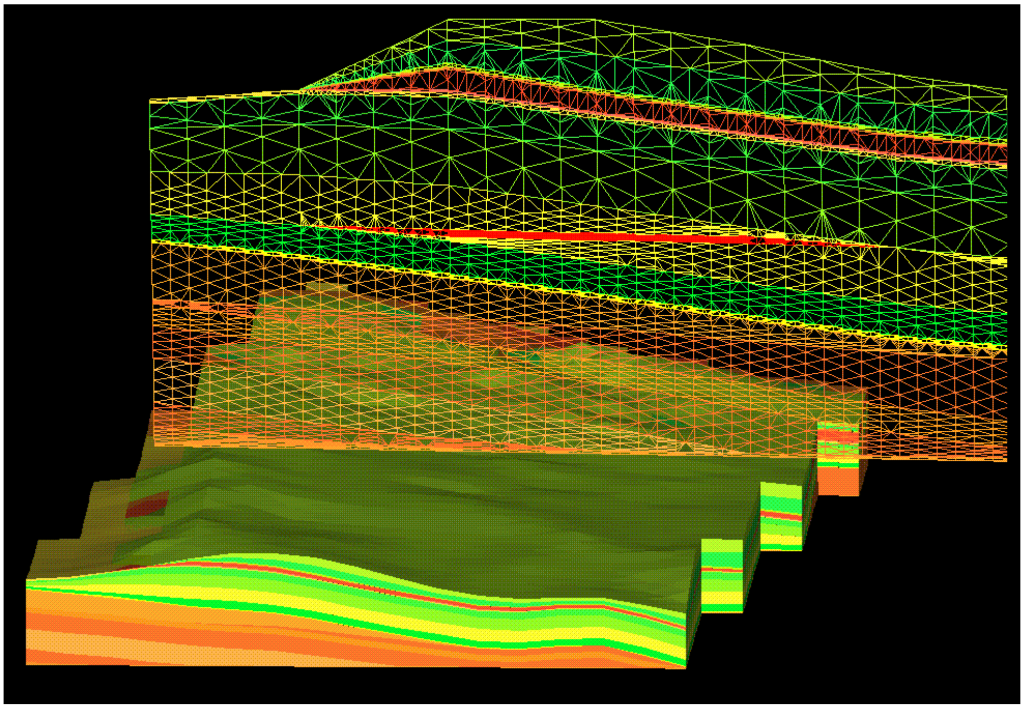
LaGriT Grid Generation for Geological Applications

OVERVIEW

There are a wide variety of geological applications where accurate representation of complex engineering systems and geologic structure and stratigraphy is critical to producing accurate numerical models of fluid flow and mass transport. Oil and gas reservoir production, groundwater resource development and waste disposal in a geologic repository are examples of the areas where modeling is used to predict the long term behavior of a system. In all the systems, grid generation is a key link between the geoscientific information systems and numerical models. Grids must capture complex geometry and insure the computationals are optimized to produce accurate and stable solutions.



A 3D model of geologic stratigraphy and a 2D computational mesh extracted from the 3D model is shown. 2D grids with arbitrary orientation or 3D grids with complex boundaries can be extracted from the geologic framework model.

LaGriT is a software tool for importing and automatically producing unstructured finite element grids tuned to the special needs of geological and geo-engineering applications. . LaGriT is a toolbox library with functions to produce 2D and 3D grids of elements that are tetrahedral, triangular, hexahedral and quadrilaterals.

LaGriT GRIDDING OVERVIEW

Maintains the geometric integrity of input data such as stratigraphy, volumes, surfaces, and material properties.

Produces multi-material Delaunay tetrahedral grids, maintains material interfaces and insures that geometric coupling coefficients of grids are positive for all elements.

Represents complex geological and engineered features such as layer truncations, domes, faulting, pinch-outs, reservoirs, wells, and tunnels.

Output geometric coupling coefficients matrix, and aid in application of initial and boundary conditions.

A spiral well is an example of a grid formed along an arbitrary well path.

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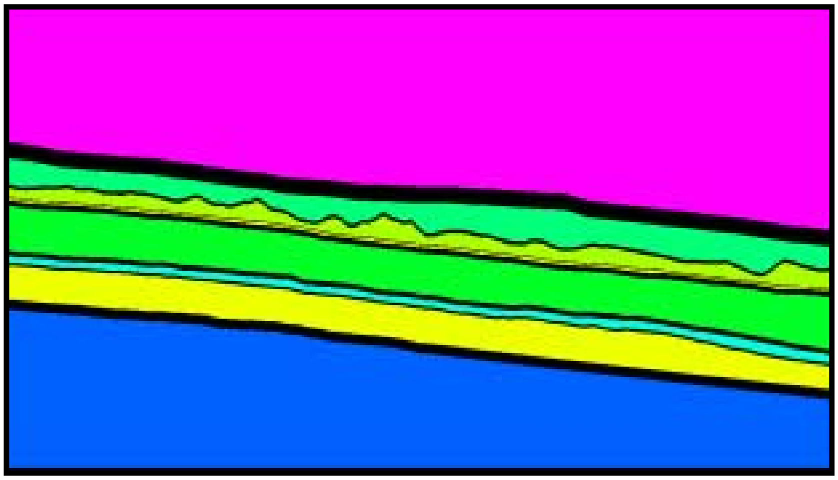
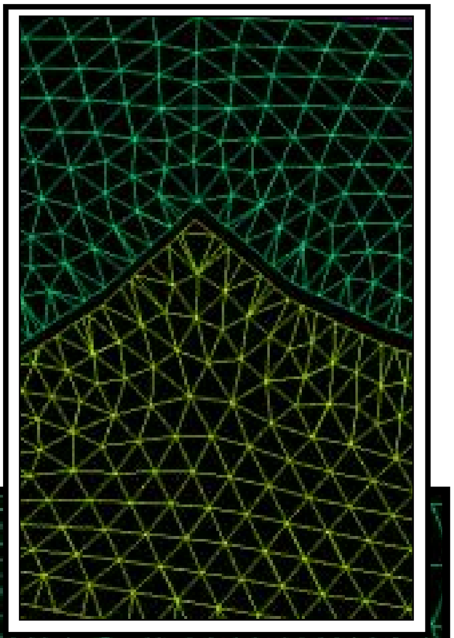
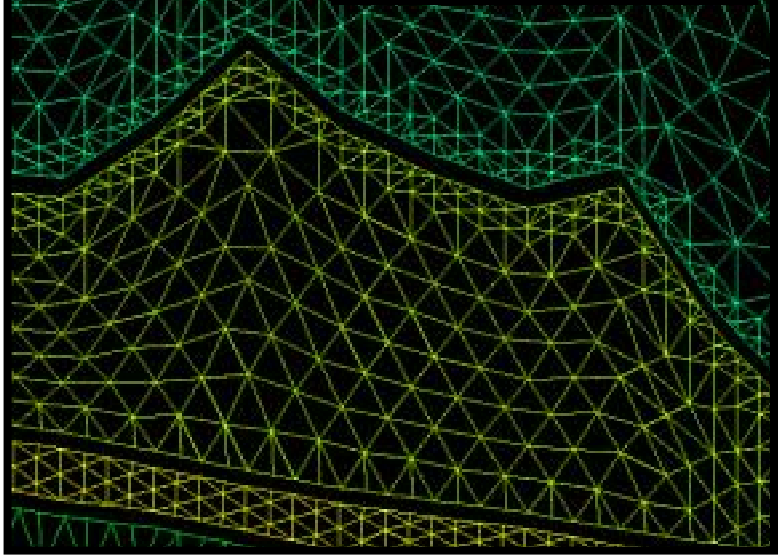






A tunnel wall digitized from photographs showing material layers and close-ups of computational grids showing increased resolution at the material interfaces (bottom right) and smoothing applied to produce a more isotropic grid (top right). Materials have been separated at interfaces for visualization.

GRID GENERATION

Defining a geometry is the first step in grid generation, and can be input in terms of bounding surfaces. These surfaces can be defined by triangular irregular networks (TINS), multi-dimensional analytic function representations such as nonuniform rational B-Splines (NURBS), or by regular grids f(i,j) where f is the grid elevation and (i,j) are regular spaced x and y coordinates. An alternative to surfaces are representations that already define volumes.

The next step involves distributing nodes within the volume of the geometry. This can be done by filling the regions with hexahedral shapes, after which they are converted to tetrahedral elements. Nodes can also be distributed within volumes using ray shooting techniques or defined point-by-point.

The last step connects the nodes into volume elements using a modified Delaunay tetrahedralization algorithm which respects material interfaces by assuring that there are no multimaterial elements and that guarantees that there are positive coupling coefficients, an essential requirement for solving the matrices used by modeling applications.

GRID OPTIMIZATION

Grid optimization combines refinement, smoothing, and reconnection tools which modify the grid to provide more spatial resolution where needed by the problem being solved. Grid refinement adds nodes based on geometric criteria such as edge length, or based on a physical field variable criterion.

For example, a cross section is digitized from photographs of a tunnel wall. It is important to represent fine scale undulations of the different materials and provide increased grid resolution near the interfaces where material properties change. Because the grid is anisotropic, a smoothing method is applied that allows nodes to move within a material region.

In another example of grid optimization, a very high resolution grid is required to model near field processes for calculations of heat and vapor transport from an underground excavation. A high density point distribution is added in the area of the excavation. As each node is added, it is determined if the node falls in an element, on an element face, along an element edge or on a node. Depending upon where the node being added lands, a different refinement algorithm is used, the location of the added point is constrained by the input point distribution.

Grid elements may become distorted or may become non-Delaunay as nodes are added as a result of refinement or moved as a result of smoothing operations. Grid reconnection then maintains the necessary element-shape quality by interchanging the connections to eliminate highly distorted elements and to maintain the positive coupling coefficient criterion of the grid.

BENEFITS

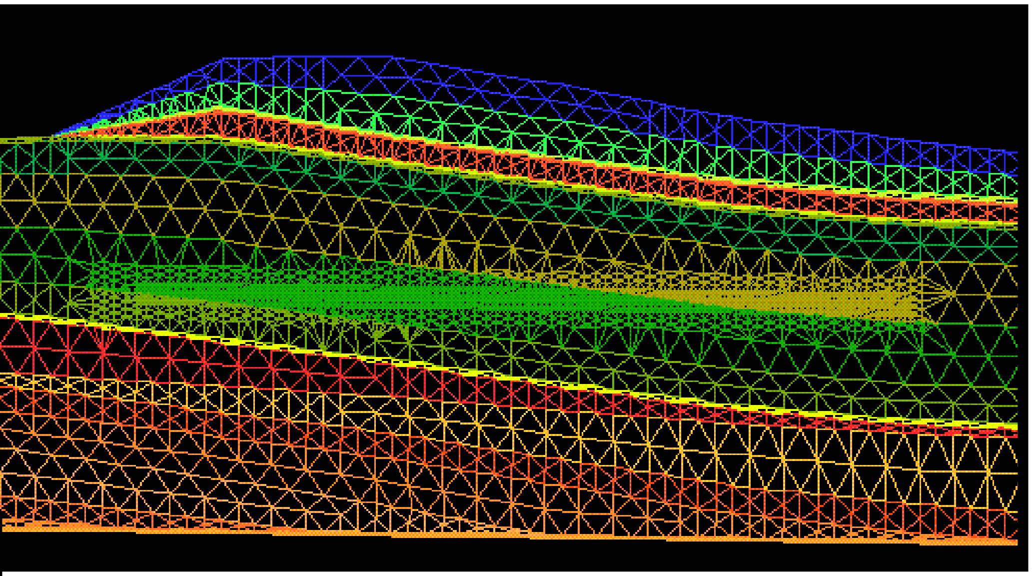
By using the grid tools provided by LaGriT allows one to create automatic and flexible grid design applications to create accurate representations of complex engineered systems and geologic structure and stratigraphy.

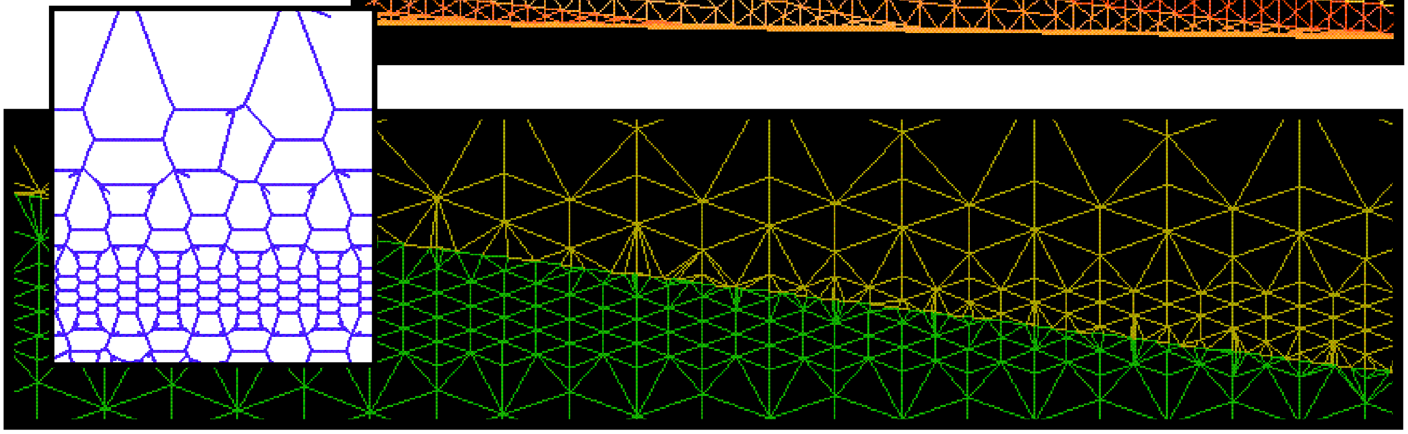
LaGriT's unstructured grid toolbox library minimizes required computer resources because grids created require a minimum number of grid nodes to resolve problem-specific properties such as moving materials, while still preserving multimaterial interface integrity.

LaGriT was intentionally designed to be easily applied by the user to any 3D application through user-extensible data objects, user-defined commands, and easy to use interfaces for linking with existing user-specified application software. Access to all LaGriT routines is retained, relieving the application from all grid chores.

The figure on the right shows a high resolution grid imbedded in a coarse grid for modeling an underground excavation. Three levels of refinement allow a gradual transition from the fine to coarse grid.

Below is a detail of the new grid area and the corresponding Voronoi mesh. Material interfaces are maintained even after a new node distribution is added.





CAPABILITIES

Input geometry can defined by TINS, NURBS, regular grids, or points.

Interfaces are available for software applications such as Stratamodel, AVS, FEHMN, and GMV.

An arbitrary number of grid objects and grid attributes can be input and manipulated.

Grid operations include add, merge, intersect, and extract.

Grid tools include hex-to-tet, interpolation (doping), and refinement.

Grid optimization is provided by using reconnection, smoothing, and AMR algorithms.

LaGriT TEAM

The LaGriT team in EES-6 includes Carl Gable,and Terry Miller. This project also derives considerable benefit from T-Division at Los Alamos National Laboratory.

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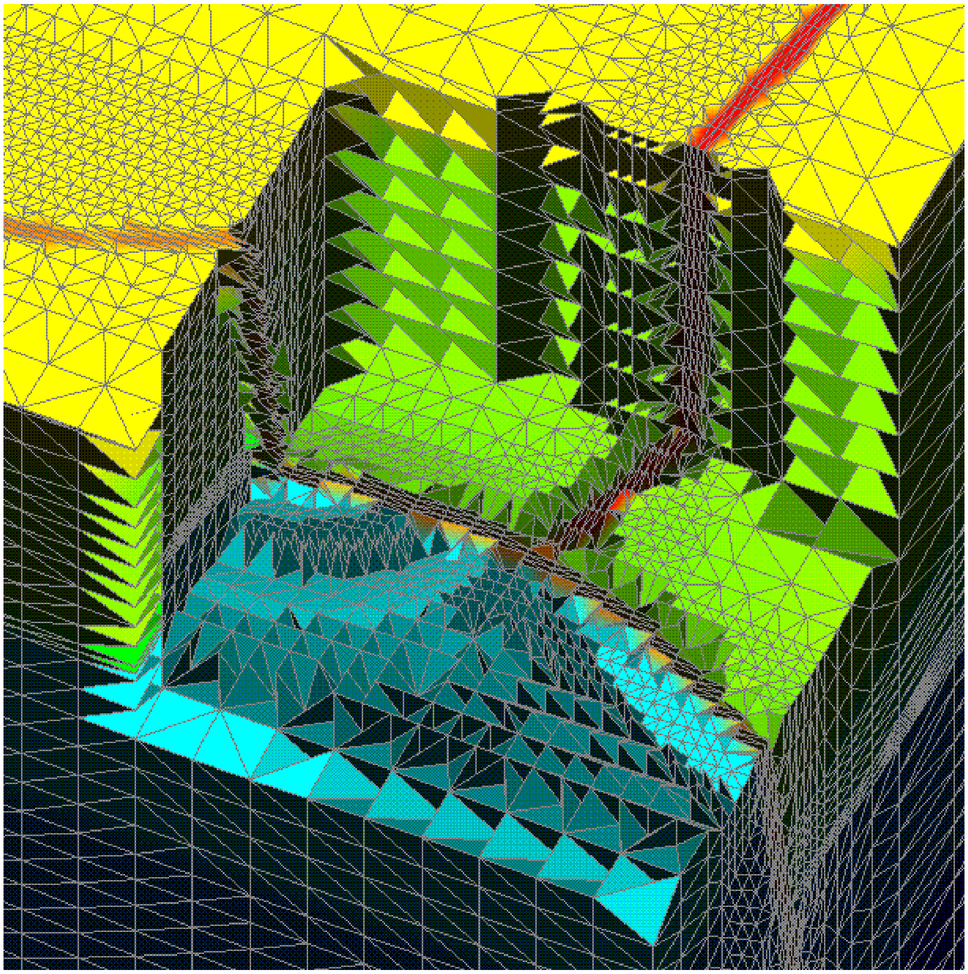
APPLICATIONS

LaGriT grids are used for modeling subsurface porous flow and reactive chemical transport by finite element (FEHMN code developed at LANL) and finite difference methods. It is also used as the first step in quality analysis of geometric data. The creation of a geometric grid is often the first time the data is visualized and obvious errors can be seen.

Projects in which LaGriT and LaGriT are utilized include:

- Yucca Mountain Site Characterization Project (YMP)
- Environmental Restoration at Los Alamos and Savannah River
- Oil and Gas Reservoir Modeling
- Semiconductor Design Modeling
- High Speed Hydrodynamics



Shown is a 3D model of geologic stratigraphy offset by intersecting faults.