Grid Generation
TGrid
What is TGrid?

- A robust and highly automated unstructured volume mesh generator:

  • **Gambit**
    - Surface Meshers exporting .msh formats
    - ANSA
    - Hypermesh
    - ICEM
    - Filters for third-party file formats
    - ANSYS (Prep7)
    - NASTRAN
    - PATRAN (Neutral)
    - I-DEAS (Universal)
    - MSC/Aries
    - HYPERMESH
    - ProE
    - STL

  • **TGrid**
    - Uses Wrapper for generating tri surface mesh
    - Includes tools for repairing/improving boundary mesh
    - Generates triangles (tris), quadrilaterals (quads) in 2D
    - Generates tets, hexcore, prisms, pyramids in 3D
    - Uses Delaunay Triangulation for tris/tets
    - Uses Advancing Layer Method for prisms
    - Includes tools to manipulate face/cell zones

  - boundary mesh + (optionally) volume mesh

  - volume mesh

  - FLUENT6
Gambit vs. TGrid

**Gambit** is a grid-generator and a geometry modeler
**TGrid** is a “pure” grid generator

**Gambit** is a general purpose grid generator for unstructured grids
**TGrid** is more focused on tet-based algorithms

**Gambit-GUI** is “more” user-friendly
**TGrid-GUI** is aligned with Fluent solver interface
Gambit and TGrid

- TGRID has powerful boundary repair and mesh generation tools, which can be used to:
  - Repair and refine surface meshes
    - Improve mesh quality and remove disconnects
    - Refine mesh based on proximity, curvature or geometric features.
  - Generate surface wrapper mesh on highly complex and “dirty” geometry.
    - Easily handle small features, gaps and disconnects.
  - Grow prism boundary layers on complex geometry.
    - Robust prism growth capabilities.
  - Advanced control of volume meshing.
    - Pinpoint meshing problems and use mesh initialization/refinement controls.
Grid generation techniques

From S. Owen, 2005

GAMBIT
TGrid
Tetrahedral Meshes

- Start from 3D boundary mesh containing only triangular faces.
- Generate mesh consisting of tetrahedra.
- Advanced control of volume meshing.
  - Set initialization and refinement controls
  - View unmeshed nodes to pinpoint problem areas.
  - Perform local refinement in a defined region.

Surface mesh for a grid containing only tetrahedra
Hybrid Meshes

- Start from 3D boundary mesh containing triangular and/or quadrilateral faces.

- Obtain better quality/more efficient mesh using:
  - Prisms (wedges) for greater resolution in boundary layer
  - Tetrahedra ("tets") for rest of domain

- Robust Prism Growth capabilities:
  - Different prism layers can be grown on adjacent geometry.
  - Four different types of prism layers available.
  - Handle complex geometry, thin gaps and sharp corners.
  - Remesh adjacent mesh.

Grid with prisms in a boundary layer region
HexCore Meshes

- Start from 3D boundary mesh containing only triangular faces
  - Automatic hexcore creation
- Suitable for curved/complex geometries with large open spaces
- Significantly smaller mesh size compared with purely tet cells
  - Fully compatible with boundary layer prism meshes

Hexcore mesh consists of two regions; an inner region of Cartesian hex cells and an outer region of tetrahedral cells
Starting Up

◆ To start TGrid
  ● On a Windows system: click on the TGrid shortcut icon and then select 2d or 3d.
  ● On a UNIX system: type `tgrid 2d` or `tgrid 3d`.
◆ Console window will appear.
◆ Text interface and complete graphical user interface (GUI)
◆ User interface similar in layout and operation to FLUENT6 interface.

◆ Complete on-line help using hypertext format
Tri/Tet Mesh Generation

Two phases:

- **Initial mesh generation**: Create initial mesh of the volume. Coarse, highly skewed elements used as a starting point for the final volume mesh.

- **Refinement on initial mesh**: Add nodes and cells to initial mesh trying to improve quality.

  ![Boundary refinement](image1)

  ![Cell zone refinement](image2)

- **Initialisation** and refinement can be automatic or manual.
Tri/Tet Mesh Quality Measure

- The chief measure of mesh quality is the Tri/Tet Skewness Method.
  - Equilateral Volume Deviation – Measures the degree of deviation of the area of the triangle from that of an ideal (equilateral) face or cell which would fit into it’s circumcircle.
    - Skewness = \frac{\text{Ideal face area} - \text{actual face area}}{\text{Ideal face area}}
  - Normalized Equiangle Deviation – Measures the degree of deviation of the internal angles of the mesh face from an ideal face with equal internal angles.
  - Skewness is plotted on a scale of 0 (good) to 1 (bad or degenerate element)
    - In TGrid, the scale from 0 to 1 divided into 100 equal divisions.
Tri/Tet Mesh Quality Measure

Two methods for determining skewness:

1. Based on the equilateral volume:
   - Skewness = \frac{\text{optimal cell size} - \text{cell size}}{\text{optimal cell size}}
   - Applies only to triangles and tetrahedra
   - Default method for tris and tets

2. Based on the deviation from a normalized equilateral angle:
   - Skewness (for a quad) = \max\left[\frac{\theta_{\max} - 90}{90}, \frac{90 - \theta_{\min}}{90}\right]
   - Applies to all cell and face shapes
   - Always used for prisms and pyramids
Tri/Tet Mesh Quality Measure

- Change in size should be gradual (smooth).
- Aspect ratio is ratio of longest edge length to shortest edge length.
  - Equal to 1 (ideal) for an equilateral triangle or a square.

- Smooth change in cell size
- Large jump in cell size

- Aspect ratio = 1
- High-aspect-ratio quad
- High-aspect-ratio triangle
Improving Quality

- A volume mesh is considered to be “bad” if it satisfies one or more the following conditions:
  - Very high skewness (skewness > 0.95)
  - Degenerate cells (skewness ~ 1)
  - High aspect ratio cells (Aspect ratios > 100)
  - Negative volumes

- Cell Quality can be improved by:
  - Improving surface mesh quality
  - Moving mesh nodes
  - Use CAD or other upstream preprocessors to fix geometric problems
  - Remove Boundary Slivers panel
  - Refine Boundary Slivers text command
Delaunay Violation

- A Delaunay violation occurs if a node of a triangle lies inside an adjacent triangle’s circumcircle.
  - Eg: Long and thin triangles which have high skewness.

- Edge Swapping is typically used to remove the Delaunay violations.
  - Replace or “Swap” the diagonal of the quadrilateral formed by the two triangles with the other diagonal.

- Many tools in TGRID detect and remove Delaunay violations using edge swapping.