The Prediction of Cellular Materials Properties Through Deep Learning and Semantic Segmentation

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Abstract

Predicting the properties of cellular materials is important in engineering design as they are used ubiquitously in a broad range of applications. Here, we propose a **deep learning-based approach** for the prediction of materials properties directly from 2D images, offering a fast and scalable alternative to conventional simulation techniques. Our framework is to train **Convolutional Neural Networks (CNNs)** by high-resolution image datasets generated using FEA simulation outputs. By using **semantic segmentation,** class labels are assigned to individual pixels based on the stress and strain associated with that pixel. It enables precise identification of material behavior and can thus learn spatial and hierarchical patterns in a cellular material structure under various loading conditions. By using deep neural networks to automatically extract complex features from raw data, the model will accurately predict cellular material responses, aiding designers in the virtual characterisation of cellular material structures. We apply **transfer learning** techniques to further enhance CNN model performance, by leveraging pre-trained CNN architectures, such as **U-Net**, **DeepLab**, **Segnet, EfficientNet,** and **ResNet**, and fine-tuning them for the task of predicting cellular material properties. This not only accelerates training, but also improves the model's ability to generalize from limited data. The results show that the deep learning model outperforms traditional methods in terms of speed, and scalability, and can be used to predict cellular material properties applicable to a diverse range of engineering applications.

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