

Title: High-Fidelity Reconstruction of 3D Temperature Fields Using Attention-Augmented CNN Autoencoders With Optimized Latent Space

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Abstract: Understanding and accurately predicting complex three-dimensional (3D) temperature distributions are critical in diverse domains, including climate science and industrial process optimization. This study presents a sophisticated framework employing a convolutional neural network (CNN)-based autoencoder (AE) architecture augmented with attention mechanisms for the efficient compression and reconstruction of 3D temperature distribution datasets. The framework integrates Singular Value Decomposition (SVD) analysis to ascertain the optimal latent space dimensionality, thereby ensuring a judicious balance between model complexity and reconstruction fidelity. Moreover, the autoencoder is trained by utilizing a customized loss function designed to prioritize higher temperature values, enhancing the reconstruction accuracy in critical regions, mathematically defined as regions where the temperature exceeds 675°C (i.e., $T > 675^{\circ}\text{C}$). This ensures enhanced reconstruction accuracy in areas of significant thermal importance, which are critical for the accuracy of the model. Through systematic exploration of the latent space dimensionality and the relative weighting of non-zero temperature data points, optimal parameters are identified that maximize the coefficient of determination score. Empirical results indicate that optimal performance is achieved with a latent space size of six, incorporating a relative weight value of 4.5 for non-zero temperature data points and appropriate handling of zero-temperature data points. After evaluating the model for both zero and non-zero temperature data, the R^2 scores improved from 95.80% to 99.27%, demonstrating a significant enhancement in overall accuracy. This proposed methodology provides profound insights into the intrinsic structure of the data and offers highly accurate predictions for applications necessitating detailed spatial and temporal temperature analyses.

Keywords: Convolutional Neural Network , Temperature Field , Latent Space , 3D Temperature Fields , Neural Network , Prediction Accuracy , Accuracy Of Model , Data Structure

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