SAND2016-9191C

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Adaptive Grid-based Hex Meshing for High Performance Computing

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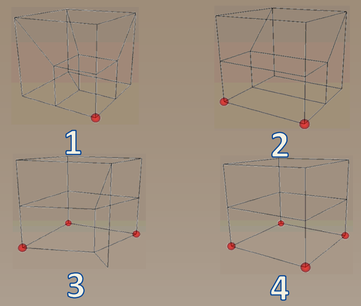
Overview

Sculpt is an MPI-based companion application to CUBIT that uses a grid-based procedure for generating all-hex meshes from volume fraction data. Recent enhancements include the ability to adaptively refine the overlay grid using a conformal 2-refinement procedure. Work this year included development of a new adaptive criteria for refinement, performance and scalability enhancements.

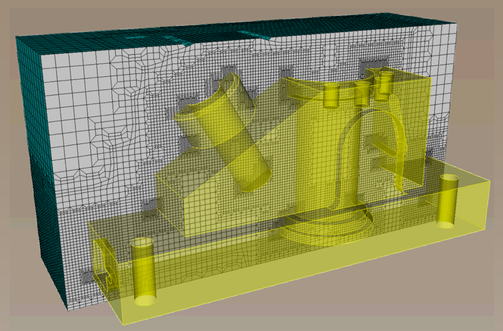


Templates used for 2-refinement.

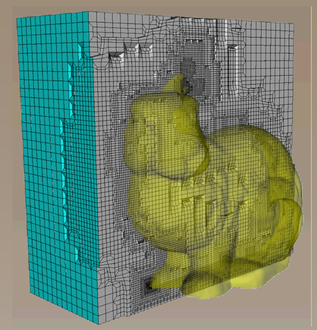
Paper Reference: S.J. Owen, R.M. Shih, C.D. Ernst, "A Template-Based Approach for Parallel Hexahedral Two-Refinement", Accepted for publication to Computer Aided Design, August, 2016

Refinement

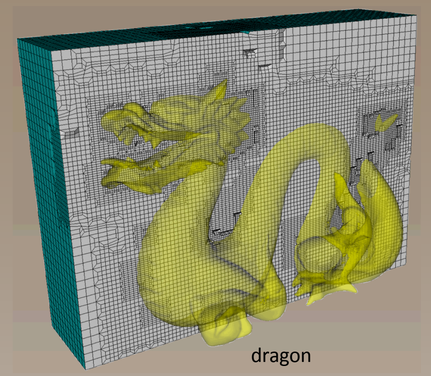
Refinement is performed on the Cartesian grid based on a 3 stage directional refinement algorithm that employs 4 templates. Cells for refinement are determined from a selected geometric criteria and their nodes marked. The grid is progressively refined in the three Cartesian directions based on node marking patterns shown at left. Images at right show the adapted grid following refinement. Sculpt is then used to generate an adaptive all-hex mesh from the refined Cartesian grid



anc101



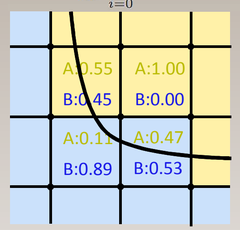
bunny



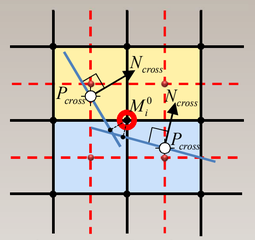
dragon

Interface Approximation

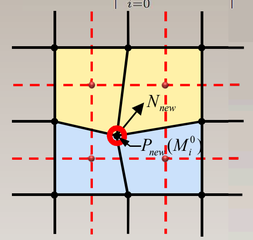
$$P_{new} = \frac{1}{nc}\sum_{i=0}^{i<nc} P_0 - (N_{cross})_i \cdot (P_0 - (P_{cross})_i) \times (N_{cross})_i \qquad (N_{new})_n = \left| \sum_{i=0}^{i<nc_n} (N_{cross})_i \right|$$



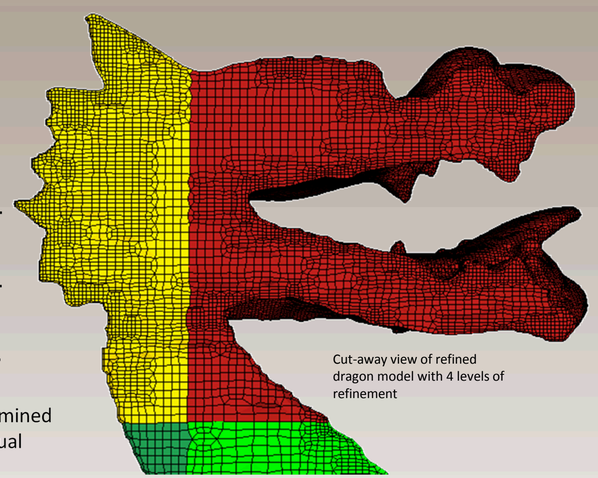
Initial cells colored based on their dominant volume fraction



Nodes at interface between materials (*M*) are moved to better approximate surface



Location of nodes are determined from interpolation on the dual using above equations.

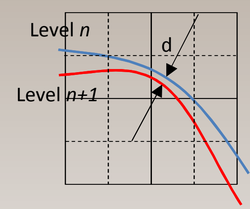


Cut-away view of refined dragon model with 4 levels of refinement

Adaptive Criteria

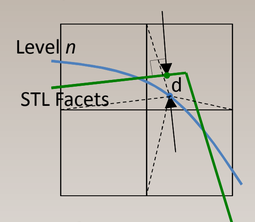
Cells are marked for refinement based on geometric criteria derived from the interface approximation

(1) Distance between interpolated geometry



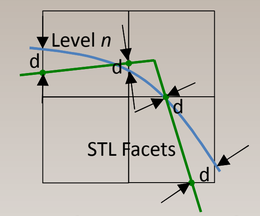
Distance between interpolated geometry at level *n* and *n+1* (Minimizer location at level *n+1* projected to closest point on level *n*)

(2) Distance between interpolated geometry and facets

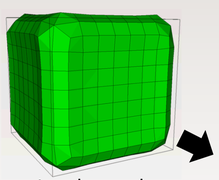


Distance from point on interpolated geometry at level *n* to closest point on STL facets (Projection of Minimizer locations on level *n* to closest facet)

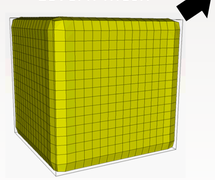
(3) Distance between facets and interpolated geometry



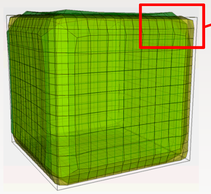
Distance from point on STL facets to closest point on interpolated geometry at level *n*. (Location of Intersections of grid edges with facets projected to level *n*)



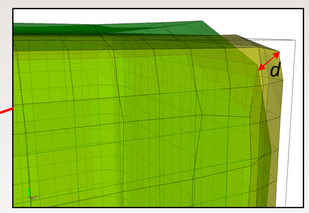
Level *n* mesh



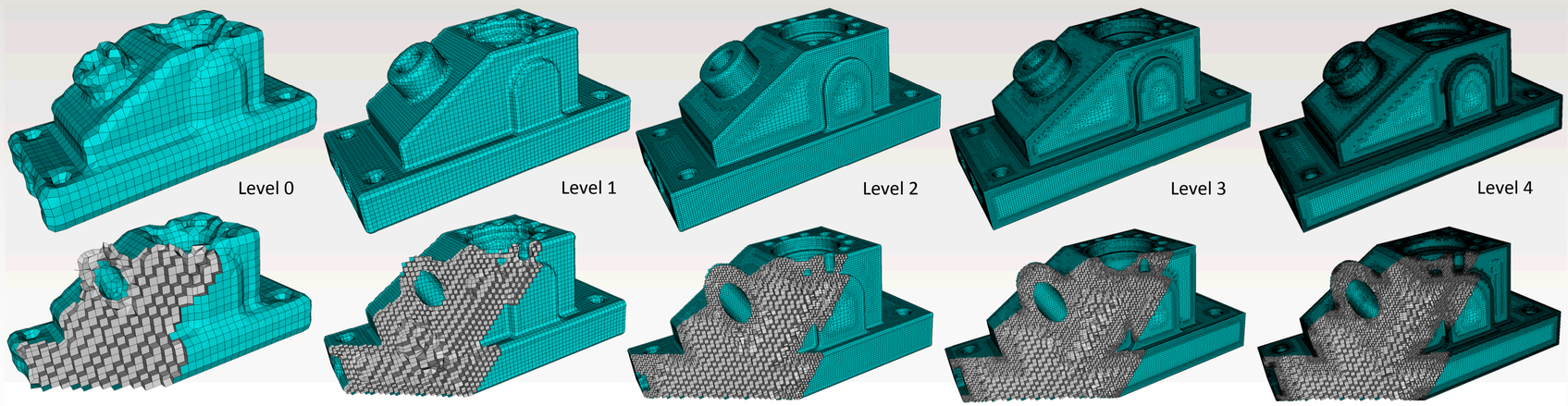
Level *n+1* mesh

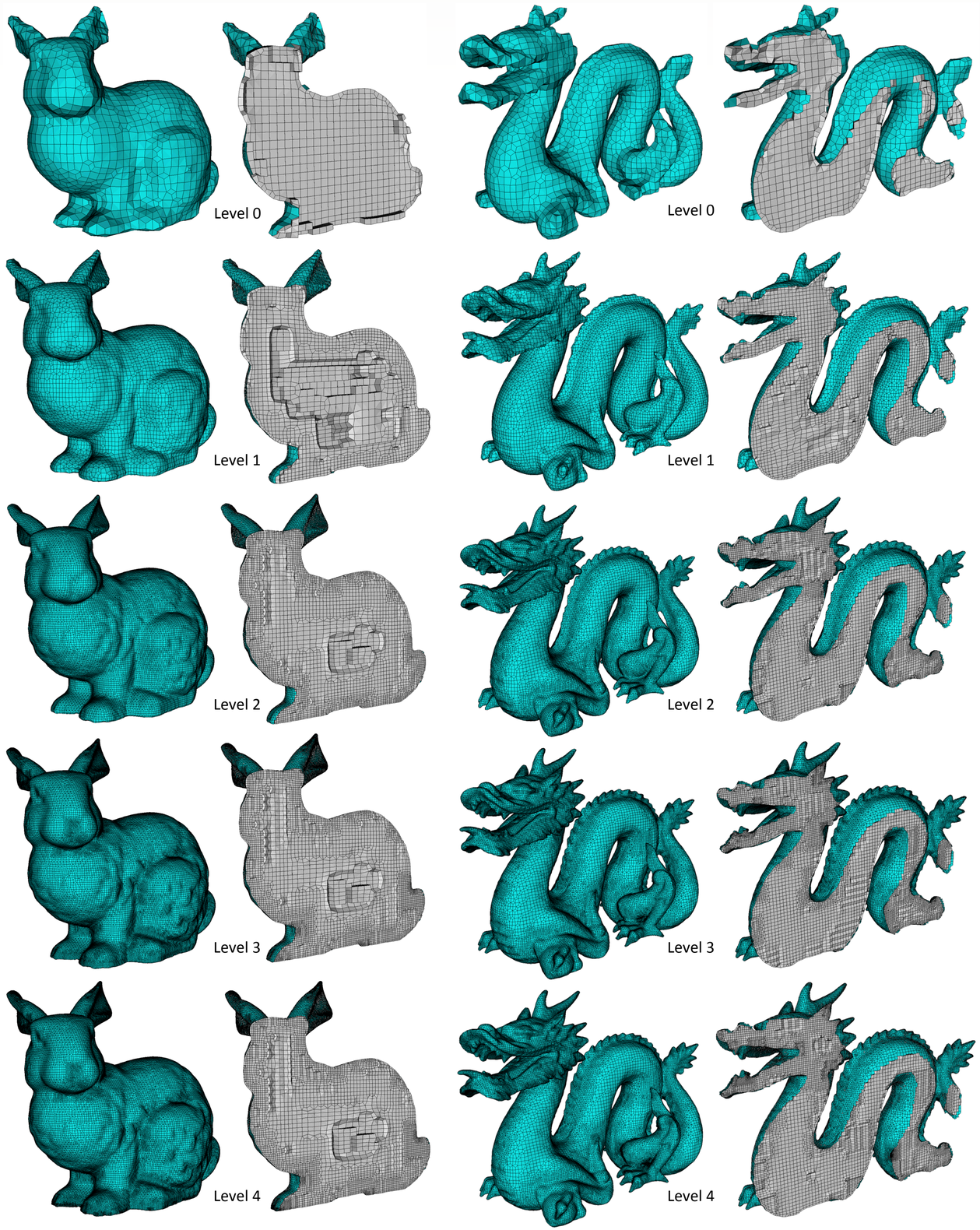


Level *n* and *n+1* meshes overlayed

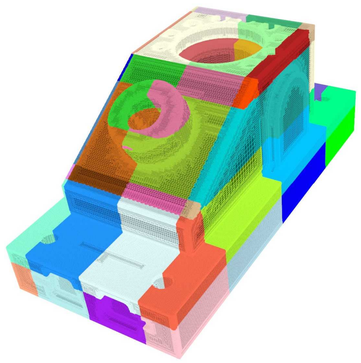


Criteria for refinement is based upon the Hausdorff distance *d* between mesh generated at level *n* and level *n+1*. Cell is refined if $d > d_t$, where d_t is a user defined threshold distance.

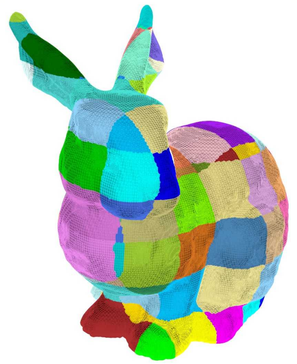




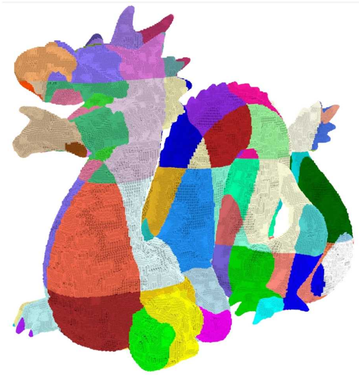
Scaling Study



anc101 model with 64 processors



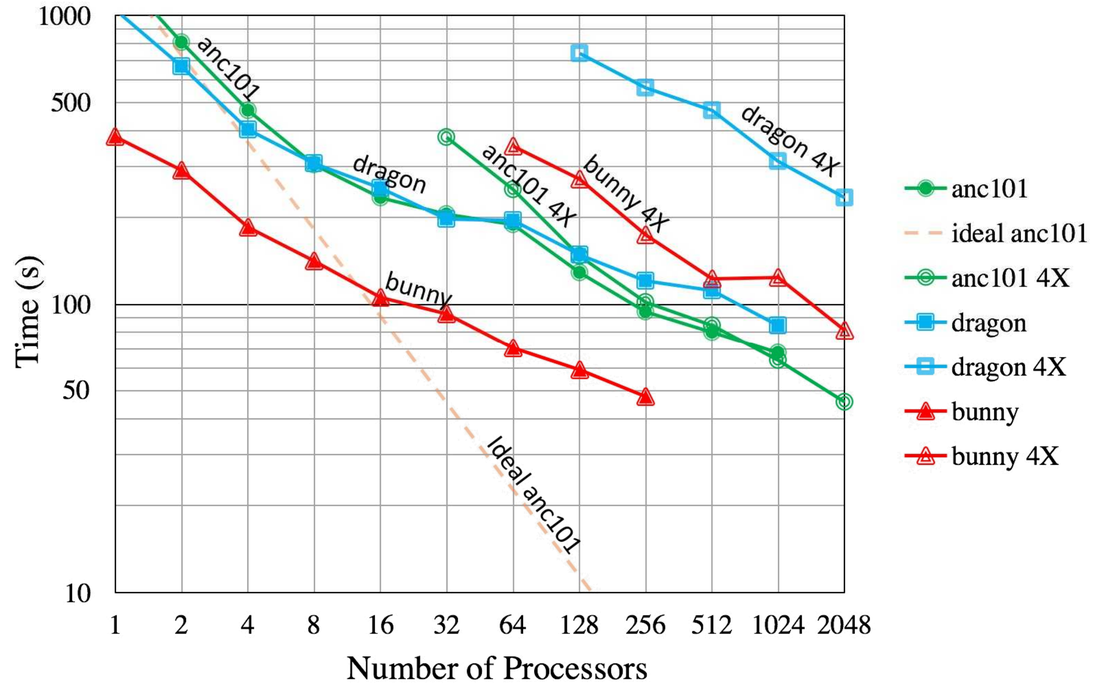
bunny model with 256 processors



dragon model with 128 processors

Table shows number of cells before and after refinement for 6 models tested. Timings are shown in graph blow for refinement stage of sculpt process only. All models resulted in a minimum scaled Jacobian of 0.329 before smoothing and projection.

	anc101	bunny	dragon	anc101 4X	bunny 4X	dragon 4X
Initial Num. Cells	32,400	38,880	44,100	2,073,600	2,488,320	2,882,400
Final Num. Cells	6,993,400	1,572,306	4,211,206	15,298,784	14,532,960	40,066,240



Log plot of performance of refinement vs number of processors for three different models. Maximum 4 levels of refinement are performed. The 4X models use the same geometry but begin at higher resolution as outlined in table above. All tests were performed on Sandia's TLCC2 Chama platform (1,232/19,712 nodes/cores 2.6GHz Intel, 64GB/node).

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National Nuclear Security Administration

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SAND No. 2011-XXXXP