Visualization Challenges in Computational Solid Mechanics

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Introduction

- Research group at MIT Institute for Soldier Nanotechnologies
- Interested in the dynamics of solids, especially over relatively short timescales
- Applications in:
  - Traumatic Brain Injury
  - Blast and ballistic protection
  - Brittle fracture
  - Wave propagation in anisotropic media
- Solve non-linear partial differential equations for deformation and failure of materials
Our Group Code

- Use continuous and discontinuous galerkin finite element method on unstructured meshes combined with particle methods
- Fortran/C/C++ group code with MPI parallelization
  - Scales to at least 10k processors
  - Have run problems as large as 1.03 billion nodes
- Output data as VTK files
  - All nodal data on an unstructured grid
  - Require point, vector and tensor data support
  - 10 million elements \( \sim 5 \) GB per timestep
Micro truss arrays

- Micro truss arrays are materials with a truss microstructures
- Truss elements on the scale of micrometers to millimeters
- Filled or hollow elements made of metal or polymer
- Interested in wave propagation properties in microtruss arrays, including scattering, attenuation, dispersion relations

Figure: Courtesy AJ Jacobsen
Wave propagation in micro truss arrays

What we have:

What we want:

- Surfaces of constant phase and constant amplitude
- 2D and 3D
- Potentially hundreds of millions of elements
Some of our research is coupling FEM with particle methods
- More flexible for extreme damage, fracture

Currently render particles as spheres
- Color of sphere represents field of interest
- Start having performance issues with millions of spheres

We would like to be able to reconstruct surfaces from particle data
Discontinuous Galerkin Data

- In DG FEM, functions are continuous only within a single element.
- Much of our data is defined at quadrature points.

Figure: Nodes (empty) and quadrature points (filled)

Figure: Discontinuous functions on two neighbouring elements

- We are transitioning to using higher order elements with DG.
We are transitioning to higher order elements, VTK only supports 2nd order.

Need interpolation and rendering schemes for arbitrary higher order elements:
- Render curved geometry of element
- Render higher order state variables within the element

Ideally have an existing tool to do it, we don’t want to write our own custom shaders for element data.

Figure: 2nd order triangle

Figure: What VTK renders