Salome Platform and Tetgen for Polyhedral Mesh Generation

Lee Sang Yong (KEPCO-E&C)

27 novembre 2014
Journée des Utilisateurs SALOME
ENSTA - Saclay

© 2014 EDF. No partial distribution of information from this document and no changes are permitted. Reference to the http://www.salome-platform.org is mandatory when distributed or referenced.
SALOME Platform in KOREA

- SALOME Platform is being evaluated for two national projects
  - CUPID project
    * Component Analysis Code Development
    * 3D 8 equations multi-fluid code
    * Korea Atomic Research Institute leads the project
  - SPACE Project
    * System Safety Analysis Code Development
    * 3D 9 equations multi-fluid code
    * Korean Nuclear Industry lead the project
      - KEPCO-E&C, KNFC, KHNP, KAERI
Contents of Presentation

- Combining SALOME Platform and Tetgen
- GEOM: OpenCascade – Solid Model
- SMESH: Netgen – Surface Mesh
- Tetgen – Volume Mesh
  * Gabriel Boundary Mesh
- PolyGen – Polyhedral Mesh Generation
  * Rely on Delaunay-Voronoi Dual Property
  * Rely on Gabriel Boundary Elements
What are Gabriel Boundary Elements

Gabriel triangle

Edge on Boundary

Non-Gabriel triangle

Gabriel tetrahedron

Face on Boundary

Non-Gabriel tetrahedron
Polyhedral mesh?

- Better convergence.
- Tetrahedral mesh non-Convergence problem for highly non-linear equation (stress analysis)
- Polyhedral mesh generation by using Delaunay-Voronoi Dual property is theoretically simple, but
  * Star-CCM only supplies polyhedral mesh commercially
  * Voro++ can handle only topologically sphere solid
  * Tetgen supplies Voronoi cells with open boundary cells
  * No open source polyhedral mesh generator yet
- Practical problems that make it difficult to generate finite volume polyhedral cells are:
  * Boundary face construction
  * Boundary non-conformity
  * Concave boundary cells
Polyhedral mesh – better convergence

Milovan Peric
(CD-adapco Group,
Nürnberg Office, Germany)

“Simulation of Flows in Complex Geometries: New Meshing and Solution Methods”

NAFEMS Seminar: Simulation of Complex Flows (CFD) Application and Trends

May 3-4, 2004

Niedernhausen/Wiesbaden, Germany

Convergence of iterations for laminar flow around sphere at Re = 100 on the two meshes
What is PolyGen?

结合 Tetgen 与 SALOME Netgen

* 限制于 Tetgen
  - 无法输入实体几何模型
  - 只能输入 Plane Straight Line Graph (PSLG) 或 Piecewise Liner Complex (PLC)

* SALOME 平台拥有所有 Tetgen 需要的工具
  - OpenCascade 作为实体几何建模器
  - Netgen 提供先进的表面网格算法
  - Surface mesh from Netgen 可以被输入到 Tetgen

构建边界面

* 使用 facet/segment 结构
* 延伸在 Tetgen 中的“Outvoronoi”概念
* 内部边界也被处理
What is PolyGen?

- **Conical cell decomposition method**
  * Decompose concave cell into conical cells
  * Bisection them along the concave edge
  * Bisected conical cells are convex conical cells !!!
  * Cells may be too small compared to neighbor ones

- **Cut along concave edges method**
  * Merge faces on the same geometrical face
  * Cut two concave edges to produce one convex cell and one concave cell
  * Keep cut concave cell along other concave edges

- **Extend PolyGen to Non-manifold geometrical faces**
  * Salome can treat internal boundary surfaces
  * Therefore extend PolyGen to treat internal boundary faces
Polyhedral mesh generation procedure

- Create a dual vertex at a Voronoi point in each primal mesh region.
- Create a dual vertex at a Voronoi point in each primal mesh face on the boundary.
- Create a dual vertex at mid-point of each mesh primal edge on a model edge.
- Create a dual vertex at each primal mesh vertex on a model vertex.
- Create an interior dual face corresponding to each primal mesh edge on the interior of the domain.
- Create one or more interior dual faces corresponding to each primal mesh edge on the boundary.
- Create one or more boundary dual faces corresponding to each boundary primal vertex.
- Create one dual volume corresponding to each interior primal vertex.
- Create one or more dual volumes corresponding to each boundary vertex.
- Merge boundary faces on the same model face.
- Cut along concave edges.
SALOME solid model

Boolean cut sphere by cube generate cut-sphere solid model
Tetgen/PolyGen generate primitive polyhedral mesh by constructing boundary covering faces. It has concave cells.
Removing Concave Cells

First method

Conical Cell Decomposition
and
Bisection of Concave Conical Cells
A typical concave polyhedral cell
Decomposed Concave Conical cells

Delaunay edge insertion

vtk error face
Bisection of Decomposed Concave Conical cells

:Applicable to any shape, but too small cells
Polyhedral Meshes of Cut-Sphere (boundary faces not merged yet)

Typical concave cell

Concave cells
Clipping view of Cut-sphere

- Bisected boundary concave conical cells
- Internal polyhedral cells
- Convex boundary polyhedral cells
Removing Concave Cells

Second method

Cut along Concave Edges
Concave Vertex Cell Types
Concave Vertex Cell Types

vertexTwoEdge

edgeTwoEdge
Cut along Edge method example
(vertexTwoEge cell)

- merge faces on the same geo face (remove edges)
- two cuts along concave edges
- one cut for obtuse cells
Completed Polyhedral Mesh (cut sphere with fused cube)
Concave-Convex Block
Salome Solid Model
Tetrahedral mesh
Polyhedral mesh - primitive
Concave-Convex Block
Completed mesh for Concave-Convex Block

Upper block

Concave edge

Internal Boundary

Internal Boundary

Lower block

Concave edge
Completed mesh for Concave-Convex Block
Completed mesh for Concave-Convex Block
Internal Concave Cells Example: Solid Model
Internal Concave Cells Example: Mesh (cut view)
Internal Concave Cells Example:
Internal Concave Cells Example: Convexly cut Concave Cells
Star-CCM Mesh Example: Final Goal

Viscous Layer: To be done

Cut in Two: Ok now
Star-CCM Mesh Example: Mesh
Check Cell Integrity
by
OpenFoam/icoFoam Calculation Results
Conclusion & Further works

- Tetgen is successfully combined with Netgen in the SALOME Platform
- Concave cells are made convex by two ways
  * Conical cell decomposition/bisection method
    - Applicable to any shape
    - Too small cell compared to neighbors
  * Cut along edges method
    - Very complicate
    - Cell sizes are reasonable
- Further works
  * Improve Polgen
    - More fluent and robust
    - STL to c++ generic type to speed up
  * Implement Viscous layer
  * Guaranteed boundary conforming surface mesh (Gabriel boundary Delaunay internal surface mesh)