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Mesh Scaling

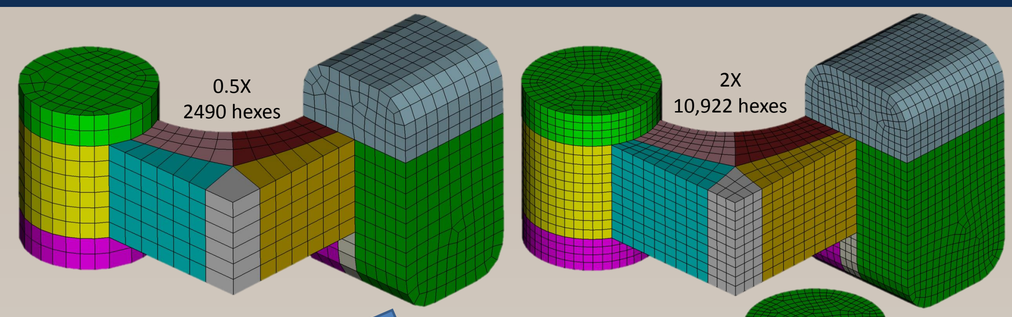
Generation of Incrementally finer meshes for Solution Verification

Matt Staten, Brian Carnes

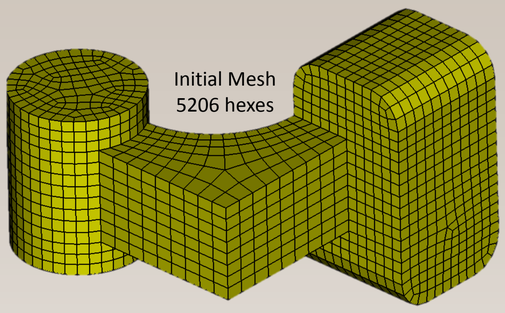
Sandia National Laboratories

What is Mesh Scaling?

Mesh Scaling is a new mesh modification algorithm which, given an input all-hex mesh and a desired element count multiplier, N, will generate a new hex mesh with approximately N times more/less hex elements, while honoring element size grading and element orientations. Mesh Scaling offers an alternative to traditional uniform mesh refinement (UMR), without the 8X multiplier limitation.



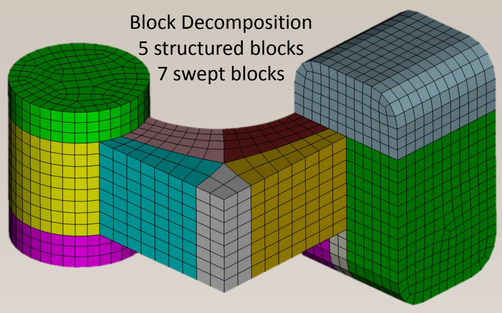
How Does Mesh Scaling Work?



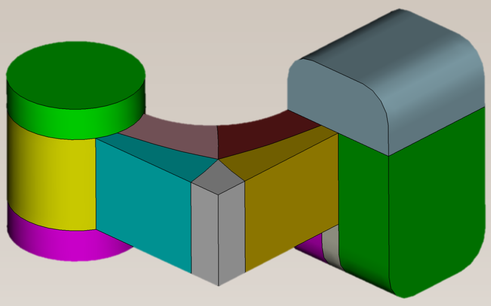
Step 1: Extract the Block Decomposition:
Hex mesh topology is traversed looking for:

1. Swept mesh connectivity, AND
2. Structured zones separated by mesh singularities

The mesh is then decomposed into both structured and swept blocks

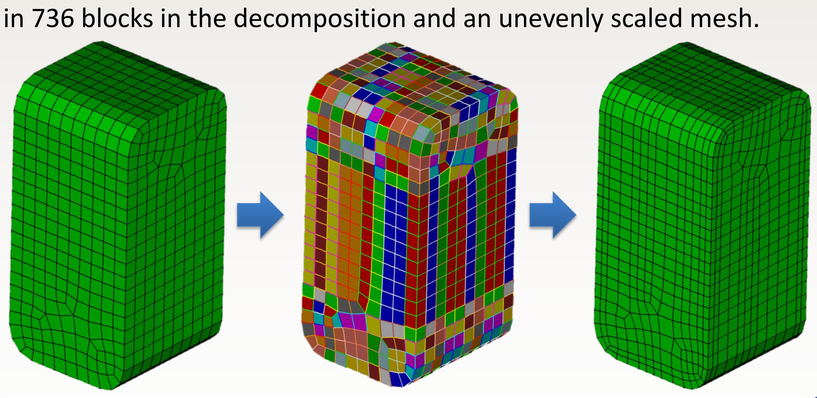


Step 2: Delete Initial Mesh:
Mesh sizing, grading, orientation, and BC loading are extracted from the mesh and stored in the block decomposition. The original mesh is then deleted.

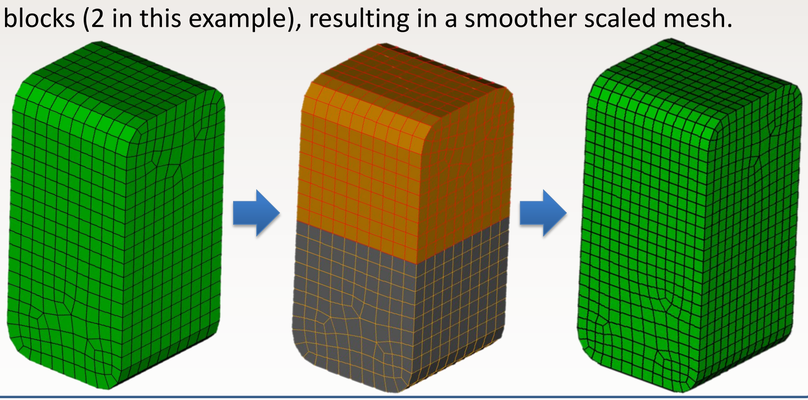


Step 3: Remesh at any size:
An optimization is performed to compute mesh intervals on all of the curves in the block decomposition, followed by remeshing of each block with either structured mapping or Pave-and-sweep.

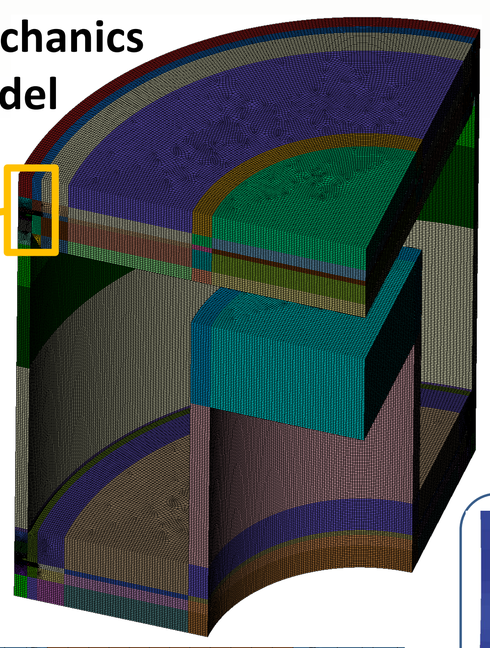
Using Structured Blocks Only: Honoring all mesh singularities results in 736 blocks in the decomposition and an unevenly scaled mesh.

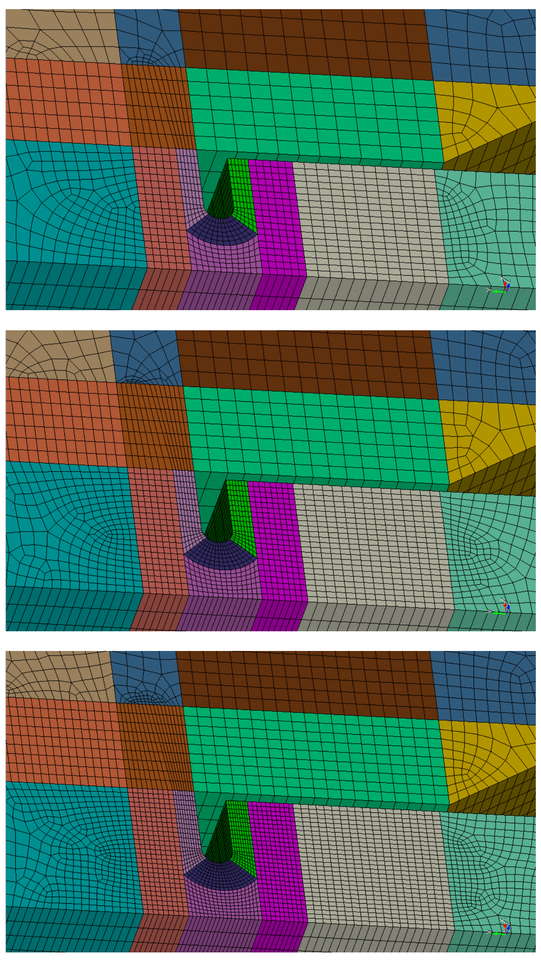


Mesh Scaling Using Swept Blocks: Swept blocks results in larger blocks (2 in this example), resulting in a smoother scaled mesh.

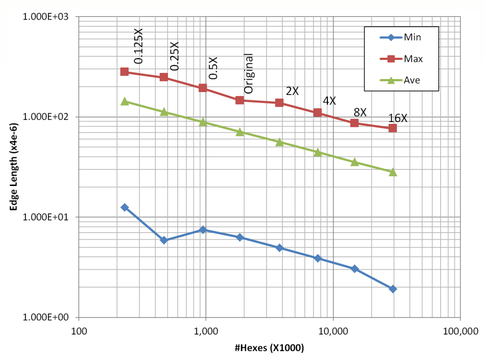


Solid Mechanics (SM) Model

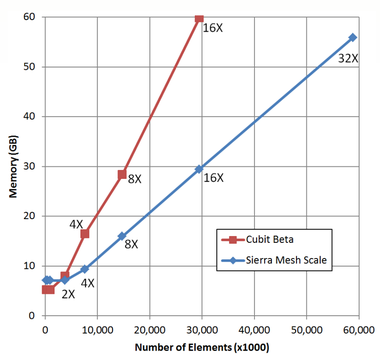




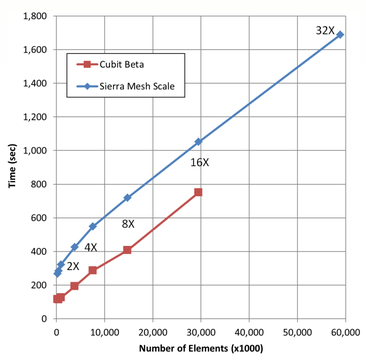
Edge Lengths



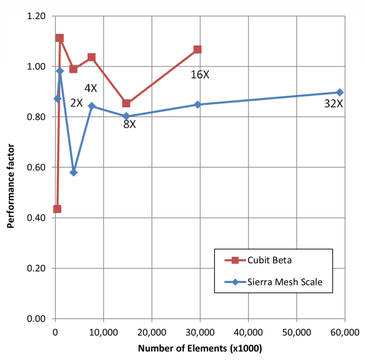
Memory



Performance

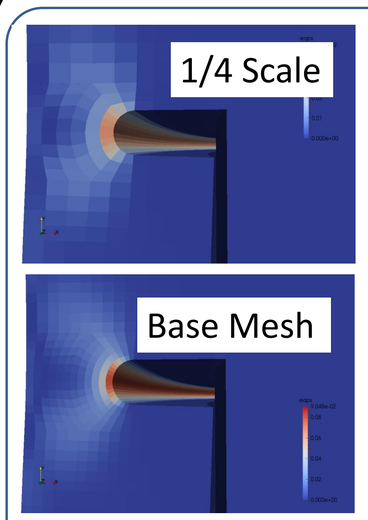


Performance Factor



Run on: 64 GB, 16 proc Intel(R) Xeon(R) CPU E5-2670 0 @ 2.60GHz

$$Performance\ Factor_i = \frac{Time_i/Time_{i-1}}{\#Elems_i/\#Elems_{i-1}} = \frac{time\ to\ remesh\ block\ decomposition\ doubles}{\#\ elems\ in\ scaled\ mesh\ doubles} \approx 1.0$$



The model simulates weld failure from thermal/mechanical loading. The main output is the maximum equivalent plastic strain (EQPS), an indicator of weld failure.

Solution Verification and Mesh Scaling

Solution verification (quantified numerical error estimation)

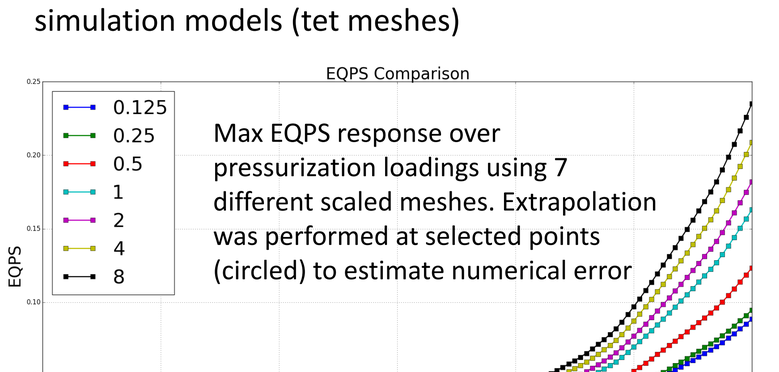
- is required for simulation prediction uncertainty
- typically requires a >100x increase in cost for a 3 grid sequence (using 8x, 64x scale factors)

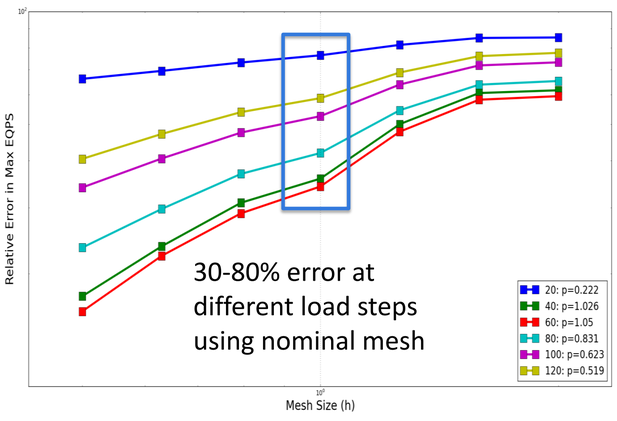
The Mesh Scaling alternative:

- provides fine grained capability to generate a sequence of meshes – including coarsening
- Is used in solution verification with significant cost savings

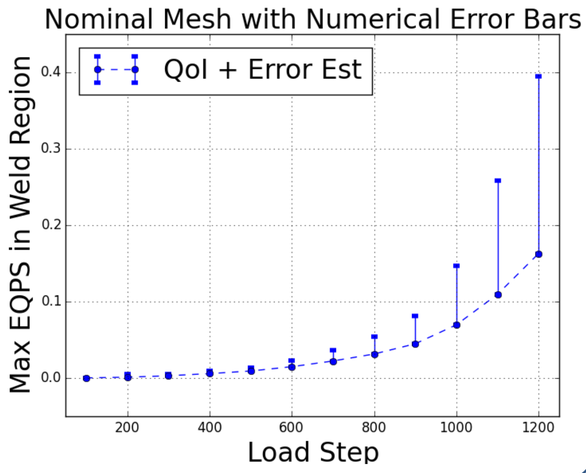
Impact of Mesh Scaling:

- has enabled solution verification of models that primarily use hex meshes - solid mechanics and structural dynamics
- future work will increase impact to all mesh-based simulation models (tet meshes)





Above: Error estimates as a function of mesh size from extrapolation using mesh scaling (at selected points on the load history). Below: Nominal model response with error bars



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National Nuclear Security Administration

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