Coupling material and mechanical design processes via computer model calibration

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January 31, 2019

Abstract

In traditional engineering design, material selection is a matter of choosing a material with appropriate properties for the project at hand from a database of known materials, often as a matter of ad-hoc satisficing. Material design usually occurs separately, and without an eye to specific end-uses. It is desirable to wed these design processes, selecting a material design by modeling its performance outcomes in a particular engineering application. Therefore, here we offer an example of calibrating material design parameters to desired performance targets for a wind turbine blade. We show that existing techniques for model calibration can be profitably reconceptualized as a method for optimization and applied to solve this material design problem. Rather than calibrating a model to find a posterior distribution of unknown parameters in order to bring the model maximally into agreement with reality, we calibrate to find a posterior distribution on controllable model inputs in order to bring the predicted system behavior into agreement with pre-determined performance targets. In essence, we treat performance targets as "desired observations" and use them as the data in the calibration problem. We demonstrate our proposed methodology in both an artificial case and in the case of a finite element model of wind turbine blade performance and cost. In the latter case, we demonstrate how to estimate the Pareto front with uncertainty bands.

Keywords: Gaussian processes, material design, optimization, Pareto optimality, Uncertainty quantification, wind turbines