Predicting behavior of heterogeneous materials through numerical modeling is a challenging topic due to the extremely high computational cost required to resolve all of the geometrical complexities. To address this problem, various homogenization models have been developed to predict the mechanical behavior of materials. However, accurately predicting highly nonlinear material response with prominent localized behavior remains elusive. In this talk, we will introduce a novo sharp volumetric billboard (SVB) based modeling technique, which predicts the macro- and micro-mechanical behavior of high energy ball milled (HEBM) Ni/Al composites in a multilevel setting. Moreover, we will also talk about the application of SVB in the development of multigrid methods.

This SVB based modeling is an image based modeling technique, which stems from the volumetric billboard (VB) method, a Google Earth like multi-resolution modeling strategy in computer graphics. This VB technique is a data-compression strategy developed for real time 3D image rendering. By creating VB series of an object, the data amount is greatly decreased while object shape is visually retained. In our work, we analyze the statistical and physical implications of the VB technique, and enhance it through the SVB scheme. A sharpening filter is created to reconstruct the original material contrast on coarser microstructures. We propose a contrast-based minimization problem and a corresponding numerical algorithm that approximates the minima through a fast sweeping strategy with local volume preservation.

In our work, we focus on the Ni/Al reactive composites produced by HEBM. We utilize a fine scale microstructure from microtomography, and create levels of detail (LODs) from the SVB scheme. The first and second order probability functions are computed, and both exhibit consistency after large data reduction. Then, we use a parallel generalized finite element code, PGFem3D, to compute the mechanical behavior under a tension-relaxation loading profile using crystal plasticity constitutive equations. We adopt both identical and random texture. The macro- and micro-mechanical robustness of data compression is demonstrated through corresponding error analysis.

The close SVB LODs naturally lend themselves in the development of multigrid methods. Specifically, they provide reliable coarse problems, and instruct the formulation of intergrid operators. Our recent study shows that the usage of SVB microstructures greatly improves the performance of the multigrid method in solving a system of equations arising from continuous problems with heterogeneous coefficients.