A Data Reduction Approach for Analysis of Simulation Bundles

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The challenge of analyzing a bundle of simulations efficiently, considered as numerical solutions of partial differential equations that model the behavior of industrial products is addressed in this work. We consider numerical simulations as being obtained from a transformation of one reference geometry. A theoretical framework is introduced using the Laplace-Beltrami operator for surfaces embedded in 3D euclidean space under isometric transformations. This operator can be constructed numerically for a specific geometry, the solution of the eigenvalue problem delivers a set of orthogonal eigenvectors for this operator that, under the assumption of isometric transformations, can be used as a basis for all simulations in a bundle. The obtained representation on this basis has a strong decay, in the sense that only few coefficients are necessary to represent the variability of all simulations in the bundle. The decay is shown to depend on the smoothness of the simulation data.

Several industrial examples of time dependent engineering simulations show the effectiveness of the approach to represent the data variability along low dimensional structures. Figure 1 shows one example of a low dimensional representation of a bundle of time dependent crash simulations [1, 2].

References

[1] R. Iza-Teran. *Geometrical Methods for the Analysis of Simulation Bundles*. PhD thesis, Rheinischen Friedrich-Wilhelms-Universität Bonn, 2016.

[2] R. Iza-Teran and J. Garcke. A geometrical method for low-dimensional representations of simulations. *SIAM/ASA Journal on Uncertainty Quantification*, 7(2):472–496, 2019.

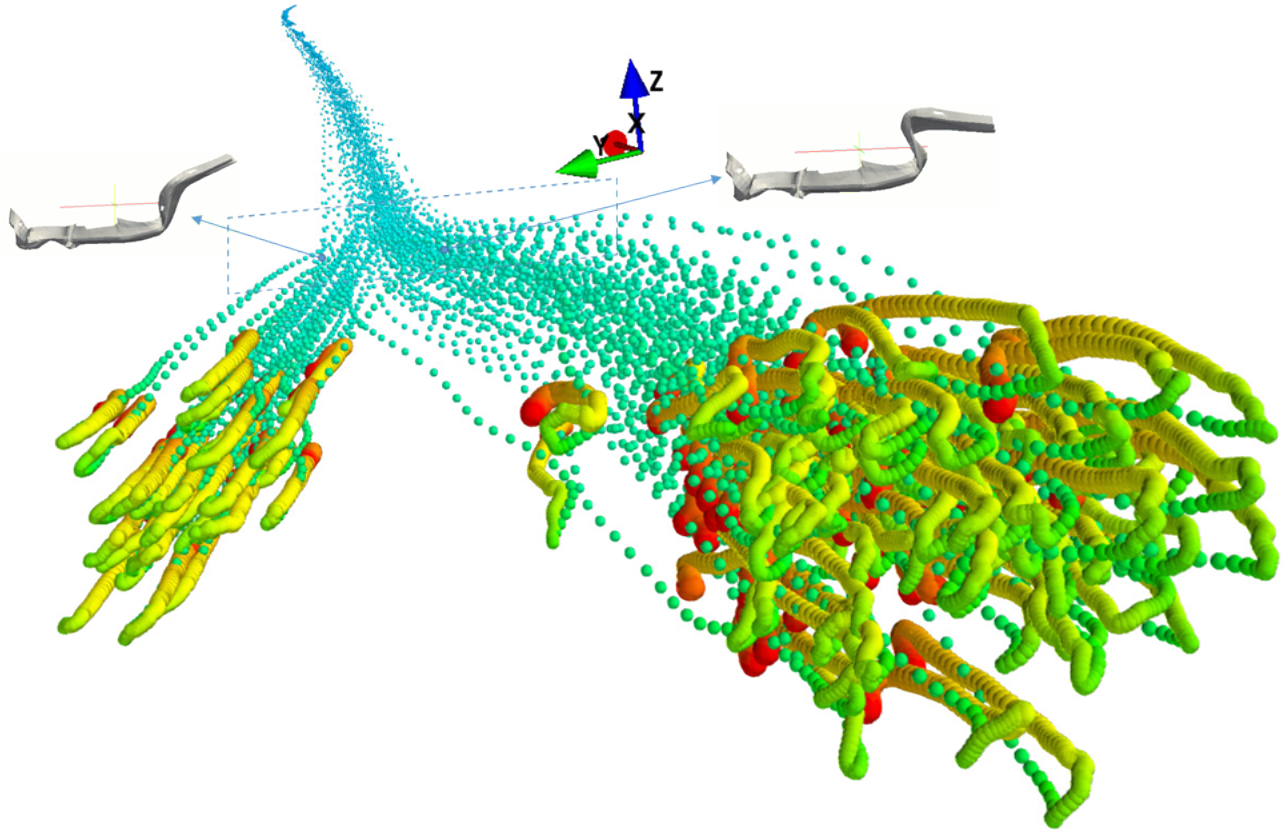

Figure 1: Reduced 3D representation of 23547 (167 simulations $\times$ 141 time steps) time dependent simulation results, obtained by the spectral decomposition of the Laplace-Beltrami operator. The coordinates of each point which represents a simulation at a specific time, are the first spectral coefficients for each direction x, y, and z of the deformations of a car part, they are colored according to the corresponding time step of the simulation.