects the efficiency and emissions of combustion processes. By controlling the mixture fraction, it is possible to optimize combustion systems for improved performance, reduced emissions, and better control over the combustion process

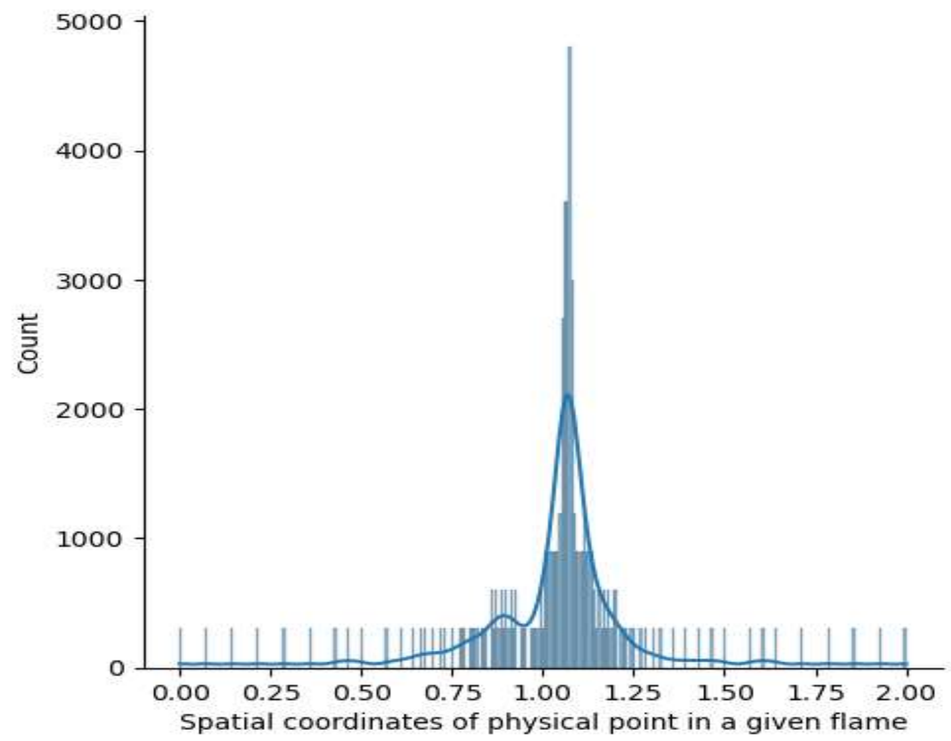
Features Responsible



As the **flame temperature** increases, the mixture fraction also changes, leading to changes in the chemical reactions occurring within the combustion process. The mixture fraction is directly related to the temperature of the combustion reaction, with lower mixture fractions associated with higher flame temperatures.



As the concentration of **nitrogen** in the air increases, the available oxygen concentration decreases. This leads to a decrease in the mixture fraction, which is the local ratio of fuel to oxidizer.



By measuring the **spatial coordinates of physical points in a flame,** it is possible to accurately determine the local fuel/air ratio and therefore the mixture fraction at each point. This information is critical for understanding the combustion process and optimizing combustion systems for improved efficiency and reduced emissions.

Auto-ML Methodology Results

Case	Percentile	No. of Features	Random Forest	XGBoost	RNN	MLP	Lasso	Avg. Accuracy
Case 1	25	7	100	100	99	97	30	85
Case 2	50	13	100	100	96	97	30	78
Case 3	75	20	100	100	98	99	45	88
Case 4	90	24	100	100	98	99	45	88

Based on our observation , 75,90 percentile has the best average accuracy and Random Forest & XG-Boost has shown to be best performer across all percentile.

Conclusion

In conclusion, predicting the mixture fraction (CSI) is a critical task in the biotech industry. It plays a crucial role in the design and optimization of combustion processes, which are essential for a wide range of biotech applications, including biomass and waste-to-energy conversion, pharmaceutical manufacturing, and bioreactor systems. The dataset has 60000 records with 28 Numerical Features.

For regression, models were created with algorithms using Auto-ML techniques like Lasso, Recurrent Neural Network, Multilayer Perceptron, Random forest and XGBoost . With these models, performance measurement values were obtained for feature sets of 7, 13, 20 and 24. The Auto-ML algorithms were able to predict the mixture of fraction with an average accuracy between 78% – 88% and helped to identify factors that impacts the mixture of fraction (csi). The major factors include Temperature of flame in Kelvin, Nitrogen Spatial coordinates of physical point in a given flame. The Random forest with 100 % accuracy in 90th percentile where tree showed a threshold of Nitrogen<= 0.63 units and CH4 <= 0.47 units which leads to high mixture of fraction (csi).

By accurately predicting the mixture fraction, biotech companies can improve the performance of their combustion systems and achieve greater operational efficiencies, leading to cost savings and improved environmental sustainability. Based on the performance measurement values obtained, it is possible to say that the study achieved success in predicting in mixture of fraction (csi).