Visualization Challenges in Computational Solid Mechanics

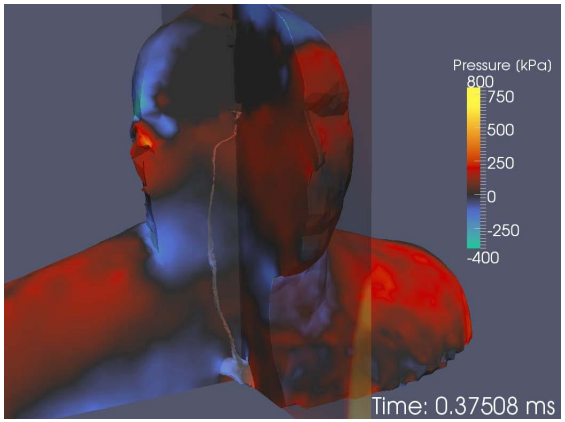
Piotr Fidkowski

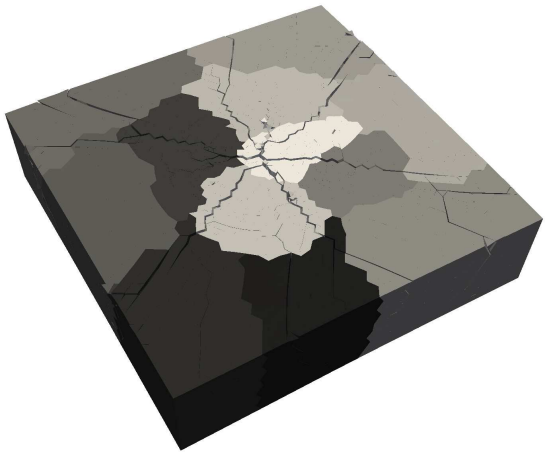
Raul Radovitzky Group, MIT

July 26, 2010

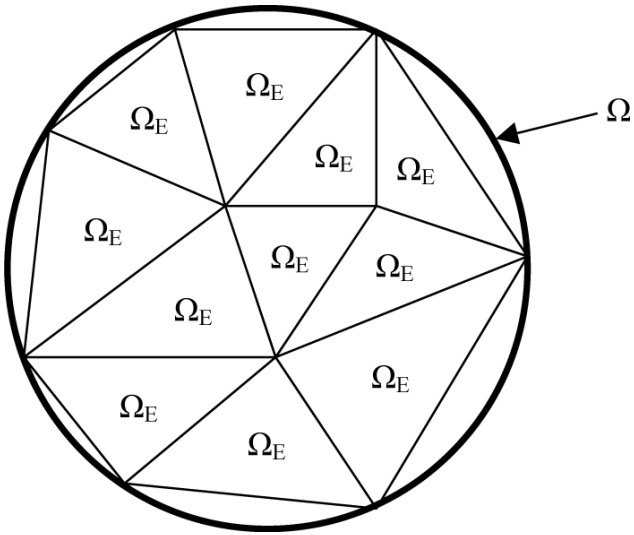
Introduction

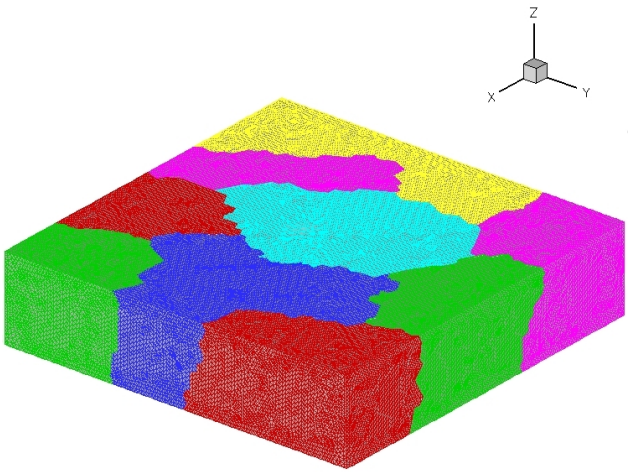
- Research group at MIT Institute for Soldier Nanotechnologies
- Interested in the dynamics of solids, especially over relatively short timescales
- Applications in:
  - Traumatic Brain Injury
  - Blast and ballistic protection
  - Brittle fracture
  - Wave propogation in anisotropic media
- Solve non-linear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





Our Group Code





- Use continuous and discontinuous galkerin 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 propogation properties in microtruss arrays, including scattering, attenuation, dispersion relations

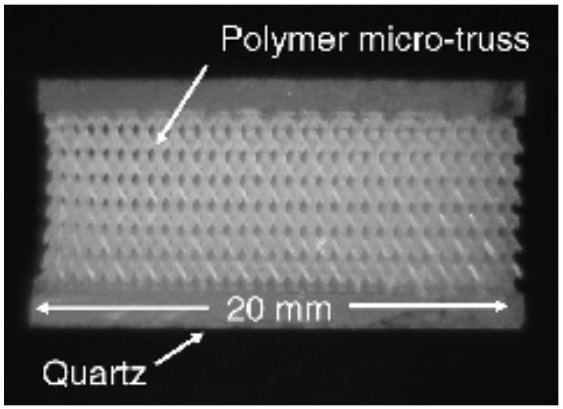
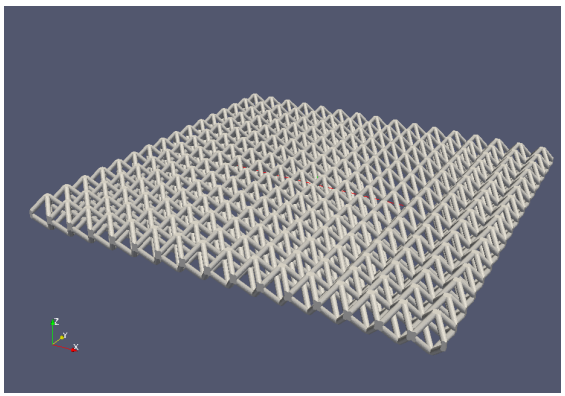
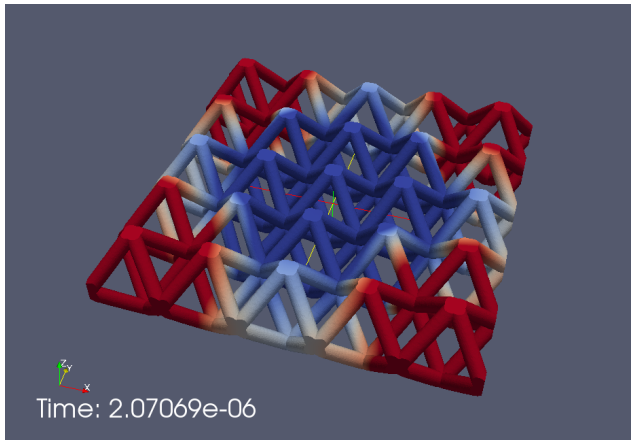


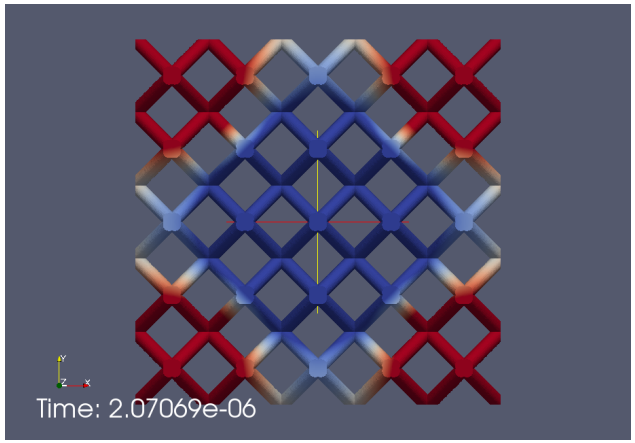
Figure: *Courtesy AJ Jacobsen*



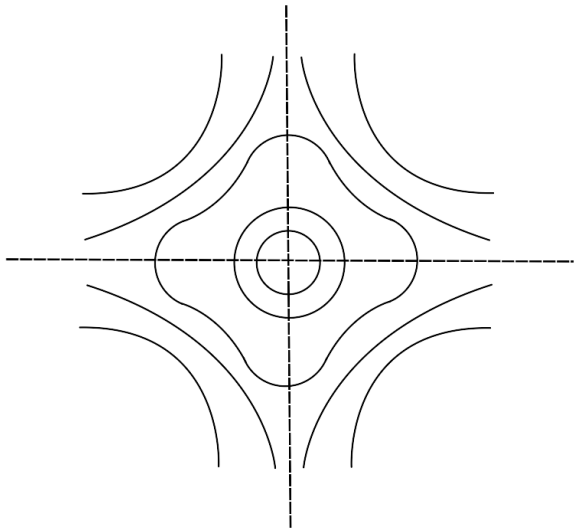
Wave propagation in micro truss arrays

What we have:



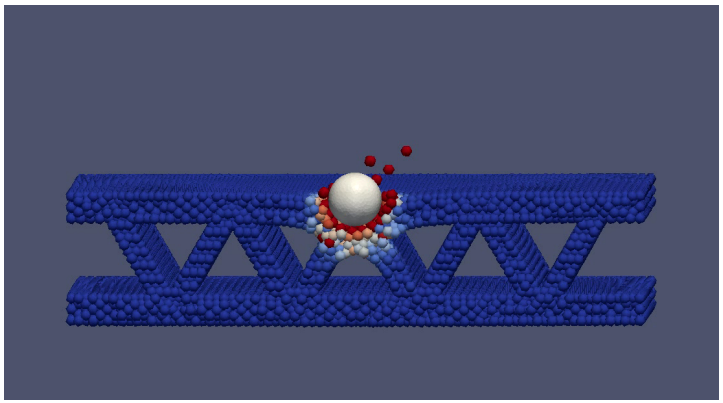


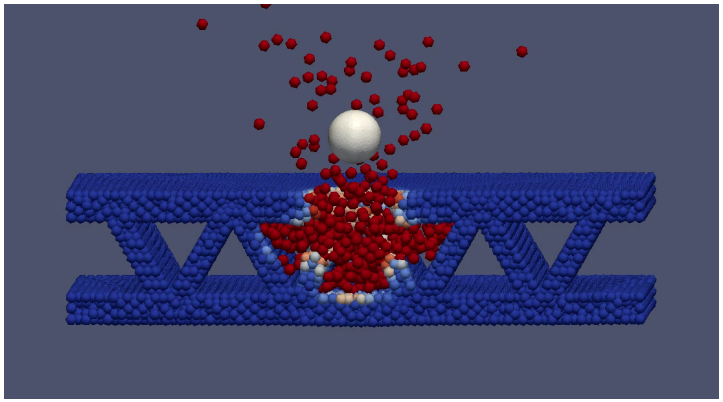
What we want:



- Surfaces of constant phase and constant amplitude
- 2D and 3D
- Potentially hundreds of millions of elements

Particle Method Data





- 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

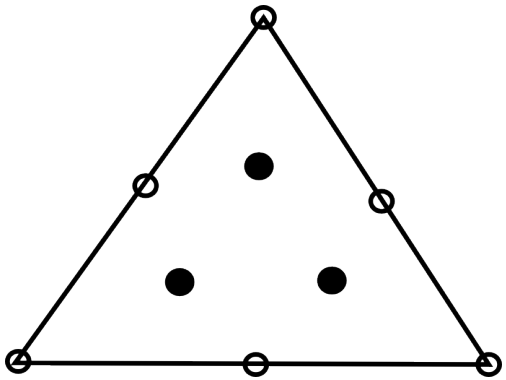


Figure: Nodes (empty) and quadrature points (filled)

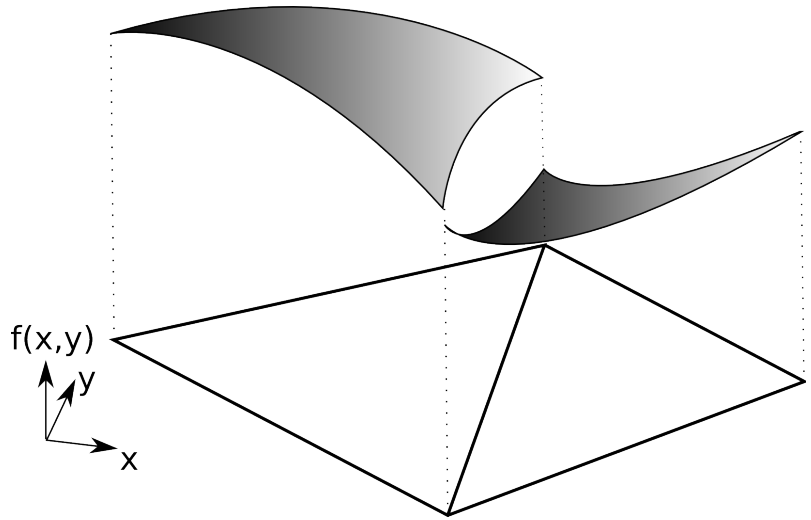


Figure: Discontinuous functions on two neighbouring elements

- We are transitioning to using higher order elements with DG

Higher Order Elements

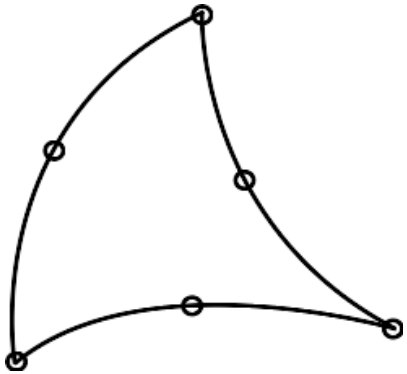


Figure: 2nd order triangle

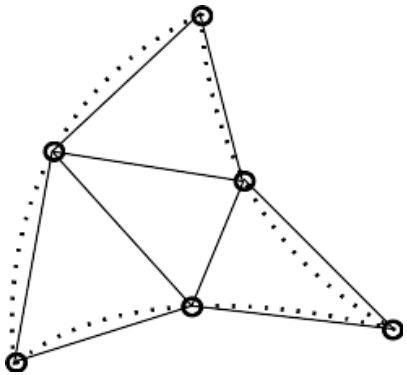


Figure: What VTK renders

- We are transitioning to higher order elements, VTK only supports 2nd order
- Need interpolation and rendering schemes for abitrary 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