Shapley additive explanations for feature ranking in additive manufacturing

This NSF-sponsored research (GRF-1937698 and EEC-2133630) aims to present an interpretable process-property predictive modeling method of directed energy deposition (DED) by developing an efficient feature extraction technique and machine learning models to explore the tensile strength-determining physics embedded in the DED thermal history. A neural network was trained using 40 process and material features and Shapley additive explanation (SHAP) values have been investigated to determine which of the 40 features are good predictors of the part's ultimate tensile and yield stresses. The SHAP values of the remaining features were investigated to confirm model consistency with physical principles underlying the DED process as reported in the published literature. An overview of the study is shown in **Fig. 1**.

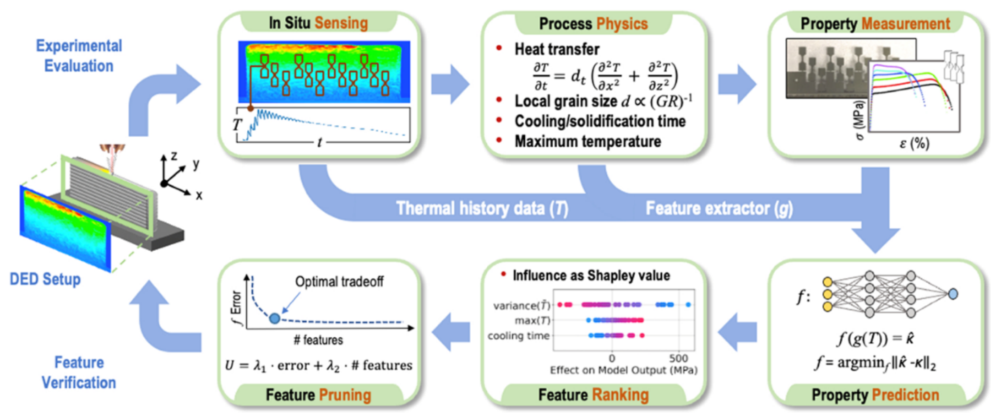

Fig. 1 Interpretable tensile strength prediction for DED using machine learning and SHAP values

Experimental data analysis demonstrates comparable or better prediction accuracy for DED-built IN718 tensile strength than the current literature with significantly reduced model complexity using only the input features shown in **Fig. 2**. This work's success indicates the importance of incorporating physical knowledge about the heat treatment field in feature selection to reduce model complexity and improving model accuracy. Additionally, previously unreported predictors such as temperature variance are observed in the presented study, which can enable new DED optimization strategies.

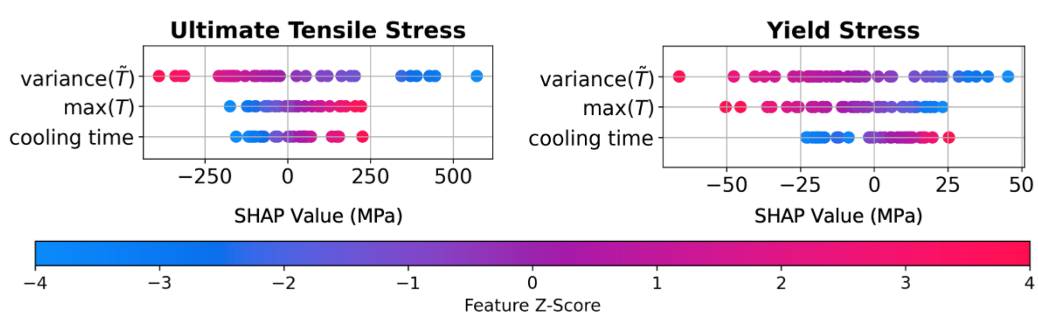

Fig. 2 Top three features for IN718 tensile strength prediction, ranked by SHAP value variance

Related Publication

[1] C. Cooper, J. Zhang, J. Huang, J. Bennett, J. Cao, and R. X. Gao*, "Tensile strength prediction in directed energy deposition through physics-informed machine learning and Shapley additive explanations," *Journal of Materials Processing Technology*, vol. 315, p. 117908, 2023, doi: 10.1016/j.jmatprotec.2023.117908.