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Machine Learning-Based Analysis of X-ray Scattering for Characterizing Guadua Bamboo

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The primary objective of the study is to leverage machine learning methodologies to discern the contributions of various cell types within bamboo structure to the observed scattering patterns. This study employs a comprehensive dataset comprising 145 two-dimensional (2D) wide-angle x-ray scattering (WAXS) patterns obtained from a linear scan over a radial slice of a Guadua bamboo specimen, accompanied by a computed tomography (CT) imaging of the subvolume of the specimen studied with WAXS.
The first approach in this study involves mapping principal components extracted by principal component analysis (PCA) from the 2D WAXS patterns against the fiber ratio. The fiber ratio, derived from the CT reconstruction, is here the proportion of fibrous tissue relative to the total tissue (fiber and parenchyma) content within the bamboo cross-section. This quantitative measure serves to assess the composition of different tissue types in the bamboo structure. Subsequently, a random forest regression algorithm is employed to establish a correlation between these principal components and the fiber ratio. The resulting model is then utilized to generate representative scattering data for each distinct tissue type within the bamboo. To validate the results, the scattering patterns generated with the model are compared to the WAXS patterns best representing the different tissue types based on CT imaging.
The second approach is similar to the first, with the distinction lying in the use of a shallow neural network instead of a random forest algorithm. The first two principal components from the PCA are fed into the neural network to establish a mapping to the fiber ratio. The resultant model is then employed to generate representative scattering data for the various bamboo tissue types. These results are subsequently compared against the parenchyma scattering pattern to assess the effectiveness of the neural network approach.
The significance of this research lies in its innovative application of machine learning techniques to elucidate the distinct contributions of different tissue types in WAXS patterns from Guadua bamboo. It uses a multimodal data set and compares the outcomes of the random forest and neural network approaches. The study aims to determine the most effective method for discerning and representing bamboo tissue types based on x-ray scattering patterns, a methodology that could also be used for other heterogeneous materials. This approach not only enhances our understanding of bamboo microstructure but also contributes valuable insights into the broader field of material characterization using machine learning methods.

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