Theory: Reduction/Hyper Reduction of Contact

ECSW compresses a FE model in a reduced subspace
\[ v^T F(x) = \sum_{i=1}^{N} \sum_{e} \sum_{k} c_{ijk} v_k \]

Local Dual Subspace for Contact Force Reduction

Clustered snapshots:
\[ k\text{means}(X_i, M_i) \rightarrow (X_i, M_i), i = 1, \ldots, k \]

Application: Simulation of Underbody Blast

Air Blast wave
- CONWEP module

Air Blast of VHull Vehicle
- 236,000 elements
- 1.4 million degrees of freedom
- J2 plasticity model
- 10kg TNT

Hyper Reduction using ECSW
- 2000 elements (100 X reduction)
- <1% relative error
- 200,000 X speed-up!

Parallel Element Sampling
- Distributed and shared memory parallelism
- Perfect scaling up to 64 processors
- Solution time <10 minutes (down from 24 hours on a single core – super linear speed-up due to algorithmic improvements)

Accuracy of ECSW

Scalability of ECSW Sampling

Collaborations
- P. Collins (Aberdeen) – Development of a parallel QR implementation of the nonnegative least-squares algorithm for mesh sampling and appropriate implementation of a projected Quasi-Newton method for the computation of positive dual basis
- P. Avery (Adelphi) – Development of a manifold-based approach for the reduction of highly nonlinear structural models with finite rotations and a robust time-integration algorithm for contact problems