Numerical modeling of heterogeneous materials is challenging due to the extremely high computational cost required to resolve all of the geometrical complexities. Despite the recent development of high performance computational frameworks and homogenization techniques, 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 multilevel modeling and computational technique, which enables accurate predictions of macro- and micro-mechanical behavior of high energy ball milled (HEBM) Ni/Al composites in a multilevel setting.

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. 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 properties of SVB LODs and their data structures naturally lend themselves in the development of multigrid methods. Our recent study shows that the SVB LODs contains reliable coarse microstructures, which can instruct the formulation of the key component – the intergrid operators -- in a multigrid method. Moreover, the coarse SVB LODs can also act as reliable preliminary to large computations. This is because the coarse SVB LODs generate coarse problems that can be used to approximate finer solution using significantly lower computational resources with acceptable numerical error.