MeshGems for SALOME

Overview and focus on hybrid meshing
The MeshGems Suite

- Fully automatic, fast, reliable and state-of-art meshing components to enhance & automate the «CAD to Mesh» process, targeting complex industrial models
  - Surface meshing from CAD geometries (incl. Discrete geometries)
  - Mesh Processing (cleaning, optimization, remeshing ... )
  - Volume meshing (from tet and hex to mixed element meshing)
  - Mesh adaptation
- Developed by DISTENE, capitalizing 20 years of R&D on meshing technology, common Inria & Distene “Meshing Lab” since 2010
- Validated through a huge and evolving data base (+5000 geometries, including thousand of real industrial test cases)
MeshGems Salome plugins

Current version of SALOMÉ includes MeshGems 2.1
Next version will include MeshGems 2.3

Surface Meshing from CAD geometry:
- MG-CADSurf, tri/quad meshing with automatic CAD preprocessor

Mesh Processing:
- MG-Cleaner, automatic mesh correction
- MG-SurfOpt, surface mesh remeshing

Volume Meshing:
- MG-Tetra and MG-Tetra_HPC, tetrahedral volume meshing
- MG-Hexa, full hexahedral volume meshing
- MG-Hybrid, mixed element volume meshing
Surface meshing with MeshGems

Overview

**MG-CADSURF**: Industry-proven surface meshing technologies including a “CAD preconditioner” for automatic and robust mesh generation on complex, native and discrete, geometries.

- **Eng_V6 case**: ~7000 patches
- **Constant size**
- **Curvature-driven size**
Surface meshing with MeshGems
SALOME MG-CADSURF Plugin

- Single workflow for continuous and discrete geometries
- Cleans up very efficiently and fully automatically a lot of CAD artifacts
- Preserves the CAD associativity
- High quality: smooth and regular meshes

Triangle or Quadrilateral, 1D wire meshes
Anisotropic or isotropic with gradation control
Curvature driven
Precise size control on a global or local basis
CAD definition enforcement, periodic mesh generation, (mesh matching)
Edges and edge discretization enforcement
Self-intersection prevention
Associativity with underlying CAD model
Volume proximity
Quadratic elements (with Jacobians controls)
Surface meshing with MeshGems
from Discrete CAD

- Not yet in SALOME but same workflow as for native CAD

Input geometry (STL)

Quad meshing (using here constant size)

Tri meshing: (here curvature driven)
Surface meshing with MeshGems

What's new in the next SALOME version?

The CAD patch mesher in MeshGems-CADSurf has been entirely redesigned, introducing many improvements:

- Better mesh regularity and quality on locally degenerated parametrisations.
- Increase of the speed for isotropic mesh generation
  
  *an average of 30% increase observed for moderately fine meshes*

- Increase of the robustness of the patch mesher
  
  *on our test base, 20% of the CAD patches which led to failure in previous version can now be meshed successfully*

- Optimization of the quadratic nodes location and the resulting Jacobians around a parametrisation degeneracy (the pole of a sphere for instance)
Surface meshing with MeshGems
What's new in the next SALOME version?

Example: Control of badly parametrized CAD definitions

Without control (MG 2.1)

With control (MG 2.3)
Surface meshing with MeshGems

What's new in the next SALOME version?

- Example: Optimization of the quadratic nodes location and the resulting Jacobians around a parametrisation degeneracy (the pole of a sphere for instance)

MeshGems 2.1

MeshGems 2.3
Mesh Processing with MeshGems

mesh cleaning overview

MG-Cleaner for mesh cleaning

- Corrects a surface mesh so as to make it suitable for tetrahedral meshing, by removing bad quality elements, self-intersections, overlaps, holes, etc.
- In SALOME: via the SMESH Plugin item in Mesh menu bar
Mesh Processing with MeshGems

mesh cleaning overview

- Makes boundary patch conformal
- Fills hole automatically
- Performs boolean operation automatically
Mesh Processing with MeshGems
What’s new in the next SALOME version?

Priority of correction operations in MG-Cleaner is now determined by the tags

- It will try to perform its correction operations in a way that preserves the mesh entities with the smallest (but positive) tags
- This behavior will allow the caller to drive more precisely the correction operations by giving some kind of priority to the mesh entities.

Single contacts between two surfaces can now be detached
Tag associativity and history mechanism extended to vertices and edges
The volume detection in MG-Cleaner has been enhanced.
Improved correction capability
Tetrahedral meshing with MeshGems

**overview**

**MG-Tetra** : Reference technology on the market

- **Fully automatic** tetrahedral mesh generator: creates a volume tetrahedral mesh defined by a watertight input triangular surface mesh
- **Very reliable**: able to mesh the most complex industrial geometries without failure

**MG-Tetra_HPC** : New parallel code addressing very large meshes

- Mixed frontal-Delaunay: better cell regularity, quality and fewer tets
- Multithread or distributed memory (MPI)
  - Parallel distributed memory systems (clusters...)
  - Parallel shared memory systems, multicore machines

Output can be a single mesh, or a parallel data structure including communication information and local/global indirections

Reproducible multithread meshing
Tetrahedral meshing with MeshGems
SALOME MG-TETRA plugin

- Input skin mesh unchanged in output volume mesh
- Enforced entities: points, edges and facets
- Cavities can be meshed or not
- Gives diagnostics if the input mesh is "false": self intersection between point-edges-facets
- Quadratic tets
- Multithreaded optimization
- Can force a given minimum number of layers for thin geometries
- Sub-domain identification with input data
- Removal of overconstrained elements and slivers
- Can be used as an optimizer only
Tetrahedral meshing with MeshGems

What's new in the next SALOME version?

- **min_size** and **max_size** parameters to control the minimum and maximum desired edge length
- **gradation** control
- Saturation enhanced in some specific situations
- The **quadratic meshing workflow** of MeshGems-Tetra has been readdressed and is now able to generate a correct quadratic mesh in many more situations

No correction
42 negative Jacobians

2.2 release Mg-Tetra correction
27 negative Jacobians

2.3 release MG-Tetra correction
0 negative Jacobian
Hexahedral meshing with MeshGems

Overview

**MG-Hexa** : Fully automated all-hex & conformal mesh generator

- create an a hex mesh and related quad surface mesh
- captures the input geometry but not preserving its topology
Hexahedral meshing with MeshGems
SALOME MG-HEXA Plugin

- Based on the Octree method
- Multiple surface & volume subdomains, non-manifold geometries - all subdomains meshed together in one go
- Forced entities: such as surface or edges
- Adaptive capabilities (input size map)
- Generation of boundary layers (with imprinting and blending)
Hybrid meshing with MeshGems

overview

MG-HYBRID: Multi-element volume mesh generation

- Extends the applicability of Tet- & Hex-Meshing to mixed surfaces (conformal)
- All-in-one generalised Mixed Tet- & Hex-meshing capabilities coupled to extrusion, fully conformal with pyramids/wedges
Hybrid meshing with MeshGems

SALOME MG-HYBRID Plugin

- HYBRID Parameters hypothesis
  - Boundary layer meshes
  - Hexahedra dominant
Hybrid meshing with MeshGems

Hexa-dominant meshes

Two modes

(1) Based on MG-Hexa's octree
   - Size of internal elements determined by
     - surface mesh size
     - aspect ratio of element
   - Variable mesh density

(2) Cartesian core (not yet in SALOME GUI)
   - Constant size hexahedra
   - Hexahedral core region constrained by:
     - The input surface element size,
     - The target element size (given by the global physical size parameter),
     - The gradation parameter.
Hybrid meshing with MeshGems

hexa_dominant versus cartesian_core

- **hexa_dominant**: as many hexahedra as possible (in volume)
- **cartesian_core**: the given edge length is preserved, the gradation being taken into account for the tetrahedral part
Hybrid meshing with MeshGems

Boundary layers meshes

- Fully automatic
- Conforming to input surface
- Extrusion approach: orthogonal prism/hex elements depending on the surface

Controls
- Number of layers,
- Size of first layer,
- Progression,
- Local (per tag basis) or global

Other features
- Automatic collision control (decrease height or stop locally) to avoid self-intersection and entangled elements
- Processing of sharp angles with multi-normals, etc...
- Smoothing of normals
Hybrid meshing with MeshGems

Boundary layers meshes

Control of the number of elements around the ridges:

User angle threshold
30° by default

nb layers : 10
h0: 0.03 size of the surface mesh progression 1.1

Number Of Vertices                      197362
Number Of Triangles                      21090
Number Of Tetrahedra                  406959
Number Of Pyramids                        4720
Number Of Prisms                        210716
Number Of Hexahedra                    17005
Hybrid meshing with MeshGems

What's new in the next SALOME version?

- Improved mesh quality in hybrid meshes

- Imprinting of boundary layers onto surface meshes (not yet in SALOME)
What's next in MG for Salome?

Volume boundary layers
- Blending between anisotropic and isotropic areas
- Optimization of the quality

Surface boundary layers

Improvement of the quadrilateral dominant meshing
- More structured meshes

Enhancement of quadratic meshing in MG-Tetra

Improvement of « safe » boundary recovery mode in MG-Tetra
- much higher success rate on very difficult cases (+22% on a 400 « hard cases » suite)