Gmsh

Gmsh Reference Manual

The documentation for Gmsh 4.12.2
A finite element mesh generator with built-in pre- and post-processing facilities

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Christophe Geuzaine
Jean-François Remacle

Short Contents

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Obtaining Gmsh

The source code and pre-compiled binary versions of Gmsh (for Windows, macOS and Linux) can be downloaded from https://gmsh.info. Gmsh packages are also directly available in various Linux and BSD distributions (Debian, Fedora, Ubuntu, FreeBSD, ...).

If you use Gmsh, we would appreciate that you mention it in your work by citing the following paper: C. Geuzaine and J.-F. Remacle, *Gmsh: a three-dimensional finite element mesh generator with built-in pre- and post-processing facilities*. International Journal for Numerical Methods in Engineering, Volume 79, Issue 11, pages 1309-1331, 2009. A preprint of that paper as well as other references and the latest news about Gmsh development are available on https://gmsh.info.

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The precise conditions of the license for Gmsh are found in the General Public License that accompanies the source code (see Appendix F [License], page 413). Further information about this license is available from the GNU Project webpage `https://www.gnu.org/copyleft/gpl-faq.html`. Detailed copyright information can be found in Appendix E [Copyright and credits], page 409.

If you want to integrate parts of Gmsh into a closed-source software, or want to sell a modified closed-source version of Gmsh, you will need to obtain a different license. Please contact us directly for more information.

Reporting a bug

If, after reading this reference manual, you think you have found a bug in Gmsh, please file an issue on `https://gitlab.onelab.info/gmsh/gmsh/issues`. Provide as precise a description of the problem as you can, including sample input files that produce the bug. Don't forget to mention both the version of Gmsh and your operation system.

See Appendix C [Frequently asked questions], page 379, and the bug tracking system to see which problems we already know about.

1 Overview of Gmsh

Gmsh is a three-dimensional finite element mesh generator with a build-in CAD engine and post-processor. Its design goal is to provide a fast, light and user-friendly meshing tool with parametric input and flexible visualization capabilities.

Gmsh is built around four modules (geometry, mesh, solver and post-processing), which can be controlled with the graphical user interface (GUI; see Chapter 3 [Gmsh graphical user interface], page 79), from the command line (see Chapter 4 [Gmsh command-line interface], page 85), using text files written in Gmsh's own scripting language ('`.geo`' files; see Chapter 5 [Gmsh scripting language], page 91), or through the C++, C, Python, Julia and Fortran application programming interface (API; see Chapter 6 [Gmsh application programming interface], page 125).

A brief description of the four modules is given hereafter, before an overview of what Gmsh does best (... and what it is not so good at), and some practical information on how to install and run Gmsh on your computer.

1.1 Geometry module

A model in Gmsh is defined using its Boundary Representation (BRep): a volume is bounded by a set of surfaces, a surface is bounded by a series of curves, and a curve is bounded by two end points. Model entities are topological entities, i.e., they only deal with adjacencies in the model, and are implemented as a set of abstract topological classes. This BRep is extended by the definition of *embedded*, or internal, model entities: internal points, curves and surfaces can be embedded in volumes; and internal points and curves can be embedded in surfaces.

The geometry of model entities can be provided by different CAD kernels. The two default kernels interfaced by Gmsh are the *built-in* kernel and the *OpenCASCADE* kernel. Gmsh does not translate the geometrical representation from one kernel to another, or from these kernels to some neutral representation. Instead, Gmsh directly queries the native data for each CAD kernel, which avoids data loss and is crucial for complex models where translations invariably introduce issues linked to slightly different representations. Selecting the CAD kernel in '`.geo`' scripts is done with the `SetFactory` command (see Section 5.2 [Geometry scripting commands], page 104), while in the Gmsh API the kernel appears explicitly in all the relevant functions from the `gmsh/model` namespace, with `geo` or `occ` prefixes for the built-in and OpenCASCADE kernel, respectively (see Section 6.3 [Namespace gmsh/model], page 130).

Entities can either be built in a *bottom-up* manner (first points, then curves, surfaces and volumes) with the built-in and OpenCASCADE kernels, or in a *top-down* constructive solid geometry fashion (solids on which boolean operations are performed) with the OpenCASCADE kernel. Both methodologies can also be combined. Finally, groups of model entities (called "physical groups") can be defined, based on the elementary geometric entities. (See Section 1.2.3 [Elementary entities vs physical groups], page 11, for more information about how physical groups affect the way meshes are saved.)

Both model entities (also referred to as "elementary entities") and physical groups are uniquely defined by a pair of integers: their dimension (0 for points, 1 for curves, 2 for surfaces, 3 for volumes) and their *tag*, a strictly positive global identification number. Entity and group tags are unique per dimension:

1. each point must possess a unique tag;
2. each curve must possess a unique tag;
3. each surface must possess a unique tag;
4. each volume must possess a unique tag.

Zero or negative tags are reserved by Gmsh for internal use.

Model entities can be manipulated and transformed in a variety of ways within the geometry module, but operations are always performed directly within their respective CAD kernels. As explained above, there is no common internal geometrical representation: rather, Gmsh directly performs the operations (translation, rotation, intersection, union, fragments, ...) on the native geometrical representation using each CAD kernel's own API. In the same philosophy, models can be imported in the geometry module through each CAD kernel's own import mechanisms. For example, by default Gmsh imports STEP and IGES files through OpenCASCADE, which will lead to the creation of model entities with an internal OpenCASCADE representation.

The Chapter 2 [Gmsh tutorial], page 15, starting with Section 2.1 [t1], page 15, is the best place to learn how to use the geometry module: it contains examples of increasing complexity based on both the built-in and the OpenCASCADE kernel. Note that many features of the geometry module can be used interactively in the GUI (see Chapter 3 [Gmsh graphical user interface], page 79), which is also a good way to learn about both Gmsh's scripting language and the API, as actions in the geometry module automatically append the related command in the input script file, and can optionally also generate input for the languages supported by the API (see the `General.ScriptingLanguages` option; this is still work-in-progress as of Gmsh 4.12.)

In addition to CAD-type geometrical entities, whose geometry is provided by a CAD kernel, Gmsh also supports *discrete* model entities, which are defined by a mesh (e.g. STL). Gmsh does not perform geometrical operations on such discrete entities, but they can be equipped with a geometry through a so-called "reparametrization" procedure[1]. The parametrization is then used for meshing, in exactly the same way as for CAD entities. See Section 2.13 [t13], page 43 for an example.

1.2 Mesh module

A finite element mesh of a model is a tessellation of its geometry by simple geometrical elements of various shapes (in Gmsh: lines, triangles, quadrangles, tetrahedra, prisms, hexahedra and pyramids), arranged in such a way that if two of them intersect, they do so along a face, an edge or a node, and never otherwise. This defines a so-called conformal mesh. The mesh module implements several algorithms to generate such meshes automatically. By default, meshes produced by Gmsh are considered as *unstructured*, even if they were generated in a *structured* way (e.g., by extrusion). This implies that the mesh elements are completely defined simply by an ordered list of their nodes, and that no predefined ordering relation is assumed between any two elements.

In order to guarantee the conformity of the mesh, mesh generation is performed in a bottom-up flow: curves are discretized first; the mesh of the curves is then used to mesh the surfaces; then the mesh of the surfaces is used to mesh the volumes. In this process, the mesh of an entity is only constrained by the mesh of its boundary, unless entities of lower dimensions are explicitly embedded in entities of higher dimension. For example, in three dimensions, the triangles discretizing a surface will be forced to be faces of tetrahedra in the final 3D mesh only if the surface is part of the boundary of a volume, or if that surface has been explicitly embedded in the volume. This automatically ensures the conformity of the mesh when, for example, two volumes share a common surface. Mesh elements are oriented according to the geometrical orientation of the underlying entity. Every meshing step is constrained by a *mesh size field*, which prescribes the desired size of the elements in the mesh. This size field can be uniform, specified by values associated with points in the geometry, or defined by general mesh size fields (for example related to the distance to some boundary, to a arbitrary scalar field defined on another mesh, etc.): see Chapter 8 [Gmsh mesh size fields], page 303. For each meshing step, all structured mesh directives are executed first, and serve as additional constraints for the unstructured parts.

[1] P. A. Beaufort, C. Geuzaine, J.-F. Remacle *Automatic surface mesh generation for discrete modelsA complete and automatic pipeline based on reparametrization.* Journal of Computational Physics, 417, 109575, 2020.

(The generation and handling of conformal meshes has important consequences on how meshes are stored internally in Gmsh, and how they are accessed through the API: see Chapter 6 [Gmsh application programming interface], page 125.)

Gmsh's mesh module regroups several 1D, 2D and 3D meshing algorithms:

- The 2D *unstructured* algorithms generate triangles and/or quadrangles (when recombination commands or options are used). The 3D *unstructured* algorithms generate tetrahedra, or tetrahedra and pyramids (when the boundary mesh contains quadrangles).
- The 2D *structured* algorithms (transfinite and extrusion) generate triangles by default, but quadrangles can be obtained by using the recombination commands or options. The 3D *structured* algorithms generate tetrahedra, hexahedra, prisms and pyramids, depending on the type of the surface meshes they are based on.

All meshes can be subdivided to generate fully quadrangular or fully hexahedral meshes with the `Mesh.SubdivisionAlgorithm` option (see Section 7.4 [Mesh options], page 259).

1.2.1 Choosing the right unstructured algorithm

Gmsh provides a choice between several 2D and 3D unstructured algorithms. Each algorithm has its own advantages and disadvantages.

For all 2D unstructured algorithms a Delaunay mesh that contains all the points of the 1D mesh is initially constructed using a divide-and-conquer algorithm[2]. Missing edges are recovered using edge swaps[3]. After this initial step several algorithms can be applied to generate the final mesh:

- The "MeshAdapt" algorithm[4] is based on local mesh modifications. This technique makes use of edge swaps, splits, and collapses: long edges are split, short edges are collapsed, and edges are swapped if a better geometrical configuration is obtained.
- The "Delaunay" algorithm is inspired by the work of the GAMMA team at INRIA[5]. New points are inserted sequentially at the circumcenter of the element that has the largest adimensional circumradius. The mesh is then reconnected using an anisotropic Delaunay criterion.
- The "Frontal-Delaunay" algorithm is inspired by the work of S. Rebay[6].
- Other experimental algorithms with specific features are also available. In particular, "Frontal-Delaunay for Quads"[7] is a variant of the "Frontal-Delaunay" algorithm aiming at generating right-angle triangles suitable for recombination; and "BAMG"[8] allows to generate anisotropic triangulations.

For very complex curved surfaces the "MeshAdapt" algorithm is the most robust. When high element quality is important, the "Frontal-Delaunay" algorithm should be tried. For very large

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[2] R. A. Dwyer, *A simple divide-and-conquer algorithm for computing Delaunay triangulations in O(n log n) expected time*, In Proceedings of the second annual symposium on computational geometry, Yorktown Heights, 2–4 June 1986.

[3] N. P. Weatherill, *The integrity of geometrical boundaries in the two-dimensional Delaunay triangulation*, Commun. Appl. Numer. Methods 6(2), pp. 101–109, 1990.

[4] C. Geuzaine and J.-F. Remacle, *Gmsh: a three-dimensional finite element mesh generator with built-in pre- and post-processing facilities*, International Journal for Numerical Methods in Engineering 79(11), pp. 1309–1331, 2009.

[5] P.-L. George and P. Frey, *Mesh generation*, Hermes, Lyon, 2000.

[6] S. Rebay, *Efficient unstructured mesh generation by means of Delaunay triangulation and Bowyer-Watson algorithm*, J. Comput. Phys. 106, pp. 25–138, 1993.

[7] J.-F. Remacle, F. Henrotte, T. Carrier-Baudouin, E. Bchet, E. Marchandise, C. Geuzaine and T. Mouton, *A frontal Delaunay quad mesh generator using the Linf norm*, International Journal for Numerical Methods in Engineering, 94(5), pp. 494-512, 2013.

[8] F. Hecht, *BAMG: bidimensional anisotropic mesh generator*, User Guide, INRIA, Rocquencourt, 1998.

meshes of plane surfaces the "Delaunay" algorithm is the fastest; it usually also handles complex mesh size fields better than the "Frontal-Delaunay". When the "Delaunay" or "Frontal-Delaunay" algorithms fail, "MeshAdapt" is automatically triggered. The "Automatic" algorithm uses "Delaunay" for plane surfaces and "MeshAdapt" for all other surfaces.

Several 3D unstructured algorithms are also available:

- The "Delaunay" algorithm is split into three separate steps. First, an initial mesh of the union of all the volumes in the model is performed, without inserting points in the volume. The surface mesh is then recovered using H. Si's boundary recovery algorithm Tetgen/BR. Then a three-dimensional version of the 2D Delaunay algorithm described above is applied to insert points in the volume to respect the mesh size constraints.
- The "Frontal" algorithm uses J. Schoeberl's Netgen algorithm[9].
- The "HXT" algorithm[10] is a new efficient and parallel reimplementaton of the Delaunay algorithm.
- Other experimental algorithms with specific features are also available. In particular, "MMG3D"[11] allows to generate anisotropic tetrahedralizations.

The "Delaunay" algorithm is currently the most robust and is the only one that supports the automatic generation of hybrid meshes with pyramids. Embedded model entities and general mesh size fields (see Section 1.2.2 [Specifying mesh element sizes], page 10) are currently only supported by the "Delaunay" and "HXT" algorithms.

When Gmsh is configured with OpenMP support (see Appendix A [Compiling the source code], page 373), most of the meshing steps can be performed in parallel:

- 1D and 2D meshing is parallelized using a coarse-grained approach, i.e. curves (resp. surfaces) are each meshed sequentially, but several curves (resp. surfaces) can be meshed at the same time.
- 3D meshing using HXT is parallelized using a fine-grained approach, i.e. the actual meshing procedure for a single volume is done is parallel.

The number of threads can be controlled with the `-nt` flag on the command line (see Chapter 4 [Gmsh command-line interface], page 85), or with the `General.NumThreads`, `Mesh.MaxNumThreads1D`, `Mesh.MaxNumThreads2D` and `Mesh.MaxNumThreads3D` options (see Section 7.1 [General options], page 223 and Section 7.4 [Mesh options], page 259).

1.2.2 Specifying mesh element sizes

There are several ways to specify the size of the mesh elements for a given geometry:

1. First, if the options `Mesh.MeshSizeFromPoints` and `Mesh.MeshSizeExtendFromBoundary` are set (they are by default; see Section 7.4 [Mesh options], page 259), you can simply specify desired mesh element sizes at the geometrical points of the model. The size of the mesh elements will then be computed by interpolating these values inside the domain during mesh generation. This might sometimes lead to over-refinement in some areas, so that you may have to add "dummy" geometrical entities in the model in order to get the desired element sizes or use more advanced methods explained below.
2. Second, if `Mesh.MeshSizeFromCurvature` is set to a positive value (it is set to 0 by default), the mesh will be adapted with respect to the curvature of the model entities, the value giving the target number of elements per 2 Pi radians.

[9] J. Schoeberl, *Netgen, an advancing front 2d/3d-mesh generator based on abstract rules*, Comput. Visual. Sci., 1, pp. 41–52, 1997.

[10] C. Marot, J. Pellerin and J.F. Remacle, *One machine, one minute, three billion tetrahedra*, International Journal for Numerical Methods in Engineering 117.9, pp 967-990, 2019.

[11] C. Dobrzynski, *MMG3D: user guide*, INRIA, 2012.

3. Next, you can specify a general target mesh size, expressed as a combination of mesh size fields (see Chapter 8 [Gmsh mesh size fields], page 303):
   - The `Box` field specifies the size of the elements inside and outside of a parallelepipedic region.
   - The `Distance` field specifies the size of the mesh according to the distance to some model entities.
   - The `MathEval` field specifies the size of the mesh using an explicit mathematical function.
   - The `PostView` field specifies an explicit background mesh in the form of a scalar post-processing view (see Section 1.4 [Post-processing module], page 12, and Chapter 10 [Gmsh file formats], page 349) in which the nodal values are the target element sizes. This method is very general but it requires a first (usually rough) mesh and a way to compute the target sizes on this mesh (usually through an error estimation procedure, e.g. in an iterative process of mesh adaptation).
   - The `Min` field specifies the size as the minimum of the sizes computed using other fields.
   - ...
4. Mesh sizes are also constrained by structured meshing constraints (e.g. transfinite or extruded meshes) as well as by any discrete model entity that is not equipped with a geometry, and which will thus preserve it mesh during mesh generation.
5. Boundary mesh sizes are interpolated inside surfaces and/or volumes depending on the value of `Mesh.MeshSizeExtendFromBoundary`.

To determine the actual mesh size at any given point in the model, Gmsh evaluates all the above mesh size constraints and selects the smallest value. Using the Gmsh API, this value can then be further modified using a C++, C, Python, Julia or Fortran mesh size callback function provided via `gmsh/model/mesh/setSizeCallback` (see Section 6.4 [Namespace gmsh/model/mesh], page 142).

The resulting value is further constrained in the interval [`Mesh.MeshSizeMin`, `Mesh.MeshSizeMax`] (which can also be provided on the command line with `-clmin` and `-clmax`). The resulting value is then finally multiplied by `Mesh.MeshSizeFactor` (`-clscale` on the command line).

Note that when the element size is fully specified by a mesh size field, it is thus often desirable to set

```
Mesh.MeshSizeFromPoints = 0;
Mesh.MeshSizeFromCurvature = 0;
Mesh.MeshSizeExtendFromBoundary = 0;
```

to prevent over-refinement inside an entity due to small mesh sizes on its boundary.

1.2.3 Elementary entities vs. physical groups

It is usually convenient to combine elementary geometrical entities into more meaningful groups, e.g. to define some mathematical ("domain", "boundary with Neumann condition"), functional ("left wing", "fuselage") or material ("steel", "carbon") properties. Such grouping is done in Gmsh's geometry module (see Section 1.1 [Geometry module], page 7) through the definition of "physical groups".

By default in the native Gmsh MSH mesh file format (see Chapter 10 [Gmsh file formats], page 349), as well as in most other mesh formats, if physical groups are defined, the output mesh only contains those elements that belong to at least one physical group. (Different mesh file formats treat physical groups in slightly different ways, depending on their capability to define groups.) To save all mesh elements whether or not physical groups are defined, use the

`Mesh.SaveAll` option (see Section 7.4 [Mesh options], page 259) or specify `-save_all` on the command line. In some formats (e.g. MSH2), setting `Mesh.SaveAll` will however discard all physical group definitions.

1.3 Solver module

Gmsh implements a ONELAB (`http://onelab.info`) server to exchange data with external solvers or other codes (called "clients"). The ONELAB interface allows to call such clients and have them share parameters and modeling information.

The implementation is based on a client-server model, with a server-side database and local or remote clients communicating in-memory or through TCP/IP sockets. Contrary to most solver interfaces, the ONELAB server has no a priori knowledge about any specifics (input file format, syntax, ...) of the clients. This is made possible by having any simulation preceded by an analysis phase, during which the clients are asked to upload their parameter set to the server. The issues of completeness and consistency of the parameter sets are completely dealt with on the client side: the role of ONELAB is limited to data centralization, modification and re-dispatching.

Using the Gmsh API, you can directly embed Gmsh in your C++, C, Python, Julia or Fortran solver, use ONELAB for interactive parameter definition and modification, and to create post-processing data on the fly. See prepro.py, custom_gui.py and custom_gui.cpp for examples.

If you prefer to keep codes separate, you can also communicate with Gmsh through a socket by providing the solver name (`Solver.Name0`, `Solver.Name1`, etc.) and the path to the executable (`Solver.Executable0`, `Solver.Executable1`, etc.). Parameters can then be exchanged using the ONELAB protocol: see the utils/solvers directory for examples. A full-featured solver interfaced in this manner is GetDP (`https://getdp.info`), a general finite element solver using mixed finite elements.

1.4 Post-processing module

The post-processing module can handle multiple scalar, vector or tensor datasets along with the geometry and the mesh. The datasets can be given in several formats: in human-readable "parsed" format (these are just part of a standard input script, but are usually put in separate files with a '`.pos`' extension – see Section 5.4 [Post-processing scripting commands], page 119), in native MSH files (ASCII or binary files with '`.msh`' extensions: see Chapter 10 [Gmsh file formats], page 349), or in standard third-party formats such as CGNS or MED. Datasets can also be directly imported using the Gmsh API (see Section 6.10 [Namespace gmsh/view], page 204).

Once loaded into Gmsh, scalar fields can be displayed as iso-curves, iso-surfaces or color maps, whereas vector fields can be represented either by three-dimensional arrows or by displacement maps. Tensor fields can be displayed as Von-Mises effective stresses, min/max eigenvalues, eigenvectors, ellipses or ellipsoids. (To display other combinations of components, you can use the `View.ForceNumComponents` option – see Section 7.6 [Post-processing options], page 284.)

Each dataset, along with the visualization options, is called a "post-processing view", or simply a "view". Each view is given a name, and can be manipulated either individually (each view has its own button in the GUI and can be referred to by its index or its unique tag in a script or in the API) or globally (see the `PostProcessing.Link` option in Section 7.6 [Post-processing options], page 284). Possible operations on post-processing views include section computation, offset, elevation, boundary and component extraction, color map and range modification, animation, vector graphic output, etc. These operations are either carried out nondestructively through the modification of post-processing options, or can lead to the actual modification of the view data or the creation of new views when done using post-processing plugins (see Chapter 9 [Gmsh plugins], page 321). Both can be fully automated in scripts or through the API (see e.g., Section 2.8 [t8], page 33, and Section 2.9 [t9], page 36).

By default, Gmsh treats all post-processing views as three-dimensional plots, i.e., draws the scalar, vector and tensor primitives (points, curves, triangles, tetrahedra, etc.) in 3D space. But Gmsh can also represent each post-processing view containing *scalar points* as two-dimensional ("X-Y") plots, either space- or time-oriented:

- in a '2D space' plot, the scalar points are taken in the same order as they are defined in the post-processing view: the abscissa of the 2D graph is the curvilinear abscissa of the curve defined by the point series, and only one curve is drawn using the values associated with the points. If several time steps are available, each time step generates a new curve;
- in a '2D time' plot, one curve is drawn for each scalar point in the view and the abscissa is the time step.

1.5 What Gmsh is pretty good at . . .

Here is a tentative list of what Gmsh does best:

- quickly describe simple and/or "repetitive" geometries with the built-in scripting language, thanks to user-defined macros, loops, conditionals and includes (see Section 5.1.7 [User-defined macros], page 98, Section 5.1.8 [Loops and conditionals], page 98, and Section 5.1.9 [Other general commands], page 99). For more advanced geometries, using the Gmsh API (see Chapter 6 [Gmsh application programming interface], page 125) in the language of your choice (C++, C, Python, Julia or Fortran) brings even greater flexibility, the only downside being that you need to either compile your code (for C++, C and Fortran) or to configure and install an interpreter (Python or Julia) in addition to Gmsh. A binary Software Development Kit (SDK) is distributed on the Gmsh web site to make the process easier (see Section 1.7 [Installing and running Gmsh on your computer], page 14);
- parametrize these geometries. Gmsh's scripting language or the Gmsh API enable all commands and command arguments to depend on previous calculations. Using the OpenCASCADE geometry kernel, Gmsh gives access to all the usual constructive solid geometry operations (see e.g. Section 2.16 [t16], page 49);
- import geometries from other CAD software in standard exchange formats. Gmsh uses OpenCASCADE to import such files, including label and color information from STEP and IGES files (see e.g. Section 2.20 [t20], page 55);
- generate unstructured 1D, 2D and 3D simplicial (i.e., using line segments, triangles and tetrahedra) finite element meshes (see Section 1.2 [Mesh module], page 8), with fine control over the element size (see Section 1.2.2 [Specifying mesh element sizes], page 10);
- create simple extruded geometries and meshes, and allow to automatically couple such structured meshes with unstructured ones (using a layer of pyramids in 3D);
- generate high-order (curved) meshes that conform to the CAD model geometry. High-order mesh optimization tools allow to guarantee the validity of such curved meshes;
- interact with external solvers by defining ONELAB parameters, shared between Gmsh and the solvers and easily modifiable in the GUI (see Section 1.3 [Solver module], page 12);
- visualize and export computational results in a great variety of ways. Gmsh can display scalar, vector and tensor datasets, perform various operations on the resulting post-processing views (see Section 1.4 [Post-processing module], page 12), can export plots in many different formats, and can generate complex animations (see e.g. Section 2.8 [t8], page 33);
- run on low end machines and/or machines with no graphical interface. Gmsh can be compiled with or without the GUI (see Appendix A [Compiling the source code], page 373), and all versions can be used either interactively or directly from the command line;
- configure your preferred options. Gmsh has a large number of configuration options that can be set interactively using the GUI, scattered inside script files, changed through the

API, set in per-user configuration files and specified on the command line (see Chapter 7 [Gmsh options], page 223);

- and do all the above on various platforms (Windows, macOS and Linux), for free (see [Copying conditions], page 3)!

1.6 . . . and what Gmsh is not so good at

Here are some known weaknesses of Gmsh:

- Gmsh is not a multi-bloc mesh generator: all meshes produced by Gmsh are conforming in the sense of finite element meshes;
- Gmsh's graphical user interface is only exposing a limited number of the available features, and many aspects of the interface could be enhanced (especially manipulators).
- Your complaints about Gmsh here :-)

If you have the skills and some free time, feel free to join the project: we gladly accept any code contributions (see Appendix B [Information for developers], page 377) to remedy the aforementioned (and all other) shortcomings!

1.7 Installing and running Gmsh on your computer

Gmsh can be used either as a standalone application, or as a library.

As a standalone application, Gmsh can be controlled with the GUI (see Chapter 3 [Gmsh graphical user interface], page 79), through the command line (see Chapter 4 [Gmsh command-line interface], page 85) and through '`.geo`' script files (see Chapter 5 [Gmsh scripting language], page 91). In addition, the ONELAB interface (see Section 1.3 [Solver module], page 12) allows to interact with the Gmsh application through Unix or TCP/IP sockets. Binary versions of the Gmsh app for Windows, Linux and macOS can be downloaded from `https://gmsh.info/#Download`. Several Linux distributions also ship the Gmsh app. See Appendix A [Compiling the source code], page 373 for instructions on how to compile the Gmsh app from source.

As a library, Gmsh can still be used in the same way as the standalone Gmsh app, but in addition it can also be embedded in external codes using the Gmsh API (see Chapter 6 [Gmsh application programming interface], page 125). The API is available in C++, C, Python, Julia and Fortran. A binary Software Development Kit (SDK) for Windows, Linux and macOS, that contains the dynamic Gmsh library and the associated header and module files, can be downloaded from `https://gmsh.info/#Download`. Python users can use

```
pip install --upgrade gmsh
```

which will download the binary SDK and install the files in the appropriate system directories. Several Linux distributions also ship the Gmsh SDK. See Appendix A [Compiling the source code], page 373 for instructions on how to compile the dynamic Gmsh library from source.

2 Gmsh tutorial

The following tutorials introduce new features gradually, starting with the first tutorial `t1` (see Section 2.1 [t1], page 15). The corresponding files are available in the tutorials directory of the Gmsh distribution.

The '`.geo`' files (e.g. '`t1.geo`') are written in Gmsh's built-in scripting language (see Chapter 5 [Gmsh scripting language], page 91). You can open them directly with the Gmsh app: in the GUI (see Chapter 3 [Gmsh graphical user interface], page 79), use the 'File->Open' menu and select e.g. '`t1.geo`'. Or on the command line, run

```
> gmsh t1.geo
```

which will launch the GUI, or run

```
> gmsh t1.geo -2
```

to perform 2D meshing in batch mode (see Chapter 4 [Gmsh command-line interface], page 85).

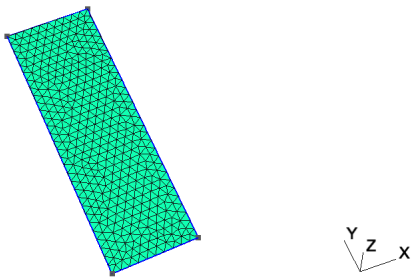
The '`c++`', '`c`', '`python`', '`julia`' and '`fortran`' subdirectories of the tutorials directory contain the C++, C, Python, Julia and Fortran versions of the tutorials, written using the Gmsh API (see Chapter 6 [Gmsh application programming interface], page 125). You will need the Gmsh dynamic library and the associated header files (for C++ and C) or modules (for Python, Julia and Fortran) to run them (see Section 1.7 [Installing and running Gmsh on your computer], page 14). Each subdirectory contains additional information on how to run the tutorials for each supported language.

All the tutorials starting with the letter '`t`' are available both using the scripting language and the API. Extended tutorials, starting with the letter '`x`', introduce features that are only available through the API.

Note that besides these tutorials, the Gmsh distribution contains many other examples written using both the built-in scripting language and the API: see examples and benchmarks.

2.1 `t1`: Geometry basics, elementary entities, physical groups

See t1.geo. Also available in C++ (t1.cpp), C (t1.c), Python (t1.py), Julia (t1.jl) and Fortran (t1.f90).




```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 1
//
//  Geometry basics, elementary entities, physical groups
//
// -------------------------------------------------------------------------

// The simplest construction in Gmsh's scripting language is the
```

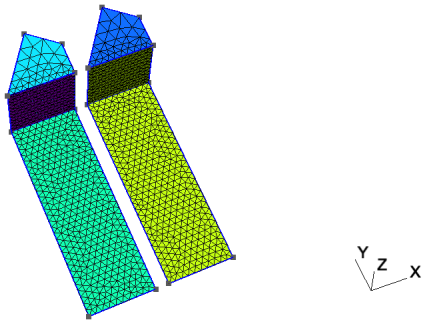
```
// ‘affectation’. The following command defines a new variable ‘lc’:

lc = 1e-2;

// This variable can then be used in the definition of Gmsh’s simplest
// ‘elementary entity’, a ‘Point’. A Point is uniquely identified by a tag (a
// strictly positive integer; here ‘1’) and defined by a list of four numbers:
// three coordinates (X, Y and Z) and the target mesh size (lc) close to the
// point:

Point(1) = {0, 0, 0, lc};

// The distribution of the mesh element sizes will then be obtained by
// interpolation of these mesh sizes throughout the geometry. Another method to
// specify mesh sizes is to use general mesh size Fields (see ‘t10.geo’). A
// particular case is the use of a background mesh (see ‘t7.geo’).

// If no target mesh size of provided, a default uniform coarse size will be
// used for the model, based on the overall model size.

// We can then define some additional points. All points should have different
// tags:

Point(2) = {.1, 0,  0, lc};
Point(3) = {.1, .3, 0, lc};
Point(4) = {0,  .3, 0, lc};

// Curves are Gmsh’s second type of elementary entities, and, amongst curves,
// straight lines are the simplest. A straight line is identified by a tag and
// is defined by a list of two point tags. In the commands below, for example,
// the line 1 starts at point 1 and ends at point 2.
//
// Note that curve tags are separate from point tags - hence we can reuse tag
// ‘1’ for our first curve. And as a general rule, elementary entity tags in
// Gmsh have to be unique per geometrical dimension.

Line(1) = {1, 2};
Line(2) = {3, 2};
Line(3) = {3, 4};
Line(4) = {4, 1};

// The third elementary entity is the surface. In order to define a simple
// rectangular surface from the four curves defined above, a curve loop has
// first to be defined. A curve loop is also identified by a tag (unique amongst
// curve loops) and defined by an ordered list of connected curves, a sign being
// associated with each curve (depending on the orientation of the curve to form
// a loop):

Curve Loop(1) = {4, 1, -2, 3};

// We can then define the surface as a list of curve loops (only one here,
// representing the external contour, since there are no holes--see ‘t4.geo’ for
```

```
// an example of a surface with a hole):

Plane Surface(1) = {1};

// At this level, Gmsh knows everything to display the rectangular surface 1 and
// to mesh it. An optional step is needed if we want to group elementary
// geometrical entities into more meaningful groups, e.g. to define some
// mathematical ("domain", "boundary"), functional ("left wing", "fuselage") or
// material ("steel", "carbon") properties.
//
// Such groups are called "Physical Groups" in Gmsh. By default, if physical
// groups are defined, Gmsh will export in output files only mesh elements that
// belong to at least one physical group. (To force Gmsh to save all elements,
// whether they belong to physical groups or not, set 'Mesh.SaveAll=1;', or
// specify '-save_all' on the command line.) Physical groups are also identified
// by tags, i.e. strictly positive integers, that should be unique per dimension
// (0D, 1D, 2D or 3D). Physical groups can also be given names.
//
// Here we define a physical curve that groups the left, bottom and right curves
// in a single group (with prescribed tag 5); and a physical surface with name
// "My surface" (with an automatic tag) containing the geometrical surface 1:

Physical Curve(5) = {1, 2, 4};
Physical Surface("My surface") = {1};

// Now that the geometry is complete, you can
// - either open this file with Gmsh and select '2D' in the 'Mesh' module to
//   create a mesh; then select 'Save' to save it to disk in the default format
//   (or use 'File->Export' to export in other formats);
// - or run 'gmsh t1.geo -2' to mesh in batch mode on the command line.

// You could also uncomment the following lines in this script:
//
//   Mesh 2;
//   Save "t1.msh";
//
// which would lead Gmsh to mesh and save the mesh every time the file is
// parsed. (To simply parse the file from the command line, you can use 'gmsh
// t1.geo -')

// By default, Gmsh saves meshes in the latest version of the Gmsh mesh file
// format (the 'MSH' format). You can save meshes in other mesh formats by
// specifying a filename with a different extension in the GUI, on the command
// line or in scripts. For example
//
//   Save "t1.unv";
//
// will save the mesh in the UNV format. You can also save the mesh in older
// versions of the MSH format:
//
// - In the GUI: open 'File->Export', enter your 'filename.msh' and then pick
//   the version in the dropdown menu.
```

```
// - On the command line: use the ‘-format’ option (e.g. ‘gmsh file.geo -format
//   msh2 -2’).
// - In a ‘.geo’ script: add ‘Mesh.MshFileVersion = x.y;’ for any version
//   number ‘x.y’.
// - As an alternative method, you can also not specify the format explicitly,
//   and just choose a filename with the ‘.msh2’ or ‘.msh4’ extension.

// Note that starting with Gmsh 3.0, models can be built using other geometry
// kernels than the default built-in kernel. By specifying
//
//   SetFactory("OpenCASCADE");
//
// any subsequent command in the ‘.geo’ file would be handled by the OpenCASCADE
// geometry kernel instead of the built-in kernel. Different geometry kernels
// have different features. With OpenCASCADE, instead of defining the surface by
// successively defining 4 points, 4 curves and 1 curve loop, one can define the
// rectangular surface directly with
//
//   Rectangle(2) = {.2, 0, 0, .1, .3};
//
// The underlying curves and points could be accessed with the ‘Boundary’ or
// ‘CombinedBoundary’ operators.
//
// See e.g. ‘t16.geo’, ‘t18.geo’, ‘t19.geo’ or ‘t20.geo’ for complete examples
// based on OpenCASCADE, and ‘examples/boolean’ for more.
```

2.2 t2: Transformations, extruded geometries, volumes

See t2.geo. Also available in C++ (t2.cpp), C (t2.c), Python (t2.py), Julia (t2.jl) and Fortran (t2.f90).




```
// ------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 2
//
//  Transformations, extruded geometries, volumes
//
// ------------------------------------------------------------------------

// We first include the previous tutorial file, in order to use it as a basis
// for this one. Including a file is equivalent to copy-pasting its contents:
```

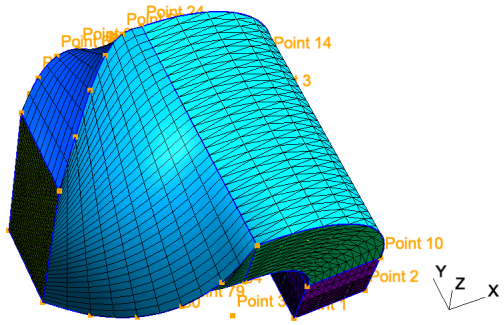
```
Include "t1.geo";

// We can then add new points and curves in the same way as we did in ‘t1.geo’:

Point(5) = {0, .4, 0, lc};
Line(5) = {4, 5};

// Gmsh also provides tools to transform (translate, rotate, etc.)
// elementary entities or copies of elementary entities. For example, point
// 5 can be moved by 0.02 to the left with:

Translate {-0.02, 0, 0} { Point{5}; }

// And it can be further rotated by -Pi/4 around (0, 0.3, 0) (with the rotation
// along the z axis) with:

Rotate {{0,0,1}, {0,0.3,0}, -Pi/4} { Point{5}; }

// Note that there are no units in Gmsh: coordinates are just numbers - it’s up
// to the user to associate a meaning to them.

// Point 3 can be duplicated and translated by 0.05 along the y axis:

Translate {0, 0.05, 0} { Duplicata{ Point{3}; } }

// This command created a new point with an automatically assigned tag. This tag
// can be obtained using the graphical user interface by hovering the mouse over
// the point: in this case, the new point has tag ‘6’.

Line(7) = {3, 6};
Line(8) = {6, 5};
Curve Loop(10) = {5,-8,-7,3};
Plane Surface(11) = {10};

// To automate the workflow, instead of using the graphical user interface to
// obtain the tags of newly created entities, one can use the return value of
// the transformation commands directly. For example, the ‘Translate’ command
// returns a list containing the tags of the translated entities. Let’s
// translate copies of the two surfaces 1 and 11 to the right with the following
// command:

my_new_surfs[] = Translate {0.12, 0, 0} { Duplicata{ Surface{1, 11}; } };

// my_new_surfs[] (note the square brackets, and the ‘;’ at the end of the
// command) denotes a list, which contains the tags of the two new surfaces
// (check ‘Tools->Message console’ to see the message):

Printf("New surfaces ’%g’ and ’%g’", my_new_surfs[0], my_new_surfs[1]);

// In Gmsh lists use square brackets for their definition (mylist[] = {1, 2,
// 3};) as well as to access their elements (myotherlist[] = {mylist[0],
// mylist[2]}; mythirdlist[] = myotherlist[];), with list indexing starting at
```

```
// 0. To get the size of a list, use the hash (pound): len = #mylist[].
//
// Note that parentheses can also be used instead of square brackets, so that we
// could also write 'myfourthlist() = {mylist(0), mylist(1)};'.

// Volumes are the fourth type of elementary entities in Gmsh. In the same way
// one defines curve loops to build surfaces, one has to define surface loops
// (i.e. 'shells') to build volumes. The following volume does not have holes
// and thus consists of a single surface loop:

Point(100) = {0., 0.3, 0.12, lc};  Point(101) = {0.1, 0.3, 0.12, lc};
Point(102) = {0.1, 0.35, 0.12, lc};

xyz[] = Point{5}; // Get coordinates of point 5
Point(103) = {xyz[0], xyz[1], 0.12, lc};

Line(110) = {4, 100};   Line(111) = {3, 101};
Line(112) = {6, 102};   Line(113) = {5, 103};
Line(114) = {103, 100}; Line(115) = {100, 101};
Line(116) = {101, 102}; Line(117) = {102, 103};

Curve Loop(118) = {115, -111, 3, 110};  Plane Surface(119) = {118};
Curve Loop(120) = {111, 116, -112, -7}; Plane Surface(121) = {120};
Curve Loop(122) = {112, 117, -113, -8}; Plane Surface(123) = {122};
Curve Loop(124) = {114, -110, 5, 113};  Plane Surface(125) = {124};
Curve Loop(126) = {115, 116, 117, 114}; Plane Surface(127) = {126};

Surface Loop(128) = {127, 119, 121, 123, 125, 11};
Volume(129) = {128};

// When a volume can be extruded from a surface, it is usually easier to use the
// 'Extrude' command directly instead of creating all the points, curves and
// surfaces by hand. For example, the following command extrudes the surface 11
// along the z axis and automatically creates a new volume (as well as all the
// needed points, curves and surfaces):

Extrude {0, 0, 0.12} { Surface{my_new_surfs[1]}; }

// The following command permits to manually assign a mesh size to some of the
// new points:

MeshSize {103, 105, 109, 102, 28, 24, 6, 5} = lc * 3;

// We finally group volumes 129 and 130 in a single physical group with tag '1'
// and name "The volume":

Physical Volume("The volume", 1) = {129,130};

// Note that, if the transformation tools are handy to create complex
// geometries, it is also sometimes useful to generate the 'flat' geometry, with
// an explicit representation of all the elementary entities.
//
```

```
// With the built-in geometry kernel, this can be achieved with 'File->Export' by
// selecting the 'Gmsh Unrolled GEO' format, or by adding
//
//   Save "file.geo_unrolled";
//
// in the script. It can also be achieved with 'gmsh t2.geo -0' on the command
// line.
//
// With the OpenCASCADE geometry kernel, unrolling the geometry can be achieved
// with 'File->Export' by selecting the 'OpenCASCADE BRep' format, or by adding
//
//   Save "file.brep";
//
// in the script. (OpenCASCADE geometries can also be exported to STEP.)

// It is important to note that Gmsh never translates geometry data into a
// common representation: all the operations on a geometrical entity are
// performed natively with the associated geometry kernel. Consequently, one
// cannot export a geometry constructed with the built-in kernel as an
// OpenCASCADE BRep file; or export an OpenCASCADE model as an Unrolled GEO
// file.
```

2.3 t3: Extruded meshes, ONELAB parameters, options

See t3.geo. Also available in C++ (t3.cpp), Python (t3.py), Julia (t3.jl) and Fortran (t3.f90).



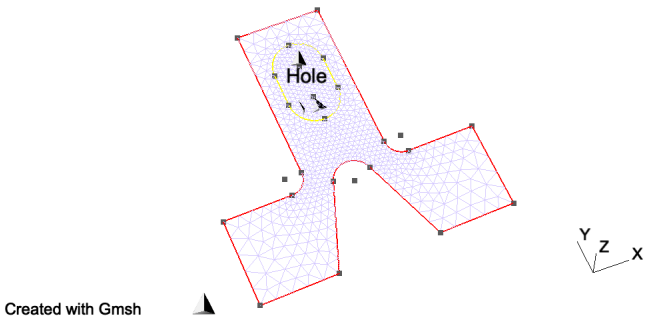

```
// ------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 3
//
//  Extruded meshes, ONELAB parameters, options
//
// ------------------------------------------------------------------------

// Again, we start by including the first tutorial:

Include "t1.geo";

// As in 't2.geo', we plan to perform an extrusion along the z axis.  But here,
// instead of only extruding the geometry, we also want to extrude the 2D
// mesh. This is done with the same 'Extrude' command, but by specifying element
// 'Layers' (2 layers in this case, the first one with 8 subdivisions and the
```

```
// second one with 2 subdivisions, both with a height of h/2):

h = 0.1;

Extrude {0,0,h} {
  Surface{1}; Layers{ {8,2}, {0.5,1} };
}

// The extrusion can also be performed with a rotation instead of a translation,
// and the resulting mesh can be recombined into prisms (we use only one layer
// here, with 7 subdivisions). All rotations are specified by an axis direction
// ({0,1,0}), an axis point ({-0.1,0,0.1}) and a rotation angle (-Pi/2):

Extrude { {0,1,0} , {-0.1,0,0.1} , -Pi/2 } {
  Surface{28}; Layers{7}; Recombine;
}

// Using the built-in geometry kernel, only rotations with angles < Pi are
// supported. To do a full turn, you will thus need to apply at least 3
// rotations. The OpenCASCADE geometry kernel does not have this limitation.

// Note that a translation ({-2*h,0,0}) and a rotation ({1,0,0}, {0,0.15,0.25},
// Pi/2) can also be combined to form a "twist". Here the angle is specified as
// a ONELAB parameter, using the 'DefineConstant' syntax. ONELAB parameters can
// be modified interactively in the GUI, and can be exchanged with other codes
// connected to the same ONELAB database:

DefineConstant[ angle = {90, Min 0, Max 120, Step 1,
                         Name "Parameters/Twisting angle"} ];

// In more details, 'DefineConstant' allows you to assign the value of the
// ONELAB parameter "Parameters/Twisting angle" to the variable 'angle'. If the
// ONELAB parameter does not exist in the database, 'DefineConstant' will create
// it and assign the default value '90'. Moreover, if the variable 'angle' was
// defined before the call to 'DefineConstant', the 'DefineConstant' call would
// simply be skipped. This allows to build generic parametric models, whose
// parameters can be frozen from the outside - the parameters ceasing to be
// "parameters".
//
// An interesting use of this feature is in conjunction with the '-setnumber
// name value' command line switch, which defines a variable 'name' with value
// 'value'. Calling 'gmsh t3.geo -setnumber angle 30' would define 'angle'
// before the 'DefineConstant', making 't3.geo' non-parametric
// ("Parameters/Twisting angle" will not be created in the ONELAB database and
// will not be available for modification in the graphical user interface).

out[] = Extrude { {-2*h,0,0}, {1,0,0} , {0,0.15,0.25} , angle * Pi / 180 } {
  Surface{50}; Layers{10}; Recombine;
};

// In this last extrusion command we retrieved the volume number
// programmatically by using the return value (a list) of the 'Extrude'
```

```
// command. This list contains the "top" of the extruded surface (in ‘out[0]’),
// the newly created volume (in ‘out[1]’) and the tags of the lateral surfaces
// (in ‘out[2]’, ‘out[3]’, ...).

// We can then define a new physical volume (with tag 101) to group all the
// elementary volumes:

Physical Volume(101) = {1, 2, out[1]};

// Let us now change some options... Since all interactive options are
// accessible in Gmsh’s scripting language, we can for example make point tags
// visible or redefine some colors directly in the input file:

Geometry.PointNumbers = 1;
Geometry.Color.Points = Orange;
General.Color.Text = White;
Mesh.Color.Points = {255, 0, 0};

// Note that all colors can be defined literally or numerically, i.e.
// ‘Mesh.Color.Points = Red’ is equivalent to ‘Mesh.Color.Points = {255,0,0}’;
// and also note that, as with user-defined variables, the options can be used
// either as right or left hand sides, so that the following command will set
// the surface color to the same color as the points:

Geometry.Color.Surfaces = Geometry.Color.Points;

// You can use the ‘Help->Current Options and Workspace’ menu to see the current
// values of all options. To save all the options in a file, use
// ‘File->Export->Gmsh Options’. To associate the current options with the
// current file use ‘File->Save Model Options’. To save the current options for
// all future Gmsh sessions use ‘File->Save Options As Default’.
```

2.4 t4: Built-in functions, holes in surfaces, annotations, entity colors

See t4.geo. Also available in C++ (t4.cpp), Python (t4.py), Julia (t4.jl) and Fortran (t4.f90).




```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 4
//
//  Built-in functions, holes in surfaces, annotations, entity colors
```

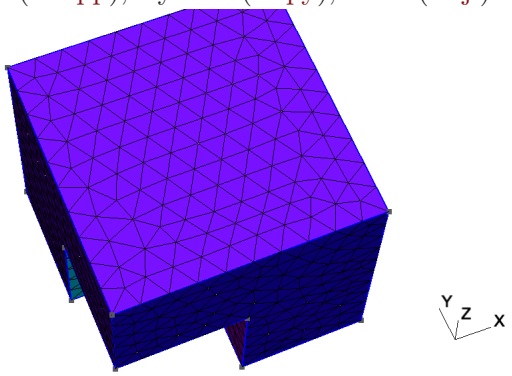
```
//
// ------------------------------------------------------------------------

// As usual, we start by defining some variables:

cm = 1e-02;
e1 = 4.5 * cm; e2 = 6 * cm / 2; e3 =  5 * cm / 2;
h1 = 5 * cm; h2 = 10 * cm; h3 = 5 * cm; h4 = 2 * cm; h5 = 4.5 * cm;
R1 = 1 * cm; R2 = 1.5 * cm; r = 1 * cm;
Lc1 = 0.01;
Lc2 = 0.003;

// We can use all the usual mathematical functions (note the capitalized first
// letters), plus some useful functions like Hypot(a, b) := Sqrt(a^2 + b^2):

ccos = (-h5*R1 + e2 * Hypot(h5, Hypot(e2, R1))) / (h5^2 + e2^2);
ssin = Sqrt(1 - ccos^2);

// Then we define some points and some lines using these variables:

Point(1) = {-e1-e2, 0    , 0, Lc1}; Point(2) = {-e1-e2, h1   , 0, Lc1};
Point(3) = {-e3-r , h1   , 0, Lc2}; Point(4) = {-e3-r , h1+r , 0, Lc2};
Point(5) = {-e3   , h1+r , 0, Lc2}; Point(6) = {-e3   , h1+h2, 0, Lc1};
Point(7) = { e3   , h1+h2, 0, Lc1}; Point(8) = { e3   , h1+r , 0, Lc2};
Point(9) = { e3+r , h1+r , 0, Lc2}; Point(10)= { e3+r , h1   , 0, Lc2};
Point(11)= { e1+e2, h1   , 0, Lc1}; Point(12)= { e1+e2, 0    , 0, Lc1};
Point(13)= { e2   , 0    , 0, Lc1};

Point(14)= { R1 / ssin, h5+R1*ccos, 0, Lc2};
Point(15)= { 0        , h5        , 0, Lc2};
Point(16)= {-R1 / ssin, h5+R1*ccos, 0, Lc2};
Point(17)= {-e2       , 0.0       , 0, Lc1};

Point(18)= {-R2 , h1+h3   , 0, Lc2}; Point(19)= {-R2 , h1+h3+h4, 0, Lc2};
Point(20)= { 0  , h1+h3+h4, 0, Lc2}; Point(21)= { R2 , h1+h3+h4, 0, Lc2};
Point(22)= { R2 , h1+h3   , 0, Lc2}; Point(23)= { 0  , h1+h3   , 0, Lc2};

Point(24)= { 0, h1+h3+h4+R2, 0, Lc2}; Point(25)= { 0, h1+h3-R2,    0, Lc2};

Line(1)  = {1 , 17};
Line(2)  = {17, 16};

// Gmsh provides other curve primitives than straight lines: splines, B-splines,
// circle arcs, ellipse arcs, etc. Here we define a new circle arc, starting at
// point 14 and ending at point 16, with the circle's center being the point 15:

Circle(3) = {14,15,16};

// Note that, in Gmsh, circle arcs should always be smaller than Pi. The
// OpenCASCADE geometry kernel does not have this limitation.

// We can then define additional lines and circles, as well as a new surface:
```

```
Line(4)  = {14, 13}; Line(5)   = {13, 12};   Line(6)    = {12, 11};
Line(7)  = {11, 10}; Circle(8) = {8, 9, 10}; Line(9)    = {8, 7};
Line(10) = {7, 6};   Line(11)  = {6, 5};     Circle(12) = {3, 4, 5};
Line(13) = {3, 2};   Line(14)  = {2, 1};     Line(15)   = {18, 19};
Circle(16) = {21, 20, 24}; Circle(17) = {24, 20, 19};
Circle(18) = {18, 23, 25}; Circle(19) = {25, 23, 22};
Line(20) = {21,22};

Curve Loop(21) = {17, -15, 18, 19, -20, 16};
Plane Surface(22) = {21};

// But we still need to define the exterior surface. Since this surface has a
// hole, its definition now requires two curves loops:

Curve Loop(23) = {11, -12, 13, 14, 1, 2, -3, 4, 5, 6, 7, -8, 9, 10};
Plane Surface(24) = {23, 21};

// As a general rule, if a surface has N holes, it is defined by N+1 curve loops:
// the first loop defines the exterior boundary; the other loops define the
// boundaries of the holes.

// Finally, we can add some comments by embedding a post-processing view
// containing some strings:

View "comments" {
  // Add a text string in window coordinates, 10 pixels from the left and 10
  // pixels from the bottom, using the 'StrCat' function to concatenate strings:
  T2(10, -10, 0){ StrCat("Created on ", Today, " with Gmsh") };

  // Add a text string in model coordinates centered at (X,Y,Z) = (0, 0.11, 0):
  T3(0, 0.11, 0, TextAttributes("Align", "Center", "Font", "Helvetica")){
    "Hole"
  };

  // If a string starts with 'file://', the rest is interpreted as an image
  // file. For 3D annotations, the size in model coordinates can be specified
  // after a '@' symbol in the form 'widthxheight' (if one of 'width' or
  // 'height' is zero, natural scaling is used; if both are zero, original image
  // dimensions in pixels are used):
  T3(0, 0.09, 0, TextAttributes("Align", "Center")){
    "file://t4_image.png@0.01x0"
  };

  // The 3D orientation of the image can be specified by proving the direction
  // of the bottom and left edge of the image in model space:
  T3(-0.01, 0.09, 0, 0){ "file://t4_image.png@0.01x0,0,0,1,0,1,0" };

  // The image can also be drawn in "billboard" mode, i.e. always parallel to
  // the camera, by using the '#' symbol:
  T3(0, 0.12, 0, TextAttributes("Align", "Center")){
    "file://t4_image.png@0.01x0#"
```

```
  };

  // The size of 2D annotations is given directly in pixels:
  T2(350, -7, 0){ "file://t4_image.png@20x0" };
};

// This post-processing view is in the "parsed" format, i.e. it is interpreted
// using the same parser as the '.geo' file. For large post-processing datasets,
// that contain actual field values defined on a mesh, you should use the MSH
// file format instead, which allows to efficiently store continuous or
// discontinuous scalar, vector and tensor fields, or arbitrary polynomial
// order.

// Views and geometrical entities can be made to respond to double-click events,
// here to print some messages to the console:

View[0].DoubleClickedCommand = "Printf('View[0] has been double-clicked!');";
Geometry.DoubleClickedCurveCommand = "Printf('Curve %g has been double-clicked!',
  Geometry.DoubleClickedEntityTag);";

// We can also change the color of some entities:

Color Grey50{ Surface{ 22 }; }
Color Purple{ Surface{ 24 }; }
Color Red{ Curve{ 1:14 }; }
Color Yellow{ Curve{ 15:20 }; }
```

2.5 t5: Mesh sizes, macros, loops, holes in volumes

See t5.geo. Also available in C++ (t5.cpp), Python (t5.py), Julia (t5.jl) and Fortran (t5.f90).




```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 5
//
//  Mesh sizes, macros, loops, holes in volumes
//
// -------------------------------------------------------------------------

// We start by defining some target mesh sizes:

lcar1 = .1;
```

```
lcar2 = .0005;
lcar3 = .055;

// If we wanted to change these mesh sizes globally (without changing the above
// definitions), we could give a global scaling factor for all mesh sizes on the
// command line with the '-clscale' option (or with 'Mesh.MeshSizeFactor' in an
// option file). For example, with:
//
// > gmsh t5.geo -clscale 1
//
// this input file produces a mesh of approximately 3000 nodes and 14,000
// tetrahedra. With
//
// > gmsh t5.geo -clscale 0.2
//
// the mesh counts approximately 231,000 nodes and 1,360,000 tetrahedra. You can
// check mesh statistics in the graphical user interface with the
// 'Tools->Statistics' menu.
//
// See 't10.geo' for more information about mesh sizes.

// We proceed by defining some elementary entities describing a truncated cube:

Point(1) = {0.5,0.5,0.5,lcar2}; Point(2) = {0.5,0.5,0,lcar1};
Point(3) = {0,0.5,0.5,lcar1};   Point(4) = {0,0,0.5,lcar1};
Point(5) = {0.5,0,0.5,lcar1};   Point(6) = {0.5,0,0,lcar1};
Point(7) = {0,0.5,0,lcar1};     Point(8) = {0,1,0,lcar1};
Point(9) = {1,1,0,lcar1};       Point(10) = {0,0,1,lcar1};
Point(11) = {0,1,1,lcar1};      Point(12) = {1,1,1,lcar1};
Point(13) = {1,0,1,lcar1};      Point(14) = {1,0,0,lcar1};

Line(1) = {8,9};    Line(2) = {9,12};  Line(3) = {12,11};
Line(4) = {11,8};   Line(5) = {9,14};  Line(6) = {14,13};
Line(7) = {13,12};  Line(8) = {11,10}; Line(9) = {10,13};
Line(10) = {10,4};  Line(11) = {4,5};  Line(12) = {5,6};
Line(13) = {6,2};   Line(14) = {2,1};  Line(15) = {1,3};
Line(16) = {3,7};   Line(17) = {7,2};  Line(18) = {3,4};
Line(19) = {5,1};   Line(20) = {7,8};  Line(21) = {6,14};

Curve Loop(22) = {-11,-19,-15,-18};   Plane Surface(23) = {22};
Curve Loop(24) = {16,17,14,15};       Plane Surface(25) = {24};
Curve Loop(26) = {-17,20,1,5,-21,13}; Plane Surface(27) = {26};
Curve Loop(28) = {-4,-1,-2,-3};       Plane Surface(29) = {28};
Curve Loop(30) = {-7,2,-5,-6};        Plane Surface(31) = {30};
Curve Loop(32) = {6,-9,10,11,12,21};  Plane Surface(33) = {32};
Curve Loop(34) = {7,3,8,9};           Plane Surface(35) = {34};
Curve Loop(36) = {-10,18,-16,-20,4,-8}; Plane Surface(37) = {36};
Curve Loop(38) = {-14,-13,-12,19};    Plane Surface(39) = {38};

// Instead of using included files, we now use a user-defined macro in order
// to carve some holes in the cube:
```

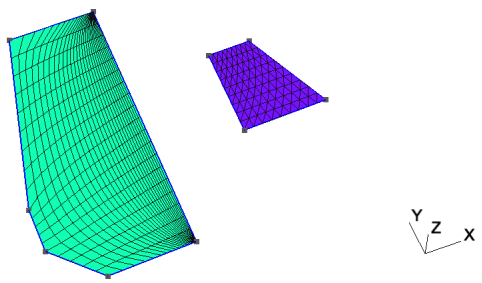
```
Macro CheeseHole

  // In the following commands we use the reserved variable name 'newp', which
  // automatically selects a new point tag. Analogously to 'newp', the special
  // variables 'newc', 'newcl', 'news', 'newsl' and 'newv' select new curve,
  // curve loop, surface, surface loop and volume tags.
  //
  // If 'Geometry.OldNewReg' is set to 0, the new tags are chosen as the highest
  // current tag for each category (points, curves, curve loops, ...), plus
  // one. By default, for backward compatibility, 'Geometry.OldNewReg' is set
  // to 1, and only two categories are used: one for points and one for the
  // rest.

  p1 = newp; Point(p1) = {x,  y,  z,  lcar3};
  p2 = newp; Point(p2) = {x+r,y,  z,  lcar3};
  p3 = newp; Point(p3) = {x,  y+r,z,  lcar3};
  p4 = newp; Point(p4) = {x,  y,  z+r,lcar3};
  p5 = newp; Point(p5) = {x-r,y,  z,  lcar3};
  p6 = newp; Point(p6) = {x,  y-r,z,  lcar3};
  p7 = newp; Point(p7) = {x,  y,  z-r,lcar3};

  c1 = newc; Circle(c1) = {p2,p1,p7}; c2 = newc; Circle(c2) = {p7,p1,p5};
  c3 = newc; Circle(c3) = {p5,p1,p4}; c4 = newc; Circle(c4) = {p4,p1,p2};
  c5 = newc; Circle(c5) = {p2,p1,p3}; c6 = newc; Circle(c6) = {p3,p1,p5};
  c7 = newc; Circle(c7) = {p5,p1,p6}; c8 = newc; Circle(c8) = {p6,p1,p2};
  c9 = newc; Circle(c9) = {p7,p1,p3}; c10 = newc; Circle(c10) = {p3,p1,p4};
  c11 = newc; Circle(c11) = {p4,p1,p6}; c12 = newc; Circle(c12) = {p6,p1,p7};

  // We need non-plane surfaces to define the spherical holes. Here we use
  // 'Surface', which can be used for surfaces with 3 or 4 curves on their
  // boundary. With the he built-in kernel, if the curves are circle arcs, ruled
  // surfaces are created; otherwise transfinite interpolation is used.
  //
  // With the OpenCASCADE kernel, 'Surface' uses a much more general generic
  // surface filling algorithm, creating a BSpline surface passing through an
  // arbitrary number of boundary curves; and 'ThruSections' allows to create
  // ruled surfaces (see 't19.geo').

  l1 = newcl; Curve Loop(l1) = {c5,c10,c4};
  l2 = newcl; Curve Loop(l2) = {c9,-c5,c1};
  l3 = newcl; Curve Loop(l3) = {c12,-c8,-c1};
  l4 = newcl; Curve Loop(l4) = {c8,-c4,c11};
  l5 = newcl; Curve Loop(l5) = {-c10,c6,c3};
  l6 = newcl; Curve Loop(l6) = {-c11,-c3,c7};
  l7 = newcl; Curve Loop(l7) = {-c2,-c7,-c12};
  l8 = newcl; Curve Loop(l8) = {-c6,-c9,c2};

  s1 = news; Surface(s1) = {l1};
  s2 = news; Surface(s2) = {l2};
  s3 = news; Surface(s3) = {l3};
  s4 = news; Surface(s4) = {l4};
  s5 = news; Surface(s5) = {l5};
```

```
  s6 = news; Surface(s6) = {l6};
  s7 = news; Surface(s7) = {l7};
  s8 = news; Surface(s8) = {l8};

  // We then store the surface loops tags in a list for later reference (we will
  // need these to define the final volume):

  theloops[t] = newsl;
  Surface Loop(theloops[t]) = {s1, s2, s3, s4, s5, s6, s7, s8};

  thehole = newv;
  Volume(thehole) = theloops[t];

Return

// We can use a 'For' loop to generate five holes in the cube:

x = 0; y = 0.75; z = 0; r = 0.09;

For t In {1:5}

  x += 0.166;
  z += 0.166;

  // We call the 'CheeseHole' macro:

  Call CheeseHole;

  // We define a physical volume for each hole:

  Physical Volume (t) = thehole;

  // We also print some variables on the terminal (note that, since all
  // variables in '.geo' files are treated internally as floating point numbers,
  // the format string should only contain valid floating point format
  // specifiers like '%g', '%f', '%e', etc.):

  Printf("Hole %g (center = {%g,%g,%g}, radius = %g) has number %g!",
         t, x, y, z, r, thehole);

EndFor

// We can then define the surface loop for the exterior surface of the cube:

theloops[0] = newreg;
Surface Loop(theloops[0]) = {23:39:2};

// The volume of the cube, without the 5 holes, is now defined by 6 surface
// loops: the first surface loop defines the exterior surface; the surface loops
// other than the first one define holes.  (Again, to reference an array of
// variables, its identifier is followed by square brackets):
```

```
Volume(186) = {theloops[]};

// Note that using solid modelling with the OpenCASCADE geometry kernel, the
// same geometry could be built quite differently: see 't16.geo'.

// We finally define a physical volume for the elements discretizing the cube,
// without the holes (for which physical groups were already created in the
// 'For' loop):

Physical Volume (10) = 186;

// We could make only part of the model visible to only mesh this subset:
//
// Hide {:}
// Recursive Show { Volume{129}; }
// Mesh.MeshOnlyVisible=1;

// Meshing algorithms can changed globally using options:

Mesh.Algorithm = 6; // Frontal-Delaunay for 2D meshes

// They can also be set for individual surfaces, e.g.

MeshAlgorithm Surface {31, 35} = 1; // MeshAdapt on surfaces 31 and 35

// To generate a curvilinear mesh and optimize it to produce provably valid
// curved elements (see A. Johnen, J.-F. Remacle and C. Geuzaine. Geometric
// validity of curvilinear finite elements. Journal of Computational Physics
// 233, pp. 359-372, 2013; and T. Toulorge, C. Geuzaine, J.-F. Remacle,
// J. Lambrechts. Robust untangling of curvilinear meshes. Journal of
// Computational Physics 254, pp. 8-26, 2013), you can uncomment the following
// lines:
//
// Mesh.ElementOrder = 2;
// Mesh.HighOrderOptimize = 2;
```

2.6 t6: Transfinite meshes, deleting entities

See t6.geo. Also available in C++ (t6.cpp), C (t6.c), Python (t6.py), Julia (t6.jl) and Fortran (t6.f90).



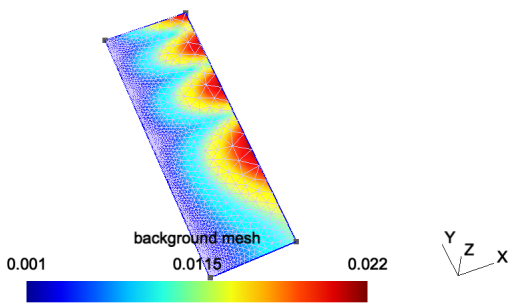

```
// ------------------------------------------------------------------------
```

```
//
//  Gmsh GEO tutorial 6
//
//  Transfinite meshes, deleting entities
//
// ------------------------------------------------------------------------

// Let's use the geometry from the first tutorial as a basis for this one:
lc = 1e-2;
Point(1) = {0, 0, 0, lc};
Point(2) = {.1, 0,  0, lc};
Point(3) = {.1, .3, 0, lc};
Point(4) = {0,  .3, 0, lc};
Line(1) = {1, 2};
Line(2) = {3, 2};
Line(3) = {3, 4};
Line(4) = {4, 1};
Curve Loop(1) = {4, 1, -2, 3};
Plane Surface(1) = {1};

// Delete the surface and the left line, and replace the line with 3 new ones:
Delete{ Surface{1}; Curve{4}; }

p1 = newp; Point(p1) = {-0.05, 0.05, 0, lc};
p2 = newp; Point(p2) = {-0.05, 0.1, 0, lc};

l1 = newc; Line(l1) = {1, p1};
l2 = newc; Line(l2) = {p1, p2};
l3 = newc; Line(l3) = {p2, 4};

// Create a surface:
Curve Loop(2) = {2, -1, l1, l2, l3, -3};
Plane Surface(1) = {-2};

// The 'Transfinite Curve' meshing constraints explicitly specifies the location
// of the nodes on the curve. For example, the following command forces 20
// uniformly placed nodes on curve 2 (including the nodes on the two end
// points):
Transfinite Curve{2} = 20;

// Let's put 20 points total on combination of curves 'l1', 'l2' and 'l3'
// (beware that the points 'p1' and 'p2' are shared by the curves, so we do not
// create 6 + 6 + 10 = 22 nodes, but 20!)
Transfinite Curve{l1} = 6;
Transfinite Curve{l2} = 6;
Transfinite Curve{l3} = 10;

// Finally, we put 30 nodes following a geometric progression on curve 1
// (reversed) and on curve 3:
Transfinite Curve{-1, 3} = 30 Using Progression 1.2;

// The 'Transfinite Surface' meshing constraint uses a transfinite interpolation
```

```
// algorithm in the parametric plane of the surface to connect the nodes on the
// boundary using a structured grid. If the surface has more than 4 corner
// points, the corners of the transfinite interpolation have to be specified by
// hand:
Transfinite Surface{1} = {1, 2, 3, 4};

// To create quadrangles instead of triangles, one can use the 'Recombine'
// command:
Recombine Surface{1};

// When the surface has only 3 or 4 points on its boundary the list of corners
// can be omitted in the 'Transfinite Surface' constraint:
Point(7) = {0.2, 0.2, 0, 1.0};
Point(8) = {0.2, 0.1, 0, 1.0};
Point(9) = {-0, 0.3, 0, 1.0};
Point(10) = {0.25, 0.2, 0, 1.0};
Point(11) = {0.3, 0.1, 0, 1.0};
Line(10) = {8, 11};
Line(11) = {11, 10};
Line(12) = {10, 7};
Line(13) = {7, 8};
Curve Loop(14) = {13, 10, 11, 12};
Plane Surface(15) = {14};
Transfinite Curve {10:13} = 10;
Transfinite Surface{15};

// The way triangles are generated can be controlled by appending "Left",
// "Right" or "Alternate" after the 'Transfinite Surface' command. Try e.g.
//
// Transfinite Surface{15} Alternate;

// Finally we apply an elliptic smoother to the grid to have a more regular
// mesh:
Mesh.Smoothing = 100;
```

2.7 t7: Background meshes

See t7.geo. Also available in C++ (t7.cpp), Python (t7.py), Julia (t7.jl) and Fortran (t7.f90).

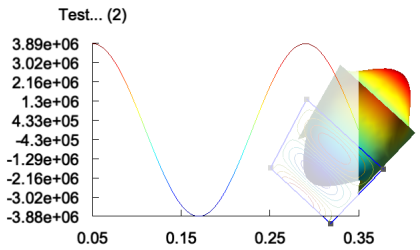



```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 7
```

```
//
//  Background meshes
//
// ------------------------------------------------------------------------

// Mesh sizes can be specified very accurately by providing a background mesh,
// i.e., a post-processing view that contains the target mesh sizes.

// Merge a list-based post-processing view containing the target mesh sizes:
Merge "t7_bgmesh.pos";

// If the post-processing view was model-based instead of list-based (i.e. if it
// was based on an actual mesh), we would need to create a new model to contain
// the geometry so that meshing it does not destroy the background mesh. It's
// not necessary here since the view is list-based, but it does no harm:
NewModel;

// Merge the first tutorial geometry:
Merge "t1.geo";

// Apply the view as the current background mesh size field:
Background Mesh View[0];

// In order to compute the mesh sizes from the background mesh only, and
// disregard any other size constraints, one can set:
Mesh.MeshSizeExtendFromBoundary = 0;
Mesh.MeshSizeFromPoints = 0;
Mesh.MeshSizeFromCurvature = 0;

// See 't10.geo' for additional information: background meshes are actually a
// particular case of general "mesh size fields".
```

2.8 t8: Post-processing, image export and animations

See t8.geo. Also available in C++ (t8.cpp), Python (t8.py), Julia (t8.jl) and Fortran (t8.f90).




```
// ------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 8
//
//  Post-processing, image export and animations
//
```

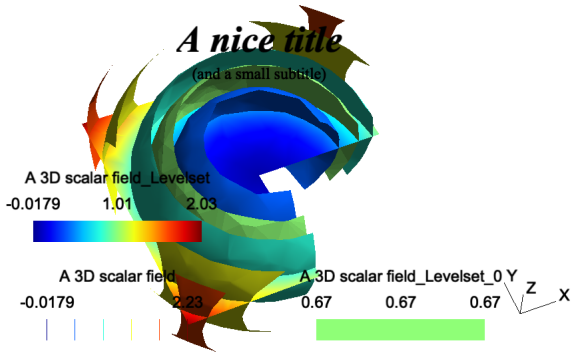
```
// ------------------------------------------------------------------------

// In addition to creating geometries and meshes, GEO scripts can also be used
// to manipulate post-processing datasets (called "views" in Gmsh).

// We first include ‘t1.geo’ as well as some post-processing views:

Include "t1.geo";
Include "view1.pos";
Include "view1.pos";
Include "view4.pos";

// Gmsh can read post-processing views in various formats. Here the ‘view1.pos’
// and ‘view4.pos’ files are in the Gmsh "parsed" format, which is interpreted
// directly by the GEO script parser. The parsed format should only be used for
// relatively small datasets of course: for larger datasets using e.g. MSH files
// is much more efficient.

// We then set some general options:

General.Trackball = 0;
General.RotationX = 0; General.RotationY = 0; General.RotationZ = 0;
General.Color.Background = White; General.Color.Foreground = Black;
General.Color.Text = Black;
General.Orthographic = 0;
General.Axes = 0; General.SmallAxes = 0;

// We also set some options for each post-processing view:

v0 = PostProcessing.NbViews-4;
v1 = v0+1; v2 = v0+2; v3 = v0+3;

View[v0].IntervalsType = 2;
View[v0].OffsetZ = 0.05;
View[v0].RaiseZ = 0;
View[v0].Light = 1;
View[v0].ShowScale = 0;
View[v0].SmoothNormals = 1;

View[v1].IntervalsType = 1;
View[v1].ColorTable = { Green, Blue };
View[v1].NbIso = 10;
View[v1].ShowScale = 0;

View[v2].Name = "Test...";
View[v2].Axes = 1;
View[v2].Color.Axes = Black;
View[v2].IntervalsType = 2;
View[v2].Type = 2;
View[v2].IntervalsType = 2;
View[v2].AutoPosition = 0;
View[v2].PositionX = 85;
```

```
View[v2].PositionY = 50;
View[v2].Width = 200;
View[v2].Height = 130;

View[v3].Visible = 0;

// You can save an MPEG movie directly by selecting 'File->Export' in the
// GUI. Several predefined animations are setup, for looping on all the time
// steps in views, or for looping between views.

// But a script can be used to build much more complex animations, by changing
// options at run-time and re-rendering the graphics. Each frame can then be
// saved to disk as an image, and multiple frames can be encoded to form a
// movie. Below is an example of such a custom animation.

t = 0; // Initial step

// Loop on num from 1 to 3
For num In {1:3}

  View[v0].TimeStep = t; // Set time step
  View[v1].TimeStep = t;
  View[v2].TimeStep = t;
  View[v3].TimeStep = t;

  t = (View[v0].TimeStep < View[v0].NbTimeStep-1) ? t+1 : 0; // Increment

  View[v0].RaiseZ += 0.01/View[v0].Max * t; // Raise view v0

  If (num == 3)
    // Resize the graphics when num == 3, to create 640x480 frames
    General.GraphicsWidth = General.MenuWidth + 640;
    General.GraphicsHeight = 480;
  EndIf

  frames = 50;

  // Loop on num2 from 1 to frames
  For num2 In {1:frames}

    // Incrementally rotate the scene
    General.RotationX += 10;
    General.RotationY = General.RotationX / 3;
    General.RotationZ += 0.1;

    // Sleep for 0.01 second
    Sleep 0.01;

    // Draw the scene (one could use 'DrawForceChanged' instead to force the
    // reconstruction of the vertex arrays, e.g. if changing element clipping)
    Draw;
```

```
    If (num == 3)
      // Uncomment the following lines to save each frame to an image file (the
      // 'Print' command saves the graphical window; the 'Sprintf' function
      // permits to create the file names on the fly):

      // Print Sprintf("t8-%g.gif", num2);
      // Print Sprintf("t8-%g.ppm", num2);
      // Print Sprintf("t8-%g.jpg", num2);
    EndIf

  EndFor

  If(num == 3)
    // Here we could make a system call to generate a movie. For example, with
    // ffmpeg:

    // System "ffmpeg -i t8-%d.jpg t8.mpg"
  EndIf

EndFor
```

2.9 t9: Plugins

See t9.geo. Also available in C++ (t9.cpp), Python (t9.py), Julia (t9.jl) and Fortran (t9.f90).

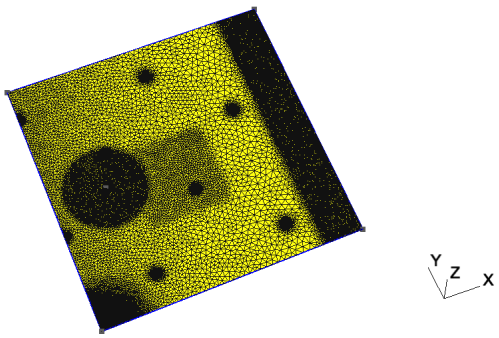



```
// ------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 9
//
//  Plugins
//
// ------------------------------------------------------------------------

// Plugins can be added to Gmsh in order to extend its capabilities. For
// example, post-processing plugins can modify views, or create new views based
// on previously loaded views. Several default plugins are statically linked
// with Gmsh, e.g. Isosurface, CutPlane, CutSphere, Skin, Transform or Smooth.
//
// Plugins can be controlled in the same way as other options: either from the
// graphical interface (right click on the view button, then 'Plugins'), or from
// the command file.
```

```
// Let us for example include a three-dimensional scalar view:

Include "view3.pos" ;

// We then set some options for the ‘Isosurface’ plugin (which extracts an
// isosurface from a 3D scalar view), and run it:

Plugin(Isosurface).Value = 0.67 ; // Iso-value level
Plugin(Isosurface).View = 0 ; // Source view is View[0]
Plugin(Isosurface).Run ; // Run the plugin!

// We also set some options for the ‘CutPlane’ plugin (which computes a section
// of a 3D view using the plane A*x+B*y+C*z+D=0), and then run it:

Plugin(CutPlane).A = 0 ;
Plugin(CutPlane).B = 0.2 ;
Plugin(CutPlane).C = 1 ;
Plugin(CutPlane).D = 0 ;
Plugin(CutPlane).View = 0 ;
Plugin(CutPlane).Run ;

// Add a title (By convention, for window coordinates a value greater than 99999
// represents the center. We could also use ‘General.GraphicsWidth / 2’, but
// that would only center the string for the current window size.):

Plugin(Annotate).Text = "A nice title" ;
Plugin(Annotate).X = 1.e5;
Plugin(Annotate).Y = 50 ;
Plugin(Annotate).Font = "Times-BoldItalic" ;
Plugin(Annotate).FontSize = 28 ;
Plugin(Annotate).Align = "Center" ;
Plugin(Annotate).View = 0 ;
Plugin(Annotate).Run ;

Plugin(Annotate).Text = "(and a small subtitle)" ;
Plugin(Annotate).Y = 70 ;
Plugin(Annotate).Font = "Times-Roman" ;
Plugin(Annotate).FontSize = 12 ;
Plugin(Annotate).Run ;

// We finish by setting some options:

View[0].Light = 1;
View[0].IntervalsType = 1;
View[0].NbIso = 6;
View[0].SmoothNormals = 1;
View[1].IntervalsType = 2;
View[2].IntervalsType = 2;
```

2.10 t10: Mesh size fields

See t10.geo. Also available in C++ (t10.cpp), Python (t10.py), Julia (t10.jl) and Fortran (t10.f90).



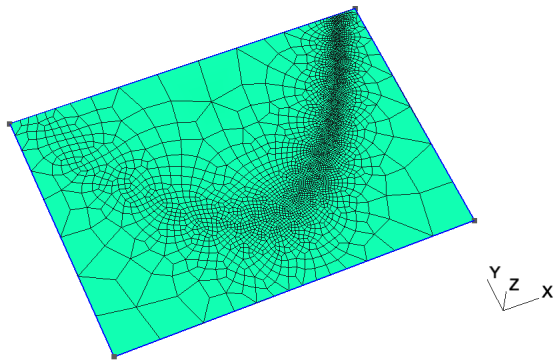

```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 10
//
//  Mesh size fields
//
// -------------------------------------------------------------------------

// In addition to specifying target mesh sizes at the points of the geometry
// (see ‘t1.geo’) or using a background mesh (see ‘t7.geo’), you can use general
// mesh size "Fields".

// Let’s create a simple rectangular geometry
lc = .15;
Point(1) = {0.0,0.0,0,lc}; Point(2) = {1,0.0,0,lc};
Point(3) = {1,1,0,lc};     Point(4) = {0,1,0,lc};
Point(5) = {0.2,.5,0,lc};

Line(1) = {1,2}; Line(2) = {2,3}; Line(3) = {3,4}; Line(4) = {4,1};

Curve Loop(5) = {1,2,3,4}; Plane Surface(6) = {5};

// Say we would like to obtain mesh elements with size lc/30 near curve 2 and
// point 5, and size lc elsewhere. To achieve this, we can use two fields:
// "Distance", and "Threshold". We first define a Distance field (‘Field[1]’) on
// points 5 and on curve 2. This field returns the distance to point 5 and to
// (100 equidistant points on) curve 2.
Field[1] = Distance;
Field[1].PointsList = {5};
Field[1].CurvesList = {2};
Field[1].Sampling = 100;


// We then define a ‘Threshold’ field, which uses the return value of the
// ‘Distance’ field 1 in order to define a simple change in element size
// depending on the computed distances
//
```

```
// SizeMax -                     /------------------
//                              /
//                             /
//                            /
// SizeMin -o----------------/
//          |                |    |
//        Point         DistMin  DistMax
Field[2] = Threshold;
Field[2].InField = 1;
Field[2].SizeMin = lc / 30;
Field[2].SizeMax = lc;
Field[2].DistMin = 0.15;
Field[2].DistMax = 0.5;

// Say we want to modulate the mesh element sizes using a mathematical function
// of the spatial coordinates. We can do this with the MathEval field:
Field[3] = MathEval;
Field[3].F = "cos(4*3.14*x) * sin(4*3.14*y) / 10 + 0.101";

// We could also combine MathEval with values coming from other fields. For
// example, let's define a 'Distance' field around point 1
Field[4] = Distance;
Field[4].PointsList = {1};

// We can then create a 'MathEval' field with a function that depends on the
// return value of the 'Distance' field 4, i.e., depending on the distance to
// point 1 (here using a cubic law, with minimum element size = lc / 100)
Field[5] = MathEval;
Field[5].F = Sprintf("F4^3 + %g", lc / 100);

// We could also use a 'Box' field to impose a step change in element sizes
// inside a box
Field[6] = Box;
Field[6].VIn = lc / 15;
Field[6].VOut = lc;
Field[6].XMin = 0.3;
Field[6].XMax = 0.6;
Field[6].YMin = 0.3;
Field[6].YMax = 0.6;
Field[6].Thickness = 0.3;

// Many other types of fields are available: see the reference manual for a
// complete list. You can also create fields directly in the graphical user
// interface by selecting 'Define->Size fields' in the 'Mesh' module.

// Let's use the minimum of all the fields as the background mesh size field
Field[7] = Min;
Field[7].FieldsList = {2, 3, 5, 6};
Background Field = 7;

// To determine the size of mesh elements, Gmsh locally computes the minimum of
//
```

```
// 1) the size of the model bounding box;
// 2) if 'Mesh.MeshSizeFromPoints' is set, the mesh size specified at
//    geometrical points;
// 3) if 'Mesh.MeshSizeFromCurvature' is positive, the mesh size based on
//    curvature (the value specifying the number of elements per 2 * pi rad);
// 4) the background mesh size field;
// 5) any per-entity mesh size constraint.
//
// This value is then constrained in the interval ['Mesh.MeshSizeMin',
// 'Mesh.MeshSizeMax'] and multiplied by 'Mesh.MeshSizeFactor'. In addition,
// boundary mesh sizes are interpolated inside surfaces and/or volumes depending
// on the value of 'Mesh.MeshSizeExtendFromBoundary' (which is set by default).
//
// When the element size is fully specified by a mesh size field (as it is in
// this example), it is thus often desirable to set

Mesh.MeshSizeExtendFromBoundary = 0;
Mesh.MeshSizeFromPoints = 0;
Mesh.MeshSizeFromCurvature = 0;

// This will prevent over-refinement due to small mesh sizes on the boundary.

// Finally, while the default "Frontal-Delaunay" 2D meshing algorithm
// (Mesh.Algorithm = 6) usually leads to the highest quality meshes, the
// "Delaunay" algorithm (Mesh.Algorithm = 5) will handle complex mesh size
// fields better - in particular size fields with large element size gradients:

Mesh.Algorithm = 5;
```

2.11 t11: Unstructured quadrangular meshes

See t11.geo. Also available in C++ (t11.cpp), Python (t11.py), Julia (t11.jl) and Fortran (t11.f90).



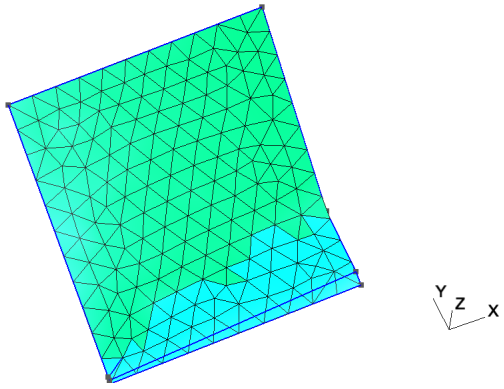

```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 11
//
//  Unstructured quadrangular meshes
//
// -------------------------------------------------------------------------
```

```
// We have seen in tutorials ‘t3.geo’ and ‘t6.geo’ that extruded and transfinite
// meshes can be "recombined" into quads, prisms or hexahedra by using the
// "Recombine" keyword. Unstructured meshes can be recombined in the same
// way. Let’s define a simple geometry with an analytical mesh size field:

Point(1) = {-1.25, -.5, 0}; Point(2) = {1.25, -.5, 0};
Point(3) = {1.25, 1.25, 0};  Point(4) = {-1.25, 1.25, 0};

Line(1) = {1, 2}; Line(2) = {2, 3};
Line(3) = {3, 4}; Line(4) = {4, 1};

Curve Loop(4) = {1, 2, 3, 4}; Plane Surface(100) = {4};

Field[1] = MathEval;
Field[1].F = "0.01*(1.0+30.*(y-x*x)*(y-x*x) + (1-x)*(1-x))";
Background Field = 1;

// To generate quadrangles instead of triangles, we can simply add

Recombine Surface{100};

// If we’d had several surfaces, we could have used ‘Recombine Surface {:};’.
// Yet another way would be to specify the global option "Mesh.RecombineAll =
// 1;".

// The default recombination algorithm is called "Blossom": it uses a minimum
// cost perfect matching algorithm to generate fully quadrilateral meshes from
// triangulations. More details about the algorithm can be found in the
// following paper: J.-F. Remacle, J. Lambrechts, B. Seny, E. Marchandise,
// A. Johnen and C. Geuzaine, "Blossom-Quad: a non-uniform quadrilateral mesh
// generator using a minimum cost perfect matching algorithm", International
// Journal for Numerical Methods in Engineering 89, pp. 1102-1119, 2012.

// For even better 2D (planar) quadrilateral meshes, you can try the
// experimental "Frontal-Delaunay for quads" meshing algorithm, which is a
// triangulation algorithm that enables to create right triangles almost
// everywhere: J.-F. Remacle, F. Henrotte, T. Carrier-Baudouin, E. Bechet,
// E. Marchandise, C. Geuzaine and T. Mouton. A frontal Delaunay quad mesh
// generator using the L^inf norm. International Journal for Numerical Methods
// in Engineering, 94, pp. 494-512, 2013. Uncomment the following line to try
// the Frontal-Delaunay algorithms for quads:
//
// Mesh.Algorithm = 8;

// The default recombination algorithm might leave some triangles in the mesh,
// if recombining all the triangles leads to badly shaped quads. In such cases,
// to generate full-quad meshes, you can either subdivide the resulting hybrid
// mesh (with Mesh.SubdivisionAlgorithm = 1), or use the full-quad recombination
// algorithm, which will automatically perform a coarser mesh followed by
// recombination, smoothing and subdivision. Uncomment the following line to try
// the full-quad algorithm:
//
```

```
// Mesh.RecombinationAlgorithm = 2; // or 3

// Note that you could also apply the recombination algorithm and/or the
// subdivision step explicitly after meshing, as follows:
//
// Mesh 2;
// RecombineMesh;
// Mesh.SubdivisionAlgorithm = 1;
// RefineMesh;
```

2.12 t12: Cross-patch meshing with compounds

See t12.geo/ Also available in C++ (t12.cpp), Python (t12.py), Julia (t12.jl) and Fortran (t12.f90).

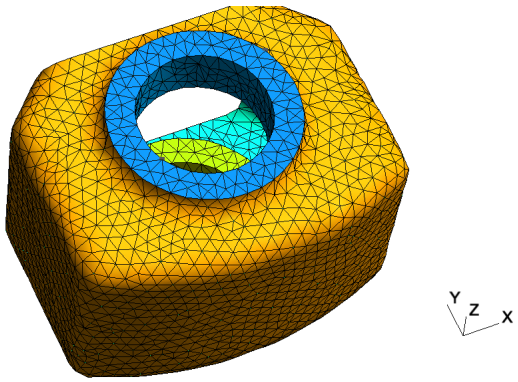



```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 12
//
//  Cross-patch meshing with compounds
//
// -------------------------------------------------------------------------

// "Compound" meshing constraints allow to generate meshes across surface
// boundaries, which can be useful e.g. for imported CAD models (e.g. STEP) with
// undesired small features.

// When a 'Compound Curve' or 'Compound Surface' meshing constraint is given,
// at mesh generation time Gmsh
//  1. meshes the underlying elementary geometrical entities, individually
//  2. creates a discrete entity that combines all the individual meshes
//  3. computes a discrete parametrization (i.e. a piece-wise linear mapping)
//     on this discrete entity
//  4. meshes the discrete entity using this discrete parametrization instead
//     of the underlying geometrical description of the underlying elementary
//     entities making up the compound
//  5. optionally, reclassifies the mesh elements and nodes on the original
//     entities

// Step 3. above can only be performed if the mesh resulting from the
// combination of the individual meshes can be reparametrized, i.e. if the shape
// is "simple enough". If the shape is not amenable to reparametrization, you
```

```
// should create a full mesh of the geometry and first re-classify it to
// generate patches amenable to reparametrization (see 't13.geo').

// The mesh of the individual entities performed in Step 1. should usually be
// finer than the desired final mesh; this can be controlled with the
// 'Mesh.CompoundMeshSizeFactor' option.

// The optional reclassification on the underlying elementary entities in Step
// 5. is governed by the 'Mesh.CompoundClassify' option.

lc = 0.1;

Point(1) = {0, 0, 0, lc};       Point(2) = {1, 0, 0, lc};
Point(3) = {1, 1, 0.5, lc};     Point(4) = {0, 1, 0.4, lc};
Point(5) = {0.3, 0.2, 0, lc};   Point(6) = {0, 0.01, 0.01, lc};
Point(7) = {0, 0.02, 0.02, lc}; Point(8) = {1, 0.05, 0.02, lc};
Point(9) = {1, 0.32, 0.02, lc};

Line(1) = {1, 2}; Line(2) = {2, 8}; Line(3) = {8, 9};
Line(4) = {9, 3}; Line(5) = {3, 4}; Line(6) = {4, 7};
Line(7) = {7, 6}; Line(8) = {6, 1}; Spline(9) = {7, 5, 9};
Line(10) = {6, 8};

Curve Loop(11) = {5, 6, 9, 4};     Surface(1) = {11};
Curve Loop(13) = {-9, 3, 10, 7}; Surface(5) = {13};
Curve Loop(15) = {-10, 2, 1, 8}; Surface(10) = {15};

// Treat curves 2, 3 and 4 as a single curve when meshing (i.e. mesh across
// points 6 and 7)
Compound Curve{2, 3, 4};

// Idem with curves 6, 7 and 8
Compound Curve{6, 7, 8};

// Treat surfaces 1, 5 and 10 as a single surface when meshing (i.e. mesh across
// curves 9 and 10)
Compound Surface{1, 5, 10};
```

2.13 t13: Remeshing an STL file without an underlying CAD model

See t13.geo. Also available in C++ (t13.cpp), Python (t13.py), Julia (t13.jl) and Fortran (t13.f90).

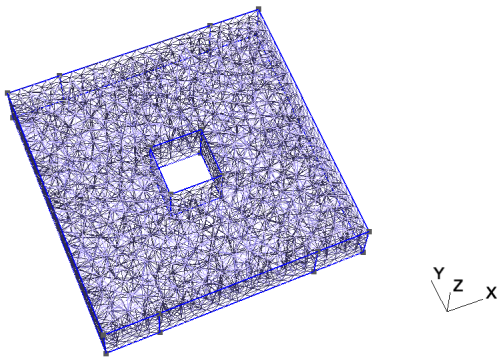



```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 13
//
//  Remeshing an STL file without an underlying CAD model
//
// -------------------------------------------------------------------------

// Let's merge an STL mesh that we would like to remesh.
Merge "t13_data.stl";

// We first classify ("color") the surfaces by splitting the original surface
// along sharp geometrical features. This will create new discrete surfaces,
// curves and points.

DefineConstant[
  // Angle between two triangles above which an edge is considered as sharp
  angle = {40, Min 20, Max 120, Step 1,
    Name "Parameters/Angle for surface detection"},
  // For complex geometries, patches can be too complex, too elongated or too
  // large to be parametrized; setting the following option will force the
  // creation of patches that are amenable to reparametrization:
  forceParametrizablePatches = {0, Choices{0,1},
    Name "Parameters/Create surfaces guaranteed to be parametrizable"},
  // For open surfaces include the boundary edges in the classification process:
  includeBoundary = 1,
  // Force curves to be split on given angle:
  curveAngle = 180
];
ClassifySurfaces{angle * Pi/180, includeBoundary, forceParametrizablePatches,
                 curveAngle * Pi / 180};

// Create a geometry for all the discrete curves and surfaces in the mesh, by
// computing a parametrization for each one
CreateGeometry;

// In batch mode the two steps above can be performed with 'gmsh t13.stl
// -reparam 40', which will save 't13.msh' containing the parametrizations, and
// which can thus subsequently be remeshed.

// Note that if a CAD model (e.g. as a STEP file, see 't20.geo') is available
// instead of an STL mesh, it is usually better to use that CAD model instead of
// the geometry created by reparametrizing the mesh. Indeed, CAD geometries will
```

```
// in general be more accurate, with smoother parametrizations, and will lead to
// more efficient and higher quality meshing. Discrete surface remeshing in Gmsh
// is optimized to handle dense STL meshes coming from e.g. imaging systems
// where no CAD is available; it is less well suited for the poor quality STL
// triangulations (optimized for size, with e.g. very elongated triangles) that
// are usually generated by CAD tools for e.g. 3D printing.

// Create a volume as usual
Surface Loop(1) = Surface{:};
Volume(1) = {1};

// We specify element sizes imposed by a size field, just because we can :-)
funny = DefineNumber[0, Choices{0,1},
  Name "Parameters/Apply funny mesh size field?" ];

Field[1] = MathEval;
If(funny)
  Field[1].F = "2*Sin((x+y)/5) + 3";
Else
  Field[1].F = "4";
EndIf
Background Field = 1;
```

2.14 t14: Homology and cohomology computation

See t14.geo. Also available in C++ (t14.cpp), Python (t14.py), Julia (t14.jl) and Fortran (t14.f90).



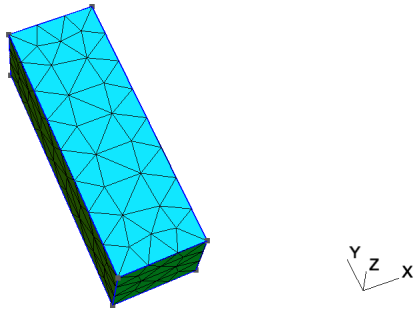

```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 14
//
//  Homology and cohomology computation
//
// -------------------------------------------------------------------------

// Homology computation in Gmsh finds representative chains of (relative)
// (co)homology space bases using a mesh of a model.  The representative basis
// chains are stored in the mesh as physical groups of Gmsh, one for each chain.

// Create an example geometry
```

```
m = 0.5; // mesh size
h = 2; // height in the z-direction

Point(1) = {0, 0, 0, m};   Point(2) = {10, 0, 0, m};
Point(3) = {10, 10, 0, m}; Point(4) = {0, 10, 0, m};
Point(5) = {4, 4, 0, m};   Point(6) = {6, 4, 0, m};
Point(7) = {6, 6, 0, m};   Point(8) = {4, 6, 0, m};

Point(9) = {2, 0, 0, m};   Point(10) = {8, 0, 0, m};
Point(11) = {2, 10, 0, m}; Point(12) = {8, 10, 0, m};

Line(1) = {1, 9};  Line(2) = {9, 10}; Line(3) = {10, 2};
Line(4) = {2, 3};  Line(5) = {3, 12}; Line(6) = {12, 11};
Line(7) = {11, 4}; Line(8) = {4, 1};  Line(9) = {5, 6};
Line(10) = {6, 7}; Line(11) = {7, 8}; Line(12) = {8, 5};

Curve Loop(13) = {6, 7, 8, 1, 2, 3, 4, 5};
Curve Loop(14) = {11, 12, 9, 10};
Plane Surface(15) = {13, 14};

e() = Extrude {0, 0, h}{ Surface{15}; };

// Create physical groups, which are used to define the domain of the
// (co)homology computation and the subdomain of the relative (co)homology
// computation.

// Whole domain
Physical Volume(1) = {e(1)};

// Four "terminals" of the model
Physical Surface(70) = {e(3)};
Physical Surface(71) = {e(5)};
Physical Surface(72) = {e(7)};
Physical Surface(73) = {e(9)};

// Whole domain surface
bnd() = Abs(Boundary{ Volume{e(1)}; });
Physical Surface(80) = bnd();

// Complement of the domain surface with respect to the four terminals
bnd() -= {e(3), e(5), e(7), e(9)};
Physical Surface(75) = bnd();

// Find bases for relative homology spaces of the domain modulo the four
// terminals.
Homology {{1}, {70, 71, 72, 73}};

// Find homology space bases isomorphic to the previous bases: homology spaces
// modulo the non-terminal domain surface, a.k.a the thin cuts.
Homology {{1}, {75}};

// Find cohomology space bases isomorphic to the previous bases: cohomology
```

```
// spaces of the domain modulo the four terminals, a.k.a the thick cuts.
Cohomology {{1}, {70, 71, 72, 73}};

// More examples:
//  Homology {1};
//  Homology;
//  Homology {{1}, {80}};
//  Homology {{}, {80}};

// For more information, see M. Pellikka, S. Suuriniemi, L. Kettunen and
// C. Geuzaine. Homology and cohomology computation in finite element
// modeling. SIAM Journal on Scientific Computing 35(5), pp. 1195-1214, 2013.
```

2.15 t15: Embedded points, lines and surfaces

See t15.geo. Also available in C++ (t15.cpp), Python (t15.py), Julia (t15.jl) and Fortran (t15.f90).

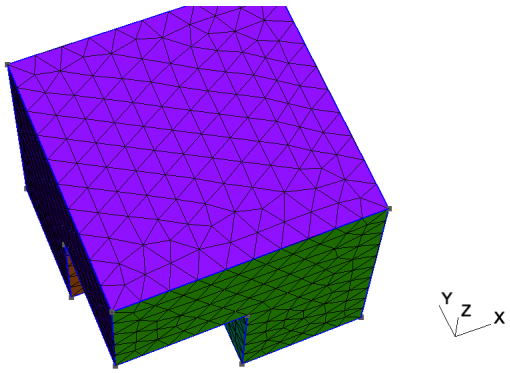



```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 15
//
//  Embedded points, lines and surfaces
//
// -------------------------------------------------------------------------

// By default, across geometrical dimensions meshes generated by Gmsh are only
// conformal if lower dimensional entities are on the boundary of higher
// dimensional ones (i.e. if points, curves or surfaces are part of the boundary
// of volumes).

// Embedding constraints allow to force a mesh to be conformal to other lower
// dimensional entities.

// We start one again by including the first tutorial:
Include "t1.geo";

// We change the mesh size to generate coarser mesh
lc = lc * 4;
MeshSize {1:4} = lc;

// We define a new point
```

```
Point(5) = {0.02, 0.02, 0, lc};

// One can force this point to be included ("embedded") in the 2D mesh, using
// the ‘Point In Surface’ command:
Point{5} In Surface{1};

// In the same way, one can force a curve to be embedded in the 2D mesh using
// the ‘Curve in Surface’ command:
Point(6) = {0.02, 0.12, 0, lc};
Point(7) = {0.04, 0.18, 0, lc};
Line(5) = {6, 7};
Curve{5} In Surface{1};

// One can also embed points and curves in a volume using the ‘Curve/Point In
// Volume’ commands:
Extrude {0, 0, 0.1}{ Surface {1}; }

p = newp;
Point(p) = {0.07, 0.15, 0.025, lc};
Point{p} In Volume {1};

l = newc;
Point(p+1) = {0.025, 0.15, 0.025, lc};
Line(l) = {7, p+1};
Curve{l} In Volume {1};

// Finally, one can also embed a surface in a volume using the ‘Surface In
// Volume’ command:
Point(p+2) = {0.02, 0.12, 0.05, lc};
Point(p+3) = {0.04, 0.12, 0.05, lc};
Point(p+4) = {0.04, 0.18, 0.05, lc};
Point(p+5) = {0.02, 0.18, 0.05, lc};
Line(l+1) = {p+2, p+3};
Line(l+2) = {p+3, p+4};
Line(l+3) = {p+4, p+5};
Line(l+4) = {p+5, p+2};
ll = newcl;
Curve Loop(ll) = {l+1:l+4};
s = news;
Plane Surface(s) = {ll};
Surface{s} In Volume {1};

// Note that with the OpenCASCADE kernel (see ‘t16.geo’), when the
// ‘BooleanFragments’ command is applied to entities of different dimensions,
// the lower dimensional entities will be autmatically embedded in the higher
// dimensional entities if necessary.

Physical Point("Embedded point") = {p};
Physical Curve("Embdded curve") = {l};
Physical Surface("Embedded surface") = {s};
Physical Volume("Volume") = {1};
```

2.16 t16: Constructive Solid Geometry, OpenCASCADE geometry kernel

See t16.geo. Also available in C++ (t16.cpp), C (t16.c), Python (t16.py), Julia (t16.jl) and Fortran (t16.f90).

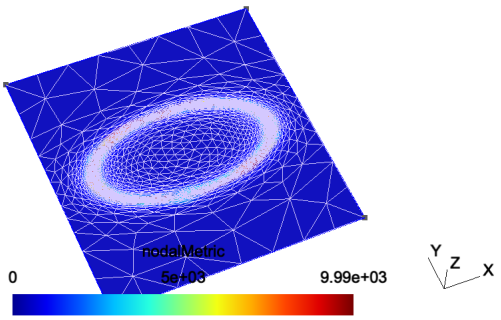



```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 16
//
//  Constructive Solid Geometry, OpenCASCADE geometry kernel
//
// -------------------------------------------------------------------------

// Instead of constructing a model in a bottom-up fashion with Gmsh's built-in
// geometry kernel, starting with version 3 Gmsh allows you to directly use
// alternative geometry kernels. Here we use the OpenCASCADE kernel:

SetFactory("OpenCASCADE");

// Let's build the same model as in 't5.geo', but using constructive solid
// geometry.

// We first create two cubes:
Box(1) = {0,0,0, 1,1,1};
Box(2) = {0,0,0, 0.5,0.5,0.5};

// We apply a boolean difference to create the "cube minus one eigth" shape:
BooleanDifference(3) = { Volume{1}; Delete; }{ Volume{2}; Delete; };

// Boolean operations with OpenCASCADE always create new entities. Adding
// 'Delete' in the arguments allows to automatically delete the original
// entities.

// We then create the five spheres:
x = 0 ; y = 0.75 ; z = 0 ; r = 0.09 ;
For t In {1:5}
  x += 0.166 ;
  z += 0.166 ;
  Sphere(3 + t) = {x,y,z,r};
  Physical Volume(t) = {3 + t};
EndFor
```

```
// If we had wanted five empty holes we would have used 'BooleanDifference'
// again. Here we want five spherical inclusions, whose mesh should be conformal
// with the mesh of the cube: we thus use 'BooleanFragments', which intersects
// all volumes in a conformal manner (without creating duplicate interfaces):
v() = BooleanFragments{ Volume{3}; Delete; }{ Volume{3 + 1 : 3 + 5}; Delete; };

// When the boolean operation leads to simple modifications of entities, and if
// one deletes the original entities with 'Delete', Gmsh tries to assign the
// same tag to the new entities. (This behavior is governed by the
// 'Geometry.OCCBooleanPreserveNumbering' option.)

// Here the 'Physical Volume' definitions made above will thus still work, as
// the five spheres (volumes 4, 5, 6, 7 and 8), which will be deleted by the
// fragment operations, will be recreated identically (albeit with new surfaces)
// with the same tags.

// The tag of the cube will change though, so we need to access it
// programmatically:
Physical Volume(10) = v(#v()-1);

// Creating entities using constructive solid geometry is very powerful, but can
// lead to practical issues for e.g. setting mesh sizes at points, or
// identifying boundaries.

// To identify points or other bounding entities you can take advantage of the
// 'PointfsOf' (a special case of the more general 'Boundary' command) and the
// 'In BoundingBox' commands.
lcar1 = .1;
lcar2 = .0005;
lcar3 = .055;
eps = 1e-3;

// Assign a mesh size to all the points of all the volumes:
MeshSize{ PointsOf{ Volume{:}; } } = lcar1;

// Override this constraint on the points of the five spheres:
MeshSize{ PointsOf{ Volume{3 + 1 : 3 + 5}; } } = lcar3;

// Select the corner point by searching for it geometrically:
p() = Point In BoundingBox{0.5-eps, 0.5-eps, 0.5-eps,
                           0.5+eps, 0.5+eps, 0.5+eps};
MeshSize{ p() } = lcar2;

// Additional examples created with the OpenCASCADE geometry kernel are
// available in 't18.geo', 't19.geo' and 't20.geo', as well as in the
// 'examples/boolean' directory.
```

2.17 t17: Anisotropic background mesh

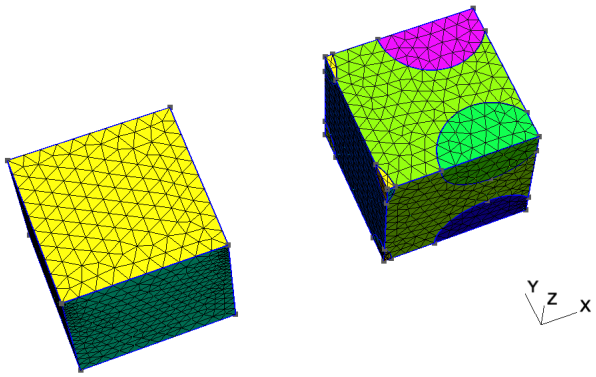
See t17.geo. Also available in C++ (t17.cpp), Python (t17.py), Julia (t17.jl) and Fortran (t17.f90).




```
// ------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 17
//
//  Anisotropic background mesh
//
// ------------------------------------------------------------------------

// As seen in 't7.geo', mesh sizes can be specified very accurately by providing
// a background mesh, i.e., a post-processing view that contains the target mesh
// sizes.

// Here, the background mesh is represented as a metric tensor field defined on
// a square. One should use bamg as 2d mesh generator to enable anisotropic
// meshes in 2D.

SetFactory("OpenCASCADE");

// Create a square
Rectangle(1) = {-2, -2, 0, 4, 4};

// Merge a post-processing view containing the target anisotropic mesh sizes
Merge "t17_bgmesh.pos";

// Apply the view as the current background mesh
Background Mesh View[0];

// Use bamg
Mesh.SmoothRatio = 3;
Mesh.AnisoMax = 1000;
Mesh.Algorithm = 7;
```

2.18 t18: Periodic meshes

See t18.geo. Also available in C++ (t18.cpp), Python (t18.py), Julia (t18.jl) and Fortran (t18.f90).



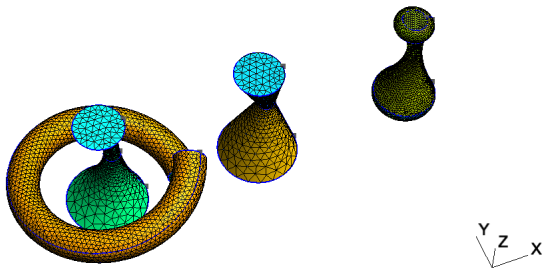

```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 18
//
//  Periodic meshes
//
// -------------------------------------------------------------------------

// Periodic meshing constraints can be imposed on surfaces and curves.

// Let's use the OpenCASCADE geometry kernel to build two geometries.

SetFactory("OpenCASCADE");

// The first geometry is very simple: a unit cube with a non-uniform mesh size
// constraint (set on purpose to be able to verify visually that the periodicity
// constraint works!):

Box(1) = {0, 0, 0, 1, 1, 1};
MeshSize {:} = 0.1;
MeshSize {1} = 0.02;

// To impose that the mesh on surface 2 (the right side of the cube) should
// match the mesh from surface 1 (the left side), the following periodicity
// constraint is set:
Periodic Surface {2} = {1} Translate {1, 0, 0};

// During mesh generation, the mesh on surface 2 will be created by copying the
// mesh from surface 1.  Periodicity constraints can be specified with a
// 'Translation', a 'Rotation' or a general 'Affine' transform.

// Multiple periodicities can be imposed in the same way:
Periodic Surface {6} = {5} Translate {0, 0, 1};
Periodic Surface {4} = {3} Translate {0, 1, 0};

// For more complicated cases, finding the corresponding surfaces by hand can be
// tedious, especially when geometries are created through solid
// modelling. Let's construct a slightly more complicated geometry.

// We start with a cube and some spheres:
Box(10) = {2, 0, 0, 1, 1, 1};
x = 2-0.3; y = 0; z = 0;
Sphere(11) = {x, y, z, 0.35};
```

```
Sphere(12) = {x+1, y, z, 0.35};
Sphere(13) = {x, y+1, z, 0.35};
Sphere(14) = {x, y, z+1, 0.35};
Sphere(15) = {x+1, y+1, z, 0.35};
Sphere(16) = {x, y+1, z+1, 0.35};
Sphere(17) = {x+1, y, z+1, 0.35};
Sphere(18) = {x+1, y+1, z+1, 0.35};

// We first fragment all the volumes, which will leave parts of spheres
// protruding outside the cube:
v() = BooleanFragments { Volume{10}; Delete; }{ Volume{11:18}; Delete; };

// Ask OpenCASCADE to compute more accurate bounding boxes of entities using the
// STL mesh:
Geometry.OCCBoundsUseStl = 1;

// We then retrieve all the volumes in the bounding box of the original cube,
// and delete all the parts outside it:
eps = 1e-3;
vin() = Volume In BoundingBox {2-eps,-eps,-eps, 2+1+eps,1+eps,1+eps};
v() -= vin();
Recursive Delete{ Volume{v()}; }

// We now set a non-uniform mesh size constraint (again to check results
// visually):
MeshSize { PointsOf{ Volume{vin()}; }} = 0.1;
p() = Point In BoundingBox{2-eps, -eps, -eps, 2+eps, eps, eps};
MeshSize {p()} = 0.001;

// We now identify corresponding surfaces on the left and right sides of the
// geometry automatically.

// First we get all surfaces on the left:
Sxmin() = Surface In BoundingBox{2-eps, -eps, -eps, 2+eps, 1+eps, 1+eps};

For i In {0:#Sxmin()-1}
  // Then we get the bounding box of each left surface
  bb() = BoundingBox Surface { Sxmin(i) };
  // We translate the bounding box to the right and look for surfaces inside it:
  Sxmax() = Surface In BoundingBox { bb(0)-eps+1, bb(1)-eps, bb(2)-eps,
                                     bb(3)+eps+1, bb(4)+eps, bb(5)+eps };
  // For all the matches, we compare the corresponding bounding boxes...
  For j In {0:#Sxmax()-1}
    bb2() = BoundingBox Surface { Sxmax(j) };
    bb2(0) -= 1;
    bb2(3) -= 1;
    // ...and if they match, we apply the periodicity constraint
    If(Fabs(bb2(0)-bb(0)) < eps && Fabs(bb2(1)-bb(1)) < eps &&
       Fabs(bb2(2)-bb(2)) < eps && Fabs(bb2(3)-bb(3)) < eps &&
       Fabs(bb2(4)-bb(4)) < eps && Fabs(bb2(5)-bb(5)) < eps)
      Periodic Surface {Sxmax(j)} = {Sxmin(i)} Translate {1,0,0};
    EndIf
```

```
  EndFor
EndFor
```

2.19 t19: Thrusections, fillets, pipes, mesh size from curvature

See t19.geo. Also available in C++ (t19.cpp), Python (t19.py), Julia (t19.jl) and Fortran (t19.f90).

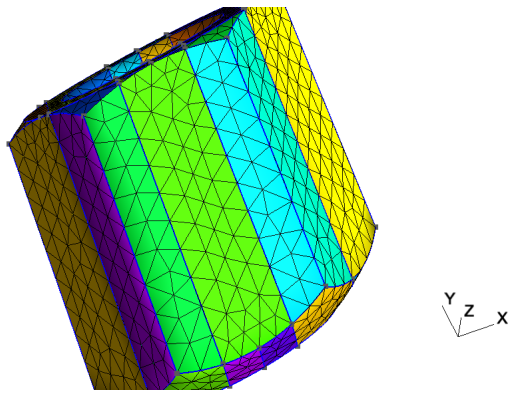



```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 19
//
//  Thrusections, fillets, pipes, mesh size from curvature
//
// -------------------------------------------------------------------------

// The OpenCASCADE geometry kernel supports several useful features for solid
// modelling.

SetFactory("OpenCASCADE");

// Volumes can be constructed from (closed) curve loops thanks to the
// 'ThruSections' command
Circle(1) = {0,0,0, 0.5};       Curve Loop(1) = 1;
Circle(2) = {0.1,0.05,1, 0.1};  Curve Loop(2) = 2;
Circle(3) = {-0.1,-0.1,2, 0.3}; Curve Loop(3) = 3;
ThruSections(1) = {1:3};

// With 'Ruled ThruSections' you can force the use of ruled surfaces:
Circle(11) = {2+0,0,0, 0.5};      Curve Loop(11) = 11;
Circle(12) = {2+0.1,0.05,1, 0.1}; Curve Loop(12) = 12;
Circle(13) = {2-0.1,-0.1,2, 0.3}; Curve Loop(13) = 13;
Ruled ThruSections(11) = {11:13};

// We copy the first volume, and fillet all its edges:
v() = Translate{4, 0, 0} { Duplicata{ Volume{1}; } };
f() = Abs(Boundary{ Volume{v(0)}; });
e() = Unique(Abs(Boundary{ Surface{f()}; }));
Fillet{v(0)}{e()}{0.1}

// OpenCASCADE also allows general extrusions along a smooth path. Let's first
// define a spline curve:
```

```
nturns = 1;
npts = 20;
r = 1;
h = 1 * nturns;
For i In {0 : npts - 1}
  theta = i * 2*Pi*nturns/npts;
  Point(1000 + i) = {r * Cos(theta), r * Sin(theta), i * h/npts};
EndFor
Spline(1000) = {1000 : 1000 + npts - 1};

// A wire is like a curve loop, but open:
Wire(1000) = {1000};

// We define the shape we would like to extrude along the spline (a disk):
Disk(1000) = {1,0,0, 0.2};
Rotate {{1, 0, 0}, {0, 0, 0}, Pi/2} { Surface{1000}; }

// We extrude the disk along the spline to create a pipe:
Extrude { Surface{1000}; } Using Wire {1000}

// We delete the source surface, and increase the number of sub-edges for a
// nicer display of the geometry:
Delete{ Surface{1000}; }
Geometry.NumSubEdges = 1000;

// We can activate the calculation of mesh element sizes based on curvature
// (here with a target of 20 elements per 2*Pi radians):
Mesh.MeshSizeFromCurvature = 20;

// We can constraint the min and max element sizes to stay within reasonnable
// values (see 't10.geo' for more details):
Mesh.MeshSizeMin = 0.001;
Mesh.MeshSizeMax = 0.3;
```

2.20 t20: STEP import and manipulation, geometry partitioning

See t20.geo. Also available in C++ (t20.cpp), Python (t20.py), Julia (t20.jl) and Fortran (t20.f90).



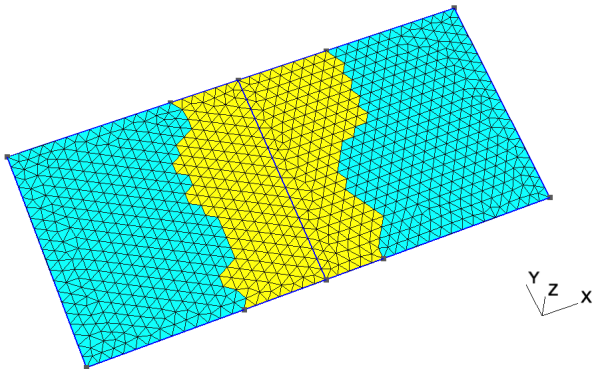

```
// ------------------------------------------------------------------------
//
```

```
//  Gmsh GEO tutorial 20
//
//  STEP import and manipulation, geometry partitioning
//
// ------------------------------------------------------------------------

// The OpenCASCADE geometry kernel allows to import STEP files and to modify
// them. In this tutorial we will load a STEP geometry and partition it into
// slices.

SetFactory("OpenCASCADE");

// Load a STEP file (using `ShapeFromFile' instead of `Merge' allows to directly
// retrieve the tags of the highest dimensional imported entities):
v() = ShapeFromFile("t20_data.step");

// If we had specified
//
// Geometry.OCCTargetUnit = "M";
//
// before merging the STEP file, OpenCASCADE would have converted the units to
// meters (instead of the default, which is millimeters).

// Get the bounding box of the volume:
bbox() = BoundingBox Volume{v()};
xmin = bbox(0);
ymin = bbox(1);
zmin = bbox(2);
xmax = bbox(3);
ymax = bbox(4);
zmax = bbox(5);

// We want to slice the model into N slices, and either keep the volume slices
// or just the surfaces obtained by the cutting:
DefineConstant[
  N = {5, Min 2, Max 100, Step 1, Name "Parameters/0Number of slices"}
  dir = {0, Choices{0="X", 1="Y", 2="Z"}, Name "Parameters/1Direction"}
  surf = {0, Choices{0, 1}, Name "Parameters/2Keep only surfaces?"}
];

dx = (xmax - xmin);
dy = (ymax - ymin);
dz = (zmax - zmin);
L = (dir == 0) ? dz : dx;
H = (dir == 1) ? dz : dy;

// Create the first cutting plane:
s() = {news};
Rectangle(s(0)) = {xmin, ymin, zmin, L, H};
If(dir == 0)
  Rotate{ {0, 1, 0}, {xmin, ymin, zmin}, -Pi/2 } { Surface{s(0)}; }
ElseIf(dir == 1)
```

```
  Rotate{ {1, 0, 0}, {xmin, ymin, zmin}, Pi/2 } { Surface{s(0)}; }
EndIf
tx = (dir == 0) ? dx / N : 0;
ty = (dir == 1) ? dy / N : 0;
tz = (dir == 2) ? dz / N : 0;
Translate{tx, ty, tz} { Surface{s(0)}; }

// Create the other cutting planes:
For i In {1:N-2}
  s() += Translate{i * tx, i * ty, i * tz} { Duplicata{ Surface{s(0)}; } };
EndFor

// Fragment (i.e. intersect) the volume with all the cutting planes:
BooleanFragments{ Volume{v()}; Delete; }{ Surface{s()}; Delete; }

// Now remove all the surfaces (and their bounding entities) that are not on the
// boundary of a volume, i.e. the parts of the cutting planes that "stick out"
// of the volume:
Recursive Delete { Surface{:}; }

If(surf)
  // If we want to only keep the surfaces, retrieve the surfaces in bounding
  // boxes around the cutting planes...
  eps = 1e-4;
  s() = {};
  For i In {1:N-1}
    xx = (dir == 0) ? xmin : xmax;
    yy = (dir == 1) ? ymin : ymax;
    zz = (dir == 2) ? zmin : zmax;
    s() += Surface In BoundingBox
      {xmin - eps + i * tx, ymin - eps + i * ty, zmin - eps + i * tz,
       xx + eps + i * tx, yy + eps + i * ty, zz + eps + i * tz};
  EndFor
  // ...and remove all the other entities:
  dels = Surface{:};
  dels -= s();
  Delete { Volume{:}; Surface{dels()}; Curve{:}; Point{:}; }
EndIf

// Finally, let's specify a global mesh size:
Mesh.MeshSizeMin = 3;
Mesh.MeshSizeMax = 3;

// To partition the mesh instead of the geometry, see 't21.geo'.
```

2.21 t21: Mesh partitioning

See t21.geo. Also available in C++ (t21.cpp), Python (t21.py), Julia (t21.jl) and Fortran (t21.f90).

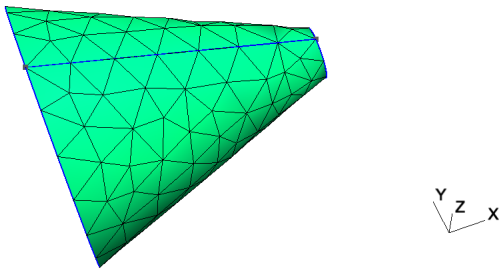



```
// -------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 21
//
//  Mesh partitioning
//
// -------------------------------------------------------------------------

// Gmsh can partition meshes using different algorithms, e.g. the graph
// partitioner Metis or the 'SimplePartition' plugin. For all the partitioning
// algorithms, the relationship between mesh elements and mesh partitions is
// encoded through the creation of new (discrete) elementary entities, called
// "partition entities".
//
// Partition entities behave exactly like other discrete elementary entities;
// the only difference is that they keep track of both a mesh partition index
// and their parent elementary entity.
//
// The major advantage of this approach is that it allows to maintain a full
// boundary representation of the partition entities, which Gmsh creates
// automatically if 'Mesh.PartitionCreateTopology' is set.

// Let us start by creating a simple geometry with two adjacent squares sharing
// an edge:
SetFactory("OpenCASCADE");
Rectangle(1) = {0, 0, 0, 1, 1};
Rectangle(2) = {1, 0, 0, 1, 1};
BooleanFragments{ Surface{1}; Delete; }{ Surface{2}; Delete; }
MeshSize {:} = 0.05;

// We create one physical group for each square, and we mesh the resulting
// geometry:
Physical Surface("Left", 100) = 1;
Physical Surface("Right", 200) = 2;
Mesh 2;

// We now define several constants to fine-tune how the mesh will be partitioned
DefineConstant[
  partitioner = {0, Choices{0="Metis", 1="SimplePartition"},
    Name "Parameters/0Mesh partitioner"}
  N = {3, Min 1, Max 256, Step 1,
    Name "Parameters/1Number of partitions"}
  topology = {1, Choices{0, 1},
```

```
    Name "Parameters/2Create partition topology (BRep)?"}
  ghosts = {0, Choices{0, 1},
    Name "Parameters/3Create ghost cells?"}
  physicals = {0, Choices{0, 1},
    Name "Parameters/3Create new physical groups?"}
  write = {1, Choices {0, 1},
    Name "Parameters/3Write file to disk?"}
  split = {0, Choices {0, 1},
    Name "Parameters/4Write one file per partition?"}
];

// Should we create the boundary representation of the partition entities?
Mesh.PartitionCreateTopology = topology;

// Should we create ghost cells?
Mesh.PartitionCreateGhostCells = ghosts;

// Should we automatically create new physical groups on the partition entities?
Mesh.PartitionCreatePhysicals = physicals;

// Should we keep backward compatibility with pre-Gmsh 4, e.g. to save the mesh
// in MSH2 format?
Mesh.PartitionOldStyleMsh2 = 0;

// Should we save one mesh file per partition?
Mesh.PartitionSplitMeshFiles = split;

If (partitioner == 0)
  // Use Metis to create N partitions
  PartitionMesh N;
  // Several options can be set to control Metis: 'Mesh.MetisAlgorithm' (1:
  // Recursive, 2: K-way), 'Mesh.MetisObjective' (1: min. edge-cut, 2:
  // min. communication volume), 'Mesh.PartitionTriWeight' (weight of
  // triangles), 'Mesh.PartitionQuadWeight' (weight of quads), ...
Else
  // Use the 'SimplePartition' plugin to create chessboard-like partitions
  Plugin(SimplePartition).NumSlicesX = N;
  Plugin(SimplePartition).NumSlicesY = 1;
  Plugin(SimplePartition).NumSlicesZ = 1;
  Plugin(SimplePartition).Run;
EndIf

// Save mesh file (or files, if 'Mesh.PartitionSplitMeshFiles' is set):
If(write)
  Save "t21.msh";
EndIf
```

2.22 x1: Geometry and mesh data

See x1.py. Also available in C++ (x1.cpp) and Julia (x1.jl).



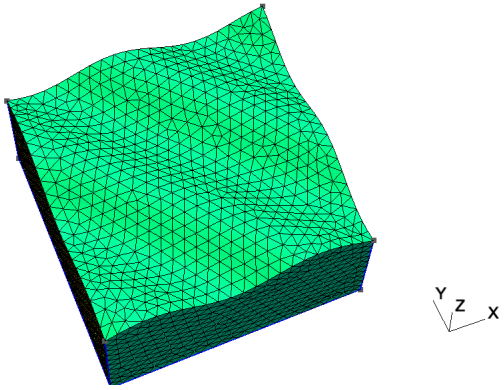

```
# ------------------------------------------------------------------------
#
#  Gmsh Python extended tutorial 1
#
#  Geometry and mesh data
#
# ------------------------------------------------------------------------

# The Python API allows to do much more than what can be done in .geo
# files. These additional features are introduced gradually in the extended
# tutorials, starting with ‘x1.py’.

# In this first extended tutorial, we start by using the API to access basic
# geometrical and mesh data.

import gmsh
import sys

gmsh.initialize()

if len(sys.argv) > 1 and sys.argv[1][0] != '-':
    # If an argument is provided, handle it as a file that Gmsh can read, e.g. a
    # mesh file in the MSH format (‘python x1.py file.msh’)
    gmsh.open(sys.argv[1])
else:
    # Otherwise, create and mesh a simple geometry
    gmsh.model.occ.addCone(1, 0, 0, 1, 0, 0, 0.5, 0.1)
    gmsh.model.occ.synchronize()
    gmsh.model.mesh.generate()

# Print the model name and dimension:
print('Model ' + gmsh.model.getCurrent() + ' (' +
      str(gmsh.model.getDimension()) + 'D)')

# Geometrical data is made of elementary model ‘entities’, called ‘points’
# (entities of dimension 0), ‘curves’ (entities of dimension 1), ‘surfaces’
# (entities of dimension 2) and ‘volumes’ (entities of dimension 3). As we have
# seen in the other Python tutorials, elementary model entities are identified
# by their dimension and by a ‘tag’: a strictly positive identification
# number. Model entities can be either CAD entities (from the built-in ‘geo’
# kernel or from the OpenCASCADE ‘occ’ kernel) or ‘discrete’ entities (defined
# by a mesh). ‘Physical groups’ are collections of model entities and are also
# identified by their dimension and by a tag.
```

```
# Get all the elementary entities in the model, as a vector of (dimension, tag)
# pairs:
entities = gmsh.model.getEntities()

for e in entities:
    # Dimension and tag of the entity:
    dim = e[0]
    tag = e[1]

    # Mesh data is made of ‘elements’ (points, lines, triangles, ...), defined
    # by an ordered list of their ‘nodes’. Elements and nodes are identified by
    # ‘tags’ as well (strictly positive identification numbers), and are stored
    # ("classified") in the model entity they discretize. Tags for elements and
    # nodes are globally unique (and not only per dimension, like entities).

    # A model entity of dimension 0 (a geometrical point) will contain a mesh
    # element of type point, as well as a mesh node. A model curve will contain
    # line elements as well as its interior nodes, while its boundary nodes will
    # be stored in the bounding model points. A model surface will contain
    # triangular and/or quadrangular elements and all the nodes not classified
    # on its boundary or on its embedded entities. A model volume will contain
    # tetrahedra, hexahedra, etc. and all the nodes not classified on its
    # boundary or on its embedded entities.

    # Get the mesh nodes for the entity (dim, tag):
    nodeTags, nodeCoords, nodeParams = gmsh.model.mesh.getNodes(dim, tag)

    # Get the mesh elements for the entity (dim, tag):
    elemTypes, elemTags, elemNodeTags = gmsh.model.mesh.getElements(dim, tag)

    # Elements can also be obtained by type, by using ‘getElementTypes()’
    # followed by ‘getElementsByType()’.

    # Let’s print a summary of the information available on the entity and its
    # mesh.

    # * Type and name of the entity:
    type = gmsh.model.getType(dim, tag)
    name = gmsh.model.getEntityName(dim, tag)
    if len(name): name += ’ ’
    print("Entity " + name + str(e) + " of type " + type)

    # * Number of mesh nodes and elements:
    numElem = sum(len(i) for i in elemTags)
    print(" - Mesh has " + str(len(nodeTags)) + " nodes and " + str(numElem) +
          " elements")

    # * Upward and downward adjacencies:
    up, down = gmsh.model.getAdjacencies(dim, tag)
    if len(up):
        print(" - Upward adjacencies: " + str(up))
```

```
    if len(down):
        print(" - Downward adjacencies: " + str(down))

    # * Does the entity belong to physical groups?
    physicalTags = gmsh.model.getPhysicalGroupsForEntity(dim, tag)
    if len(physicalTags):
        s = ''
        for p in physicalTags:
            n = gmsh.model.getPhysicalName(dim, p)
            if n: n += ' '
            s += n + '(' + str(dim) + ', ' + str(p) + ') '
        print(" - Physical groups: " + s)

    # * Is the entity a partition entity? If so, what is its parent entity?
    partitions = gmsh.model.getPartitions(dim, tag)
    if len(partitions):
        print(" - Partition tags: " + str(partitions) + " - parent entity " +
              str(gmsh.model.getParent(dim, tag)))

    # * List all types of elements making up the mesh of the entity:
    for t in elemTypes:
        name, dim, order, numv, parv, _ = gmsh.model.mesh.getElementProperties(
            t)
        print(" - Element type: " + name + ", order " + str(order) + " (" +
              str(numv) + " nodes in param coord: " + str(parv) + ")")

# Launch the GUI to see the model:
if '-nopopup' not in sys.argv:
    gmsh.fltk.run()

# We can use this to clear all the model data:
gmsh.clear()

gmsh.finalize()
```

2.23 x2: Mesh import, discrete entities, hybrid models, terrain meshing

See x2.py. Also available in C++ (x2.cpp) and Julia (x2.jl).




```
# ------------------------------------------------------------------------------
#
```

```
#  Gmsh Python extended tutorial 2
#
#  Mesh import, discrete entities, hybrid models, terrain meshing
#
# ------------------------------------------------------------------------

import gmsh
import sys
import math

# The API can be used to import a mesh without reading it from a file, by
# creating nodes and elements on the fly and storing them in model
# entities. These model entities can be existing CAD entities, or can be
# discrete entities, entirely defined by the mesh.
#
# Discrete entities can be reparametrized (see 't13.py') so that they can be
# remeshed later on; and they can also be combined with built-in CAD entities to
# produce hybrid models.
#
# We combine all these features in this tutorial to perform terrain meshing,
# where the terrain is described by a discrete surface (that we then
# reparametrize) combined with a CAD representation of the underground.

gmsh.initialize()

gmsh.model.add("x2")

# We will create the terrain surface mesh from N x N input data points:
N = 100


# Helper function to return a node tag given two indices i and j:
def tag(i, j):
    return (N + 1) * i + j + 1


# The x, y, z coordinates of all the nodes:
coords = []

# The tags of the corresponding nodes:
nodes = []

# The connectivities of the triangle elements (3 node tags per triangle) on the
# terrain surface:
tris = []

# The connectivities of the line elements on the 4 boundaries (2 node tags
# for each line element):
lin = [[], [], [], []]

# The connectivities of the point elements on the 4 corners (1 node tag for each
# point element):
```

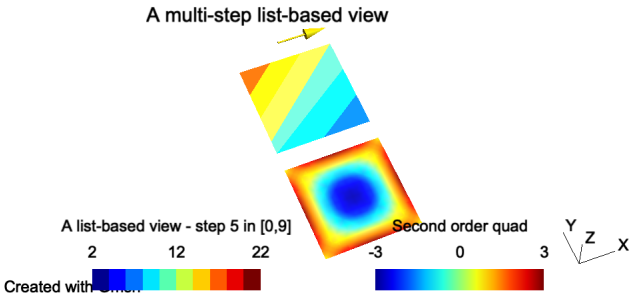
```
pnt = [tag(0, 0), tag(N, 0), tag(N, N), tag(0, N)]

for i in range(N + 1):
    for j in range(N + 1):
        nodes.append(tag(i, j))
        coords.extend([
            float(i) / N,
            float(j) / N, 0.05 * math.sin(10 * float(i + j) / N)
        ])
        if i > 0 and j > 0:
            tris.extend([tag(i - 1, j - 1), tag(i, j - 1), tag(i - 1, j)])
            tris.extend([tag(i, j - 1), tag(i, j), tag(i - 1, j)])
        if (i == 0 or i == N) and j > 0:
            lin[3 if i == 0 else 1].extend([tag(i, j - 1), tag(i, j)])
        if (j == 0 or j == N) and i > 0:
            lin[0 if j == 0 else 2].extend([tag(i - 1, j), tag(i, j)])

# Create 4 discrete points for the 4 corners of the terrain surface:
for i in range(4):
    gmsh.model.addDiscreteEntity(0, i + 1)
gmsh.model.setCoordinates(1, 0, 0, coords[3 * tag(0, 0) - 1])
gmsh.model.setCoordinates(2, 1, 0, coords[3 * tag(N, 0) - 1])
gmsh.model.setCoordinates(3, 1, 1, coords[3 * tag(N, N) - 1])
gmsh.model.setCoordinates(4, 0, 1, coords[3 * tag(0, N) - 1])

# Create 4 discrete bounding curves, with their boundary points:
for i in range(4):
    gmsh.model.addDiscreteEntity(1, i + 1, [i + 1, i + 2 if i < 3 else 1])

# Create one discrete surface, with its bounding curves:
gmsh.model.addDiscreteEntity(2, 1, [1, 2, -3, -4])

# Add all the nodes on the surface (for simplicity... see below):
gmsh.model.mesh.addNodes(2, 1, nodes, coords)

# Add point elements on the 4 points, line elements on the 4 curves, and
# triangle elements on the surface:
for i in range(4):
    # Type 15 for point elements:
    gmsh.model.mesh.addElementsByType(i + 1, 15, [], [pnt[i]])
    # Type 1 for 2-node line elements:
    gmsh.model.mesh.addElementsByType(i + 1, 1, [], lin[i])
# Type 2 for 3-node triangle elements:
gmsh.model.mesh.addElementsByType(1, 2, [], tris)

# Reclassify the nodes on the curves and the points (since we put them all on
# the surface before with 'addNodes' for simplicity)
gmsh.model.mesh.reclassifyNodes()

# Create a geometry for the discrete curves and surfaces, so that we can remesh
# them later on:
gmsh.model.mesh.createGeometry()
```

```
# Note that for more complicated meshes, e.g. for on input unstructured STL
# mesh, we could use 'classifySurfaces()' to automatically create the discrete
# entities and the topology; but we would then have to extract the boundaries
# afterwards.

# Create other build-in CAD entities to form one volume below the terrain
# surface. Beware that only built-in CAD entities can be hybrid, i.e. have
# discrete entities on their boundary: OpenCASCADE does not support this
# feature.
p1 = gmsh.model.geo.addPoint(0, 0, -0.5)
p2 = gmsh.model.geo.addPoint(1, 0, -0.5)
p3 = gmsh.model.geo.addPoint(1, 1, -0.5)
p4 = gmsh.model.geo.addPoint(0, 1, -0.5)
c1 = gmsh.model.geo.addLine(p1, p2)
c2 = gmsh.model.geo.addLine(p2, p3)
c3 = gmsh.model.geo.addLine(p3, p4)
c4 = gmsh.model.geo.addLine(p4, p1)
c10 = gmsh.model.geo.addLine(p1, 1)
c11 = gmsh.model.geo.addLine(p2, 2)
c12 = gmsh.model.geo.addLine(p3, 3)
c13 = gmsh.model.geo.addLine(p4, 4)
ll1 = gmsh.model.geo.addCurveLoop([c1, c2, c3, c4])
s1 = gmsh.model.geo.addPlaneSurface([ll1])
ll3 = gmsh.model.geo.addCurveLoop([c1, c11, -1, -c10])
s3 = gmsh.model.geo.addPlaneSurface([ll3])
ll4 = gmsh.model.geo.addCurveLoop([c2, c12, -2, -c11])
s4 = gmsh.model.geo.addPlaneSurface([ll4])
ll5 = gmsh.model.geo.addCurveLoop([c3, c13, 3, -c12])
s5 = gmsh.model.geo.addPlaneSurface([ll5])
ll6 = gmsh.model.geo.addCurveLoop([c4, c10, 4, -c13])
s6 = gmsh.model.geo.addPlaneSurface([ll6])
sl1 = gmsh.model.geo.addSurfaceLoop([s1, s3, s4, s5, s6, 1])
v1 = gmsh.model.geo.addVolume([sl1])
gmsh.model.geo.synchronize()

# Set this to True to build a fully hex mesh:
#transfinite = True
transfinite = False
transfiniteAuto = False

if transfinite:
    NN = 30
    for c in gmsh.model.getEntities(1):
        gmsh.model.mesh.setTransfiniteCurve(c[1], NN)
    for s in gmsh.model.getEntities(2):
        gmsh.model.mesh.setTransfiniteSurface(s[1])
        gmsh.model.mesh.setRecombine(s[0], s[1])
        gmsh.model.mesh.setSmoothing(s[0], s[1], 100)
    gmsh.model.mesh.setTransfiniteVolume(v1)
elif transfiniteAuto:
    gmsh.option.setNumber('Mesh.MeshSizeMin', 0.5)
```

```
    gmsh.option.setNumber('Mesh.MeshSizeMax', 0.5)
    # setTransfiniteAutomatic() uses the sizing constraints to set the number
    # of points
    gmsh.model.mesh.setTransfiniteAutomatic()
else:
    gmsh.option.setNumber('Mesh.MeshSizeMin', 0.05)
    gmsh.option.setNumber('Mesh.MeshSizeMax', 0.05)

gmsh.model.mesh.generate(3)
gmsh.write('x2.msh')

# Launch the GUI to see the results:
if '-nopopup' not in sys.argv:
    gmsh.fltk.run()

gmsh.finalize()
```

2.24 x3: Post-processing data import: list-based

See x3.py. Also available in C++ (x3.cpp) and Julia (x3.jl).




```
# ------------------------------------------------------------------------
#
#  Gmsh Python extended tutorial 3
#
#  Post-processing data import: list-based
#
# ------------------------------------------------------------------------

import gmsh
import sys

gmsh.initialize(sys.argv)

# Gmsh supports two types of post-processing data: "list-based" and
# "model-based". Both types of data are handled through the 'view' interface.

# List-based views are completely independent from any model and any mesh: they
# are self-contained and simply contain lists of coordinates and values, element
# by element, for 3 types of fields (scalar "S", vector "V" and tensor "T") and
# several types of element shapes (point "P", line "L", triangle "T", quadrangle
# "Q", tetrahedron "S", hexahedron "H", prism "I" and pyramid "Y"). (See 'x4.py'
```

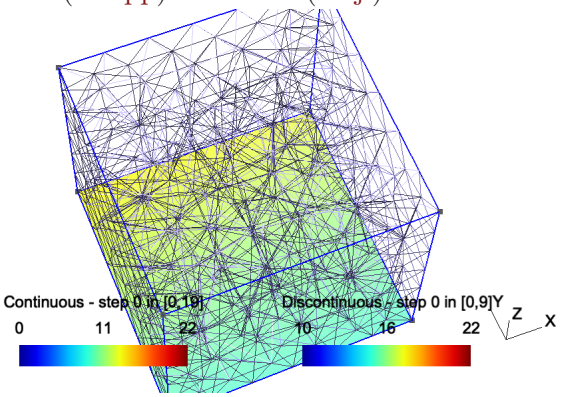
```
# for a tutorial on model-based views.)

# To create a list-based view one should first create a view:
t1 = gmsh.view.add("A list-based view")

# List-based data is then added by specifying the type as a 2 character string
# that combines a field type and an element shape (e.g. "ST" for a scalar field
# on triangles), the number of elements to be added, and the concatenated list
# of coordinates (e.g. 3 "x" coordinates, 3 "y" coordinates, 3 "z" coordinates
# for first order triangles) and values for each element (e.g. 3 values for
# first order scalar triangles, repeated for each step if there are several time
# steps).

# Let's create two triangles...
triangle1 = [0., 1., 1., # x coordinates of the 3 triangle nodes
             0., 0., 1., # y coordinates of the 3 triangle nodes
             0., 0., 0.] # z coordinates of the 3 triangle nodes
triangle2 = [0., 1., 0., 0., 1., 1., 0., 0., 0.]

# ... and append values for 10 time steps
for step in range(0, 10):
    triangle1.extend([10., 11. - step, 12.])  # 3 node values for each step
    triangle2.extend([11., 12., 13. + step])

# List-based data is just added by concatenating the data for all the triangles:
gmsh.view.addListData(t1, "ST", 2, triangle1 + triangle2)

# Internally, post-processing views parsed by the .geo file parser create such
# list-based data (see e.g. 't7.py', 't8.py' and 't9.py'), independently of any
# mesh.

# Vector or tensor fields can be imported in the same way, the only difference
# beeing the type (starting with "V" for vector fields and "T" for tensor
# fields) and the number of components. For example a vector field on a line
# element can be added as follows:
line = [
    0., 1.,   # x coordinate of the 2 line nodes
    1.2, 1.2, # y coordinate of the 2 line nodes
    0., 0.    # z coordinate of the 2 line nodes
]
for step in range(0, 10):
    # 3 vector components for each node (2 nodes here), for each step
    line.extend([10. + step, 0., 0.,
                 10. + step, 0., 0.])
gmsh.view.addListData(t1, "VL", 1, line)

# List-based data can also hold 2D (in window coordinates) and 3D (in model
# coordinates) strings (see 't4.py'). Here we add a 2D string located on the
# bottom-left of the window (with a 20 pixels offset), as well as a 3D string
# located at model coordinates (0.5, 0.5. 0):
gmsh.view.addListDataString(t1, [20., -20.], ["Created with Gmsh"])
gmsh.view.addListDataString(t1, [0.5, 1.5, 0.],
```

```
                            ["A multi-step list-based view"],
                            ["Align", "Center", "Font", "Helvetica"])

# The various attributes of the view can be queried and changed using the option
# interface:
gmsh.view.option.setNumber(t1, "TimeStep", 5)
gmsh.view.option.setNumber(t1, "IntervalsType", 3)
ns = gmsh.view.option.getNumber(t1, "NbTimeStep")
print("View " + str(t1) + " has " + str(ns) + " time steps")

# Views can be queried and modified in various ways using plugins (see 't9.py'),
# or probed directly using 'gmsh.view.probe()' - here at point (0.9, 0.1, 0):
print("Value at (0.9, 0.1, 0)", gmsh.view.probe(t1, 0.9, 0.1, 0))

# Views can be saved to disk using 'gmsh.view.write()':
gmsh.view.write(t1, "x3.pos")

# High-order datasets can be provided by setting the interpolation matrices
# explicitly. Let's create a second view with second order interpolation on
# a 4-node quadrangle.

# Add a new view:
t2 = gmsh.view.add("Second order quad")

# Set the node coordinates:
quad = [0., 1., 1., 0., # x coordinates of the 4 quadrangle nodes
        -1.2, -1.2, -0.2, -0.2, # y coordinates of the 4 quadrangle nodes
        0., 0., 0., 0.] # z coordinates of the 4 quadrangle nodes

# Add nine values that will be interpolated by second order basis functions
quad.extend([1., 1., 1., 1., 3., 3., 3., 3., -3.])

# Set the two interpolation matrices c[i][j] and e[i][j] defining the d = 9
# basis functions: f[i](u, v, w) = sum_(j = 0, ..., d - 1) c[i][j] u^e[j][0]
# v^e[j][1] w^e[j][2], i = 0, ..., d-1, with u, v, w the coordinates in the
# reference element:
gmsh.view.setInterpolationMatrices(t2, "Quadrangle", 9,
                                   [0, 0, 0.25, 0, 0, -0.25, -0.25, 0, 0.25,
                                    0, 0, 0.25, 0, 0, -0.25, 0.25, 0, -0.25,
                                    0, 0, 0.25, 0, 0, 0.25, 0.25, 0, 0.25,
                                    0, 0, 0.25, 0, 0, 0.25, -0.25, 0, -0.25,
                                    0, 0, -0.5, 0.5, 0, 0.5, 0, -0.5, 0,
                                    0, 0.5, -0.5, 0, 0.5, 0, -0.5, 0, 0,
                                    0, 0, -0.5, 0.5, 0, -0.5, 0, 0.5, 0,
                                    0, 0.5, -0.5, 0, -0.5, 0, 0.5, 0, 0,
                                    1, -1, 1, -1, 0, 0, 0, 0, 0],
                                   [0, 0, 0,
                                    2, 0, 0,
                                    2, 2, 0,
                                    0, 2, 0,
                                    1, 0, 0,
                                    2, 1, 0,
```

```
                                    1, 2, 0,
                                    0, 1, 0,
                                    1, 1, 0])

# Note that two additional interpolation matrices could also be provided to
# interpolate the geometry, i.e. to interpolate curved elements.

# Add the data to the view:
gmsh.view.addListData(t2, "SQ", 1, quad)

# In order to visualize the high-order field, one must activate adaptive
# visualization, set a visualization error threshold and a maximum subdivision
# level (Gmsh does automatic mesh refinement to visualize the high-order field
# with the requested accuracy):
gmsh.view.option.setNumber(t2, "AdaptVisualizationGrid", 1)
gmsh.view.option.setNumber(t2, "TargetError", 1e-2)
gmsh.view.option.setNumber(t2, "MaxRecursionLevel", 5)

# Note that the adapted visualization data can be retrived by setting the
# 'returnAdaptive' argument to the 'gmsh.view.getListData()' function.

# Launch the GUI to see the results:
if '-nopopup' not in sys.argv:
    gmsh.fltk.run()

gmsh.finalize()
```

2.25 x4: Post-processing data import: model-based

See x4.py. Also available in C++ (x4.cpp) and Julia (x4.jl).



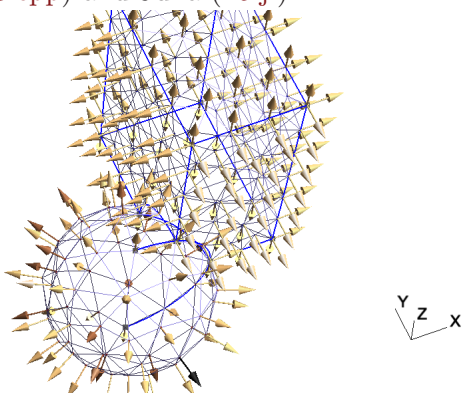

```
# ------------------------------------------------------------------------------
#
#  Gmsh Python extended tutorial 4
#
#  Post-processing data import: model-based
#
# ------------------------------------------------------------------------------

import gmsh
import sys
```

```
gmsh.initialize(sys.argv)

# Contrary to list-based view (see ‘x3.py’), model-based views are based on one
# or more meshes. Compared to list-based views, they are thus linked to one
# model (per step). Post-processing data stored in MSH files create such
# model-based views.

# Let’s create a first model-based view using a simple mesh constructed by
# hand. We create a model with a discrete surface
gmsh.model.add("simple model")
surf = gmsh.model.addDiscreteEntity(2)

# We add 4 nodes and 2 3-node triangles (element type "2")
gmsh.model.mesh.addNodes(2, surf, [1, 2, 3, 4],
                         [0., 0., 0., 1., 0., 0., 1., 1., 0., 0., 1., 0.])
gmsh.model.mesh.addElementsByType(surf, 2, [1, 2], [1, 2, 3, 1, 3, 4])

# We can now create a new model-based view, to which we add 10 steps of
# node-based data:
t1 = gmsh.view.add("Continuous")
for step in range(0, 10):
    gmsh.view.addHomogeneousModelData(
        t1, step, "simple model", "NodeData",
        [1, 2, 3, 4],  # tags of nodes
        [10., 10., 12. + step, 13. + step])  # data, per node

# Besided node-based data, which result in continuous fields, one can also add
# general discontinous fields defined at the nodes of each element, using
# "ElementNodeData":
t2 = gmsh.view.add("Discontinuous")
for step in range(0, 10):
    gmsh.view.addHomogeneousModelData(
        t2, step, "simple model", "ElementNodeData",
        [1, 2],  # tags of elements
        [10., 10., 12. + step, 14., 15., 13. + step])  # data per element nodes

# Constant per element datasets can also be created using "ElementData". Note
# that a more general function ‘addModelData’ to add data for hybrid meshes
# (when data is not homogeneous, i.e. when the number of nodes changes between
# elements) is also available.

# Each step of a model-based view can be defined on a different model, i.e. on a
# different mesh. Let’s define a second model and mesh it
gmsh.model.add("another model")
gmsh.model.occ.addBox(0, 0, 0, 1, 1, 1)
gmsh.model.occ.synchronize()
gmsh.model.mesh.generate(3)

# We can add other steps to view "t" based on this new mesh:
nodes, coord, _ = gmsh.model.mesh.getNodes()
for step in range(11, 20):
    gmsh.view.addHomogeneousModelData(
```

```
        t1, step, "another model", "NodeData", nodes,
        [step * coord[i] for i in range(0, len(coord), 3)])

# This feature allows to create seamless animations for time-dependent datasets
# on deforming or remeshed models.

# High-order node-based datasets are supported without needing to supply the
# interpolation matrices (iso-parametric Lagrange elements). Arbitrary
# high-order datasets can be specified as "ElementNodeData", with the
# interpolation matrices specified in the same as as for list-based views (see
# 'x3.py').

# Model-based views can be saved to disk using 'gmsh.view.write()'; note that
# saving a view based on multiple meshes (like the view 't1') will automatically
# create several files. If the 'PostProcessing.SaveMesh' option is not set,
# 'gmsh.view.write()' will only save the view data, without the mesh (which
# could be saved independently with 'gmsh.write()').
gmsh.view.write(t1, "x4_t1.msh")
gmsh.view.write(t2, "x4_t2.msh")

# Launch the GUI to see the results:
if '-nopopup' not in sys.argv:
    gmsh.fltk.run()

gmsh.finalize()
```

2.26 x5: Additional geometrical data: parametrizations, normals, curvatures

See x5.py. Also available in C++ (x5.cpp) and Julia (x5.jl).




```
# ------------------------------------------------------------------------------
#
#  Gmsh Python extended tutorial 5
#
#  Additional geometrical data: parametrizations, normals, curvatures
#
# ------------------------------------------------------------------------------

import gmsh
import sys
import math
```

```
gmsh.initialize(sys.argv)

# The API provides access to geometrical data in a CAD kernel agnostic manner.

# Let's create a simple CAD model by fusing a sphere and a cube, then mesh the
# surfaces:
gmsh.model.add("x5")
s = gmsh.model.occ.addSphere(0, 0, 0, 1)
b = gmsh.model.occ.addBox(0.5, 0, 0, 1.3, 2, 3)
gmsh.model.occ.fuse([(3, s)], [(3, b)])
gmsh.model.occ.synchronize()
gmsh.model.mesh.generate(2)

# We can for example retrieve the exact normals and the curvature at all the
# mesh nodes (i.e. not normals and curvatures computed from the mesh, but
# directly evaluated on the geometry), by querying the CAD kernels at the
# corresponding parametric coordinates.
normals = []
curvatures = []

# For each surface in the model:
for e in gmsh.model.getEntities(2):
    # Retrieve the surface tag
    s = e[1]

    # Get the mesh nodes on the surface, including those on the boundary
    # (contrary to internal nodes, which store their parametric coordinates,
    # boundary nodes will be reparametrized on the surface in order to compute
    # their parametric coordinates, the result being different when
    # reparametrized on another adjacent surface)
    tags, coord, param = gmsh.model.mesh.getNodes(2, s, True)

    # Get the surface normals on all the points on the surface corresponding to
    # the parametric coordinates of the nodes
    norm = gmsh.model.getNormal(s, param)

    # In the same way, get the curvature
    curv = gmsh.model.getCurvature(2, s, param)

    # Store the normals and the curvatures so that we can display them as
    # list-based post-processing views
    for i in range(0, len(coord), 3):
        normals.append(coord[i])
        normals.append(coord[i + 1])
        normals.append(coord[i + 2])
        normals.append(norm[i])
        normals.append(norm[i + 1])
        normals.append(norm[i + 2])
        curvatures.append(coord[i])
        curvatures.append(coord[i + 1])
        curvatures.append(coord[i + 2])
```

```
        curvatures.append(curv[i // 3])

# Create a list-based vector view on points to display the normals, and a scalar
# view on points to display the curvatures
vn = gmsh.view.add("normals")
gmsh.view.addListData(vn, "VP", len(normals) // 6, normals)
gmsh.view.option.setNumber(vn, 'ShowScale', 0)
gmsh.view.option.setNumber(vn, 'ArrowSizeMax', 30)
gmsh.view.option.setNumber(vn, 'ColormapNumber', 19)
vc = gmsh.view.add("curvatures")
gmsh.view.addListData(vc, "SP", len(curvatures) // 4, curvatures)
gmsh.view.option.setNumber(vc, 'ShowScale', 0)

# We can also retrieve the parametrization bounds of model entities, e.g. of
# curve 5, and evaluate the parametrization for several parameter values:
bounds = gmsh.model.getParametrizationBounds(1, 5)
N = 20
t = [bounds[0][0] + i * (bounds[1][0] - bounds[0][0]) / N for i in range(N)]
xyz1 = gmsh.model.getValue(1, 5, t)

# We can also reparametrize curve 5 on surface 1, and evaluate the points in the
# parametric plane of the surface:
uv = gmsh.model.reparametrizeOnSurface(1, 5, t, 1)
xyz2 = gmsh.model.getValue(2, 1, uv)

# Hopefully we get the same x, y, z coordinates!
if max([abs(a - b) for (a, b) in zip(xyz1, xyz2)]) < 1e-12:
    gmsh.logger.write('Evaluation on curve and surface match!')
else:
    gmsh.logger.write('Evaluation on curve and surface do not match!', 'error')

# Launch the GUI to see the results:
if '-nopopup' not in sys.argv:
    gmsh.fltk.run()

gmsh.finalize()
```

2.27 x6: Additional mesh data: integration points, Jacobians and basis functions

See x6.py. Also available in C++ (x6.cpp) and Julia (x6.jl).

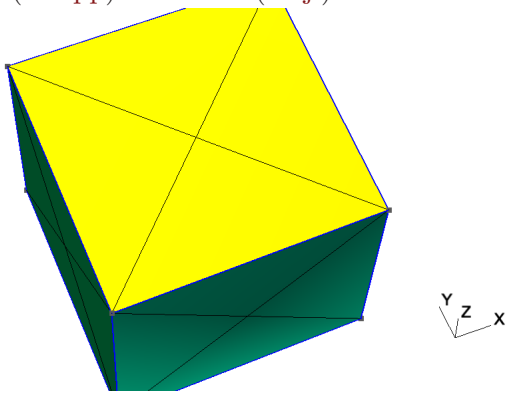
```
# ------------------------------------------------------------------------------
#
#  Gmsh Python extended tutorial 6
#
#  Additional mesh data: integration points, Jacobians and basis functions
#
# ------------------------------------------------------------------------------

import gmsh
import sys
```

```
gmsh.initialize(sys.argv)

gmsh.model.add("x6")

# The API provides access to all the elementary building blocks required to
# implement finite-element-type numerical methods. Let's create a simple 2D
# model and mesh it:
gmsh.model.occ.addRectangle(0, 0, 0, 1, 0.1)
gmsh.model.occ.synchronize()
gmsh.model.mesh.setTransfiniteAutomatic()
gmsh.model.mesh.generate(2)

# Set the element order and the desired interpolation order:
elementOrder = 1
interpolationOrder = 2
gmsh.model.mesh.setOrder(elementOrder)

def pp(label, v, mult):
    print(" * " + str(len(v) / mult) + " " + label + ": " + str(v))

# Iterate over all the element types present in the mesh:
elementTypes = gmsh.model.mesh.getElementTypes()

for t in elementTypes:
    # Retrieve properties for the given element type
    elementName, dim, order, numNodes, numPrimNodes, localNodeCoord =\
    gmsh.model.mesh.getElementProperties(t)
    print("\n** " + elementName + " **\n")

    # Retrieve integration points for that element type, enabling exact
    # integration of polynomials of order "interpolationOrder". The "Gauss"
    # integration family returns the "economical" Gauss points if available, and
    # defaults to the "CompositeGauss" (tensor product) rule if not.
    localCoords, weights =\
    gmsh.model.mesh.getIntegrationPoints(t, "Gauss" + str(interpolationOrder))
    pp("integration points to integrate order " +
       str(interpolationOrder) + " polynomials", localCoords, 3)

    # Return the basis functions evaluated at the integration points. Selecting
    # "Lagrange" and "GradLagrange" returns the isoparamtric basis functions and
    # their gradient (in the reference space of the given element type). A
    # specific interpolation order can be requested using "LagrangeN" and
    # "GradLagrangeN" with N = 1, 2, ... Other supported function spaces include
    # "H1LegendreN", "GradH1LegendreN", "HcurlLegendreN", "CurlHcurlLegendreN".
    numComponents, basisFunctions, numOrientations =\
    gmsh.model.mesh.getBasisFunctions(t, localCoords, "Lagrange")
    pp("basis functions at integration points", basisFunctions, 1)
    numComponents, basisFunctions, numOrientations =\
    gmsh.model.mesh.getBasisFunctions(t, localCoords, "GradLagrange")
    pp("basis function gradients at integration points", basisFunctions, 3)

    # Compute the Jacobians (and their determinants) at the integration points
```

```
    # for all the elements of the given type in the mesh. Beware that the
    # Jacobians are returned "by column": see the API documentation for details.
    jacobians, determinants, coords =\
    gmsh.model.mesh.getJacobians(t, localCoords)
    pp("Jacobian determinants at integration points", determinants, 1)

gmsh.finalize()
```

2.28 x7: Additional mesh data: internal edges and faces

See x7.py. Also available in C++ (x7.cpp) and Julia (x7.jl).




```
# ------------------------------------------------------------------------------
#
#  Gmsh Python extended tutorial 7
#
#  Additional mesh data: internal edges and faces
#
# ------------------------------------------------------------------------------

import sys
import gmsh

gmsh.initialize(sys.argv)

gmsh.model.add("x7")

# Meshes are fully described in Gmsh by nodes and elements, both associated to
# model entities. The API can be used to generate and handle other mesh
# entities, i.e. mesh edges and faces, which are not stored by default.

# Let's create a simple model and mesh it:
gmsh.model.occ.addBox(0, 0, 0, 1, 1, 1)
gmsh.model.occ.synchronize()
gmsh.option.setNumber("Mesh.MeshSizeMin", 2.)
gmsh.model.mesh.generate(3)

# Like elements, mesh edges and faces are described by (an ordered list of)
# their nodes. Let us retrieve the edges and the (triangular) faces of all the
# first order tetrahedra in the mesh:
elementType = gmsh.model.mesh.getElementType("tetrahedron", 1)
edgeNodes = gmsh.model.mesh.getElementEdgeNodes(elementType)
```

```
faceNodes = gmsh.model.mesh.getElementFaceNodes(elementType, 3)

# Edges and faces are returned for each element as a list of nodes corresponding
# to the canonical orientation of the edges and faces for a given element type.

# Gmsh can also identify unique edges and faces (a single edge or face whatever
# the ordering of their nodes) and assign them a unique tag. This identification
# can be done internally by Gmsh (e.g. when generating keys for basis
# functions), or requested explicitly as follows:
gmsh.model.mesh.createEdges()
gmsh.model.mesh.createFaces()

# Edge and face tags can then be retrieved by providing their nodes:
edgeTags, edgeOrientations = gmsh.model.mesh.getEdges(edgeNodes)
faceTags, faceOrientations = gmsh.model.mesh.getFaces(3, faceNodes)

# Since element edge and face nodes are returned in the same order as the
# elements, one can easily keep track of which element(s) each edge or face is
# connected to:
elementTags, elementNodeTags = gmsh.model.mesh.getElementsByType(elementType)
edges2Elements = {}
faces2Elements = {}
for i in range(len(edgeTags)): # 6 edges per tetrahedron
    if not edgeTags[i] in edges2Elements:
        edges2Elements[edgeTags[i]] = [elementTags[i // 6]]
    else:
        edges2Elements[edgeTags[i]].append(elementTags[i // 6])
for i in range(len(faceTags)): # 4 faces per tetrahedron
    if not faceTags[i] in faces2Elements:
        faces2Elements[faceTags[i]] = [elementTags[i // 4]]
    else:
        faces2Elements[faceTags[i]].append(elementTags[i // 4])

# New unique lower dimensional elements can also be easily created given the
# edge or face nodes. This is especially useful for numerical methods that
# require integrating or interpolating on internal edges or faces (like
# e.g. Discontinuous Galerkin techniques), since creating elements for the
# internal entities will make this additional mesh data readily available (see
# 'x6.py'). For example, we can create a new discrete surface...
s = gmsh.model.addDiscreteEntity(2)

# ... and fill it with unique triangles corresponding to the faces of the
# tetrahedra:
maxElementTag = gmsh.model.mesh.getMaxElementTag()
uniqueFaceTags = set()
tagsForTriangles = []
faceNodesForTriangles = []
for i in range(len(faceTags)):
    if faceTags[i] not in uniqueFaceTags:
        uniqueFaceTags.add(faceTags[i])
        tagsForTriangles.append(faceTags[i] + maxElementTag)
        faceNodesForTriangles.append(faceNodes[3 * i])
```

```
        faceNodesForTriangles.append(faceNodes[3 * i + 1])
        faceNodesForTriangles.append(faceNodes[3 * i + 2])
elementType2D = gmsh.model.mesh.getElementType("triangle", 1)
gmsh.model.mesh.addElementsByType(s, elementType2D, tagsForTriangles,
                                  faceNodesForTriangles)

# Since the tags for the triangles have been created based on the face tags,
# the information about neighboring elements can also be readily created,
# useful e.g. in Finite Volume or Discontinuous Galerkin techniques:
for t in tagsForTriangles:
    print("triangle " + str(int(t)) + " is connected to tetrahedra " +
          str(faces2Elements[t - maxElementTag]))

# If all you need is the list of all edges or faces in terms of their nodes, you
# can also directly call:
edgeTags, edgeNodes = gmsh.model.mesh.getAllEdges()
faceTags, faceNodes = gmsh.model.mesh.getAllFaces(3)

# Launch the GUI to see the results:
if '-nopopup' not in sys.argv:
    gmsh.fltk.run()

gmsh.finalize()
```

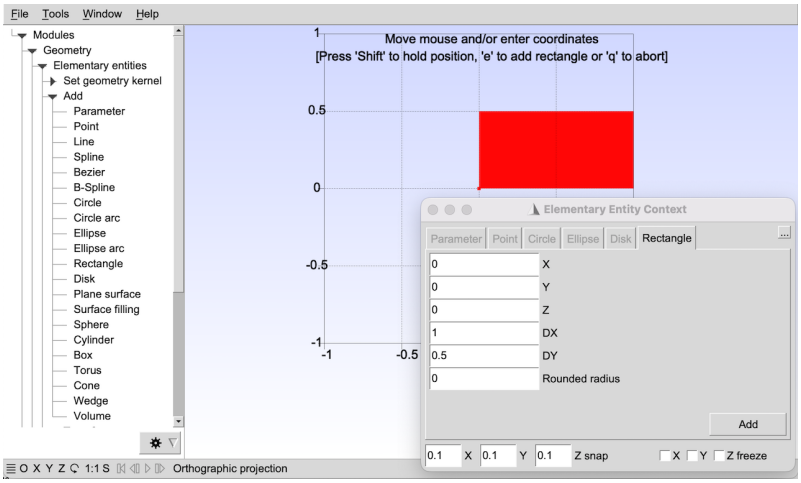
3 Gmsh graphical user interface

Once you have the Gmsh application installed (see Section 1.7 [Installing and running Gmsh on your computer], page 14), to launch the graphical interface just double-click on the Gmsh icon, or type

```
> gmsh
```

at the shell prompt in a terminal. This will open the main window of the Gmsh GUI, with a menu bar on top (except on macOS, where by default the menu bar is on the top of the screen – this can be changed with the `General.SystemMenuBar` option, see Section 7.1 [General options], page 223), a tree menu on the left (which by default contains a 'Modules' entry with three children: 'Geometry', 'Mesh' and 'Solver'), a graphic area on the right, and a status bar with some shortcut buttons at the bottom. (You can detach the tree menu using 'Window->Attach/Detach Menu'.)

To create a new geometrical model, use the 'File->New' menu to create a new model file, and choose for example '`mymodel.geo`' as file name. Then in the tree menu, successively open the 'Geometry', 'Elementary entities' and 'Add' submenus, and click for example on 'Rectangle'. A context window with parameters will pop up: you can enter some parameters in this window (e.g. the width and height of the rectangle) and move the mouse to place it on the canvas. If you don't want to place the rectangle with the mouse, select 'X', 'Y' and 'Z freeze' in the window and enter the coordinates manually in the context window. Once you are done, either press `e` (see the status message on the top of the graphic window) or click on the 'Add' button in the context window.



There is no need to save your geometrical model: when the rectangle was added, scripting commands were automatically appended to your model file '`mymodel.geo`':

```
//+
SetFactory("OpenCASCADE");
Rectangle(1) = {0, 0, 0, 1, 0.5, 0};
```

You can edit this script with any text editor; clicking on 'Edit script' in the tree menu will launch the default text editor specified by the `General.Editor` option (see Section 7.1 [General options], page 223). If you edit the script, you should click on 'Reload script' in the tree menu to reload the modifications in the GUI. The `//+` line in the script is a comment that is used as a placemark between commands added by the GUI; see Chapter 5 [Gmsh scripting language], page 91 for the scripting language reference.

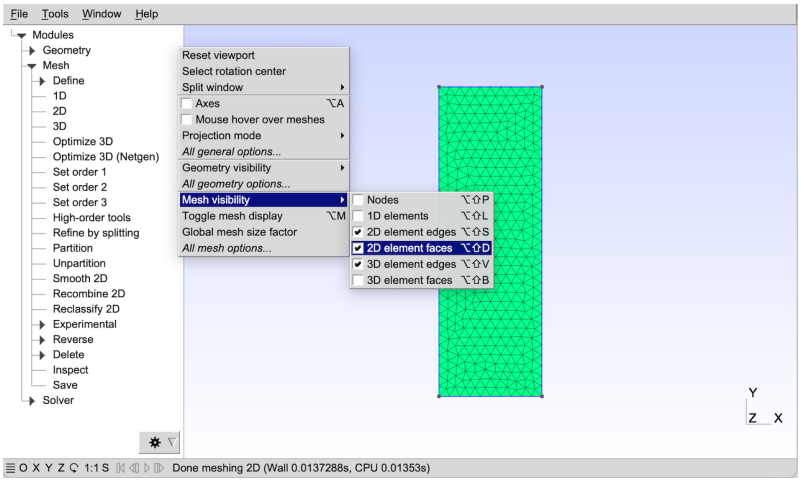
Combining GUI actions and script file editing is a classical way of working with the Gmsh app. For example, it is often faster to define variables and points directly in the script file, and then use the GUI to define the curves, the surfaces and the volumes interactively.

To load an existing model instead of creating a model from scratch, use the 'File->Open' menu. For example, to open the first tutorial (see Chapter 2 [Gmsh tutorial], page 15), choose t1.geo. On the terminal, you can also specify the file name directly on the command line, i.e.:

```
> gmsh t1.geo
```

To generate a mesh, open 'Mesh' in the tree menu and choose the desired dimension: '1D' will mesh all the curves; '2D' will mesh all the surfaces—as well as all the curves if '1D' was not called before; '3D' will mesh all the volumes—and all the surfaces if '2D' was not called before. To save the resulting mesh in the current mesh format click on 'Save' in the tree menu, or select the appropriate format and file name with the 'File->Export' menu. The default mesh file name is based on the name of the current active model, with an appended extension depending on the mesh format. Note that most interactive commands have keyboard shortcuts: see Section 3.2 [Keyboard shortcuts], page 82, or select 'Help->Keyboard and Mouse Usage' in the menu. For example, to quickly generate the 2D mesh and save a mesh, you can first press *2*, then *`Ctrl+Shift+s`*.

A double-click in the graphic window will pop up a quick shortcut menu, which can be used e.g. to quickly toggle the visibility of mesh entities (like surface faces), reset the viewport, select the rotation center, display axes, or access the full module options (from the 'Tools->Options' menu). The shortcut buttons on the bottom left of the status bar can be used to quickly adjust the viewport: 'X', 'Y', 'Z' set viewports with the corresponding axis perpendicular to graphic plane; the rotation button rotates the view by 90 degrees; and '1:1' resets the scale.



Several files can be loaded simultaneously. When specified on the command line, the first one defines the active model (in the same way as using the 'File->Open' menu) and the others are

'merged' into this model (in the same way as using the the 'File->Merge' menu). For example, to merge the post-processing views contained in the files view1.pos and view5.msh together with the geometry of the first tutorial Section 2.1 [t1], page 15, you can type the following command:

```
> gmsh t1.geo view1.pos view5.msh
```

When one or more more post-processing views are loaded, a 'Post-Processing' entry in the tree menu appears. With the previous command, three views will appear in the tree menu under 'Post-processing', respectively labeled 'A scalar map', 'Nodal scalar map' and 'Element 1 vector'. In this example the views contain several time steps: you can loop through them with the shortcuts icons on the left of the status bar. A mouse click on the view name will toggle the visibility of the selected view, while a click on the arrow button on the right will provide access to the view's options.

Note that all the options specified interactively can also be directly specified in the script files. You can save the current options of the current active model with the 'File->Save Model Options'. This will create a new option file with the same filename as the active model, but with an extra '`.opt`' extension added. The next time you open this model, the associated options will be automatically loaded, too. To save the current options as your default preferences for all future Gmsh sessions, use the 'File->Save Options As Default' menu instead. You can also save the current options in an arbitrary file by choosing the 'Gmsh options' format in 'File->Export'. For more information about available options (and how to reset them to their default values), see Chapter 7 [Gmsh options], page 223. A full list of options with their current values is also available using the 'Help->Current Options' menu.

Finally, note that the GUI can also be run (and modified) using the API: see Section 6.14 [Namespace gmsh/fltk], page 212 for details.

The two next sections describe the mouse actions in the GUI, as well as all the predefined keyboard shortcuts. Screencasts explaining how to use the Gmsh GUI are available online at the following address: `https://gmsh.info/screencasts/`.

3.1 Mouse actions

`Move`
: Highlight the entity under the mouse pointer and display its properties / Resize a lasso zoom or a lasso (un)selection

`Left button`
: Rotate / Select an entity / Accept a lasso zoom or a lasso selection

`Ctrl+Left button`
: Start a lasso zoom or a lasso (un)selection

`Middle button`
: Zoom / Unselect an entity / Accept a lasso zoom or a lasso unselection

`Ctrl+Middle button`
: Orthogonalize display

`Right button`
: Pan / Cancel a lasso zoom or a lasso (un)selection / Pop-up menu on post-processing view button

`Ctrl+Right button`
: Reset to default viewpoint

For a 2 button mouse, Middle button = Shift+Left button.

For a 1 button mouse, Middle button = Shift+Left button, Right button = Alt+Left button.

3.2 Keyboard shortcuts

(On macOS, *Ctrl* is replaced by *Cmd* in the shortcuts below.)

Left arrow
: Go to previous time step

Right arrow
: Go to next time step

Up arrow
: Make previous view visible

Down arrow
: Make next view visible

0
: Reload geometry

Ctrl+0 or 9
: Reload full project

1 or F1
: Mesh lines

2 or F2
: Mesh surfaces

3 or F3
: Mesh volumes

Escape
: Cancel lasso zoom/selection, toggle mouse selection ON/OFF

e
: End/accept selection in geometry creation mode

g
: Go to geometry module

m
: Go to mesh module

p
: Go to post-processing module

q
: Abort selection in geometry creation mode

s
: Go to solver module

x
: Toggle x coordinate freeze in geometry creation mode

y
: Toggle y coordinate freeze in geometry creation mode

z
: Toggle z coordinate freeze in geometry creation mode

Shift+a
: Bring all windows to front

Shift+g
: Show geometry options

Shift+m
: Show mesh options

Shift+o
: Show general options

Shift+p
: Show post-processing options

Shift+s
: Show solver options

Shift+u
: Show post-processing view plugins

Shift+w
: Show post-processing view options

Shift+x
: Move only along x coordinate in geometry creation mode

Shift+y
: Move only along y coordinate in geometry creation mode

Shift+z
: Move only along z coordinate in geometry creation mode

Shift+Escape
: Enable full mouse selection

Ctrl+d Attach/detach menu

Ctrl+e Export project

Ctrl+f Enter full screen

Ctrl+i Show statistics window

Ctrl+j Save model options

Ctrl+l Show message console

Ctrl+m Minimize window

Ctrl+n Create new project file

Ctrl+o Open project file

Ctrl+q Quit

Ctrl+r Rename project file

Ctrl+s Save mesh in default format

Shift+Ctrl+c
Show clipping plane window

Shift+Ctrl+h
Show current options and workspace window

Shift+Ctrl+j
Save options as default

Shift+Ctrl+m
Show manipulator window

Shift+Ctrl+n
Show option window

Shift+Ctrl+o
Merge file(s)

Shift+Ctrl+r
Open next-to-last opened file

Shift+Ctrl+u
Show plugin window

Shift+Ctrl+v
Show visibility window

Alt+a Loop through axes modes

Alt+b Hide/show bounding boxes

Alt+c Loop through predefined color schemes

Alt+e Hide/Show element outlines for visible post-pro views

Alt+f Change redraw mode (fast/full)

Alt+h Hide/show all post-processing views

Alt+i Hide/show all post-processing view scales

Alt+l Hide/show geometry lines

Alt+m Toggle visibility of all mesh entities

Alt+n Hide/show all post-processing view annotations

Alt+o Change projection mode (orthographic/perspective)

Alt+p Hide/show geometry points

Alt+r Loop through range modes for visible post-pro views

Alt+s Hide/show geometry surfaces

Alt+t Loop through interval modes for visible post-pro views

Alt+v Hide/show geometry volumes

Alt+w Enable/disable all lighting

Alt+x Set X view

Alt+y Set Y view

Alt+z Set Z view

Alt+1 Set 1:1 view

Alt+Shift+a
: Hide/show small axes

Alt+Shift+b
: Hide/show mesh volume faces

Alt+Shift+c
: Loop through predefined colormaps

Alt+Shift+d
: Hide/show mesh surface faces

Alt+Shift+l
: Hide/show mesh lines

Alt+Shift+p
: Hide/show mesh nodes

Alt+Shift+s
: Hide/show mesh surface edges

Alt+Shift+t
: Same as Alt+t, but with numeric mode included

Alt+Shift+v
: Hide/show mesh volume edges

Alt+Shift+x
: Set -X view

Alt+Shift+y
: Set -Y view

Alt+Shift+z
: Set -Z view

Alt+Shift+1
: Reset bounding box around visible entities

Alt+Ctrl++1
: Sync scale between viewports

4 Gmsh command-line interface

Gmsh defines a number of commands-line switches that can be used to control Gmsh in "batch" mode from the command line, and pass options without resorting to a script (see Chapter 5 [Gmsh scripting language], page 91) or the API (see Chapter 6 [Gmsh application programming interface], page 125).

For example, meshing the first tutorial in batch mode can be done in a terminal by passing the `-2` command-line switch:

```
> gmsh t1.geo -2
```

The same effect could be achieved by adding the `Mesh 2;` command at the end of '`t1.geo`' and running

```
> gmsh t1.geo -parse_and_exit
```

or further adding the `Exit;` command at the end of the script and simply opening this new file:

```
> gmsh t1.geo
```

Note that all numeric and string options (see Chapter 7 [Gmsh options], page 223) can be set from the command line with the `-setnumber` and `-setstring` switches

```
> gmsh t1.geo -setnumber Mesh.Nodes 1 -setnumber Geometry.SurfaceLabels 1
```

The list of all command-line switches is given hereafter.

(Related option names, if any, are given between parentheses)

Geometry:

`-0` Output model, then exit

`-tol value`
: Set geometrical tolerance (Geometry.Tolerance)

`-match` Match geometries and meshes

Mesh:

`-1, -2, -3`
: Perform 1D, 2D or 3D mesh generation, then exit

`-format string`
: Select output mesh format: auto, msh1, msh2, msh22, msh3, msh4, msh40, msh41, msh, unv, vtk, wrl, mail, stl, p3d, mesh, bdf, cgns, med, diff, ir3, inp, ply2, celum, su2, x3d, dat, neu, m, key, off, rad (Mesh.Format)

`-bin` Create binary files when possible (Mesh.Binary)

`-refine` Perform uniform mesh refinement, then exit

`-barycentric_refine`
: Perform barycentric mesh refinement, then exit

`-reclassify angle`
: Reclassify surface mesh, then exit

`-reparam angle`
: Reparametrize surface mesh, then exit

`-part int` Partition after batch mesh generation (Mesh.NbPartitions)

`-part_weight [tri,quad,tet,hex,pri,pyr,trih] int`
: Weight of a triangle/quad/etc. during partitioning (Mesh.Partition[Tri,Quad,...]Weight)

`-part_split`
: Save mesh partitions in separate files (Mesh.PartitionSplitMeshFiles)

`-part_[no_]topo`
: Create the partition topology (Mesh.PartitionCreateTopology)

`-part_[no_]ghosts`
: Create ghost cells (Mesh.PartitionCreateGhostCells)

`-part_[no_]physicals`
: Create physical groups for partitions (Mesh.PartitionCreatePhysicals)

`-part_topo_pro`
: Save the partition topology .pro file (Mesh.PartitionTopologyFile)

`-preserve_numbering_msh2`
: Preserve element numbering in MSH2 format (Mesh.PreserveNumberingMsh2)

`-save_all`
: Save all elements (Mesh.SaveAll)

`-save_parametric`
: Save nodes with their parametric coordinates (Mesh.SaveParametric)

`-save_topology`
: Save model topology (Mesh.SaveTopology)

`-algo string`
: Select mesh algorithm: auto, meshadapt, del2d, front2d, delquad, quadqs, initial2d, del3d, front3d, mmg3d, hxt, initial3d (Mesh.Algorithm and Mesh.Algorithm3D)

`-smooth int`
: Set number of mesh smoothing steps (Mesh.Smoothing)

`-order int`
: Set mesh order (Mesh.ElementOrder)

`-optimize[_netgen]`
: Optimize quality of tetrahedral elements (Mesh.Optimize[Netgen])

`-optimize_threshold`
: Optimize tetrahedral elements that have a quality less than a threshold (Mesh.OptimizeThreshold)

`-optimize_ho`
: Optimize high order meshes (Mesh.HighOrderOptimize)

`-ho_[min,max,nlayers]`
: High-order optimization parameters (Mesh.HighOrderThreshold[Min,Max], Mesh.HighOrderNumLayers)

`-clscale value`
: Set mesh element size factor (Mesh.MeshSizeFactor)

`-clmin value`
: Set minimum mesh element size (Mesh.MeshSizeMin)

`-clmax value`
: Set maximum mesh element size (Mesh.MeshSizeMax)

`-clextend value`
: Extend mesh element sizes from boundaries (Mesh.MeshSizeExtendFromBoundary)

`-clcurv value`
: Compute mesh element size from curvature, with value the target number of elements per 2*pi radians (Mesh.MeshSizeFromCurvature)

`-aniso_max value`
: Set maximum anisotropy for bamg (Mesh.AnisoMax)

`-smooth_ratio value`
: Set smoothing ration between mesh sizes at nodes of a same edge for bamg (Mesh.SmoothRatio)

`-epslc1d value`
: Set accuracy of evaluation of mesh size field for 1D mesh (Mesh.LcIntegrationPrecision)

`-swapangle value`
: Set the threshold angle (in degrees) between two adjacent faces below which a swap is allowed (Mesh.AllowSwapAngle)

`-rand value`
: Set random perturbation factor (Mesh.RandomFactor)

`-bgm file` Load background mesh from file

`-check` Perform various consistency checks on mesh

`-ignore_periocity`
: Ignore periodic boundaries (Mesh.IgnorePeriodicity)

Post-processing:

`-link int` Select link mode between views (PostProcessing.Link)

`-combine` Combine views having identical names into multi-time-step views

Solver:

`-listen string`
: Always listen to incoming connection requests (Solver.AlwaysListen) on the given socket (uses Solver.SocketName if not specified)

`-minterpreter string`
: Name of Octave interpreter (Solver.OctaveInterpreter)

`-pyinterpreter string`
: Name of Python interpreter (Solver.OctaveInterpreter)

`-run` Run ONELAB solver(s)

Display:

`-n` Hide all meshes and post-processing views on startup (View.Visible, Mesh.[Points,Lines,SurfaceEdges,...])

`-nodb` Disable double buffering (General.DoubleBuffer)

`-numsubedges`
: Set num of subdivisions for high order element display (Mesh.NumSubEdges)

`-fontsize int`
: Specify the font size for the GUI (General.FontSize)

`-theme string`
: Specify FLTK GUI theme (General.FltkTheme)

`-display string`
: Specify display (General.Display)

`-camera` Use camera mode view (General.CameraMode)

`-stereo` OpenGL quad-buffered stereo rendering (General.Stereo)

`-gamepad` Use gamepad controller if available

Other:

`-, -parse_and_exit`
: Parse input files, then exit

`-save` Save output file, then exit

`-o file` Specify output file name

`-new` Create new model before merge next file

`-merge` Merge next files

`-open` Open next files

`-log filename`
: Log all messages to filename

`-a, -g, -m, -s, -p`
: Start in automatic, geometry, mesh, solver or post-processing mode (General.InitialModule)

`-pid` Print process id on stdout

`-watch pattern`
: Pattern of files to merge as they become available (General.WatchFilePattern)

`-bg file` Load background (image or PDF) file (General.BackgroundImageFileName)

`-v int` Set verbosity level (General.Verbosity)

`-string "string"`
: Parse command string at startup

`-setnumber name value`
: Set constant, ONELAB or option number name=value

`-setstring name value`
: Set constant, ONELAB or option string name=value

`-nopopup` Don't popup dialog windows in scripts (General.NoPopup)

`-noenv` Don't modify the environment at startup

`-nolocale`
: Don't modify the locale at startup

`-option file`
: Parse option file at startup

`-convert files`
: Convert files into latest binary formats, then exit

`-nt int` Set number of threads (General.NumThreads)

`-cpu` Report CPU times for all operations

`-version` Show version number

`-info` Show detailed version information

`-help` Show command line usage

`-help_options`
Show all options

5 Gmsh scripting language

The Gmsh scripting language is interpreted at runtime by Gmsh's parser. Scripts are written in ASCII files and are usually given the '`.geo`' extension, but any extension (or no extension at all) can also be used. For example Gmsh often uses the '`.pos`' extension for scripts that contain post-processing commands, in particular parsed post-processing views (see Section 5.4 [Post-processing scripting commands], page 119).

Historically, '`.geo`' scripts have been the primary way to perform complex tasks with Gmsh, and they are indeed quite powerful: they can handle (lists of) floating point (see Section 5.1.2 [Floating point expressions], page 91) and string (see Section 5.1.3 [String expressions], page 94) variables, loops and tests (see Section 5.1.8 [Loops and conditionals], page 98), macros (see Section 5.1.7 [User-defined macros], page 98), etc. However Gmsh's scripting language is still quite limited compared to actual programming languages: for example there are no private variables, macros don't take arguments, and the runtime interpretation by the parser can penalize performance on large models. Depending on the workflow and the application, using the Gmsh API (see Chapter 6 [Gmsh application programming interface], page 125) can thus sometimes be preferable. The downside of the API is that, while the scripting language is baked into Gmsh and is thus available directly in the standalone Gmsh app, the API requires external dependencies (a C++, C or Fortran compiler; or a Python or Julia interpreter).

This chapter describes the scripting language by detailing general commands first (see Section 5.1 [General scripting commands], page 91), before detailing the scripting commands specific to the geometry (see Section 5.2 [Geometry scripting commands], page 104), mesh (see Section 5.3 [Mesh scripting commands], page 113) and post-processing (see Section 5.4 [Post-processing scripting commands], page 119) modules.

The following rules are used when describing the scripting language in the rest of this chapter (note that metasyntactic variable definitions stay valid throughout the chapter, not only in the section where the definitions appear):

1. Keywords and literal symbols are printed like `this`.
2. Metasyntactic variables (i.e., text bits that are not part of the syntax, but stand for other text bits) are printed like *this*.
3. A colon (`:`) after a metasyntactic variable separates the variable from its definition.
4. Optional rules are enclosed in `< >` pairs.
5. Multiple choices are separated by `|`.
6. Three dots (. . .) indicate a possible (multiple) repetition of the preceding rule.

5.1 General scripting commands

5.1.1 Comments

Gmsh script files support both C and C++ style comments:

1. any text comprised between `/*` and `*/` pairs is ignored;
2. the rest of a line after a double slash `//` is ignored.

These commands won't have the described effects inside double quotes or inside keywords. Also note that 'white space' (spaces, tabs, new line characters) is ignored inside all expressions.

5.1.2 Floating point expressions

The two constant types used in Gmsh scripts are *real* and *string* (there is no integer type). These types have the same meaning and syntax as in the C or C++ programming languages.

Floating point expressions (or, more simply, "expressions") are denoted by the metasyntactic variable *expression*, and are evaluated during the parsing of the script file:

```
expression:
  real |
  string |
  string ~ { expression }
  string [ expression ] |
  # string [ ] |
  ( expression ) |
  operator-unary-left expression |
  expression operator-unary-right |
  expression operator-binary expression |
  expression operator-ternary-left expression
    operator-ternary-right expression |
  built-in-function |
  number-option |
  Find(expression-list-item, expression-list-item) |
  StrFind(string-expression, string-expression) |
  StrCmp(string-expression, string-expression) |
  StrLen(string-expression) |
  TextAttributes(string-expression<,string-expression...>) |
  Exists(string) | Exists(string~{ expression }) |
  FileExists(string-expression) |
  StringToName(string-expression) | S2N(string-expression) |
  GetNumber(string-expression <,expression>) |
  GetValue("string", expression) |
  DefineNumber(expression, onelab-options)
```

Such *expression*s are used in most of Gmsh's scripting commands. When `~{`*expression*`}` is appended to a string *string*, the result is a new string formed by the concatenation of *string*, `_` (an underscore) and the value of the *expression*. This is most useful in loops (see Section 5.1.8 [Loops and conditionals], page 98), where it permits to define unique strings automatically. For example,

```
For i In {1:3}
  x~{i} = i;
EndFor
```

is the same as

```
x_1 = 1;
x_2 = 2;
x_3 = 3;
```

The brackets `[]` permit to extract one item from a list (parentheses can also be used instead of brackets). The `#` permits to get the size of a list. The operators *operator-unary-left*, *operator-unary-right*, *operator-binary*, *operator-ternary-left* and *operator-ternary-right* are defined in Section 5.1.5 [Operators], page 95. For the definition of *built-in-function*s, see Section 5.1.6 [Built-in functions], page 97. The various *number-option*s are listed in Chapter 7 [Gmsh options], page 223. `Find` searches for occurrences of the first expression in the second (both of which can be lists). `StrFind` searches the first *string-expression* for any occurrence of the second *string-expression*. `StrCmp` compares the two strings (returns an integer greater than, equal to, or less than 0, according as the first string is greater than, equal to, or less than the second string). `StrLen` returns the length of the string. `TextAttributes` creates attributes for text strings. `Exists` checks if a variable with the given name exists (i.e., has been defined previously), and `FileExists` checks if the file with the given name exists. `StringToName` creates a name from the provided string. `GetNumber` allows to get the value of a ONELAB variable (the optional second argument is the default value returned if the variable does not exist). `GetValue` allows to ask

the user for a value interactively (the second argument is the value returned in non-interactive mode). For example, inserting `GetValue("Value of parameter alpha?", 5.76)` in an input file will query the user for the value of a certain parameter alpha, assuming the default value is 5.76. If the option `General.NoPopup` is set (see Section 7.1 [General options], page 223), no question is asked and the default value is automatically used.

`DefineNumber` allows to define a ONELAB variable in-line. The *expression* given as the first argument is the default value; this is followed by the various ONELAB options. See the ONELAB tutorial wiki for more information.

List of expressions are also widely used, and are defined as:

expression-list:
  expression-list-item <, *expression-list-item*> ...

with

expression-list-item:
  expression |
  expression : *expression* |
  expression : *expression* : *expression* |
  string [ ] | *string* ( ) |
  List [*string*] |
  List [*expression-list-item*] |
  List [{ *expression-list* }] |
  Unique [*expression-list-item*] |
  Abs [*expression-list-item*] |
  ListFromFile [*expression-char*] |
  LinSpace[*expression*, *expression*, *expression*] |
  LogSpace[*expression*, *expression*, *expression*] |
  string [{ *expression-list* }] |
  Point { *expression* } |
  transform |
  extrude |
  boolean |
  Point|Curve|Surface|Volume In BoundingBox { *expression-list* } |
  BoundingBox Point|Curve|Surface|Volume { *expression-list* } |
  Mass Curve|Surface|Volume { *expression* } |
  CenterOfMass Curve|Surface|Volume { *expression* } |
  MatrixOfInertia Curve|Surface|Volume { *expression* } |
  Point { *expression* } |
  Physical Point|Curve|Surface|Volume { *expression-list* } |
  <Physical> Point|Curve|Surface|Volume { : } |

The second case in this last definition permits to create a list containing the range of numbers comprised between two *expression*s, with a unit incrementation step. The third case also permits to create a list containing the range of numbers comprised between two *expression*s, but with a positive or negative incrementation step equal to the third *expression*. The fourth, fifth and sixth cases permit to reference an expression list (parentheses can also be used instead of brackets). `Unique` sorts the entries in the list and removes all duplicates. `Abs` takes the absolute value of all entries in the list. `ListFromFile` reads a list of numbers from a file. `LinSpace` and `LogSpace` construct lists using linear or logarithmic spacing. The next two cases permit to reference an expression sublist (whose elements are those corresponding to the indices provided by the *expression-list*). The next cases permit to retrieve the indices of entities created through geometrical transformations, extrusions and boolean operations (see Section 5.2.7 [Transformations], page 110, Section 5.2.5 [Extrusions], page 108 and Section 5.2.6 [Boolean operations], page 109).

The next two cases allow to retrieve entities in a given bounding box, or get the bounding box of a given entity, with the bounding box specified as (X min, Y min, Z min, X max, Y max, Z max). Beware that the order of coordinates is different than in the `BoundingBox` command for the scene: see Section 5.1.9 [Other general commands], page 99. The last cases permit to retrieve the mass, the center of mass or the matrix of inertia of an entity, the coordinates of a given geometry point (see Section 5.2.1 [Points], page 104), the elementary entities making up physical groups, and the tags of all (physical or elementary) points, curves, surfaces or volumes in the model. These operations all trigger a synchronization of the CAD model with the internal Gmsh model.

To see the practical use of such expressions, have a look at the first couple of examples in Chapter 2 [Gmsh tutorial], page 15. Note that, in order to lighten the syntax, you can omit the braces `{}` enclosing an *expression-list* if this *expression-list* only contains a single item. Also note that a braced *expression-list* can be preceded by a minus sign in order to change the sign of all the *expression-list-item*s.

For some commands it makes sense to specify all the possible expressions in a list. This is achieved with *expression-list-or-all*, defined as:

expression-list-or-all:
  expression-list | :

The meaning of "all" (`:`) depends on context. For example, `Curve { : }` will get the ids of all the existing curves in the model, while `Surface { : }` will get the ids of all existing surfaces.

5.1.3 String expressions

String expressions are defined as:

string-expression:
  "*string*" |
  string | *string*[*expression*] |
  Today | OnelabAction | GmshExecutableName |
  CurrentDirectory | CurrentDir | CurrentFileName
  StrPrefix (*string-expression*) |
  StrRelative (*string-expression*) |
  StrCat (*string-expression* <,...>) |
  Str (*string-expression* <,...>) |
  StrChoice (*expression*, *string-expression*, *string-expression*) |
  StrSub(*string-expression*, *expression*, *expression*) |
  StrSub(*string-expression*, *expression*) |
  UpperCase (*string-expression*) |
  AbsolutePath (*string-expression*) |
  DirName (*string-expression*) |
  Sprintf (*string-expression* , *expression-list*) |
  Sprintf (*string-expression*) |
  Sprintf (*string-option*) |
  GetEnv (*string-expression*) |
  GetString (*string-expression* <,*string-expression*>) |
  GetStringValue (*string-expression* , *string-expression*) |
  StrReplace (*string-expression* , *string-expression* , *string-expression*)
  NameToString (*string*) | N2S (*string*) |
  <Physical> Point|Curve|Surface|Volume { *expression* } |
  DefineString(*string-expression*, *onelab-options*)

`Today` returns the current date. `OnelabAction` returns the current ONELAB action (e.g. `check` or `compute`). `GmshExecutableName` returns the full path of the Gmsh executable.

`CurrentDirectory` (or `CurrentDir`) and `CurrentFileName` return the directory and file name of the script being parsed. `StrPrefix` and `StrRelative` take the prefix (e.g. to remove the extension) or the relative path of a given file name. `StrCat` and `Str` concatenate string expressions (`Str` adds a newline character after each string except the last). `StrChoice` returns the first or second *string-expression* depending on the value of *expression*. `StrSub` returns the portion of the string that starts at the character position given by the first *expression* and spans the number of characters given by the second *expression* or until the end of the string (whichever comes first; or always if the second *expression* is not provided). `UpperCase` converts the *string-expression* to upper case. `AbsolutePath` returns the absolute path of a file. `DirName` returns the directory of a file. `Sprintf` is equivalent to the `sprintf` C function (where *string-expression* is a format string that can contain floating point formatting characters: `%e`, `%g`, etc.) The various *string-option*s are listed in Chapter 7 [Gmsh options], page 223. `GetEnvThe` gets the value of an environment variable from the operating system. `GetString` allows to get a ONELAB string value (the second optional argument is the default value returned if the variable does not exist). `GetStringValue` asks the user for a value interactively (the second argument is the value used in non-interactive mode). `StrReplace`'s arguments are: input string, old substring, new substring (brackets can be used instead of parentheses in `Str` and `Sprintf`). `Physical Point`, etc., or `Point`, etc., retrieve the name of the physical or elementary entity, if any. `NameToString` converts a variable name into a string.

`DefineString` allows to define a ONELAB variable in-line. The *string-expression* given as the first argument is the default value; this is followed by the various ONELAB options. See the ONELAB tutorial wiki for more information.

String expressions are mostly used to specify non-numeric options and input/output file names. See Section 2.8 [t8], page 33, for an interesting usage of *string-expression*s in an animation script.

List of string expressions are defined as:

string-expression-list:
  string-expression <,...>

5.1.4 Color expressions

Colors expressions are hybrids between fixed-length braced *expression-list*s and *string*s:

color-expression:
  string-expression |
  { *expression*, *expression*, *expression* } |
  { *expression*, *expression*, *expression*, *expression* } |
  color-option

The first case permits to use the X Windows names to refer to colors, e.g., `Red`, `SpringGreen`, `LavenderBlush3`, ... (see src/common/Colors.h in the source code for a complete list). The second case permits to define colors by using three expressions to specify their red, green and blue components (with values comprised between 0 and 255). The third case permits to define colors by using their red, green and blue color components as well as their alpha channel. The last case permits to use the value of a *color-option* as a *color-expression*. The various *color-option*s are listed in Chapter 7 [Gmsh options], page 223.

See Section 2.3 [t3], page 21, for an example of the use of color expressions.

5.1.5 Operators

Gmsh's operators are similar to the corresponding operators in C and C++. Here is the list of available unary, binary and ternary operators.

operator-unary-left:

- Unary minus.

`!` Logical not.

operator-unary-right:

`++` Post-incrementation.

`--` Post-decrementation.

operator-binary:

`^` Exponentiation.

`*` Multiplication.

`/` Division.

`%` Modulo.

`+` Addition.

`-` Subtraction.

`==` Equality.

`!=` Inequality.

`>` Greater.

`>=` Greater or equality.

`<` Less.

`<=` Less or equality.

`&&` Logical 'and'.

`||` Logical 'or'. (Warning: the logical 'or' always implies the evaluation of both arguments. That is, unlike in C or C++, the second operand of `||` is evaluated even if the first one is true).

operator-ternary-left:

`?`

operator-ternary-right:

`:` The only ternary operator, formed by *operator-ternary-left* and *operator-ternary-right*, returns the value of its second argument if the first argument is non-zero; otherwise it returns the value of its third argument.

The evaluation priorities are summarized below[1] (from stronger to weaker, i.e., `*` has a highest evaluation priority than `+`). Parentheses `()` may be used anywhere to change the order of evaluation:

1. `()`, `[]`, `.`, `#`
2. `^`
3. `!`, `++`, `--`, `-` (unary)
4. `*`, `/`, `%`
5. `+`, `-`
6. `<`, `>`, `<=`, `>=`
7. `==`, `!=`
8. `&&`
9. `||`
10. `?:`
11. `=`, `+=`, `-=`, `*=`, `/=`

[1] The affectation operators are introduced in Section 5.1.9 [Other general commands], page 99.

5.1.6 Built-in functions

A built-in function is composed of an identifier followed by a pair of parentheses containing an *expression-list*, the list of its arguments. This list of arguments can also be provided in between brackets, instead of parentheses. Here is the list of the built-in functions currently implemented:

build-in-function:

`Acos ( expression )`
: Arc cosine (inverse cosine) of an *expression* in [-1,1]. Returns a value in [0,Pi].

`Asin ( expression )`
: Arc sine (inverse sine) of an *expression* in [-1,1]. Returns a value in [-Pi/2,Pi/2].

`Atan ( expression )`
: Arc tangent (inverse tangent) of *expression*. Returns a value in [-Pi/2,Pi/2].

`Atan2 ( expression, expression )`
: Arc tangent (inverse tangent) of the first *expression* divided by the second. Returns a value in [-Pi,Pi].

`Ceil ( expression )`
: Rounds *expression* up to the nearest integer.

`Cos ( expression )`
: Cosine of *expression*.

`Cosh ( expression )`
: Hyperbolic cosine of *expression*.

`Exp ( expression )`
: Returns the value of e (the base of natural logarithms) raised to the power of *expression*.

`Fabs ( expression )`
: Absolute value of *expression*.

`Fmod ( expression, expression )`
: Remainder of the division of the first *expression* by the second, with the sign of the first.

`Floor ( expression )`
: Rounds *expression* down to the nearest integer.

`Hypot ( expression, expression )`
: Returns the square root of the sum of the square of its two arguments.

`Log ( expression )`
: Natural logarithm of *expression* (*expression* > 0).

`Log10 ( expression )`
: Base 10 logarithm of *expression* (*expression* > 0).

`Max ( expression, expression )`
: Maximum of the two arguments.

`Min ( expression, expression )`
: Minimum of the two arguments.

`Modulo ( expression, expression )`
: see `Fmod( expression, expression )`.

`Rand ( expression )`
: Random number between zero and *expression*.

`Round ( expression )`
: Rounds *expression* to the nearest integer.

`Sqrt ( expression )`
: Square root of *expression* (*expression* >= 0).

`Sin ( expression )`
: Sine of *expression*.

`Sinh ( expression )`
: Hyperbolic sine of *expression*.

`Tan ( expression )`
: Tangent of *expression*.

`Tanh ( expression )`
: Hyperbolic tangent of *expression*.

5.1.7 User-defined macros

User-defined macros take no arguments, and are evaluated as if a file containing the macro body was included at the location of the `Call` statement.

`Macro string | string-expression`
: Begin the declaration of a user-defined macro named *string*. The body of the macro starts on the line after '`Macro string`', and can contain any Gmsh command. A synonym for `Macro` is `Function`.

`Return`
: End the body of the current user-defined macro. Macro declarations cannot be imbricated.

`Call string | string-expression ;`
: Execute the body of a (previously defined) macro named *string*.

See Section 2.5 [t5], page 26, for an example of a user-defined macro. A shortcoming of Gmsh's scripting language is that all variables are "public". Variables defined inside the body of a macro will thus be available outside, too!

5.1.8 Loops and conditionals

Loops and conditionals are defined as follows, and can be imbricated:

`For ( expression : expression )`
: Iterate from the value of the first *expression* to the value of the second *expression*, with a unit incrementation step. At each iteration, the commands comprised between '`For ( expression : expression )`' and the matching `EndFor` are executed.

`For ( expression : expression : expression )`
: Iterate from the value of the first *expression* to the value of the second *expression*, with a positive or negative incrementation step equal to the third *expression*. At each iteration, the commands comprised between '`For ( expression : expression : expression )`' and the matching `EndFor` are executed.

`For string In { expression : expression }`
: Iterate from the value of the first *expression* to the value of the second *expression*, with a unit incrementation step. At each iteration, the value of the iterate is affected to an expression named *string*, and the commands comprised between '`For string In { expression : expression }`' and the matching `EndFor` are executed.

`For string In { expression : expression : expression }`
: Iterate from the value of the first *expression* to the value of the second *expression*, with a positive or negative incrementation step equal to the third *expression*. At

each iteration, the value of the iterate is affected to an expression named *string*, and the commands comprised between '`For` *string* `In {` *expression* `:` *expression* `:` *expression* `}`' and the matching `EndFor` are executed.

`EndFor` End a matching `For` command.

`If (` *expression* `)`
The body enclosed between '`If (` *expression* `)`' and the matching `ElseIf`, `Else` or `EndIf`, is evaluated if *expression* is non-zero.

`ElseIf (` *expression* `)`
The body enclosed between '`ElseIf (` *expression* `)`' and the next matching `ElseIf`, `Else` or `EndIf`, is evaluated if *expression* is non-zero and none of the *expression* of the previous matching codes `If` and `ElseIf` were non-zero.

`Else` The body enclosed between `Else` and the matching `EndIf` is evaluated if none of the *expression* of the previous matching codes `If` and `ElseIf` were non-zero.

`EndIf` End a matching `If` command.

5.1.9 Other general commands

The following commands can be used anywhere in a Gmsh script:

string `=` *expression* `;`
Create a new expression identifier *string*, or affects *expression* to an existing expression identifier. The following expression identifiers are predefined (hardcoded in Gmsh's parser):

`Pi` Return 3.1415926535897932.

`GMSH_MAJOR_VERSION`
Return Gmsh's major version number.

`GMSH_MINOR_VERSION`
Return Gmsh's minor version number.

`GMSH_PATCH_VERSION`
Return Gmsh's patch version number.

`MPI_Size` Return the number of processors on which Gmsh is running. It is always 1, except if you compiled Gmsh with `ENABLE_MPI` (see Appendix A [Compiling the source code], page 373).

`MPI_Rank` Return the rank of the current processor.

`Cpu` Return the current CPU time (in seconds).

`Memory` Return the current memory usage (in Mb).

`TotalMemory`
Return the total memory available (in Mb).

`newp` Return the next available point tag. As explained in Section 1.1 [Geometry module], page 7, a unique tag must be associated with every geometrical point: `newp` permits to know the highest tag already attributed (plus one). This is mostly useful when writing user-defined macros (see Section 5.1.7 [User-defined macros], page 98) or general geometric primitives, when one does not know *a priori* which tags are already attributed, and which ones are still available.

`newc` Return the next available curve tag.

`news` Return the next available surface tag.

`newv` Return the next available volume tag.

`newcl` Return the next available curve loop tag.

`newsl` Return the next available surface loop tag.

`newreg` Return the next available region tag. That is, `newreg` returns the maximum of `newp`, `newl`, `news`, `newv`, `newll`, `newsl` and all physical group tags[2].

string `= { };`
Create a new expression list identifier *string* with an empty list.

string `[] = {` *expression-list* `};`
Create a new expression list identifier *string* with the list *expression-list*, or affects *expression-list* to an existing expression list identifier. Parentheses are also allowed instead of square brackets; although not recommended, brackets and parentheses can also be completely ommitted.

string `[ {` *expression-list* `} ] = {` *expression-list* `};`
Affect each item in the right hand side *expression-list* to the elements (indexed by the left hand side *expression-list*) of an existing expression list identifier. The two *expression-list*s must contain the same number of items. Parentheses can also be used instead of brackets.

string `+=` *expression* `;`
Add and affect *expression* to an existing expression identifier.

string `-=` *expression* `;`
Subtract and affect *expression* to an existing expression identifier.

string `*=` *expression* `;`
Multiply and affect *expression* to an existing expression identifier.

string `/=` *expression* `;`
Divide and affect *expression* to an existing expression identifier.

string `+= {` *expression-list* `};`
Append *expression-list* to an existing expression list or creates a new expression list with *expression-list*.

string `-= {` *expression-list* `};`
Remove the items in *expression-list* from the existing expression list.

string `[ {` *expression-list* `} ] += {` *expression-list* `};`
Add and affect, item per item, the right hand side *expression-list* to an existing expression list identifier. Parentheses can also be used instead of brackets.

string `[ {` *expression-list* `} ] -= {` *expression-list* `};`
Subtract and affect, item per item, the right hand side *expression-list* to an existing expression list identifier. Parentheses can also be used instead of brackets.

string `[ {` *expression-list* `} ] *= {` *expression-list* `};`
Multiply and affect, item per item, the right hand side *expression-list* to an existing expression list identifier. Parentheses can also be used instead of brackets.

[2] For compatibility purposes, the behavior of `newl`, `news`, `newv` and `newreg` can be modified with the `Geometry.OldNewReg` option (see Section 7.3 [Geometry options], page 250).

string [{ *expression-list* }] /= { *expression-list* };
: Divide and affect, item per item, the right hand side *expression-list* to an existing expression list identifier. Parentheses can also be used instead of brackets.

string = *string-expression*;
: Create a new string expression identifier *string* with a given *string-expression*.

string[] = Str(*string-expression-list*) ;
: Create a new string expression list identifier *string* with a given *string-expression-list*. Parentheses can also be used instead of brackets.

string[] += Str(*string-expression-list*) ;
: Append a string expression list to an existing list. Parentheses can also be used instead of brackets.

DefineConstant[*string* = *expression*|*string-expression* <, ...>];
: Create a new expression identifier *string*, with value *expression*, only if has not been defined before.

DefineConstant[*string* = { *expression*|*string-expression*, *onelab-options* } <, ...>];
: Same as the previous case, except that the variable is also exchanged with the ONELAB database if it has not been defined before. See the ONELAB tutorial wiki for more information.

SetNumber(*string-expression* , *expression*);
: Set the value a numeric ONELAB variable *string-expression*.

SetString(*string-expression* , *string-expression*);
: Set the value a string ONELAB variable *string-expression*.

number-option = *expression*;
: Affect *expression* to a real option.

string-option = *string-expression*;
: Affect *string-expression* to a string option.

color-option = *color-expression*;
: Affect *color-expression* to a color option.

number-option += *expression*;
: Add and affect *expression* to a real option.

number-option -= *expression*;
: Subtract and affect *expression* to a real option.

number-option *= *expression*;
: Multiply and affect *expression* to a real option.

number-option /= *expression*;
: Divide and affect *expression* to a real option.

Abort;
: Abort the current script.

Exit < *expression* >;
: Exit Gmsh (optionally with level *expression* instead of 0).

CreateDir *string-expression*;
: Create the directory *string-expression*.

Printf (*string-expression* <, *expression-list*>);
: Print a string expression in the information window and/or on the terminal. `Printf` is equivalent to the `printf` C function: *string-expression* is a format string that can

contain formatting characters (`%f`, `%e`, etc.). Note that all *expression*s are evaluated as floating point values in Gmsh (see Section 5.1.2 [Floating point expressions], page 91), so that only valid floating point formatting characters make sense in *string-expression*. See Section 2.5 [t5], page 26, for an example of the use of `Printf`.

`Printf ( `*`string-expression`*` , `*`expression-list`*` ) > `*`string-expression`*`;`
Same as `Printf` above, but output the expression in a file.

`Printf ( `*`string-expression`*` , `*`expression-list`*` ) >> `*`string-expression`*`;`
Same as `Printf` above, but appends the expression at the end of the file.

`Warning|Error ( `*`string-expression`*` <, `*`expression-list`*`> );`
Same as `Printf`, but raises a warning or an error.

`Merge `*`string-expression`*`;`
Merge a file named *string-expression*. This command is equivalent to the 'File->Merge' menu in the GUI. If the path in *string-expression* is not absolute, *string-expression* is appended to the path of the current file. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`ShapeFromFile( `*`string-expression`*` );`
Merge a BREP, STEP or IGES file and returns the tags of the highest-dimensional entities. Only available with the OpenCASCADE geometry kernel.

`Draw;` Redraw the scene.

`SplitCurrentWindowHorizontal `*`expression`*`;`
Split the current window horizontally, with the ratio given by *expression*.

`SplitCurrentWindowVertical `*`expression`*`;`
Split the current window vertically, with the ratio given by *expression*.

`SetCurrentWindow `*`expression`*`;`
Set the current window by speficying its index (starting at 0) in the list of all windows. When new windows are created by splits, new windows are appended at the end of the list.

`UnsplitWindow;`
Restore a single window.

`SetChanged;`
Force the mesh and post-processing vertex arrays to be regenerated. Useful e.g. for creating animations with changing clipping planes, etc.

`BoundingBox;`
Recompute the bounding box of the scene (which is normally computed only after new model entities are added or after files are included or merged). The bounding box is computed as follows:

1. If there is a mesh (i.e., at least one mesh node), the bounding box is taken as the box enclosing all the mesh nodes;
2. If there is no mesh but there is a geometry (i.e., at least one geometrical point), the bounding box is taken as the box enclosing all the geometrical points;
3. If there is no mesh and no geometry, but there are some post-processing views, the bounding box is taken as the box enclosing all the primitives in the views.

This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`BoundingBox { expression, expression, expression, expression, expression, expression };`
: Force the bounding box of the scene to the given *expression*s (X min, X max, Y min, Y max, Z min, Z max). Beware that order of the coordinates is different than in the `BoundingBox` commands for model entities: see Section 5.1.2 [Floating point expressions], page 91.

`Delete Model;`
: Delete the current model (all model entities and their associated meshes).

`Delete Meshes;`
: Delete all the meshes in the current model.

`Delete Physicals;`
: Delete all physical groups.

`Delete Variables;`
: Delete all the expressions.

`Delete Options;`
: Delete the current options and revert to the default values.

`Delete string;`
: Delete the expression *string*.

`Print string-expression;`
: Print the graphic window in a file named *string-expression*, using the current `Print.Format` (see Section 7.1 [General options], page 223). If the path in *string-expression* is not absolute, *string-expression* is appended to the path of the current file. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Sleep expression;`
: Suspend the execution of Gmsh during *expression* seconds.

`SystemCall string-expression;`
: Executes a (blocking) system call.

`NonBlockingSystemCall string-expression;`
: Execute a (non-blocking) system call.

`OnelabRun ( string-expression <, string-expression > )`
: Run a ONELAB client (first argument is the client name, second optional argument is the command line).

`SetName string-expression;`
: Change the name of the current model.

`SetFactory(string-expression);`
: Change the current geometry kernel (i.e. determines the CAD kernel that is used for all subsequent geometrical commands). Currently available kernels: `"Built-in"` and `"OpenCASCADE"`.

`SyncModel;`
: Force an immediate transfer from the old geometrical database into the new one (this transfer normally occurs right after a file is read).

`NewModel;`
: Create a new current model.

`Include` *`string-expression`* `;`
: Include the file named *string-expression* at the current position in the input file. The include command should be given on a line of its own. If the path in *string-expression* is not absolute, *string-expression* is appended to the path of the current file.

5.2 Geometry scripting commands

Both the built-in and the OpenCASCADE CAD kernels can be used in the scripting language, by specifying `SetFactory("Built-in")` or `SetFactory("OpenCASCADE")`, respectively, before geometrical scripting commands. If `SetFactory` is not specified, the built-in kernel is used.

A bottom-up boundary representation approach can be used by first defining points (using the `Point` command), then curves (using `Line`, `Circle`, `Spline`, ..., commands or by extruding points), then surfaces (using for example the `Plane Surface` or `Surface` commands, or by extruding curves), and finally volumes (using the `Volume` command or by extruding surfaces). Entities can then be manipulated in various ways, for example using the `Translate`, `Rotate`, `Scale` or `Symmetry` commands. They can be deleted with the `Delete` command, provided that no higher-dimension entity references them. With the OpenCASCADE kernel, additional boolean operations are available: `BooleanIntersection`, `BooleanUnion`, `BooleanDifference` and `BooleanFragments`.

The next subsections describe all the available geometry commands in the scripting language. Note that the following general rule is followed for the definition of model entities: if an *expression* defines a new entity, it is enclosed between parentheses. If an *expression* refers to a previously defined entity, it is enclosed between braces.

5.2.1 Points

`Point ( ` *`expression`* ` ) = { ` *`expression`*`, ` *`expression`*`, ` *`expression`* ` <, ` *`expression`* ` > };`
: Create a point. The *expression* inside the parentheses is the point's tag; the three first *expression*s inside the braces on the right hand side give the three X, Y and Z coordinates of the point in the three-dimensional Euclidean space; the optional last *expression* sets the prescribed mesh element size at that point. See Section 1.2.2 [Specifying mesh element sizes], page 10, for more information about how this value is used in the meshing process.

`Physical Point ( ` *`expression`* ` | ` *`string-expression`* ` <, ` *`expression`*`> ) <+|->= { ` *`expression-list`* ` };`
: Create a physical point. The *expression* inside the parentheses is the physical point's tag; the *expression-list* on the right hand side should contain the tags of all the elementary points that need to be grouped inside the physical point. If a *string-expression* is given instead instead of *expression* inside the parentheses, a string label is associated with the physical tag, which can be either provided explicitly (after the comma) or not (in which case a unique tag is automatically created).

5.2.2 Curves

`Line ( ` *`expression`* ` ) = { ` *`expression`*`, ` *`expression`* ` };`
: Create a straight line segment. The *expression* inside the parentheses is the line segment's tag; the two *expression*s inside the braces on the right hand side give tags of the start and end points of the segment.

`Bezier ( ` *`expression`* ` ) = { ` *`expression-list`* ` };`
: Create a Bezier curve. The *expression-list* contains the tags of the control points.

`BSpline ( expression ) = { expression-list };`
: Create a cubic BSpline. The *expression-list* contains the tags of the control points. Creates a periodic curve if the first and last points are identical.

`Spline ( expression ) = { expression-list };`
: Create a spline going through the points in *expression-list*. With the built-in geometry kernel this constructs a Catmull-Rom spline. With the OpenCASCADE kernel, this constructs a C2 BSpline. Creates a periodic curve if the first and last points are identical.

`Circle ( expression ) = { expression, expression, expression <, ...> };`
: Create a circle arc. If three *expression*s are provided on the right-hand-side they define the start point, the center and the end point of the arc. With the built-in geometry kernel the arc should be strictly smaller than Pi. With the OpenCASCADE kernel, if between 4 and 6 expressions are provided, the first three define the coordinates of the center, the next one defines the radius, and the optional next two the start and end angle.

`Ellipse ( expression ) = { expression, expression, expression <, ...> };`
: Create an ellipse arc. If four *expression*s are provided on the right-hand-side they define the start point, the center point, a point anywhere on the major axis and the end point. If the first point is a major axis point, the third expression can be ommitted. With the OpenCASCADE kernel, if between 5 and 7 expressions are provided, the first three define the coordinates of the center, the next two define the major (along the x-axis) and minor radii (along the y-axis), and the next two the start and end angle. Note that OpenCASCADE does not allow creating ellipse arcs with the major radius smaller than the minor radius.

`Compound Spline | BSpline ( expression ) = { expression-list } Using expression;`
: Create a spline or a BSpline from control points sampled on the curves in *expression-list*. `Using` *expression* specifies the number of intervals on each curve to compute the sampling points. Compound splines and BSplines are only available with the built-in geometry kernel.

`Curve Loop ( expression ) = { expression-list };`
: Create an oriented loop of curves, i.e. a closed wire. The *expression* inside the parentheses is the curve loop's tag; the *expression-list* on the right hand side should contain the tags of all the curves that constitute the curve loop. A curve loop must be a closed loop. With the built-in geometry kernel, the curves should be ordered and oriented, using negative tags to specify reverse orientation. (If the orientation is correct, but the ordering is wrong, Gmsh will actually reorder the list internally to create a consistent loop; the built-in kernel also supports multiple curve loops (or subloops) in a single `Curve Loop` command, but this is not recommended). With the OpenCASCADE kernel the curve loop is always oriented according to the orientation of its first curve; negative tags can be specified for compatibility with the built-in kernel, but are simply ignored. Curve loops are used to create surfaces: see Section 5.2.3 [Surfaces], page 106.

`Wire ( expression ) = { expression-list };`
: Create a path made of curves. Wires are only available with the OpenCASCADE kernel. They are used to create `ThruSections` and extrusions along paths.

`Physical Curve ( expression | string-expression <, expression> ) <+|->= { expression-list };`
: Create a physical curve. The *expression* inside the parentheses is the physical curve's tag; the *expression-list* on the right hand side should contain the tags of all the

elementary curves that need to be grouped inside the physical curve. If a *string-expression* is given instead instead of *expression* inside the parentheses, a string label is associated with the physical tag, which can be either provided explicitly (after the comma) or not (in which case a unique tag is automatically created). In some mesh file formats (e.g. MSH2), specifying negative tags in the *expression-list* will reverse the orientation of the mesh elements belonging to the corresponding elementary curves in the saved mesh file.

5.2.3 Surfaces

`Plane Surface ( expression ) = { expression-list };`
Create a plane surface. The *expression* inside the parentheses is the plane surface's tag; the *expression-list* on the right hand side should contain the tags of all the curve loops defining the surface. The first curve loop defines the exterior boundary of the surface; all other curve loops define holes in the surface. A curve loop defining a hole should not have any curves in common with the exterior curve loop (in which case it is not a hole, and the two surfaces should be defined separately). Likewise, a curve loop defining a hole should not have any curves in common with another curve loop defining a hole in the same surface (in which case the two curve loops should be combined).

`Surface ( expression ) = { expression-list } < In Sphere { expression }, Using Point { expression-list } >;`
Create a surface filling. With the built-in kernel, the first curve loop should be composed of either three or four curves, the surface is constructed using transfinite interpolation, and the optional `In Sphere` argument forces the surface to be a spherical patch (the extra parameter gives the tag of the center of the sphere). With the OpenCASCADE kernel, a BSpline surface is constructucted by optimization to match the bounding curves, as well as the (optional) points provided after `Using Point`.

`BSpline Surface ( expression ) = { expression-list };`
Create a BSpline surface filling. Only a single curve loop made of 2, 3 or 4 BSpline curves can be provided. `BSpline Surface` is only available with the OpenCASCADE kernel.

`Bezier Surface ( expression ) = { expression-list };`
Create a Bezier surface filling. Only a single curve loop made of 2, 3 or 4 Bezier curves can be provided. `Bezier Surface` is only available with the OpenCASCADE kernel.

`Disk ( expression ) = { expression-list };`
Creates a disk. When four expressions are provided on the right hand side (3 coordinates of the center and the radius), the disk is circular. A fifth expression defines the radius along Y, leading to an ellipse. `Disk` is only available with the OpenCASCADE kernel.

`Rectangle ( expression ) = { expression-list };`
Create a rectangle. The 3 first expressions define the lower-left corner; the next 2 define the width and height. If a 6th expression is provided, it defines a radius to round the rectangle corners. `Rectangle` is only available with the OpenCASCADE kernel.

`Surface Loop ( expression ) = { expression-list } < Using Sewing >;`
Create a surface loop (a shell). The *expression* inside the parentheses is the surface loop's tag; the *expression-list* on the right hand side should contain the tags

of all the surfaces that constitute the surface loop. A surface loop must always represent a closed shell, and the surfaces should be oriented consistently (using negative tags to specify reverse orientation). (Surface loops are used to create volumes: see Section 5.2.4 [Volumes], page 107.) With the OpenCASCADE kernel, the optional `Using Sewing` argument allows to build a shell made of surfaces that share geometrically identical (but topologically different) curves.

`Physical Surface ( `*expression* `|` *string-expression* `<,` *expression*`> ) <+|->= {` *expression-list* `};`

Create a physical surface. The *expression* inside the parentheses is the physical surface's tag; the *expression-list* on the right hand side should contain the tags of all the elementary surfaces that need to be grouped inside the physical surface. If a *string-expression* is given instead instead of *expression* inside the parentheses, a string label is associated with the physical tag, which can be either provided explicitly (after the comma) or not (in which case a unique tag is automatically created). In some mesh file formats (e.g. MSH2), specifying negative tags in the *expression-list* will reverse the orientation of the mesh elements belonging to the corresponding elementary surfaces in the saved mesh file.

5.2.4 Volumes

`Volume ( `*expression* `) = { `*expression-list* `};`

Create a volume. The *expression* inside the parentheses is the volume's tag; the *expression-list* on the right hand side should contain the tags of all the surface loops defining the volume. The first surface loop defines the exterior boundary of the volume; all other surface loops define holes in the volume. A surface loop defining a hole should not have any surfaces in common with the exterior surface loop (in which case it is not a hole, and the two volumes should be defined separately). Likewise, a surface loop defining a hole should not have any surfaces in common with another surface loop defining a hole in the same volume (in which case the two surface loops should be combined).

`Sphere ( `*expression* `) = { `*expression-list* `};`

Create a sphere, defined by the 3 coordinates of its center and a radius. Additional expressions define 3 angle limits. The first two optional arguments define the polar angle opening (from -Pi/2 to Pi/2). The optional 'angle3' argument defines the azimuthal opening (from 0 to 2*Pi). `Sphere` is only available with the OpenCASCADE kernel.

`Box ( `*expression* `) = { `*expression-list* `};`

Create a box, defined by the 3 coordinates of a point and the 3 extents. `Box` is only available with the OpenCASCADE kernel.

`Cylinder ( `*expression* `) = { `*expression-list* `};`

Create a cylinder, defined by the 3 coordinates of the center of the first circular face, the 3 components of the vector defining its axis and its radius. An additional expression defines the angular opening. `Cylinder` is only available with the OpenCASCADE kernel.

`Torus ( `*expression* `) = { `*expression-list* `};`

Create a torus, defined by the 3 coordinates of its center and 2 radii. An additional expression defines the angular opening. `Torus` is only available with the OpenCASCADE kernel.

`Cone ( `*expression* `) = { `*expression-list* `};`

Create a cone, defined by the 3 coordinates of the center of the first circular face, the 3 components of the vector defining its axis and the two radii of the faces (these

radii can be zero). An additional expression defines the angular opening. `Cone` is only available with the OpenCASCADE kernel.

`Wedge ( expression ) = { expression-list };`
Create a right angular wedge, defined by the 3 coordinates of the right-angle point and the 3 extends. An additional parameter defines the top X extent (zero by default). `Wedge` is only available with the OpenCASCADE kernel.

`ThruSections ( expression ) = { expression-list };`
Create a volume defined through curve loops. `ThruSections` is only available with the OpenCASCADE kernel.

`Ruled ThruSections ( expression ) = { expression-list };`
Same as `ThruSections`, but the surfaces created on the boundary are forced to be ruled. `Ruled ThruSections` is only available with the OpenCASCADE kernel.

`Physical Volume ( expression | string-expression <, expression> ) <+|->= { expression-list };`
Create a physical volume. The *expression* inside the parentheses is the physical volume's tag; the *expression-list* on the right hand side should contain the tags of all the elementary volumes that need to be grouped inside the physical volume. If a *string-expression* is given instead instead of *expression* inside the parentheses, a string label is associated with the physical tag, which can be either provided explicitly (after the comma) or not (in which case a unique tag is automatically created).

5.2.5 Extrusions

Curves, surfaces and volumes can also be created through extrusion of points, curves and surfaces, respectively. Here is the syntax of the geometrical extrusion commands (go to Section 5.3.2 [Structured grids], page 113, to see how these commands can be extended in order to also extrude the mesh):

extrude:

`Extrude { expression-list } { extrude-list }`
Extrude all elementary entities (points, curves or surfaces) in *extrude-list* using a translation. The *expression-list* should contain three *expression*s giving the X, Y and Z components of the translation vector.

`Extrude { { expression-list }, { expression-list }, expression } { extrude-list }`
Extrude all elementary entities (points, curves or surfaces) in *extrude-list* using a rotation. The first *expression-list* should contain three *expression*s giving the X, Y and Z direction of the rotation axis; the second *expression-list* should contain three *expression*s giving the X, Y and Z components of any point on this axis; the last *expression* should contain the rotation angle (in radians). With the built-in geometry kernel the angle should be strictly smaller than Pi.

`Extrude { { expression-list }, { expression-list }, { expression-list }, expression } { extrude-list }`
Extrude all elementary entities (points, curves or surfaces) in *extrude-list* using a translation combined with a rotation (to produce a "twist"). The first *expression-list* should contain three *expression*s giving the X, Y and Z components of the translation vector; the second *expression-list* should contain three *expression*s giving the X, Y and Z direction of the rotation axis, which should match the direction of the translation; the third *expression-list* should contain three *expression*s giving the X, Y and Z components of any point on this axis; the last *expression* should contain

the rotation angle (in radians). With the built-in geometry kernel the angle should be strictly smaller than Pi.

`Extrude { `*`extrude-list`*` }`
: Extrude entities in *extrude-list* using a translation along their normal. Only available with the built-in geometry kernel.

`Extrude { `*`extrude-list`*` } Using Wire { `*`expression-list`*` }`
: Extrude entities in *extrude-list* along the give wire. Only available with the OpenCASCADE geometry kernel.

`ThruSections { `*`expression-list`*` }`
: Create surfaces through the given curve loops or wires. `ThruSections` is only available with the OpenCASCADE kernel.

`Ruled ThruSections { `*`expression-list`*` }`
: Create ruled surfaces through the given curve loops or wires. `Ruled ThruSections` is only available with the OpenCASCADE kernel.

`Fillet { `*`expression-list`*` } { `*`expression-list`*` } { `*`expression-list`*` }`
: Fillet volumes (first list) on some curves (second list), using the provided radii (third list). The radius list can either contain a single radius, as many radii as curves, or twice as many as curves (in which case different radii are provided for the begin and end points of the curves). `Fillet` is only available with the OpenCASCADE kernel.

`Chamfer { `*`expression-list`*` } { `*`expression-list`*` } { `*`expression-list`*` } { `*`expression-list`*` }`
: Chamfer volumes (first list) on some curves (second list), using the provided distance (fourth list) measured on the given surfaces (third list). The distance list can either contain a single distance, as many distances as curves, or twice as many as curves (in which case the first in each pair is measured on the given corresponding surface). `Chamfer` is only available with the OpenCASCADE kernel.

with

`extrude-list``:`
  `<Physical> Point | Curve | Surface { `*`expression-list-or-all`*` }; ...`

As explained in Section 5.1.2 [Floating point expressions], page 91, *extrude* can be used in an expression, in which case it returns a list of tags. By default, the list contains the "top" of the extruded entity at index 0 and the extruded entity at index 1, followed by the "sides" of the extruded entity at indices 2, 3, etc. For example:

```
Point(1) = {0,0,0};
Point(2) = {1,0,0};
Line(1) = {1, 2};
out[] = Extrude{0,1,0}{ Curve{1}; };
Printf("top curve = %g", out[0]);
Printf("surface = %g", out[1]);
Printf("side curves = %g and %g", out[2], out[3]);
```

This behaviour can be changed with the `Geometry.ExtrudeReturnLateralEntities` option (see Section 7.3 [Geometry options], page 250).

5.2.6 Boolean operations

Boolean operations can be applied on curves, surfaces and volumes. All boolean operation act on two lists of elementary entities. The first list represents the object; the second represents the tool. The general syntax for boolean operations is as follows:

boolean:

`BooleanIntersection { boolean-list } { boolean-list }`
: Compute the intersection of the object and the tool.

`BooleanUnion { boolean-list } { boolean-list }`
: Compute the union of the object and the tool.

`BooleanDifference { boolean-list } { boolean-list }`
: Subtract the tool from the object.

`BooleanFragments { boolean-list } { boolean-list }`
: Compute all the fragments resulting from the intersection of the entities in the object and in the tool, making all interfaces conformal. When applied to entities of different dimensions, the lower dimensional entities will be automatically embedded in the higher dimensional entities if they are not on their boundary.

with

boolean-list:
`<Physical> Curve | Surface | Volume { expression-list-or-all }; ... |`
`Delete ;`

If `Delete` is specified in the *boolean-list*, the tool and/or the object is deleted.

As explained in Section 5.1.2 [Floating point expressions], page 91, *boolean* can be used in an expression, in which case it returns the list of tags of the highest dimensional entities created by the boolean operation. See examples/boolean for examples.

An alternative syntax exists for boolean operations, which can be used when it is known beforehand that the operation will result in a single (highest-dimensional) entity:

boolean-explicit:

`BooleanIntersection ( expression ) = { boolean-list } { boolean-list };`
: Compute the intersection of the object and the tool and assign the result the tag *expression*.

`BooleanUnion ( expression ) = { boolean-list } { boolean-list };`
: Compute the union of the object and the tool and assign the result the tag *expression*.

`BooleanDifference ( expression ) = { boolean-list } { boolean-list };`
: Subtract the tool from the object and assign the result the tag *expression*.

Again, see examples/boolean for examples.

Boolean operations are only available with the OpenCASCADE geometry kernel.

5.2.7 Transformations

Geometrical transformations can be applied to elementary entities, or to copies of elementary entities (using the `Duplicata` command: see below). The syntax of the transformation commands is:

transform:

`Dilate { { expression-list }, expression } { transform-list }`
: Scale all elementary entities in *transform-list* by a factor *expression*. The *expression-list* should contain three *expression*s giving the X, Y, and Z coordinates of the center of the homothetic transformation.

`Dilate { { expression-list }, { expression, expression, expression } } { transform-list }`
: Scale all elementary entities in *transform-list* using different factors along X, Y and Z (the three *expression*s). The *expression-list* should contain three *expression*s giving the X, Y, and Z coordinates of the center of the homothetic transformation.

`Rotate { { expression-list }, { expression-list }, expression } { transform-list }`
Rotate all elementary entities in *transform-list* by an angle of *expression* radians. The first *expression-list* should contain three *expression*s giving the X, Y and Z direction of the rotation axis; the second *expression-list* should contain three *expression*s giving the X, Y and Z components of any point on this axis.

`Symmetry { expression-list } { transform-list }`
Transform all elementary entities symmetrically to a plane. The *expression-list* should contain four *expression*s giving the coefficients of the plane's equation.

`Affine { expression-list } { transform-list }`
Apply a 4 x 4 affine transformation matrix (16 entries given by row; only 12 can be provided for convenience) to all elementary entities. Currently only available with the OpenCASCADE kernel.

`Translate { expression-list } { transform-list }`
Translate all elementary entities in *transform-list*. The *expression-list* should contain three *expression*s giving the X, Y and Z components of the translation vector.

`Boundary { transform-list }`
(Not a transformation per-se.) Return the entities on the boundary of the elementary entities in *transform-list*, with signs indicating their orientation in the boundary. To get unsigned tags (e.g. to reuse the output in other commands), apply the `Abs` function on the returned list. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`CombinedBoundary { transform-list }`
(Not a transformation per-se.) Return the boundary of the elementary entities, combined as if a single entity, in *transform-list*. Useful to compute the boundary of a complex part. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`PointsOf { transform-list }`
(Not a transformation per-se.) Return all the geometrical points on the boundary of the elementary entities. Useful to compute the boundary of a complex part. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Intersect Curve { expression-list } Surface { expression }`
(Not a transformation per-se.) Return the intersections of the curves given in *expression-list* with the specified surface. Currently only available with the built-in kernel.

`Split Curve { expression } Point { expression-list }`
(Not a transformation per-se.) Split the curve *expression* on the specified control points. Only available with the built-in kernel, for lines, splines and BSplines.

with

```
transform-list:
  <Physical> Point | Curve | Surface | Volume
    { expression-list-or-all }; ... |
  Duplicata { <Physical> Point | Curve | Surface | Volume
    { expression-list-or-all }; ... } |
  transform
```

5.2.8 Other geometry commands

Here is a list of all other geometry commands currently available:

`Coherence;`
: Remove all duplicate elementary entities (e.g., points having identical coordinates). Note that with the built-in geometry kernel Gmsh executes the `Coherence` command automatically after each geometrical transformation, unless `Geometry.AutoCoherence` is set to zero (see Section 7.3 [Geometry options], page 250). With the OpenCASCADE geometry kernel, `Coherence` is simply a shortcut for a `BooleanFragments` operation on all entities, with the `Delete` operator applied to all operands.

`HealShapes;`
: Apply the shape healing procedure(s), according to `Geometry.OCCFixDegenerated`, `Geometry.OCCFixSmallEdges`, `Geometry.OCCFixSmallFaces`, `Geometry.OCCSewFaces`, `Geometry.OCCMakeSolids`. Only available with the OpenCASCADE geometry kernel.

`< Recursive > Delete { <Physical> Point | Curve | Surface | Volume {` *`expression-list-or-all`* `}; ... }`
: Delete all elementary entities whose tags are given in *expression-list-or-all*. If an entity is linked to another entity (for example, if a point is used as a control point of a curve), `Delete` has no effect (the curve will have to be deleted before the point can). The `Recursive` variant deletes the entities as well as all its sub-entities of lower dimension. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Delete Embedded { <Physical> Point | Curve | Surface | Volume {` *`expression-list-or-all`* `}; ... }`
: Delete all the embedded entities in the elementary entities whose tags are given in *expression-list-or-all*. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`SetMaxTag Point | Curve | Surface | Volume ( ` *`expression`* ` )`
: Force the maximum tag for a category of entities to a given value, so that subsequently created entities in the same category will not have tags smaller than the given value.

`< Recursive > Hide { <Physical> Point | Curve | Surface | Volume {` *`expression-list-or-all`* `}; ... }`
: Hide the entities listed in *expression-list-or-all*.

`Hide { : }`
: Hide all entities.

`< Recursive > Show { <Physical> Point | Curve | Surface | Volume {` *`expression-list-or-all`* `}; ... }`
: Show the entities listed in *expression-list-or-all*.

`Show { : }`
: Show all entities.

`Sphere | PolarSphere ( ` *`expression`* ` ) = {`*`expression, expression`*`};`
: Change the current (surface) geometry used by the built-in geometry kernel to a (polar) sphere, defined by the two point tags specified on the right hand side. The *expression* between parentheses on the left hand side specifies a new unique tag for this geometry.

`Parametric Surface ( ` *`expression`* ` ) = "`*`string`*`" "`*`string`*`" "`*`string`*`";`
: Change the current (surface) geometry used by the built-in geometry kernel to a parametric surface defined by the three strings expression evaluating to the x, y and

z coordinates. The *expression* between parentheses on the left hand side specifies a new unique tag for this geometry.

`Coordinates Surface` *expression* `;`
: Change the current (surface) geometry used by the built-in geometry kernel to the geometry identified by the given *expression*.

`Euclidian Coordinates ;`
: Restore the default planar geometry for the built-in geometry kernel.

5.3 Mesh scripting commands

The mesh module scripting commands allow to modify the mesh element sizes and specify structured grid parameters. Certain meshing actions (e.g. "mesh all the surfaces") can also be specified in the script files, but are usually performed either in the GUI or on the command line (see Chapter 3 [Gmsh graphical user interface], page 79, and Chapter 4 [Gmsh command-line interface], page 85).

5.3.1 Mesh element sizes

Here are the mesh commands that are related to the specification of mesh element sizes:

`MeshSize { ` *expression-list* ` } = ` *expression* `;`
: Modify the prescribed mesh element size of the points whose tags are listed in *expression-list*. The new value is given by *expression*.

`Field[` *expression* `] = ` *string* `;`
: Create a new field (with tag *expression*), of type *string*.

`Field[` *expression* `].` *string* `=` *string-expression* ` | ` *expression* ` | ` *expression-list* `;`
: Set the option *string* of the *expression*-th field.

`Background Field = ` *expression* `;`
: Select the *expression*-th field as the one used to compute element sizes. Only one background field can be given; if you want to combine several field, use the `Min` or `Max` field (see below).

5.3.2 Structured grids

`Extrude { ` *expression-list* ` } { ` *extrude-list layers* ` }`
: Extrude both the geometry and the mesh using a translation (see Section 5.2.5 [Extrusions], page 108). The *layers* option determines how the mesh is extruded and has the following syntax:

```
layers:
  Layers { expression } |
  Layers { { expression-list }, { expression-list } } |
  Recombine < expression >; ...
  QuadTriNoNewVerts <RecombLaterals>; |
  QuadTriAddVerts <RecombLaterals>; ...
```

In the first `Layers` form, *expression* gives the number of elements to be created in the (single) layer. In the second form, the first *expression-list* defines how many elements should be created in each extruded layer, and the second *expression-list* gives the normalized height of each layer (the list should contain a sequence of *n* numbers 0 < *h1* < *h2* < . . . < *hn* <= 1). See Section 2.3 [t3], page 21, for an example.

For curve extrusions, the `Recombine` option will recombine triangles into quadrangles when possible. For surface extrusions, the `Recombine` option will recombine tetrahedra into prisms, hexahedra or pyramids.

Please note that, starting with Gmsh 2.0, region tags cannot be specified explicitly anymore in `Layers` commands. Instead, as with all other geometry commands, you must use the automatically created entity identifier created by the extrusion command. For example, the following extrusion command will return the tag of the new "top" surface in `num[0]` and the tag of the new volume in `num[1]`:

```
num[] = Extrude {0,0,1} { Surface{1}; Layers{10}; };
```

`QuadTriNoNewVerts` and `QuadTriAddVerts` allow to connect structured, extruded volumes containing quadrangle-faced elements to structured or unstructured tetrahedral volumes, by subdividing into triangles any quadrangles on boundary surfaces shared with tetrahedral volumes. (They have no effect for 1D or 2D extrusions.) `QuadTriNoNewVerts` subdivides any of the region's quad-faced 3D elements that touch these boundary triangles into pyramids, prisms, or tetrahedra as necessary, all without adding new nodes. `QuadTriAddVerts` works in a similar way, but subdivides 3D elements touching the boundary triangles by adding a new node inside each element at the node-based centroid. Either method results in a structured extrusion with an outer layer of subdivided elements that interface the inner, unmodified elements to the triangle-meshed region boundaries.

In some rare cases, due to certain lateral boundary conditions, it may not be possible make a valid element subdivision with `QuadTriNoNewVerts` without adding additional nodes. In this case, an internal node is created at the node-based centroid of the element. The element is then divided using that node. When an internal node is created with `QuadTriNoNewVerts`, the user is alerted by a warning message sent for each instance; however, the mesh will still be valid and conformal.

Both `QuadTriNoNewVerts` and `QuadTriAddVerts` can be used with the optional `RecombLaterals` keyword. By default, the QuadTri algorithms will mesh any free laterals as triangles, if possible. `RecombLaterals` forces any free laterals to remain as quadrangles, if possible. Lateral surfaces between two QuadTri regions will always be meshed as quadrangles.

Note that the QuadTri algorithms will handle all potential meshing conflicts along the lateral surfaces of the extrusion. In other words, QuadTri will not subdivide a lateral that must remain as quadrangles, nor will it leave a lateral as quadrangles if it *must* be divided. The user should therefore feel free to mix different types of neighboring regions with a QuadTri meshed region; the mesh should work. However, be aware that the top surface of the QuadTri extrusion will always be meshed as triangles, unless it is extruded back onto the original source in a toroidal loop (a case which also works with QuadTri).

`QuadTriNoNewVerts` and `QuadTriAddVerts` may be used interchangeably, but `QuadTriAddVerts` often gives better element quality.

If the user wishes to interface a structured extrusion to a tetrahedral volume without modifying the original structured mesh, the user may create dedicated interface volumes around the structured geometry and apply a QuadTri algorithm to those volumes only.

`Extrude { { `*`expression-list`*` }, { `*`expression-list`*` }, `*`expression`*` } { `*`extrude-list layers`*` }`

Extrude both the geometry and the mesh using a rotation (see Section 5.2.5 [Extrusions], page 108). The *layers* option is defined as above. With the built-in geometry kernel the angle should be strictly smaller than Pi. With the OpenCASCADE kernel the angle should be strictly smaller than 2 Pi.

`Extrude { { expression-list }, { expression-list }, { expression-list }, expression } { extrude-list layers }`

Extrude both the geometry and the mesh using a combined translation and rotation (see Section 5.2.5 [Extrusions], page 108). The *layers* option is defined as above. With the built-in geometry kernel the angle should be strictly smaller than Pi. With the OpenCASCADE kernel the angle should be strictly smaller than 2 Pi.

`Extrude { Surface { expression-list }; layers < Using Index[expr]; > < Using View[expr]; > < ScaleLastLayer; > }`

Extrude a "topological" boundary layer from the specified surfaces. If no view is specified, the mesh of the boundary layer entities is created using a gouraud-shaded (smoothed) normal field. If a scalar view is specified, it locally prescribes the thickness of the layer. If a vector-valued view is specified it locally prescribes both the extrusion direction and the thickness. Specifying a boundary layer index allows to extrude several independent boundary layers (with independent normal smoothing). `ScaleLastLayer` scales the height of the last (top) layer of each normal's extrusion by the average length of the edges in all the source elements that contain the source node (actually, the average of the averages for each element–edges actually touching the source node are counted twice). This allows the height of the last layer to vary along with the size of the source elements in order to achieve better element quality. For example, in a boundary layer extruded with the Layers definition 'Layers{ {1,4,2}, {0.5, 0.6, 1.6} },' a source node adjacent to elements with an overall average edge length of 5.0 will extrude to have a last layer height = (1.6-0.6) * 5.0 = 5.0. Topological boundary layers are only available with the built-in kernel. See sphere_boundary_layer.geo or sphere_boundary_layer_from_view.geo for '`.geo`' file examples, and aneurysm.py for an API example.

The advantage of this approach is that it provides a topological description of the boundary layer, which means that it can be connected to other geometrical entities. The disadvantage is that the mesh is just a "simple" extrusion: no fans, no special treatments of reentrant corners, etc. Another boundary layer algorithm is currently available through the `BoundaryLayer` field (see Section 1.2.2 [Specifying mesh element sizes], page 10). It only works in 2D however, and is a meshing constraint: it works directly at the mesh level, without creating geometrical entities. See e.g. BL0.geo or naca12_2d.geo.

`Transfinite Curve { expression-list-or-all } = expression < Using Progression | Bump expression >;`

Select the curves in *expression-list* to be meshed with the 1D transfinite algorithm. The *expression* on the right hand side gives the number of nodes that will be created on the curve (this overrides any other mesh element size prescription—see Section 1.2.2 [Specifying mesh element sizes], page 10). The optional argument '`Using Progression expression`' instructs the transfinite algorithm to distribute the nodes following a geometric progression (`Progression 2` meaning for example that each line element in the series will be twice as long as the preceding one). The optional argument '`Using Bump expression`' instructs the transfinite algorithm to distribute the nodes with a refinement at both ends of the curve. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Transfinite Surface { expression-list-or-all } < = { expression-list } > < Left | Right | Alternate | AlternateRight | AlternateLeft > ;`

Select surfaces to be meshed with the 2D transfinite algorithm. The *expression-list* on the right-hand-side should contain the tags of three or four points on the boundary of the surface that define the corners of the transfinite interpolation. If

no tags are given, the transfinite algorithm will try to find the corners automatically. The optional argument specifies the way the triangles are oriented when the mesh is not recombined. `Alternate` is a synonym for `AlternateRight`. For 3-sided surfaces a specific algorithm can be used to generate structured triangular by setting `Mesh.TransfiniteTri` to 1. Examples can be found in benchmarks/transfinite. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Transfinite Volume { `*expression-list*` } < = { `*expression-list*` } > ;`
Select five- or six-face volumes to be meshed with the 3D transfinite algorithm. The *expression-list* on the right-hand-side should contain the tags of the six or eight points on the boundary of the volume that define the corners of the transfinite interpolation. If no tags are given, the transfinite algorithm will try to find the corners automatically. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`TransfQuadTri { `*expression-list*` } ;`
Apply the transfinite QuadTri algorithm on the *expression-list* list of volumes. A transfinite volume with any combination of recombined and un-recombined transfinite boundary surfaces is valid when meshed with `TransfQuadTri`. When applied to non-Transfinite volumes, TransfQuadTri has no effect on those volumes. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

5.3.3 Other mesh commands

Here is a list of all other mesh commands currently available:

`Mesh `*expression*`;`
Generate *expression*-D mesh. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`TransformMesh { `*expression-list*` };`
Transform all the node coordinates in the current mesh using the 4x4 affine transformation matrix given by row (only 12 entries can be provided for convenience).

`TransformMesh { `*expression-list*` } { `*transform-list*` };`
Transform the node coordinates in the current mesh of all the elementary entities in *transform-list* using the 4x4 affine transformation matrix given by row (only 12 entries can be provided for convenience).

`RefineMesh;`
Refine the current mesh by splitting all elements. If `Mesh.SecondOrderLinear` is set, the new nodes are inserted by linear interpolation. Otherwise they are snapped on the actual geometry. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`OptimizeMesh `*string-expression*`;`
Optimize the current mesh with the given algorithm (currently `"Gmsh"` for default tetrahedral mesh optimizer, `"Netgen"` for Netgen optimizer, `"HighOrder"` for direct high-order mesh optimizer, `"HighOrderElastic"` for high-order elastic smoother, `"HighOrderFastCurving"` for fast curving algorithm, `"Laplace2D"` for Laplace smoothing, `"Relocate2D"` and `"Relocate3D"` for node relocation).

`AdaptMesh { `*expression-list*` } { `*expression-list*` } { { `*expression-list*` < , ... > } };`
Perform adaptive mesh generation. Documentation not yet available.

`RelocateMesh Point | Curve | Surface { expression-list-or-all };`
: Relocate the mesh nodes on the given entities using the parametric coordinates stored in the nodes. Useful for creating perturbation of meshes e.g. for sensitivity analyzes. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`RecombineMesh;`
: Recombine the current mesh into quadrangles. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`SetOrder expression;`
: Change the order of the elements in the current mesh.

`PartitionMesh expression;`
: Partition the mesh into *expression*, using current partitioning options.

`Point | Curve { expression-list } In Surface { expression };`
: Add a meshing constraint to embed the point(s) or curve(s) in the given surface. The surface mesh will conform to the mesh of the point(s) or curves(s). This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Point | Curve | Surface { expression-list } In Volume { expression };`
: Add a meshing constraint to embed the point(s), curve(s) or surface(s) in the given volume. The volume mesh will conform to the mesh of the corresponding point(s), curve(s) or surface(s). This is only supported with the 3D Delaunay algorithms. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Periodic Curve { expression-list } = { expression-list } ;`
: Add a meshing constraint to force the mesh of the curves on the left-hand side to match the mesh of the curves on the right-hand side (masters). If used after meshing, generate the periodic node correspondence information assuming the mesh of the curves on the left-hand side effectively matches the mesh of the curves on the right-hand side. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Periodic Surface expression { expression-list } = expression { expression-list } ;`
: Add a meshing constraint to force the mesh of the surface on the left-hand side (with boundary edges specified between braces) to match the mesh of the master surface on the right-hand side (with boundary edges specified between braces). If used after meshing, generate the periodic node correspondence information assuming the mesh of the surface on the left-hand side effectively matches the mesh of the master surface on the right-hand side (useful for structured and extruded meshes). This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Periodic Curve | Surface { expression-list } = { expression-list } Affine | Translate { expression-list } ;`
: Add a meshing constraint to force mesh of curves or surfaces on the left-hand side to match the mesh of the curves or surfaces on the right-hand side (masters), using prescribed geometrical transformations. If used after meshing, generate the periodic node correspondence information assuming the mesh of the curves or surfaces on the left-hand side effectively matches the mesh of the curves or surfaces on the right-hand side (useful for structured and extruded meshes). `Affine` takes a 4 x 4 affine transformation matrix given by row (only 12 entries can be provided for convenience); `Translate` takes the 3 components of the translation as in Section 5.2.7 [Transformations], page 110. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Periodic Curve | Surface { expression-list } = { expression-list } Rotate { expression-list }, { expression-list }, expression } ;`
: Add a meshing constraint to force the mesh of curves or surfaces on the left-hand side to match the mesh of the curves on the right-hand side (masters), using a rotation specified as in Section 5.2.7 [Transformations], page 110. If used after meshing, generate the periodic node correspondence information assuming the mesh of the curves or surfaces on the left-hand side effectively matches the mesh of the curves or surfaces on the right-hand side (useful for structured and extruded meshes). This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Coherence Mesh;`
: Remove all duplicate mesh nodes in the current mesh.

`CreateTopology < { expression , expression } > ;`
: Create a boundary representation from the mesh of the current model if the model does not have one (e.g. when imported from mesh file formats with no BRep representation of the underlying model). If the first optional argument is set (or not given), make all volumes and surfaces simply connected first; if the second optional argument is set (or not given), clear any built-in CAD kernel entities and export the discrete entities in the built-in CAD kernel.

`CreateGeometry < { <Physical> Point | Curve | Surface | Volume { expression-list-or-all }; ... } > ;`
: Create a geometry for discrete entities (represented solely by a mesh, without an underlying CAD description) in the current model, i.e. create a parametrization for discrete curves and surfaces, assuming that each can be parametrized with a single map. If no entities are given, create a geometry for all discrete entities.

`ClassifySurfaces { expression , expression , expression < , expression > };`
: Classify ("color") the current surface mesh based on an angle threshold (the first argument, in radians), and create new discrete surfaces, curves and points accordingly. If the second argument is set, also create discrete curves on the boundary if the surface is open. If the third argument is set, create edges and surfaces than can be reparametrized with `CreateGeometry`. The last optional argument sets an angle threshold to force splitting of the generated curves.

`RenumberMeshNodes;`
: Renumber the node tags in the current mesh in a continuous sequence.

`RenumberMeshElements;`
: Renumber the elements tags in the current mesh in a continuous sequence.

`< Recursive > Color color-expression { <Physical> Point | Curve | Surface | Volume { expression-list-or-all }; ... }`
: Set the mesh color of the entities in *expression-list* to *color-expression*. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Recombine Surface { expression-list-or-all } < = expression >;`
: Recombine the triangular meshes of the surfaces listed in *expression-list* into mixed triangular/quadrangular meshes. The optional *expression* on the right hand side specifies the maximum difference (in degrees) allowed between the largest angle of a quadrangle and a right angle (a value of 0 would only accept quadrangles with right angles; a value of 90 would allow degenerate quadrangles; default value is 45). This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`MeshAlgorithm Surface { expression-list } = expression ;`
: Specify the meshing algorithm for the surfaces *expression-list*.

`MeshSizeFromBoundary Surface { expression-list } = expression ;`
: Force the mesh size to be extended from the boundary (or not, depending on the value of *expression*) for the surfaces *expression-list*.

`Compound Curve | Surface { expression-list-or-all } ;`
: Treat the given entities as a single entity when meshing, i.e. perform cross-patch meshing of the entities.

`ReverseMesh Curve | Surface { expression-list-or-all } ;`
: Add a constraint to reverse the orientation of the mesh of the given curve(s) or surface(s) during meshing. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`ReorientMesh Volume { expression-list } ;`
: Add a constraint to reorient the meshes (during mesh generation) of the bounding surfaces of the given volumes so that the normals point outward to the volumes; and if a mesh already exists, reorient it. Currently only available with the OpenCASCADE kernel, as it relies on the STL triangulation. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Save string-expression ;`
: Save the current mesh in a file named *string-expression*, using the current `Mesh.Format` (see Section 7.4 [Mesh options], page 259). If the path in *string-expression* is not absolute, *string-expression* is appended to the path of the current file. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Smoother Surface { expression-list } = expression ;`
: Set the number of elliptic smoothing steps for the surfaces listed in *expression-list* (smoothing only applies to transfinite meshes at the moment). This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Homology ( { expression-list } ) { { expression-list } , { expression-list } };`
: Compute a basis representation for homology spaces after a mesh has been generated. The first *expression-list* is a list of dimensions whose homology bases are computed; if empty, all bases are computed. The second *expression-list* is a list physical groups that constitute the computation domain; if empty, the whole mesh is the domain. The third *expression-list* is a list of physical groups that constitute the relative subdomain of relative homology computation; if empty, absolute homology is computed. Resulting basis representation chains are stored as physical groups in the mesh.

`Cohomology ( { expression-list } ) { { expression-list } , { expression-list } };`
: Similar to command `Homology`, but computes a basis representation for cohomology spaces instead.

5.4 Post-processing scripting commands

Here is the list of available post-processing scripting commands.

`Alias View[expression];`
: Create an alias of the *expression*-th post-processing view.

  Note that `Alias` creates a logical duplicate of the view without actually duplicating the data in memory. This is very useful when you want multiple simultaneous

renderings of the same large dataset (usually with different display options), but you cannot afford to store all copies in memory. If what you really want is multiple physical copies of the data, just merge the file containing the post-processing view multiple times.

`AliasWithOptions View[`*expression*`];`
: Create an alias of the *expression*-th post-processing view and copies all the options of the *expression*-th view to the new aliased view.

`CopyOptions View[`*expression*`,` *expression*`];`
: Copy all the options from the first *expression*-th post-processing view to the second one.

`Combine ElementsByViewName;`
: Combine all the post-processing views having the same name into new views. The combination is done "spatially", i.e., simply by appending the elements at the end of the new views.

`Combine ElementsFromAllViews | Combine Views;`
: Combine all the post-processing views into a single new view. The combination is done "spatially", i.e., simply by appending the elements at the end of the new view.

`Combine ElementsFromVisibleViews;`
: Combine all the visible post-processing views into a single new view. The combination is done "spatially", i.e., simply by appending the elements at the end of the new view.

`Combine TimeStepsByViewName | Combine TimeSteps;`
: Combine the data from all the post-processing views having the same name into new multi-time-step views. The combination is done "temporally", i.e., as if the data in each view corresponds to a different time instant. The combination will fail if the meshes in all the views are not identical.

`Combine TimeStepsFromAllViews;`
: Combine the data from all the post-processing views into a new multi-time-step view. The combination is done "temporally", i.e., as if the data in each view corresponds to a different time instant. The combination will fail if the meshes in all the views are not identical.

`Combine TimeStepsFromVisibleViews;`
: Combine the data from all the visible post-processing views into a new multi-time-step view. The combination is done "temporally", i.e., as if the data in each view corresponds to a different time instant. The combination will fail if the meshes in all the views are not identical.

`Delete View[`*expression*`];`
: Delete (remove) the *expression*-th post-processing view. Note that post-processing view indices start at 0.

`Delete Empty Views;`
: Delete (remove) all the empty post-processing views.

`Background Mesh View[`*expression*`];`
: Apply the *expression*-th post-processing view as the current background mesh. Note that post-processing view indices start at 0.

`Plugin (`*string*`) . Run;`
: Execute the plugin *string*. The list of default plugins is given in Chapter 9 [Gmsh plugins], page 321.

`Plugin (`*string*`) . `*string*` = `*expression* | *string-expression*`;`
Set an option for a given plugin. See Chapter 9 [Gmsh plugins], page 321, for a list of default plugins and Section 2.9 [t9], page 36, for some examples.

`Save View[`*expression*`] `*string-expression*`;`
Save the *expression*-th post-processing view in a file named *string-expression*. If the path in *string-expression* is not absolute, *string-expression* is appended to the path of the current file.

`SendToServer View[`*expression*`] `*string-expression*`;`
Send the *expression*-th post-processing view to the ONELAB server, with parameter name *string-expression*.

`View "`*string*`" { `*string* `< ( `*expression-list* ` ) > { `*expression-list* ` }; ... };`
Create a new post-processing view, named "*string*". This is an easy and quite powerful way to import post-processing data: all the values are *expressions*, you can embed datasets directly into your geometrical descriptions (see, e.g., Section 2.4 [t4], page 23), the data can be easily generated "on-the-fly" (there is no header containing *a priori* information on the size of the dataset). The syntax is also very permissive, which makes it ideal for testing purposes.

However this "parsed format" is read by Gmsh's script parser, which makes it inefficient if there are many elements in the dataset. Also, there is no connectivity information in parsed views and all the elements are independent (all fields can be discontinuous), so a lot of information can be duplicated. For large datasets, you should thus use the mesh-based post-processing file format described in Chapter 10 [Gmsh file formats], page 349, or use one of the standard formats like MED.

More explicitly, the syntax for a parsed `View` is the following

```
View "string" {
  type ( coordinates ) { values }; ...
  < TIME { expression-list }; >
  < INTERPOLATION_SCHEME { val-coef-matrix }
      { val-exp-matrix }
      < { geo-coef-matrix } { geo-exp-matrix } > ; >
};
```

where the 47 object *type*s that can be displayed are:

	type	*#coordinates*	*#values*
Scalar point	SP	3	1 * *nb-time-steps*
Vector point	VP	3	3 * *nb-time-steps*
Tensor point	TP	3	9 * *nb-time-steps*
Scalar line	SL	6	2 * *nb-time-steps*
Vector line	VL	6	6 * *nb-time-steps*
Tensor line	TL	6	18 * *nb-time-steps*
Scalar triangle	ST	9	3 * *nb-time-steps*
Vector triangle	VT	9	9 * *nb-time-steps*
Tensor triangle	TT	9	27 * *nb-time-steps*
Scalar quadrangle	SQ	12	4 * *nb-time-steps*
Vector quadrangle	VQ	12	12 * *nb-time-steps*
Tensor quadrangle	TQ	12	36 * *nb-time-steps*
Scalar tetrahedron	SS	12	4 * *nb-time-steps*
Vector tetrahedron	VS	12	12 * *nb-time-steps*
Tensor tetrahedron	TS	12	36 * *nb-time-steps*
Scalar hexahedron	SH	24	8 * *nb-time-steps*

Vector hexahedron	VH	24	24 * *nb-time-steps*
Tensor hexahedron	TH	24	72 * *nb-time-steps*
Scalar prism	SI	18	6 * *nb-time-steps*
Vector prism	VI	18	18 * *nb-time-steps*
Tensor prism	TI	18	54 * *nb-time-steps*
Scalar pyramid	SY	15	5 * *nb-time-steps*
Vector pyramid	VY	15	15 * *nb-time-steps*
Tensor pyramid	TY	15	45 * *nb-time-steps*
2D text	T2	3	arbitrary
3D text	T3	4	arbitrary

The coordinates are given 'by node', i.e.,

- (*coord1*, *coord2*, *coord3*) for a point,
- (*coord1-node1*, *coord2-node1*, *coord3-node1*, *coord1-node2*, *coord2-node2*, *coord3-node2*) for a line,
- (*coord1-node1*, *coord2-node1*, *coord3-node1*, *coord1-node2*, *coord2-node2*, *coord3-node2*, *coord1-node3*, *coord2-node3*, *coord3-node3*) for a triangle,
- etc.

The ordering of the nodes is given in Section 10.2 [Node ordering], page 356.

The values are given by time step, by node and by component, i.e.:

comp1-node1-time1, *comp2-node1-time1*, *comp3-node1-time1*,
comp1-node2-time1, *comp2-node2-time1*, *comp3-node2-time1*,
comp1-node3-time1, *comp2-node3-time1*, *comp3-node3-time1*,
comp1-node1-time2, *comp2-node1-time2*, *comp3-node1-time2*,
comp1-node2-time2, *comp2-node2-time2*, *comp3-node2-time2*,
comp1-node3-time2, *comp2-node3-time2*, *comp3-node3-time2*,
...

For the 2D text objects, the two first *expression*s in *coordinates* give the X-Y position of the string in screen coordinates, measured from the top-left corner of the window. If the first (respectively second) *expression* is negative, the position is measured from the right (respectively bottom) edge of the window. If the value of the first (respectively second) *expression* is larger than 99999, the string is centered horizontally (respectively vertically). If the third *expression* is equal to zero, the text is aligned bottom-left and displayed using the default font and size. Otherwise, the third *expression* is converted into an integer whose eight lower bits give the font size, whose eight next bits select the font (the index corresponds to the position in the font menu in the GUI), and whose eight next bits define the text alignment (0=bottom-left, 1=bottom-center, 2=bottom-right, 3=top-left, 4=top-center, 5=top-right, 6=center-left, 7=center-center, 8=center-right).

For the 3D text objects, the three first *expression*s in *coordinates* give the XYZ position of the string in model (real world) coordinates. The fourth *expression* has the same meaning as the third *expression* in 2D text objects.

For both 2D and 3D text objects, the *values* can contain an arbitrary number of *string-expression*s. If the *string-expression* starts with `file://`, the remainder of the string is interpreted as the name of an image file, and the image is displayed instead of the string. A format string in the form `@wxh` or `@wxh,wx,wy,wz,hx,hy,hz`, where `w` and `h` are the width and height (in model coordinates for `T3` or in pixels for `T2`) of the image, `wx,wy,wz` is the direction of the bottom edge of the image and `hx,hy,hz` is the direction of the left edge of the image.

The optional `TIME` list can contain a list of expressions giving the value of the time (or any other variable) for which an evolution was saved.

The optional `INTERPOLATION_SCHEME` lists can contain the interpolation matrices used for high-order adaptive visualization.

Let us assume that the approximation of the view's value over an element is written as a linear combination of d basis functions $f[i]$, i=0, ..., d-1 (the coefficients being stored in *values*). Defining $f[i]$ = Sum(j=0, ..., d-1) $F[i][j]$ $p[j]$, with $p[j] = u\hat{}P[j][0]$ $v\hat{}P[j][1]$ $w\hat{}P[j][2]$ (u, v and w being the coordinates in the element's parameter space), then *val-coef-matrix* denotes the d x d matrix F and *val-exp-matrix* denotes the d x *3* matrix P.

In the same way, let us also assume that the coordinates x, y and z of the element are obtained through a geometrical mapping from parameter space as a linear combination of m basis functions $g[i]$, i=0, ..., m-1 (the coefficients being stored in *coordinates*). Defining $g[i]$ = Sum(j=0, ..., m-1) $G[i][j]$ $q[j]$, with $q[j] = u\hat{}Q[j][0]$ $v\hat{}Q[j][1]$ $w\hat{}Q[j][2]$, then *geo-coef-matrix* denotes the m x m matrix G and *geo-exp-matrix* denotes the m x *3* matrix Q.

Here are for example the interpolation matrices for a first order quadrangle:

```
INTERPOLATION_SCHEME
{
  {1/4,-1/4, 1/4,-1/4},
  {1/4, 1/4,-1/4,-1/4},
  {1/4, 1/4, 1/4, 1/4},
  {1/4,-1/4,-1/4, 1/4}
}
{
  {0, 0, 0},
  {1, 0, 0},
  {0, 1, 0},
  {1, 1, 0}
};
```

6 Gmsh application programming interface

The Gmsh application programming interface (API) allows to integrate the Gmsh library in external applications written in C++, C, Python, Julia or Fortran. By design, the Gmsh API is purely functional, and only uses elementary types from the target languages. See the tutorials/c++, tutorials/c, tutorials/python, tutorials/julia and tutorials/fortran directories from the Chapter 2 [Gmsh tutorial], page 15 for examples. For other API examples, see the examples/api directory.

The different versions of the API are generated automatically from the master API definition file api/gen.py:

- C++ API: gmsh.h
- C API: gmshc.h
- Python API: gmsh.py
- Julia API: gmsh.jl
- Fortran API: gmsh.f90

The additional gmsh.h_cwrap header redefines the C++ API in terms of the C API. This is provided as a convenience for users of the binary Gmsh Software Development Kit (SDK) whose C++ compiler Application Binary Interface (ABI) is not compatible with the ABI of the C++ compiler used to create the SDK. To use these C++ bindings of the C API instead of the native C++ API, simply rename `gmsh.h_cwrap` as `gmsh.h`. Note that this will lead to (slightly) reduced performance compared to using the native Gmsh C++ API, as it entails additional data copies between the C++ wrapper, the C API and the native C++ code.

The structure of the API reflects the underlying Gmsh data model (see also Section B.1 [Source code structure], page 377):

- There are two main data containers: *models* (which hold the geometrical and the mesh data) and *views* (which hold post-processing data). These are manipulated by the API functions in the top-level namespaces `gmsh/model` and `gmsh/view`, respectively. The other top-level namespaces are `gmsh/option` (which handles all options), `gmsh/plugin` (which handles extensions to core Gmsh functionality), `gmsh/graphics` (which handles drawing), `gmsh/fltk` (which handles the graphical user interface), `gmsh/parser` (which handles the Gmsh parser), `gmsh/onelab` (which handles ONELAB parameters and communications with external codes) and `gmsh/logger` (which handles information logging).
- Geometrical data is made of model *entities*, called *points* (entities of dimension 0), *curves* (entities of dimension 1), *surfaces* (entities of dimension 2) or *volumes* (entities of dimension 3). Model entities are stored using a boundary representation: a volume is bounded by a set of surfaces, a surface is bounded by a series of curves, and a curve is bounded by two end points. Volumes and surfaces can also store *embedded* entities of lower dimension, to force a subsequent mesh to be conformal to internal features like a point in the middle of a surface. Model entities are identified by a pair of integers: their dimension *dim* (0, 1, 2 or 3) and their *tag*, a strictly positive identification number. When dealing with multiple geometrical entities of possibly different dimensions, the API packs them as a vector of (dim, tag) integer pairs. *Physical groups* are collections of model entities and are also identified by their dimension and by a *tag*. Operations which do not directly reference a model are performed on the *current* model.
- Model entities can be either CAD entities (from the built-in *geo* kernel or from the OpenCASCADE *occ* kernel) or *discrete* entities (defined by a mesh). Operations on CAD entities are performed directly within their respective CAD kernels (i.e. using functions from the `gmsh/model/geo` or `gmsh/model/occ` namespaces, respectively), as Gmsh does not translate across CAD formats but rather directly accesses the native representation. CAD entities

must be *synchronized* with the model in order to be meshed, or, more generally, for functions outside of `gmsh/model/geo` or `gmsh/model/occ` to manipulate them. 1D and 2D meshing algorithms use the *parametrization* of the underlying geometrical curve or surface to generate the mesh. Discrete entities can be remeshed provided that a parametrization is explicitly recomputed for them.

- Mesh data is made of *elements* (points, lines, triangles, quadrangles, tetrahedra, hexahedra, prisms, pyramids, ...), defined by an ordered list of their *nodes*. Elements and nodes are identified by *tags* (strictly positive identification numbers), and are stored (*classified*) in the model entity they discretize. Once meshed, a model entity of dimension 0 (a geometrical point) will thus contain a mesh element of type point (MSH type 15: cf. Section 10.1 [MSH file format], page 349), as well as a mesh node. A model curve will contain line elements (e.g. of MSH type 1 or 8 for first order or second order meshes, respectively) as well as its interior nodes, while its boundary nodes will be stored in the bounding model points. A model surface will contain triangular and/or quadrangular elements and all the nodes not classified on its boundary or on its embedded entities (curves and points). A model volume will contain tetrahedra, hexahedra, etc. and all the nodes not classified on its boundary or on its embedded entities (surfaces, curves and points). This data model allows to easily and efficiently handle the creation, modification and destruction of conformal meshes. All the mesh-related functions are provided in the `gmsh/model/mesh` namespace.
- Post-processing data is made of *views*. Each view is identified by a *tag*, and can also be accessed by its *index* (which can change when views are sorted, added or deleted). A view stores both display *options* and *data*, unless the view is an *alias* of another view (in which case it only stores display options, and the data points to a reference view). View data can contain several *steps* (e.g. to store time series) and can be either linked to one or more models[1] (*mesh-based* data, as stored in MSH files: cf. Section 10.1 [MSH file format], page 349) or independent from any model (*list-based* data, as stored in parsed POS files: cf. Section 5.4 [Post-processing scripting commands], page 119). Various *plugins* exist to modify and create views.

All the functions available in the API are given below. See the relevant header/module file for the exact definition in each supported language: in C++ `gmsh/model/geo/addPoint` will lead to a namespaced function `gmsh::model::geo::addPoint`, while in Python and Julia it will lead to `gmsh.model.geo.addPoint`, in C to `gmshModelGeoAddPoint` and in Fortran to `gmsh%model%geo%addPoint`. In addition to the default "camelCase" function names, the Python and Julia APIs also define "snake case" aliases, i.e. `gmsh.model.geo.add_point`, as this is the recommended style in these languages. Output values are passed by reference in C++, as pointers in C and directly returned (after the return value, if any) in Python and Julia.

6.1 Namespace gmsh: top-level functions

`gmsh/initialize`

Initialize the Gmsh API. This must be called before any call to the other functions in the API. If `argc` and `argv` (or just `argv` in Python or Julia) are provided, they will be handled in the same way as the command line arguments in the Gmsh app. If `readConfigFiles` is set, read system Gmsh configuration files (gmshrc and gmsh-options). If `run` is set, run in the same way as the Gmsh app, either interactively or in batch mode depending on the command line arguments. If `run` is not set, initializing the API sets the options `"General.AbortOnError"` to 2 and `"General.Terminal"` to 1.

[1] Each step can be linked to a different model, which allows to have a single time series based on multiple (e.g. deforming or moving) meshes.

Input: `(argc = 0)`, `argv = []` (command line arguments), `readConfigFiles = True` (boolean), `run = False` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t4.cpp, t5.cpp, ...), Python (t1.py, t2.py, t3.py, t4.py, t5.py, ...)

`gmsh/isInitialized`

Return 1 if the Gmsh API is initialized, and 0 if not.

Input: -

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/finalize`

Finalize the Gmsh API. This must be called when you are done using the Gmsh API.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t4.cpp, t5.cpp, ...), Python (t1.py, t2.py, t3.py, t4.py, t5.py, ...)

`gmsh/open`

Open a file. Equivalent to the `File->Open` menu in the Gmsh app. Handling of the file depends on its extension and/or its contents: opening a file with model data will create a new model.

Input: `fileName` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py, explore.py, flatten2.py, flatten.py, heal.py, ...)

`gmsh/merge`

Merge a file. Equivalent to the `File->Merge` menu in the Gmsh app. Handling of the file depends on its extension and/or its contents. Merging a file with model data will add the data to the current model.

Input: `fileName` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t7.cpp, t8.cpp, t9.cpp, t13.cpp, t17.cpp), Python (t7.py, t8.py, t9.py, t13.py, t17.py, ...)

`gmsh/write`

Write a file. The export format is determined by the file extension.

Input: `fileName` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t4.cpp, t5.cpp, ...), Python (t1.py, t2.py, t3.py, t4.py, t5.py, ...)

`gmsh/clear`

Clear all loaded models and post-processing data, and add a new empty model.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, x1.cpp), Python (t3.py, t13.py, x1.py, x3d_export.py)

6.2 Namespace `gmsh/option`: option handling functions

`gmsh/option/setNumber`

Set a numerical option to `value`. `name` is of the form "Category.Option" or "Category[num].Option". Available categories and options are listed in the "Gmsh options" chapter of the Gmsh reference manual.

Input: `name` (string), `value` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t5.cpp, t6.cpp, t7.cpp, t8.cpp, ...), Python (t3.py, t5.py, t6.py, t7.py, t8.py, ...)

`gmsh/option/getNumber`

Get the `value` of a numerical option. `name` is of the form "Category.Option" or "Category[num].Option". Available categories and options are listed in the "Gmsh options" chapter of the Gmsh reference manual.

Input: `name` (string)

Output: `value` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t8.cpp), Python (t8.py, test.py)

`gmsh/option/setString`

Set a string option to `value`. `name` is of the form "Category.Option" or "Category[num].Option". Available categories and options are listed in the "Gmsh options" chapter of the Gmsh reference manual.

Input: `name` (string), `value` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t4.cpp), Python (t4.py, step_header_data.py)

`gmsh/option/getString`

Get the `value` of a string option. `name` is of the form "Category.Option" or "Category[num].Option". Available categories and options are listed in the "Gmsh options" chapter of the Gmsh reference manual.

Input: `name` (string)

Output: `value` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (test.py)

`gmsh/option/setColor`

Set a color option to the RGBA value (`r`, `g`, `b`, `a`), where where `r`, `g`, `b` and `a` should be integers between 0 and 255. `name` is of the form "Category.Color.Option" or "Category[num].Color.Option". Available categories and options are listed in the "Gmsh options" chapter of the Gmsh reference manual. For conciseness "Color." can be ommitted in `name`.

Input: `name` (string), `r` (integer), `g` (integer), `b` (integer), `a = 255` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t8.cpp), Python (t3.py, t8.py)

`gmsh/option/getColor`

Get the `r`, `g`, `b`, `a` value of a color option. `name` is of the form "Category.Color.Option" or "Category[num].Color.Option". Available categories and options are listed in the "Gmsh options" chapter of the Gmsh reference manual. For conciseness "Color." can be ommitted in `name`.

Input: `name` (string)

Output: `r` (integer), `g` (integer), `b` (integer), `a` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp), Python (t3.py)

6.3 Namespace `gmsh/model`: model functions

`gmsh/model/add`

Add a new model, with name `name`, and set it as the current model.

Input: `name` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t4.cpp, t6.cpp, ...), Python (t1.py, t2.py, t3.py, t4.py, t5.py, ...)

`gmsh/model/remove`

Remove the current model.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/list`

List the names of all models.

Input: -

Output: `names` (vector of strings)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getCurrent`

Get the name of the current model.

Input: -

Output: `name` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py, explore.py)

`gmsh/model/setCurrent`

Set the current model to the model with name `name`. If several models have the same name, select the one that was added first.

Input: `name` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (copy_mesh.py)

`gmsh/model/getFileName`

Get the file name (if any) associated with the current model. A file name is associated when a model is read from a file on disk.

Input: -

Output: `fileName` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/setFileName`

Set the file name associated with the current model.

Input: `fileName` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getEntities`

Get all the entities in the current model. A model entity is represented by two integers: its dimension (dim == 0, 1, 2 or 3) and its tag (its unique, strictly positive identifier). If `dim` is >= 0, return only the entities of the specified dimension (e.g. points if `dim` == 0). The entities are returned as a vector of (dim, tag) pairs.

Input: `dim = -1` (integer)

Output: `dimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t13.cpp, t16.cpp, t18.cpp, t20.cpp, t21.cpp, ...), Python (t13.py, t16.py, t18.py, t20.py, t21.py, ...)

`gmsh/model/setEntityName`

Set the name of the entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer), `name` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getEntityName`
Get the name of the entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `name` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py, step_assembly.py)

`gmsh/model/removeEntityName`
Remove the entity name `name` from the current model.

Input: `name` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getPhysicalGroups`
Get all the physical groups in the current model. If `dim` is >= 0, return only the entities of the specified dimension (e.g. physical points if `dim` == 0). The entities are returned as a vector of (dim, tag) pairs.

Input: `dim = -1` (integer)

Output: `dimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (poisson.py)

`gmsh/model/getEntitiesForPhysicalGroup`
Get the tags of the model entities making up the physical group of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `tags` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (poisson.py, test.py)

`gmsh/model/getEntitiesForPhysicalName`
Get the model entities (as a vector (dim, tag) pairs) making up the physical group with name `name`.

Input: `name` (string)

Output: `dimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getPhysicalGroupsForEntity`
Get the tags of the physical groups (if any) to which the model entity of dimension `dim` and tag `tag` belongs.

Input: `dim` (integer), `tag` (integer)

Output: `physicalTags` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py)

`gmsh/model/addPhysicalGroup`
Add a physical group of dimension `dim`, grouping the model entities with tags `tags`. Return the tag of the physical group, equal to `tag` if `tag` is positive, or a new tag if `tag` < 0. Set the name of the physical group if `name` is not empty.

Input: `dim` (integer), `tags` (vector of integers), `tag = -1` (integer), `name = ""` (string)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t5.cpp, t14.cpp, ...), Python (t1.py, t2.py, t3.py, t5.py, t14.py, ...)

`gmsh/model/removePhysicalGroups`
Remove the physical groups `dimTags` (given as a vector of (dim, tag) pairs) from the current model. If `dimTags` is empty, remove all groups.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/setPhysicalName`
Set the name of the physical group of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer), `name` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (poisson.py, step_assembly.py)

`gmsh/model/getPhysicalName`

Get the name of the physical group of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `name` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py, poisson.py)

`gmsh/model/removePhysicalName`

Remove the physical name `name` from the current model.

Input: `name` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/setTag`

Set the tag of the entity of dimension `dim` and tag `tag` to the new value `newTag`.

Input: `dim` (integer), `tag` (integer), `newTag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getBoundary`

Get the boundary of the model entities `dimTags`, given as a vector of (dim, tag) pairs. Return in `outDimTags` the boundary of the individual entities (if `combined` is false) or the boundary of the combined geometrical shape formed by all input entities (if `combined` is true). Return tags multiplied by the sign of the boundary entity if `oriented` is true. Apply the boundary operator recursively down to dimension 0 (i.e. to points) if `recursive` is true.

Input: `dimTags` (vector of pairs of integers), `combined = True` (boolean), `oriented = True` (boolean), `recursive = False` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t14.cpp, t16.cpp, t18.cpp, t19.cpp, t21.cpp), Python (t14.py, t16.py, t18.py, t19.py, t21.py, ...)

`gmsh/model/getAdjacencies`

Get the upward and downward adjacencies of the model entity of dimension `dim` and tag `tag`. The `upward` vector returns the tags of adjacent entities of dimension `dim + 1`; the `downward` vector returns the tags of adjacent entities of dimension `dim - 1`.

Input: `dim` (integer), `tag` (integer)

Output: `upward` (vector of integers), `downward` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py)

`gmsh/model/getEntitiesInBoundingBox`

Get the model entities in the bounding box defined by the two points (`xmin`, `ymin`, `zmin`) and (`xmax`, `ymax`, `zmax`). If `dim` is >= 0, return only the entities of the specified dimension (e.g. points if `dim` == 0).

Input: `xmin` (double), `ymin` (double), `zmin` (double), `xmax` (double), `ymax` (double), `zmax` (double), `dim = -1` (integer)

Output: `dimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp, t18.cpp, t20.cpp), Python (t16.py, t18.py, t20.py, naca_boundary_layer_3d.py)

`gmsh/model/getBoundingBox`

Get the bounding box (`xmin`, `ymin`, `zmin`), (`xmax`, `ymax`, `zmax`) of the model entity of dimension `dim` and tag `tag`. If `dim` and `tag` are negative, get the bounding box of the whole model.

Input: `dim` (integer), `tag` (integer)

Output: `xmin` (double), `ymin` (double), `zmin` (double), `xmax` (double), `ymax` (double), `zmax` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t18.cpp), Python (t18.py)

`gmsh/model/getDimension`

Return the geometrical dimension of the current model.

Input: -

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py)

`gmsh/model/addDiscreteEntity`

Add a discrete model entity (defined by a mesh) of dimension `dim` in the current model. Return the tag of the new discrete entity, equal to `tag` if `tag` is positive, or a new tag if `tag` < 0. `boundary` specifies the tags of the entities on the boundary of the discrete entity, if any. Specifying `boundary` allows Gmsh to construct the topology of the overall model.

Input: `dim` (integer), `tag = -1` (integer), `boundary = []` (vector of integers)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp, x4.cpp, x7.cpp), Python (x2.py, x4.py, x7.py, copy_mesh.py, cylinderFFD.py, ...)

`gmsh/model/removeEntities`
Remove the entities `dimTags` (given as a vector of (dim, tag) pairs) of the current model, provided that they are not on the boundary of (or embedded in) higher-dimensional entities. If `recursive` is true, remove all the entities on their boundaries, down to dimension 0.

Input: `dimTags` (vector of pairs of integers), `recursive = False` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t18.cpp, t20.cpp), Python (t18.py, t20.py, spherical_surf.py)

`gmsh/model/getType`
Get the type of the entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `entityType` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t21.cpp, x1.cpp), Python (t21.py, x1.py, explore.py, partition.py)

`gmsh/model/getParent`
In a partitioned model, get the parent of the entity of dimension `dim` and tag `tag`, i.e. from which the entity is a part of, if any. `parentDim` and `parentTag` are set to -1 if the entity has no parent.

Input: `dim` (integer), `tag` (integer)

Output: `parentDim` (integer), `parentTag` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t21.cpp, x1.cpp), Python (t21.py, x1.py, explore.py, partition.py)

`gmsh/model/getNumberOfPartitions`
Return the number of partitions in the model.

Input: -

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getPartitions`
In a partitioned model, return the tags of the partition(s) to which the entity belongs.

Input: `dim` (integer), `tag` (integer)

Output: `partitions` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t21.cpp, x1.cpp), Python (t21.py, x1.py, explore.py, partition.py)

`gmsh/model/getValue`
Evaluate the parametrization of the entity of dimension `dim` and tag `tag` at the parametric coordinates `parametricCoord`. Only valid for `dim` equal to 0 (with empty `parametricCoord`), 1 (with `parametricCoord` containing parametric coordinates on the curve) or 2 (with `parametricCoord` containing u, v parametric coordinates on the surface, concatenated: [p1u, p1v, p2u, ...]). Return x, y, z coordinates in `coord`, concatenated: [p1x, p1y, p1z, p2x, ...].

Input: `dim` (integer), `tag` (integer), `parametricCoord` (vector of doubles)

Output: `coord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t2.cpp, x5.cpp), Python (t2.py, x5.py, reparamOnFace.py, terrain_stl.py)

`gmsh/model/getDerivative`
Evaluate the derivative of the parametrization of the entity of dimension `dim` and tag `tag` at the parametric coordinates `parametricCoord`. Only valid for `dim` equal to 1 (with `parametricCoord` containing parametric coordinates on the curve) or 2 (with `parametricCoord` containing u, v parametric coordinates on the surface, concatenated: [p1u, p1v, p2u, ...]). For `dim` equal to 1 return the x, y, z components of the derivative with respect to u [d1ux, d1uy, d1uz, d2ux, ...]; for `dim` equal to 2 return the x, y, z components of the derivative with respect to u and v: [d1ux, d1uy, d1uz, d1vx, d1vy, d1vz, d2ux, ...].

Input: `dim` (integer), `tag` (integer), `parametricCoord` (vector of doubles)

Output: `derivatives` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getSecondDerivative`
Evaluate the second derivative of the parametrization of the entity of dimension `dim` and tag `tag` at the parametric coordinates `parametricCoord`. Only valid for `dim` equal to 1 (with `parametricCoord` containing parametric coordinates on the curve)

or 2 (with `parametricCoord` containing u, v parametric coordinates on the surface, concatenated: [p1u, p1v, p2u, ...]). For `dim` equal to 1 return the x, y, z components of the second derivative with respect to u [d1uux, d1uuy, d1uuz, d2uux, ...]; for `dim` equal to 2 return the x, y, z components of the second derivative with respect to u and v, and the mixed derivative with respect to u and v: [d1uux, d1uuy, d1uuz, d1vvx, d1vvy, d1vvz, d1uvx, d1uvy, d1uvz, d2uux, ...].

Input: `dim` (integer), `tag` (integer), `parametricCoord` (vector of doubles)

Output: `derivatives` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getCurvature`

Evaluate the (maximum) curvature of the entity of dimension `dim` and tag `tag` at the parametric coordinates `parametricCoord`. Only valid for `dim` equal to 1 (with `parametricCoord` containing parametric coordinates on the curve) or 2 (with `parametricCoord` containing u, v parametric coordinates on the surface, concatenated: [p1u, p1v, p2u, ...]).

Input: `dim` (integer), `tag` (integer), `parametricCoord` (vector of doubles)

Output: `curvatures` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x5.cpp), Python (x5.py, normals.py)

`gmsh/model/getPrincipalCurvatures`

Evaluate the principal curvatures of the surface with tag `tag` at the parametric coordinates `parametricCoord`, as well as their respective directions. `parametricCoord` are given by pair of u and v coordinates, concatenated: [p1u, p1v, p2u, ...].

Input: `tag` (integer), `parametricCoord` (vector of doubles)

Output: `curvatureMax` (vector of doubles), `curvatureMin` (vector of doubles), `directionMax` (vector of doubles), `directionMin` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getNormal`

Get the normal to the surface with tag `tag` at the parametric coordinates `parametricCoord`. The `parametricCoord` vector should contain u and v coordinates, concatenated: [p1u, p1v, p2u, ...]. `normals` are returned as a vector of x, y, z components, concatenated: [n1x, n1y, n1z, n2x, ...].

Input: `tag` (integer), `parametricCoord` (vector of doubles)

Output: `normals` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x5.cpp), Python (x5.py, normals.py)

`gmsh/model/getParametrization`

Get the parametric coordinates `parametricCoord` for the points `coord` on the entity of dimension `dim` and tag `tag`. `coord` are given as x, y, z coordinates, concatenated: [p1x, p1y, p1z, p2x, ...]. `parametricCoord` returns the parametric coordinates t on the curve (if `dim` = 1) or u and v coordinates concatenated on the surface (if `dim` == 2), i.e. [p1t, p2t, ...] or [p1u, p1v, p2u, ...].

Input: `dim` (integer), `tag` (integer), `coord` (vector of doubles)

Output: `parametricCoord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getParametrizationBounds`

Get the `min` and `max` bounds of the parametric coordinates for the entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `min` (vector of doubles), `max` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x5.cpp), Python (x5.py, reparamOnFace.py)

`gmsh/model/isInside`

Check if the coordinates (or the parametric coordinates if `parametric` is set) provided in `coord` correspond to points inside the entity of dimension `dim` and tag `tag`, and return the number of points inside. This feature is only available for a subset of entities, depending on the underlying geometrical representation.

Input: `dim` (integer), `tag` (integer), `coord` (vector of doubles), `parametric` = `False` (boolean)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/getClosestPoint`

Get the points `closestCoord` on the entity of dimension `dim` and tag `tag` to the points `coord`, by orthogonal projection. `coord` and `closestCoord` are given as x, y, z coordinates, concatenated: [p1x, p1y, p1z, p2x, ...]. `parametricCoord` returns the parametric coordinates t on the curve (if `dim` == 1) or u and v coordinates concatenated on the surface (if `dim` = 2), i.e. [p1t, p2t, ...] or [p1u, p1v, p2u, ...].

Input: `dim` (integer), `tag` (integer), `coord` (vector of doubles)

Output: `closestCoord` (vector of doubles), `parametricCoord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (closest_point.py)

`gmsh/model/reparametrizeOnSurface`
Reparametrize the boundary entity (point or curve, i.e. with `dim` == 0 or `dim` == 1) of tag `tag` on the surface `surfaceTag`. If `dim` == 1, reparametrize all the points corresponding to the parametric coordinates `parametricCoord`. Multiple matches in case of periodic surfaces can be selected with `which`. This feature is only available for a subset of entities, depending on the underlying geometrical representation.

Input: `dim` (integer), `tag` (integer), `parametricCoord` (vector of doubles), `surfaceTag` (integer), `which = 0` (integer)

Output: `surfaceParametricCoord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x5.cpp), Python (x5.py, reparamOnFace.py)

`gmsh/model/setVisibility`
Set the visibility of the model entities `dimTags` (given as a vector of (dim, tag) pairs) to `value`. Apply the visibility setting recursively if `recursive` is true.

Input: `dimTags` (vector of pairs of integers), `value` (integer), `recursive = False` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (gui.py, hybrid_order.py)

`gmsh/model/getVisibility`
Get the visibility of the model entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `value` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/setVisibilityPerWindow`
Set the global visibility of the model per window to `value`, where `windowIndex` identifies the window in the window list.

Input: `value` (integer), `windowIndex = 0` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/setColor`

Set the color of the model entities `dimTags` (given as a vector of (dim, tag) pairs) to the RGBA value (`r`, `g`, `b`, `a`), where `r`, `g`, `b` and `a` should be integers between 0 and 255. Apply the color setting recursively if `recursive` is true.

Input: `dimTags` (vector of pairs of integers), `r` (integer), `g` (integer), `b` (integer), `a = 255` (integer), `recursive = False` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t4.cpp), Python (t4.py, gui.py)

`gmsh/model/getColor`

Get the color of the model entity of dimension `dim` and tag `tag`. If no color is specified for the entity, return fully transparent blue, i.e. (0, 0, 255, 0).

Input: `dim` (integer), `tag` (integer)

Output: `r` (integer), `g` (integer), `b` (integer), `a` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (step_boundary_colors.py)

`gmsh/model/setCoordinates`

Set the `x`, `y`, `z` coordinates of a geometrical point.

Input: `tag` (integer), `x` (double), `y` (double), `z` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp), Python (x2.py, reparamOnFace.py)

`gmsh/model/setAttribute`

Set the values of the attribute with name `name`.

Input: `name` (string), `values` (vector of strings)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (msh_attributes.py)

`gmsh/model/getAttribute`

Get the values of the attribute with name `name`.

Input: `name` (string)

Output: `values` (vector of strings)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (msh_attributes.py)

`gmsh/model/getAttributeNames`
Get the names of any optional attributes stored in the model.

Input: -

Output: `names` (vector of strings)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (msh_attributes.py)

`gmsh/model/removeAttribute`
Remove the attribute with name `name`.

Input: `name` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

6.4 Namespace `gmsh/model/mesh`: mesh functions

`gmsh/model/mesh/generate`
Generate a mesh of the current model, up to dimension `dim` (0, 1, 2 or 3).

Input: `dim = 3` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t4.cpp, t5.cpp, ...), Python (t1.py, t2.py, t3.py, t4.py, t5.py, ...)

`gmsh/model/mesh/partition`
Partition the mesh of the current model into `numPart` partitions. Optionally, `elementTags` and `partitions` can be provided to specify the partition of each element explicitly.

Input: `numPart` (integer), `elementTags = []` (vector of sizes), `partitions = []` (vector of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t21.cpp), Python (t21.py, partition.py)

`gmsh/model/mesh/unpartition`

Unpartition the mesh of the current model.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/optimize`

Optimize the mesh of the current model using `method` (empty for default tetrahedral mesh optimizer, "Netgen" for Netgen optimizer, "HighOrder" for direct high-order mesh optimizer, "HighOrderElastic" for high-order elastic smoother, "HighOrderFastCurving" for fast curving algorithm, "Laplace2D" for Laplace smoothing, "Relocate2D" and "Relocate3D" for node relocation, "QuadQuasiStructured" for quad mesh optimization, "UntangleMeshGeometry" for untangling). If `force` is set apply the optimization also to discrete entities. If `dimTags` (given as a vector of (dim, tag) pairs) is given, only apply the optimizer to the given entities.

Input: `method = ""` (string), `force = False` (boolean), `niter = 1` (integer), `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (naca_boundary_layer_2d.py, naca_boundary_layer_3d.py, opt.py, tube_boundary_layer.py)

`gmsh/model/mesh/recombine`

Recombine the mesh of the current model.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (stl_to_mesh.py)

`gmsh/model/mesh/refine`

Refine the mesh of the current model by uniformly splitting the elements.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/setOrder`

Set the order of the elements in the mesh of the current model to `order`.

Input: `order` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x6.cpp), Python (x6.py, hybrid_order.py, naca_boundary_layer_2d.py, naca_boundary_layer_3d.py, tube_boundary_layer.py)

`gmsh/model/mesh/getLastEntityError`
Get the last entities `dimTags` (as a vector of (dim, tag) pairs) where a meshing error occurred. Currently only populated by the new 3D meshing algorithms.

Input: -

Output: `dimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getLastNodeError`
Get the last node tags `nodeTags` where a meshing error occurred. Currently only populated by the new 3D meshing algorithms.

Input: -

Output: `nodeTags` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/clear`
Clear the mesh, i.e. delete all the nodes and elements, for the entities `dimTags`, given as a vector of (dim, tag) pairs. If `dimTags` is empty, clear the whole mesh. Note that the mesh of an entity can only be cleared if this entity is not on the boundary of another entity with a non-empty mesh.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (copy_mesh.py, flatten.py, remesh_partial_move.py)

`gmsh/model/mesh/reverse`
Reverse the orientation of the elements in the entities `dimTags`, given as a vector of (dim, tag) pairs. If `dimTags` is empty, reverse the orientation of the elements in the whole mesh.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (mirror_mesh.py)

`gmsh/model/mesh/reverseElements`
Reverse the orientation of the elements with tags `elementTags`.

Input: `elementTags` (vector of sizes)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/affineTransform`
Apply the affine transformation `affineTransform` (16 entries of a 4x4 matrix, by row; only the 12 first can be provided for convenience) to the coordinates of the nodes classified on the entities `dimTags`, given as a vector of (dim, tag) pairs. If `dimTags` is empty, transform all the nodes in the mesh.

Input: `affineTransform` (vector of doubles), `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (flatten2.py, remesh_partial_move.py)

`gmsh/model/mesh/getNodes`
Get the nodes classified on the entity of dimension `dim` and tag `tag`. If `tag` < 0, get the nodes for all entities of dimension `dim`. If `dim` and `tag` are negative, get all the nodes in the mesh. `nodeTags` contains the node tags (their unique, strictly positive identification numbers). `coord` is a vector of length 3 times the length of `nodeTags` that contains the x, y, z coordinates of the nodes, concatenated: [n1x, n1y, n1z, n2x, ...]. If `dim` >= 0 and `returnParamtricCoord` is set, `parametricCoord` contains the parametric coordinates ([u1, u2, ...] or [u1, v1, u2, ...]) of the nodes, if available. The length of `parametricCoord` can be 0 or `dim` times the length of `nodeTags`. If `includeBoundary` is set, also return the nodes classified on the boundary of the entity (which will be reparametrized on the entity if `dim` >= 0 in order to compute their parametric coordinates).

Input: `dim = -1` (integer), `tag = -1` (integer), `includeBoundary = False` (boolean), `returnParametricCoord = True` (boolean)

Output: `nodeTags` (vector of sizes), `coord` (vector of doubles), `parametricCoord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp, x4.cpp, x5.cpp), Python (x1.py, x4.py, x5.py, adapt_mesh.py, copy_mesh.py, ...)

`gmsh/model/mesh/getNodesByElementType`

Get the nodes classified on the entity of tag `tag`, for all the elements of type `elementType`. The other arguments are treated as in `getNodes`.

Input: `elementType` (integer), `tag = -1` (integer), `returnParametricCoord = True` (boolean)

Output: `nodeTags` (vector of sizes), `coord` (vector of doubles), `parametricCoord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (stl_to_brep.py)

`gmsh/model/mesh/getNode`

Get the coordinates and the parametric coordinates (if any) of the node with tag `tag`, as well as the dimension `dim` and tag `tag` of the entity on which the node is classified. This function relies on an internal cache (a vector in case of dense node numbering, a map otherwise); for large meshes accessing nodes in bulk is often preferable.

Input: `nodeTag` (size)

Output: `coord` (vector of doubles), `parametricCoord` (vector of doubles), `dim` (integer), `tag` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/setNode`

Set the coordinates and the parametric coordinates (if any) of the node with tag `tag`. This function relies on an internal cache (a vector in case of dense node numbering, a map otherwise); for large meshes accessing nodes in bulk is often preferable.

Input: `nodeTag` (size), `coord` (vector of doubles), `parametricCoord` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/rebuildNodeCache`

Rebuild the node cache.

Input: `onlyIfNecessary = True` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/rebuildElementCache`

Rebuild the element cache.

Input: `onlyIfNecessary = True` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getNodesForPhysicalGroup`

Get the nodes from all the elements belonging to the physical group of dimension `dim` and tag `tag`. `nodeTags` contains the node tags; `coord` is a vector of length 3 times the length of `nodeTags` that contains the x, y, z coordinates of the nodes, concatenated: [n1x, n1y, n1z, n2x, ...].

Input: `dim` (integer), `tag` (integer)

Output: `nodeTags` (vector of sizes), `coord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getMaxNodeTag`

Get the maximum tag `maxTag` of a node in the mesh.

Input: -

Output: `maxTag` (size)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/addNodes`

Add nodes classified on the model entity of dimension `dim` and tag `tag`. `nodeTags` contains the node tags (their unique, strictly positive identification numbers). `coord` is a vector of length 3 times the length of `nodeTags` that contains the x, y, z coordinates of the nodes, concatenated: [n1x, n1y, n1z, n2x, ...]. The optional `parametricCoord` vector contains the parametric coordinates of the nodes, if any. The length of `parametricCoord` can be 0 or `dim` times the length of `nodeTags`. If the `nodeTags` vector is empty, new tags are automatically assigned to the nodes.

Input: `dim` (integer), `tag` (integer), `nodeTags` (vector of sizes), `coord` (vector of doubles), `parametricCoord = []` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp, x4.cpp), Python (x2.py, x4.py, copy_mesh.py, cylinderFFD.py, discrete.py, ...)

`gmsh/model/mesh/reclassifyNodes`

Reclassify all nodes on their associated model entity, based on the elements. Can be used when importing nodes in bulk (e.g. by associating them all to a single volume), to reclassify them correctly on model surfaces, curves, etc. after the elements have been set.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp), Python (x2.py, terrain.py)

`gmsh/model/mesh/relocateNodes`

Relocate the nodes classified on the entity of dimension `dim` and tag `tag` using their parametric coordinates. If `tag` < 0, relocate the nodes for all entities of dimension `dim`. If `dim` and `tag` are negative, relocate all the nodes in the mesh.

Input: `dim` = `-1` (integer), `tag` = `-1` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (relocate_nodes.py)

`gmsh/model/mesh/getElements`

Get the elements classified on the entity of dimension `dim` and tag `tag`. If `tag` < 0, get the elements for all entities of dimension `dim`. If `dim` and `tag` are negative, get all the elements in the mesh. `elementTypes` contains the MSH types of the elements (e.g. 2 for 3-node triangles: see `getElementProperties` to obtain the properties for a given element type). `elementTags` is a vector of the same length as `elementTypes`; each entry is a vector containing the tags (unique, strictly positive identifiers) of the elements of the corresponding type. `nodeTags` is also a vector of the same length as `elementTypes`; each entry is a vector of length equal to the number of elements of the given type times the number N of nodes for this type of element, that contains the node tags of all the elements of the given type, concatenated: [e1n1, e1n2, ..., e1nN, e2n1, ...].

Input: `dim` = `-1` (integer), `tag` = `-1` (integer)

Output: `elementTypes` (vector of integers), `elementTags` (vector of vectors of sizes), `nodeTags` (vector of vectors of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py, copy_mesh.py, cylinderFFD.py, explore.py, flatten.py, ...)

`gmsh/model/mesh/getElement`

Get the type and node tags of the element with tag `tag`, as well as the dimension `dim` and tag `tag` of the entity on which the element is classified. This function relies on an internal cache (a vector in case of dense element numbering, a map otherwise); for large meshes accessing elements in bulk is often preferable.

Input: `elementTag` (size)

Output: `elementType` (integer), `nodeTags` (vector of sizes), `dim` (integer), `tag` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getElementByCoordinates`
Search the mesh for an element located at coordinates (`x`, `y`, `z`). This function performs a search in a spatial octree. If an element is found, return its tag, type and node tags, as well as the local coordinates (`u`, `v`, `w`) within the reference element corresponding to search location. If `dim` is >= 0, only search for elements of the given dimension. If `strict` is not set, use a tolerance to find elements near the search location.

Input: `x` (double), `y` (double), `z` (double), `dim = -1` (integer), `strict = False` (boolean)

Output: `elementTag` (size), `elementType` (integer), `nodeTags` (vector of sizes), `u` (double), `v` (double), `w` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getElementsByCoordinates`
Search the mesh for element(s) located at coordinates (`x`, `y`, `z`). This function performs a search in a spatial octree. Return the tags of all found elements in `elementTags`. Additional information about the elements can be accessed through `getElement` and `getLocalCoordinatesInElement`. If `dim` is >= 0, only search for elements of the given dimension. If `strict` is not set, use a tolerance to find elements near the search location.

Input: `x` (double), `y` (double), `z` (double), `dim = -1` (integer), `strict = False` (boolean)

Output: `elementTags` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getLocalCoordinatesInElement`
Return the local coordinates (`u`, `v`, `w`) within the element `elementTag` corresponding to the model coordinates (`x`, `y`, `z`). This function relies on an internal cache (a vector in case of dense element numbering, a map otherwise); for large meshes accessing elements in bulk is often preferable.

Input: `elementTag` (size), `x` (double), `y` (double), `z` (double)

Output: `u` (double), `v` (double), `w` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getElementTypes`
Get the types of elements in the entity of dimension `dim` and tag `tag`. If `tag < 0`, get the types for all entities of dimension `dim`. If `dim` and `tag` are negative, get all the types in the mesh.

Input: `dim = -1` (integer), `tag = -1` (integer)

Output: `elementTypes` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x6.cpp), Python (tri.py, x6.py, poisson.py)

`gmsh/model/mesh/getElementType`

Return an element type given its family name `familyName` ("Point", "Line", "Triangle", "Quadrangle", "Tetrahedron", "Pyramid", "Prism", "Hexahedron") and polynomial order `order`. If `serendip` is true, return the corresponding serendip element type (element without interior nodes).

Input: `familyName` (string), `order` (integer), `serendip = False` (boolean)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (x7.py)

`gmsh/model/mesh/getElementProperties`

Get the properties of an element of type `elementType`: its name (`elementName`), dimension (`dim`), order (`order`), number of nodes (`numNodes`), local coordinates of the nodes in the reference element (`localNodeCoord` vector, of length `dim` times `numNodes`) and number of primary (first order) nodes (`numPrimaryNodes`).

Input: `elementType` (integer)

Output: `elementName` (string), `dim` (integer), `order` (integer), `numNodes` (integer), `localNodeCoord` (vector of doubles), `numPrimaryNodes` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py, x6.py, explore.py, poisson.py)

`gmsh/model/mesh/getElementsByType`

Get the elements of type `elementType` classified on the entity of tag `tag`. If `tag < 0`, get the elements for all entities. `elementTags` is a vector containing the tags (unique, strictly positive identifiers) of the elements of the corresponding type. `nodeTags` is a vector of length equal to the number of elements of the given type times the number N of nodes for this type of element, that contains the node tags of all the elements of the given type, concatenated: [e1n1, e1n2, ..., e1nN, e2n1, ...]. If `numTasks > 1`, only compute and return the part of the data indexed by `task` (for C++ only; output vectors must be preallocated).

Input: `elementType` (integer), `tag = -1` (integer), `task = 0` (size), `numTasks = 1` (size)

Output: `elementTags` (vector of sizes), `nodeTags` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (tri.py, x7.py, adapt_mesh.py, neighbors.py, poisson.py, ...)

`gmsh/model/mesh/getMaxElementTag`

Get the maximum tag `maxTag` of an element in the mesh.

Input: -

Output: `maxTag` (size)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (x7.py)

`gmsh/model/mesh/preallocateElementsByType`

Preallocate data before calling `getElementsByType` with `numTasks` > 1. For C++ only.

Input: `elementType` (integer), `elementTag` (boolean), `nodeTag` (boolean), `tag` = -1 (integer)

Output: `elementTags` (vector of sizes), `nodeTags` (vector of sizes)

Return: -

Language-specific definition:
C++, C

`gmsh/model/mesh/getElementQualities`

Get the quality `elementQualities` of the elements with tags `elementTags`. `qualityType` is the requested quality measure: "minDetJac" and "maxDetJac" for the adaptively computed minimal and maximal Jacobian determinant, "minSJ" for the sampled minimal scaled jacobien, "minSICN" for the sampled minimal signed inverted condition number, "minSIGE" for the sampled signed inverted gradient error, "gamma" for the ratio of the inscribed to circumcribed sphere radius, "innerRadius" for the inner radius, "outerRadius" for the outerRadius, "minIsotropy" for the minimum isotropy measure, "angleShape" for the angle shape measure, "minEdge" for the minimum straight edge length, "maxEdge" for the maximum straight edge length, "volume" for the volume. If `numTasks` > 1, only compute and return the part of the data indexed by `task` (for C++ only; output vector must be preallocated).

Input: `elementTags` (vector of sizes), `qualityName` = "minSICN" (string), `task` = 0 (size), `numTasks` = 1 (size)

Output: `elementsQuality` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (mesh_quality.py, min_edge.py, view_element_size.py)

`gmsh/model/mesh/addElements`

Add elements classified on the entity of dimension `dim` and tag `tag`. `types` contains the MSH types of the elements (e.g. 2 for 3-node triangles: see the Gmsh reference

manual). `elementTags` is a vector of the same length as `types`; each entry is a vector containing the tags (unique, strictly positive identifiers) of the elements of the corresponding type. `nodeTags` is also a vector of the same length as `types`; each entry is a vector of length equal to the number of elements of the given type times the number N of nodes per element, that contains the node tags of all the elements of the given type, concatenated: [e1n1, e1n2, ..., e1nN, e2n1, ...].

Input: `dim` (integer), `tag` (integer), `elementTypes` (vector of integers), `elementTags` (vector of vectors of integers (size)), `nodeTags` (vector of vectors of integers (size))

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (copy_mesh.py, cylinderFFD.py, discrete.py, flatten.py, mesh_from_discrete_curve.py, ...)

`gmsh/model/mesh/addElementsByType`

Add elements of type `elementType` classified on the entity of tag `tag`. `elementTags` contains the tags (unique, strictly positive identifiers) of the elements of the corresponding type. `nodeTags` is a vector of length equal to the number of elements times the number N of nodes per element, that contains the node tags of all the elements, concatenated: [e1n1, e1n2, ..., e1nN, e2n1, ...]. If the `elementTag` vector is empty, new tags are automatically assigned to the elements.

Input: `tag` (integer), `elementType` (integer), `elementTags` (vector of sizes), `nodeTags` (vector of sizes)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp, x4.cpp, x7.cpp), Python (x2.py, x4.py, x7.py, import_perf.py, raw_tetrahedralization.py, ...)

`gmsh/model/mesh/getIntegrationPoints`

Get the numerical quadrature information for the given element type `elementType` and integration rule `integrationType`, where `integrationType` concatenates the integration rule family name with the desired order (e.g. `"Gauss4"` for a quadrature suited for integrating 4th order polynomials). The `"CompositeGauss"` family uses tensor-product rules based the 1D Gauss-Legendre rule; the `"Gauss"` family uses an economic scheme when available (i.e. with a minimal number of points), and falls back to `"CompositeGauss"` otherwise. Note that integration points for the `"Gauss"` family can fall outside of the reference element for high-order rules. `localCoord` contains the u, v, w coordinates of the G integration points in the reference element: [g1u, g1v, g1w, ..., gGu, gGv, gGw]. `weights` contains the associated weights: [g1q, ..., gGq].

Input: `elementType` (integer), `integrationType` (string)

Output: `localCoord` (vector of doubles), `weights` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (x6.py, adapt_mesh.py, poisson.py)

`gmsh/model/mesh/getJacobians`

Get the Jacobians of all the elements of type `elementType` classified on the entity of tag `tag`, at the G evaluation points `localCoord` given as concatenated u, v, w coordinates in the reference element [g1u, g1v, g1w, ..., gGu, gGv, gGw]. Data is returned by element, with elements in the same order as in `getElements` and `getElementsByType`. `jacobians` contains for each element the 9 entries of the 3x3 Jacobian matrix at each evaluation point. The matrix is returned by column: [e1g1Jxu, e1g1Jyu, e1g1Jzu, e1g1Jxv, ..., e1g1Jzw, e1g2Jxu, ..., e1gGJzw, e2g1Jxu, ...], with Jxu = dx/du, Jyu = dy/du, etc. `determinants` contains for each element the determinant of the Jacobian matrix at each evaluation point: [e1g1, e1g2, ... e1gG, e2g1, ...]. `coord` contains for each element the x, y, z coordinates of the evaluation points. If `tag` < 0, get the Jacobian data for all entities. If `numTasks` > 1, only compute and return the part of the data indexed by `task` (for C++ only; output vectors must be preallocated).

Input: `elementType` (integer), `localCoord` (vector of doubles), `tag` = -1 (integer), `task` = 0 (size), `numTasks` = 1 (size)

Output: `jacobians` (vector of doubles), `determinants` (vector of doubles), `coord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (x6.py, adapt_mesh.py, poisson.py)

`gmsh/model/mesh/preallocateJacobians`

Preallocate data before calling `getJacobians` with `numTasks` > 1. For C++ only.

Input: `elementType` (integer), `numEvaluationPoints` (integer), `allocateJacobians` (boolean), `allocateDeterminants` (boolean), `allocateCoord` (boolean), `tag` = -1 (integer)

Output: `jacobians` (vector of doubles), `determinants` (vector of doubles), `coord` (vector of doubles)

Return: -

Language-specific definition:
C++, C

`gmsh/model/mesh/getJacobian`

Get the Jacobian for a single element `elementTag`, at the G evaluation points `localCoord` given as concatenated u, v, w coordinates in the reference element [g1u, g1v, g1w, ..., gGu, gGv, gGw]. `jacobians` contains the 9 entries of the 3x3 Jacobian matrix at each evaluation point. The matrix is returned by column: [e1g1Jxu, e1g1Jyu, e1g1Jzu, e1g1Jxv, ..., e1g1Jzw, e1g2Jxu, ..., e1gGJzw, e2g1Jxu, ...], with Jxu = dx/du, Jyu = dy/du, etc. `determinants` contains the determinant of the Jacobian matrix at each evaluation point. `coord` contains the x, y, z coordinates of the evaluation points. This function relies on an internal cache (a vector in case of dense element numbering, a map otherwise); for large meshes accessing Jacobians in bulk is often preferable.

Input: `elementTag` (size), `localCoord` (vector of doubles)

Output: `jacobians` (vector of doubles), `determinants` (vector of doubles), `coord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getBasisFunctions`

Get the basis functions of the element of type `elementType` at the evaluation points `localCoord` (given as concatenated u, v, w coordinates in the reference element [g1u, g1v, g1w, ..., gGu, gGv, gGw]), for the function space `functionSpaceType`. Currently supported function spaces include `"Lagrange"` and `"GradLagrange"` for isoparametric Lagrange basis functions and their gradient in the u, v, w coordinates of the reference element; `"LagrangeN"` and `"GradLagrangeN"`, with N = 1, 2, ..., for N-th order Lagrange basis functions; `"H1LegendreN"` and `"GradH1LegendreN"`, with N = 1, 2, ..., for N-th order hierarchical H1 Legendre functions; `"HcurlLegendreN"` and `"CurlHcurlLegendreN"`, with N = 1, 2, ..., for N-th order curl-conforming basis functions. `numComponents` returns the number C of components of a basis function (e.g. 1 for scalar functions and 3 for vector functions). `basisFunctions` returns the value of the N basis functions at the evaluation points, i.e. [g1f1, g1f2, ..., g1fN, g2f1, ...] when C == 1 or [g1f1u, g1f1v, g1f1w, g1f2u, ..., g1fNw, g2f1u, ...] when C == 3. For basis functions that depend on the orientation of the elements, all values for the first orientation are returned first, followed by values for the second, etc. `numOrientations` returns the overall number of orientations. If the `wantedOrientations` vector is not empty, only return the values for the desired orientation indices.

Input: `elementType` (integer), `localCoord` (vector of doubles), `functionSpaceType` (string), `wantedOrientations = []` (vector of integers)

Output: `numComponents` (integer), `basisFunctions` (vector of doubles), `numOrientations` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (x6.py, adapt_mesh.py, poisson.py)

`gmsh/model/mesh/getBasisFunctionsOrientation`

Get the orientation index of the elements of type `elementType` in the entity of tag `tag`. The arguments have the same meaning as in `getBasisFunctions`. `basisFunctionsOrientation` is a vector giving for each element the orientation index in the values returned by `getBasisFunctions`. For Lagrange basis functions the call is superfluous as it will return a vector of zeros. If `numTasks > 1`, only compute and return the part of the data indexed by `task` (for C++ only; output vector must be preallocated).

Input: `elementType` (integer), `functionSpaceType` (string), `tag = -1` (integer), `task = 0` (size), `numTasks = 1` (size)

Output: `basisFunctionsOrientation` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getBasisFunctionsOrientationForElement`
Get the orientation of a single element `elementTag`.

Input: `elementTag` (size), `functionSpaceType` (string)

Output: `basisFunctionsOrientation` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getNumberOfOrientations`
Get the number of possible orientations for elements of type `elementType` and function space named `functionSpaceType`.

Input: `elementType` (integer), `functionSpaceType` (string)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/preallocateBasisFunctionsOrientation`
Preallocate data before calling `getBasisFunctionsOrientation` with `numTasks > 1`. For C++ only.

Input: `elementType` (integer), `tag = -1` (integer)

Output: `basisFunctionsOrientation` (vector of integers)

Return: -

Language-specific definition:
C++, C

`gmsh/model/mesh/getEdges`
Get the global unique mesh edge identifiers `edgeTags` and orientations `edgeOrientation` for an input list of node tag pairs defining these edges, concatenated in the vector `nodeTags`. Mesh edges are created e.g. by `createEdges()`, `getKeys()` or `addEdges()`. The reference positive orientation is n1 < n2, where n1 and n2 are the tags of the two edge nodes, which corresponds to the local orientation of edge-based basis functions as well.

Input: `nodeTags` (vector of sizes)

Output: `edgeTags` (vector of sizes), `edgeOrientations` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (x7.py)

`gmsh/model/mesh/getFaces`
Get the global unique mesh face identifiers `faceTags` and orientations `faceOrientations` for an input list of a multiple of three (if `faceType` == 3) or four (if `faceType` == 4) node tags defining these faces, concatenated in the vector `nodeTags`. Mesh faces are created e.g. by `createFaces()`, `getKeys()` or `addFaces()`.

Input: `faceType` (integer), `nodeTags` (vector of sizes)

Output: `faceTags` (vector of sizes), `faceOrientations` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (x7.py)

`gmsh/model/mesh/createEdges`

Create unique mesh edges for the entities `dimTags`, given as a vector of (dim, tag) pairs.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (x7.py)

`gmsh/model/mesh/createFaces`

Create unique mesh faces for the entities `dimTags`, given as a vector of (dim, tag) pairs.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (x7.py)

`gmsh/model/mesh/getAllEdges`

Get the global unique identifiers `edgeTags` and the nodes `edgeNodes` of the edges in the mesh. Mesh edges are created e.g. by `createEdges()`, `getKeys()` or addEdges().

Input: -

Output: `edgeTags` (vector of sizes), `edgeNodes` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (x7.py)

`gmsh/model/mesh/getAllFaces`

Get the global unique identifiers `faceTags` and the nodes `faceNodes` of the faces of type `faceType` in the mesh. Mesh faces are created e.g. by `createFaces()`, `getKeys()` or addFaces().

Input: `faceType` (integer)

Output: `faceTags` (vector of sizes), `faceNodes` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (x7.py)

`gmsh/model/mesh/addEdges`
Add mesh edges defined by their global unique identifiers `edgeTags` and their nodes `edgeNodes`.

Input: `edgeTags` (vector of sizes), `edgeNodes` (vector of sizes)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/addFaces`
Add mesh faces of type `faceType` defined by their global unique identifiers `faceTags` and their nodes `faceNodes`.

Input: `faceType` (integer), `faceTags` (vector of sizes), `faceNodes` (vector of sizes)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getKeys`
Generate the pair of keys for the elements of type `elementType` in the entity of tag `tag`, for the `functionSpaceType` function space. Each pair (`typeKey`, `entityKey`) uniquely identifies a basis function in the function space. If `returnCoord` is set, the `coord` vector contains the x, y, z coordinates locating basis functions for sorting purposes. Warning: this is an experimental feature and will probably change in a future release.

Input: `elementType` (integer), `functionSpaceType` (string), `tag = -1` (integer), `returnCoord = True` (boolean)

Output: `typeKeys` (vector of integers), `entityKeys` (vector of sizes), `coord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getKeysForElement`
Get the pair of keys for a single element `elementTag`.

Input: `elementTag` (size), `functionSpaceType` (string), `returnCoord = True` (boolean)

Output: `typeKeys` (vector of integers), `entityKeys` (vector of sizes), `coord` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getNumberOfKeys`
Get the number of keys by elements of type `elementType` for function space named `functionSpaceType`.

Input: `elementType` (integer), `functionSpaceType` (string)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getKeysInformation`
Get information about the pair of `keys`. `infoKeys` returns information about the functions associated with the pairs (`typeKeys`, `entityKey`). `infoKeys[0].first` describes the type of function (0 for vertex function, 1 for edge function, 2 for face function and 3 for bubble function). `infoKeys[0].second` gives the order of the function associated with the key. Warning: this is an experimental feature and will probably change in a future release.

Input: `typeKeys` (vector of integers), `entityKeys` (vector of sizes), `elementType` (integer), `functionSpaceType` (string)

Output: `infoKeys` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getBarycenters`
Get the barycenters of all elements of type `elementType` classified on the entity of tag `tag`. If `primary` is set, only the primary nodes of the elements are taken into account for the barycenter calculation. If `fast` is set, the function returns the sum of the primary node coordinates (without normalizing by the number of nodes). If `tag < 0`, get the barycenters for all entities. If `numTasks > 1`, only compute and return the part of the data indexed by `task` (for C++ only; output vector must be preallocated).

Input: `elementType` (integer), `tag` (integer), `fast` (boolean), `primary` (boolean), `task = 0` (size), `numTasks = 1` (size)

Output: `barycenters` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/preallocateBarycenters`
Preallocate data before calling `getBarycenters` with `numTasks > 1`. For C++ only.

Input: `elementType` (integer), `tag = -1` (integer)

Output: `barycenters` (vector of doubles)

Return: -

Language-specific definition:
C++, C

`gmsh/model/mesh/getElementEdgeNodes`

Get the nodes on the edges of all elements of type `elementType` classified on the entity of tag `tag`. `nodeTags` contains the node tags of the edges for all the elements: [e1a1n1, e1a1n2, e1a2n1, ...]. Data is returned by element, with elements in the same order as in `getElements` and `getElementsByType`. If `primary` is set, only the primary (begin/end) nodes of the edges are returned. If `tag` < 0, get the edge nodes for all entities. If `numTasks` > 1, only compute and return the part of the data indexed by `task` (for C++ only; output vector must be preallocated).

Input: `elementType` (integer), `tag` = `-1` (integer), `primary` = `False` (boolean), `task` = `0` (size), `numTasks` = `1` (size)

Output: `nodeTags` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (tri.py, x7.py, stl_to_brep.py)

`gmsh/model/mesh/getElementFaceNodes`

Get the nodes on the faces of type `faceType` (3 for triangular faces, 4 for quadrangular faces) of all elements of type `elementType` classified on the entity of tag `tag`. `nodeTags` contains the node tags of the faces for all elements: [e1f1n1, ..., e1f1nFaceType, e1f2n1, ...]. Data is returned by element, with elements in the same order as in `getElements` and `getElementsByType`. If `primary` is set, only the primary (corner) nodes of the faces are returned. If `tag` < 0, get the face nodes for all entities. If `numTasks` > 1, only compute and return the part of the data indexed by `task` (for C++ only; output vector must be preallocated).

Input: `elementType` (integer), `faceType` (integer), `tag` = `-1` (integer), `primary` = `False` (boolean), `task` = `0` (size), `numTasks` = `1` (size)

Output: `nodeTags` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x7.cpp), Python (x7.py, neighbors.py)

`gmsh/model/mesh/getGhostElements`

Get the ghost elements `elementTags` and their associated `partitions` stored in the ghost entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `elementTags` (vector of sizes), `partitions` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/setSize`

Set a mesh size constraint on the model entities `dimTags`, given as a vector of (dim, tag) pairs. Currently only entities of dimension 0 (points) are handled.

Input: `dimTags` (vector of pairs of integers), `size` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp, t18.cpp, t21.cpp), Python (t16.py, t18.py, t21.py, adapt_mesh.py, extend_field.py, ...)

`gmsh/model/mesh/getSizes`

Get the mesh size constraints (if any) associated with the model entities `dimTags`, given as a vector of (dim, tag) pairs. A zero entry in the output `sizes` vector indicates that no size constraint is specified on the corresponding entity.

Input: `dimTags` (vector of pairs of integers)

Output: `sizes` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/setSizeAtParametricPoints`

Set mesh size constraints at the given parametric points `parametricCoord` on the model entity of dimension `dim` and tag `tag`. Currently only entities of dimension 1 (lines) are handled.

Input: `dim` (integer), `tag` (integer), `parametricCoord` (vector of doubles), `sizes` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/setSizeCallback`

Set a mesh size callback for the current model. The callback function should take six arguments as input (`dim`, `tag`, `x`, `y`, `z` and `lc`). The first two integer arguments correspond to the dimension `dim` and tag `tag` of the entity being meshed. The next four double precision arguments correspond to the coordinates `x`, `y` and `z` around which to prescribe the mesh size and to the mesh size `lc` that would be prescribed if the callback had not been called. The callback function should return a double precision number specifying the desired mesh size; returning `lc` is equivalent to a no-op.

Input: `callback` ()

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t10.cpp), Python (t10.py)

`gmsh/model/mesh/removeSizeCallback`

Remove the mesh size callback from the current model.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/setTransfiniteCurve`

Set a transfinite meshing constraint on the curve `tag`, with `numNodes` nodes distributed according to `meshType` and `coef`. Currently supported types are "Progression" (geometrical progression with power `coef`), "Bump" (refinement toward both extremities of the curve) and "Beta" (beta law).

Input: `tag` (integer), `numNodes` (integer), `meshType = "Progression"` (string), `coef = 1.` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp), Python (x2.py, terrain.py, terrain_bspline.py, terrain_stl.py)

`gmsh/model/mesh/setTransfiniteSurface`

Set a transfinite meshing constraint on the surface `tag`. `arrangement` describes the arrangement of the triangles when the surface is not flagged as recombined: currently supported values are "Left", "Right", "AlternateLeft" and "AlternateRight". `cornerTags` can be used to specify the (3 or 4) corners of the transfinite interpolation explicitly; specifying the corners explicitly is mandatory if the surface has more that 3 or 4 points on its boundary.

Input: `tag` (integer), `arrangement = "Left"` (string), `cornerTags = []` (vector of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp), Python (x2.py, get_data_perf.py, terrain.py, terrain_bspline.py, terrain_stl.py)

`gmsh/model/mesh/setTransfiniteVolume`

Set a transfinite meshing constraint on the surface `tag`. `cornerTags` can be used to specify the (6 or 8) corners of the transfinite interpolation explicitly.

Input: `tag` (integer), `cornerTags = []` (vector of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp), Python (x2.py, terrain.py, terrain_bspline.py, terrain_stl.py)

`gmsh/model/mesh/setTransfiniteAutomatic`

Set transfinite meshing constraints on the model entities in `dimTags`, given as a vector of (dim, tag) pairs. Transfinite meshing constraints are added to the curves

of the quadrangular surfaces and to the faces of 6-sided volumes. Quadragular faces with a corner angle superior to `cornerAngle` (in radians) are ignored. The number of points is automatically determined from the sizing constraints. If `dimTag` is empty, the constraints are applied to all entities in the model. If `recombine` is true, the recombine flag is automatically set on the transfinite surfaces.

Input: `dimTags = []` (vector of pairs of integers), `cornerAngle = 2.35` (double), `recombine = True` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp, x6.cpp), Python (x2.py, x6.py)

`gmsh/model/mesh/setRecombine`

Set a recombination meshing constraint on the model entity of dimension `dim` and tag `tag`. Currently only entities of dimension 2 (to recombine triangles into quadrangles) are supported; `angle` specifies the threshold angle for the simple recombination algorithm..

Input: `dim` (integer), `tag` (integer), `angle = 45.` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t11.cpp, x2.cpp), Python (t11.py, x2.py, poisson.py, terrain.py, terrain_bspline.py, ...)

`gmsh/model/mesh/setSmoothing`

Set a smoothing meshing constraint on the model entity of dimension `dim` and tag `tag`. `val` iterations of a Laplace smoother are applied.

Input: `dim` (integer), `tag` (integer), `val` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x2.cpp), Python (x2.py, terrain.py, terrain_bspline.py, terrain_stl.py)

`gmsh/model/mesh/setReverse`

Set a reverse meshing constraint on the model entity of dimension `dim` and tag `tag`. If `val` is true, the mesh orientation will be reversed with respect to the natural mesh orientation (i.e. the orientation consistent with the orientation of the geometry). If `val` is false, the mesh is left as-is.

Input: `dim` (integer), `tag` (integer), `val = True` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/setAlgorithm`
Set the meshing algorithm on the model entity of dimension `dim` and tag `tag`. Supported values are those of the `Mesh.Algorithm` option, as listed in the Gmsh reference manual. Currently only supported for `dim` == 2.

Input: `dim` (integer), `tag` (integer), `val` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t5.cpp), Python (t5.py)

`gmsh/model/mesh/setSizeFromBoundary`
Force the mesh size to be extended from the boundary, or not, for the model entity of dimension `dim` and tag `tag`. Currently only supported for `dim` == 2.

Input: `dim` (integer), `tag` (integer), `val` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/setCompound`
Set a compound meshing constraint on the model entities of dimension `dim` and tags `tags`. During meshing, compound entities are treated as a single discrete entity, which is automatically reparametrized.

Input: `dim` (integer), `tags` (vector of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t12.cpp), Python (t12.py)

`gmsh/model/mesh/setOutwardOrientation`
Set meshing constraints on the bounding surfaces of the volume of tag `tag` so that all surfaces are oriented with outward pointing normals; and if a mesh already exists, reorient it. Currently only available with the OpenCASCADE kernel, as it relies on the STL triangulation.

Input: `tag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/removeConstraints`
Remove all meshing constraints from the model entities `dimTags`, given as a vector of (dim, tag) pairs. If `dimTags` is empty, remove all constraings.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (terrain_bspline.py)

`gmsh/model/mesh/embed`

Embed the model entities of dimension `dim` and tags `tags` in the (`inDim`, `inTag`) model entity. The dimension `dim` can 0, 1 or 2 and must be strictly smaller than `inDim`, which must be either 2 or 3. The embedded entities should not intersect each other or be part of the boundary of the entity `inTag`, whose mesh will conform to the mesh of the embedded entities. With the OpenCASCADE kernel, if the `fragment` operation is applied to entities of different dimensions, the lower dimensional entities will be automatically embedded in the higher dimensional entities if they are not on their boundary.

Input: `dim` (integer), `tags` (vector of integers), `inDim` (integer), `inTag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t15.cpp), Python (t15.py)

`gmsh/model/mesh/removeEmbedded`

Remove embedded entities from the model entities `dimTags`, given as a vector of (dim, tag) pairs. if `dim` is >= 0, only remove embedded entities of the given dimension (e.g. embedded points if `dim` == 0).

Input: `dimTags` (vector of pairs of integers), `dim = -1` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getEmbedded`

Get the entities (if any) embedded in the model entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `dimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/reorderElements`

Reorder the elements of type `elementType` classified on the entity of tag `tag` according to the `ordering` vector.

Input: `elementType` (integer), `tag` (integer), `ordering` (vector of sizes)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/computeRenumbering`
Compute a renumbering vector `newTags` corresponding to the input tags `oldTags` for a given list of element tags `elementTags`. If `elementTags` is empty, compute the renumbering on the full mesh. If `method` is equal to "RCMK", compute a node renumering with Reverse Cuthill McKee. If `method` is equal to "Hilbert", compute a node renumering along a Hilbert curve. If `method` is equal to "Metis", compute a node renumering using Metis. Element renumbering is not available yet.

Input: `method = "RCMK"` (string), `elementTags = []` (vector of sizes)

Output: `oldTags` (vector of sizes), `newTags` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (renumbering.py)

`gmsh/model/mesh/renumberNodes`
Renumber the node tags. If no explicit renumbering is provided through the `oldTags` and `newTags` vectors, renumber the nodes in a continuous sequence, taking into account the subset of elements to be saved later on if the option "Mesh.SaveAll" is not set.

Input: `oldTags = []` (vector of sizes), `newTags = []` (vector of sizes)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (renumbering.py, view_renumbering.py)

`gmsh/model/mesh/renumberElements`
Renumber the element tags in a continuous sequence. If no explicit renumbering is provided through the `oldTags` and `newTags` vectors, renumber the elements in a continuous sequence, taking into account the subset of elements to be saved later on if the option "Mesh.SaveAll" is not set.

Input: `oldTags = []` (vector of sizes), `newTags = []` (vector of sizes)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (view_renumbering.py)

`gmsh/model/mesh/setPeriodic`
Set the meshes of the entities of dimension `dim` and tag `tags` as periodic copies of the meshes of entities `tagsMaster`, using the affine transformation specified in `affineTransformation` (16 entries of a 4x4 matrix, by row). If used after meshing,

generate the periodic node correspondence information assuming the meshes of entities `tags` effectively match the meshes of entities `tagsMaster` (useful for structured and extruded meshes). Currently only available for `dim` == 1 and `dim` == 2.

Input: `dim` (integer), `tags` (vector of integers), `tagsMaster` (vector of integers), `affineTransform` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t18.cpp), Python (t18.py, periodic.py)

`gmsh/model/mesh/getPeriodic`

Get master entities `tagsMaster` for the entities of dimension `dim` and tags `tags`.

Input: `dim` (integer), `tags` (vector of integers)

Output: `tagMaster` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getPeriodicNodes`

Get the master entity `tagMaster`, the node tags `nodeTags` and their corresponding master node tags `nodeTagsMaster`, and the affine transform `affineTransform` for the entity of dimension `dim` and tag `tag`. If `includeHighOrderNodes` is set, include high-order nodes in the returned data.

Input: `dim` (integer), `tag` (integer), `includeHighOrderNodes = False` (boolean)

Output: `tagMaster` (integer), `nodeTags` (vector of sizes), `nodeTagsMaster` (vector of sizes), `affineTransform` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (periodic.py)

`gmsh/model/mesh/getPeriodicKeys`

Get the master entity `tagMaster` and the key pairs (`typeKeyMaster`, `entityKeyMaster`) corresponding to the entity `tag` and the key pairs (`typeKey`, `entityKey`) for the elements of type `elementType` and function space type `functionSpaceType`. If `returnCoord` is set, the `coord` and `coordMaster` vectors contain the x, y, z coordinates locating basis functions for sorting purposes.

Input: `elementType` (integer), `functionSpaceType` (string), `tag` (integer), `returnCoord = True` (boolean)

Output: `tagMaster` (integer), `typeKeys` (vector of integers), `typeKeysMaster` (vector of integers), `entityKeys` (vector of sizes), `entityKeysMaster` (vector of sizes), `coord` (vector of doubles), `coordMaster` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (periodic.py)

`gmsh/model/mesh/importStl`
Import the model STL representation (if available) as the current mesh.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (stl_to_mesh.py)

`gmsh/model/mesh/getDuplicateNodes`
Get the `tags` of any duplicate nodes in the mesh of the entities `dimTags`, given as a vector of (dim, tag) pairs. If `dimTags` is empty, consider the whole mesh.

Input: `dimTags = []` (vector of pairs of integers)

Output: `tags` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/removeDuplicateNodes`
Remove duplicate nodes in the mesh of the entities `dimTags`, given as a vector of (dim, tag) pairs. If `dimTags` is empty, consider the whole mesh.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (glue_and_remesh_stl.py, mirror_mesh.py, stl_to_mesh.py, view_adaptive_to_mesh.py)

`gmsh/model/mesh/removeDuplicateElements`
Remove duplicate elements (defined by the same nodes, in the same entity) in the mesh of the entities `dimTags`, given as a vector of (dim, tag) pairs. If `dimTags` is empty, consider the whole mesh.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/splitQuadrangles`
Split (into two triangles) all quadrangles in surface `tag` whose quality is lower than `quality`. If `tag` < 0, split quadrangles in all surfaces.

Input: `quality = 1.` (double), `tag = -1` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/setVisibility`
Set the visibility of the elements of tags `elementTags` to `value`.

Input: `elementTags` (vector of sizes), `value` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/getVisibility`
Get the visibility of the elements of tags `elementTags`.

Input: `elementTags` (vector of sizes)

Output: `values` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/classifySurfaces`
Classify ("color") the surface mesh based on the angle threshold `angle` (in radians), and create new discrete surfaces, curves and points accordingly. If `boundary` is set, also create discrete curves on the boundary if the surface is open. If `forReparametrization` is set, create curves and surfaces that can be reparametrized using a single map. If `curveAngle` is less than Pi, also force curves to be split according to `curveAngle`. If `exportDiscrete` is set, clear any built-in CAD kernel entities and export the discrete entities in the built-in CAD kernel.

Input: `angle` (double), `boundary = True` (boolean), `forReparametrization = False` (boolean), `curveAngle = pi` (double), `exportDiscrete = True` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t13.cpp), Python (t13.py, aneurysm.py, glue_and_remesh_stl.py, remesh_stl.py, terrain_stl.py)

`gmsh/model/mesh/createGeometry`
Create a geometry for the discrete entities `dimTags` (given as a vector of (dim, tag) pairs) represented solely by a mesh (without an underlying CAD description), i.e. create a parametrization for discrete curves and surfaces, assuming that each can be parametrized with a single map. If `dimTags` is empty, create a geometry for all the discrete entities.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t13.cpp, x2.cpp), Python (t13.py, x2.py, aneurysm.py, glue_and_remesh_stl.py, remesh_stl.py, ...)

`gmsh/model/mesh/createTopology`

Create a boundary representation from the mesh if the model does not have one (e.g. when imported from mesh file formats with no BRep representation of the underlying model). If `makeSimplyConnected` is set, enforce simply connected discrete surfaces and volumes. If `exportDiscrete` is set, clear any built-in CAD kernel entities and export the discrete entities in the built-in CAD kernel.

Input: `makeSimplyConnected = True` (boolean), `exportDiscrete = True` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/addHomologyRequest`

Add a request to compute a basis representation for homology spaces (if `type` == "Homology") or cohomology spaces (if `type` == "Cohomology"). The computation domain is given in a list of physical group tags `domainTags`; if empty, the whole mesh is the domain. The computation subdomain for relative (co)homology computation is given in a list of physical group tags `subdomainTags`; if empty, absolute (co)homology is computed. The dimensions of the (co)homology bases to be computed are given in the list `dim`; if empty, all bases are computed. Resulting basis representation (co)chains are stored as physical groups in the mesh. If the request is added before mesh generation, the computation will be performed at the end of the meshing pipeline.

Input: `type = "Homology"` (string), `domainTags = []` (vector of integers), `subdomainTags = []` (vector of integers), `dims = []` (vector of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t14.cpp), Python (t14.py)

`gmsh/model/mesh/clearHomologyRequests`

Clear all (co)homology computation requests.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/computeHomology`

Perform the (co)homology computations requested by addHomologyRequest(). The newly created physical groups are returned in `dimTags` as a vector of (dim, tag) pairs.

Input: -

Output: `dimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/computeCrossField`

Compute a cross field for the current mesh. The function creates 3 views: the H function, the Theta function and cross directions. Return the tags of the views.

Input: -

Output: `viewTags` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/triangulate`

Triangulate the points given in the `coord` vector as pairs of u, v coordinates, and return the node tags (with numbering starting at 1) of the resulting triangles in `tri`.

Input: `coord` (vector of doubles)

Output: `tri` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (raw_triangulation.py)

`gmsh/model/mesh/tetrahedralize`

Tetrahedralize the points given in the `coord` vector as x, y, z coordinates, concatenated, and return the node tags (with numbering starting at 1) of the resulting tetrahedra in `tetra`.

Input: `coord` (vector of doubles)

Output: `tetra` (vector of sizes)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (raw_tetrahedralization.py)

6.5 Namespace `gmsh/model/mesh/field`: mesh size field functions

`gmsh/model/mesh/field/add`

Add a new mesh size field of type `fieldType`. If `tag` is positive, assign the tag explicitly; otherwise a new tag is assigned automatically. Return the field tag. Available field types are listed in the "Gmsh mesh size fields" chapter of the Gmsh reference manual.

Input: `fieldType` (string), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t7.cpp, t10.cpp, t11.cpp, t13.cpp, t17.cpp), Python (t7.py, t10.py, t13.py, t17.py, adapt_mesh.py, ...)

`gmsh/model/mesh/field/remove`

Remove the field with tag `tag`.

Input: `tag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/field/list`

Get the list of all fields.

Input: -

Output: `tags` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/field/getType`

Get the type `fieldType` of the field with tag `tag`.

Input: `tag` (integer)

Output: `fileType` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/field/setNumber`

Set the numerical option `option` to value `value` for field `tag`.

Input: `tag` (integer), `option` (string), `value` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t7.cpp, t10.cpp, t17.cpp), Python (t7.py, t10.py, t17.py, adapt_mesh.py, copy_mesh.py, ...)

`gmsh/model/mesh/field/getNumber`

Get the value of the numerical option `option` for field `tag`.

Input: `tag` (integer), `option` (string)

Output: `value` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/field/setString`

Set the string option `option` to value `value` for field `tag`.

Input: `tag` (integer), `option` (string), `value` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t10.cpp, t11.cpp, t13.cpp), Python (t10.py, t13.py)

`gmsh/model/mesh/field/getString`

Get the value of the string option `option` for field `tag`.

Input: `tag` (integer), `option` (string)

Output: `value` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/field/setNumbers`

Set the numerical list option `option` to value `values` for field `tag`.

Input: `tag` (integer), `option` (string), `values` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t10.cpp), Python (t10.py, extend_field.py, naca_boundary_layer_2d.py, ocean.py)

`gmsh/model/mesh/field/getNumbers`

Get the value of the numerical list option `option` for field `tag`.

Input: `tag` (integer), `option` (string)

Output: `values` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/mesh/field/setAsBackgroundMesh`
Set the field `tag` as the background mesh size field.

Input: `tag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t7.cpp, t10.cpp, t11.cpp, t13.cpp, t17.cpp), Python (t7.py, t10.py, t13.py, t17.py, adapt_mesh.py, ...)

`gmsh/model/mesh/field/setAsBoundaryLayer`
Set the field `tag` as a boundary layer size field.

Input: `tag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (naca_boundary_layer_2d.py)

6.6 Namespace `gmsh/model/geo`: built-in CAD kernel functions

`gmsh/model/geo/addPoint`
Add a geometrical point in the built-in CAD representation, at coordinates (`x`, `y`, `z`). If `meshSize` is > 0, add a meshing constraint at that point. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the point. (Note that the point will be added in the current model only after `synchronize` is called. This behavior holds for all the entities added in the geo module.)

Input: `x` (double), `y` (double), `z` (double), `meshSize = 0.` (double), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t5.cpp, t6.cpp, ...), Python (t1.py, t2.py, t3.py, t5.py, t6.py, ...)

`gmsh/model/geo/addLine`
Add a straight line segment in the built-in CAD representation, between the two points with tags `startTag` and `endTag`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the line.

Input: `startTag` (integer), `endTag` (integer), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t5.cpp, t6.cpp, ...), Python (t1.py, t2.py, t3.py, t5.py, t6.py, ...)

`gmsh/model/geo/addCircleArc`

Add a circle arc (strictly smaller than Pi) in the built-in CAD representation, between the two points with tags `startTag` and `endTag`, and with center `centerTag`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. If (`nx`, `ny`, `nz`) != (0, 0, 0), explicitly set the plane of the circle arc. Return the tag of the circle arc.

Input: `startTag` (integer), `centerTag` (integer), `endTag` (integer), `tag = -1` (integer), `nx = 0.` (double), `ny = 0.` (double), `nz = 0.` (double)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t5.cpp), Python (t5.py)

`gmsh/model/geo/addEllipseArc`

Add an ellipse arc (strictly smaller than Pi) in the built-in CAD representation, between the two points `startTag` and `endTag`, and with center `centerTag` and major axis point `majorTag`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. If (`nx`, `ny`, `nz`) != (0, 0, 0), explicitly set the plane of the circle arc. Return the tag of the ellipse arc.

Input: `startTag` (integer), `centerTag` (integer), `majorTag` (integer), `endTag` (integer), `tag = -1` (integer), `nx = 0.` (double), `ny = 0.` (double), `nz = 0.` (double)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/addSpline`

Add a spline (Catmull-Rom) curve in the built-in CAD representation, going through the points `pointTags`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Create a periodic curve if the first and last points are the same. Return the tag of the spline curve.

Input: `pointTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t12.cpp), Python (t12.py)

`gmsh/model/geo/addBSpline`

Add a cubic b-spline curve in the built-in CAD representation, with `pointTags` control points. If `tag` is positive, set the tag explicitly; otherwise a new tag is

selected automatically. Creates a periodic curve if the first and last points are the same. Return the tag of the b-spline curve.

Input: `pointTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/addBezier`
Add a Bezier curve in the built-in CAD representation, with `pointTags` control points. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the Bezier curve.

Input: `pointTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/addPolyline`
Add a polyline curve in the built-in CAD representation, going through the points `pointTags`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Create a periodic curve if the first and last points are the same. Return the tag of the polyline curve.

Input: `pointTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/addCompoundSpline`
Add a spline (Catmull-Rom) curve in the built-in CAD representation, going through points sampling the curves in `curveTags`. The density of sampling points on each curve is governed by `numIntervals`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the spline.

Input: `curveTags` (vector of integers), `numIntervals = 5` (integer), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/addCompoundBSpline`
Add a b-spline curve in the built-in CAD representation, with control points sampling the curves in `curveTags`. The density of sampling points on each curve is governed by `numIntervals`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the b-spline.

Input: `curveTags` (vector of integers), `numIntervals = 20` (integer), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/addCurveLoop`
Add a curve loop (a closed wire) in the built-in CAD representation, formed by the curves `curveTags`. `curveTags` should contain (signed) tags of model entities of dimension 1 forming a closed loop: a negative tag signifies that the underlying curve is considered with reversed orientation. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. If `reorient` is set, automatically reorient the curves if necessary. Return the tag of the curve loop.

Input: `curveTags` (vector of integers), `tag = -1` (integer), `reorient = False` (boolean)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t5.cpp, t6.cpp, ...), Python (t1.py, t2.py, t3.py, t5.py, t6.py, ...)

`gmsh/model/geo/addCurveLoops`
Add curve loops in the built-in CAD representation based on the curves `curveTags`. Return the `tags` of found curve loops, if any.

Input: `curveTags` (vector of integers)

Output: `tags` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (aneurysm.py, tube_boundary_layer.py)

`gmsh/model/geo/addPlaneSurface`
Add a plane surface in the built-in CAD representation, defined by one or more curve loops `wireTags`. The first curve loop defines the exterior contour; additional curve loop define holes. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the surface.

Input: `wireTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t5.cpp, t6.cpp, ...), Python (t1.py, t2.py, t3.py, t5.py, t6.py, ...)

`gmsh/model/geo/addSurfaceFilling`

Add a surface in the built-in CAD representation, filling the curve loops in `wireTags` using transfinite interpolation. Currently only a single curve loop is supported; this curve loop should be composed by 3 or 4 curves only. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the surface.

Input: `wireTags` (vector of integers), `tag = -1` (integer), `sphereCenterTag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t5.cpp, t12.cpp), Python (t5.py, t12.py)

`gmsh/model/geo/addSurfaceLoop`

Add a surface loop (a closed shell) formed by `surfaceTags` in the built-in CAD representation. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the shell.

Input: `surfaceTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t2.cpp, t5.cpp, t13.cpp, x2.cpp), Python (t2.py, t5.py, t13.py, x2.py, aneurysm.py, ...)

`gmsh/model/geo/addVolume`

Add a volume (a region) in the built-in CAD representation, defined by one or more shells `shellTags`. The first surface loop defines the exterior boundary; additional surface loop define holes. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the volume.

Input: `shellTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t2.cpp, t5.cpp, t13.cpp, x2.cpp), Python (t2.py, t5.py, t13.py, x2.py, aneurysm.py, ...)

`gmsh/model/geo/addGeometry`

Add a `geometry` in the built-in CAD representation. `geometry` can currently be one of `"Sphere"` or `"PolarSphere"` (where `numbers` should contain the x, y, z coordinates of the center, followed by the radius), or `"Parametric"` (where `strings` should contains three expression evaluating to the x, y and z coordinates. If `tag` is positive, set the tag of the geometry explicitly; otherwise a new tag is selected automatically. Return the tag of the geometry.

Input: `geometry` (string), `numbers = []` (vector of doubles), `strings = []` (vector of strings), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (ocean.py)

`gmsh/model/geo/addPointOnGeometry`

Add a point in the built-in CAD representation, at coordinates (`x`, `y`, `z`) on the geometry `geometryTag`. If `meshSize` is > 0, add a meshing constraint at that point. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the point. For surface geometries, only the `x` and `y` coordinates are used.

Input: `geometryTag` (integer), `x` (double), `y` (double), `z = 0.` (double), `meshSize = 0.` (double), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (ocean.py)

`gmsh/model/geo/extrude`

Extrude the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation, using a translation along (`dx`, `dy`, `dz`). Return extruded entities in `outDimTags`. If the `numElements` vector is not empty, also extrude the mesh: the entries in `numElements` give the number of elements in each layer. If the `height` vector is not empty, it provides the (cumulative) height of the different layers, normalized to 1. If `recombine` is set, recombine the mesh in the layers.

Input: `dimTags` (vector of pairs of integers), `dx` (double), `dy` (double), `dz` (double), `numElements = []` (vector of integers), `heights = []` (vector of doubles), `recombine = False` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t2.cpp, t3.cpp, t14.cpp, t15.cpp), Python (t2.py, t3.py, t14.py, t15.py, hex.py)

`gmsh/model/geo/revolve`

Extrude the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation, using a rotation of `angle` radians around the axis of revolution defined by the point (`x`, `y`, `z`) and the direction (`ax`, `ay`, `az`). The angle should be strictly smaller than Pi. Return extruded entities in `outDimTags`. If the `numElements` vector is not empty, also extrude the mesh: the entries in `numElements` give the number of elements in each layer. If the `height` vector is not empty, it provides the (cumulative) height of the different layers, normalized to 1. If `recombine` is set, recombine the mesh in the layers.

Input: `dimTags` (vector of pairs of integers), `x` (double), `y` (double), `z` (double), `ax` (double), `ay` (double), `az` (double), `angle` (double), `numElements = []` (vector of integers), `heights = []` (vector of doubles), `recombine = False` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp), Python (t3.py)

`gmsh/model/geo/twist`

Extrude the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation, using a combined translation and rotation of `angle` radians, along (`dx`, `dy`, `dz`) and around the axis of revolution defined by the point (`x`, `y`, `z`) and the direction (`ax`, `ay`, `az`). The angle should be strictly smaller than Pi. Return extruded entities in `outDimTags`. If the `numElements` vector is not empty, also extrude the mesh: the entries in `numElements` give the number of elements in each layer. If the `height` vector is not empty, it provides the (cumulative) height of the different layers, normalized to 1. If `recombine` is set, recombine the mesh in the layers.

Input: `dimTags` (vector of pairs of integers), `x` (double), `y` (double), `z` (double), `dx` (double), `dy` (double), `dz` (double), `ax` (double), `ay` (double), `az` (double), `angle` (double), `numElements = []` (vector of integers), `heights = []` (vector of doubles), `recombine = False` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp), Python (t3.py)

`gmsh/model/geo/extrudeBoundaryLayer`

Extrude the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation along the normals of the mesh, creating discrete boundary layer entities. Return extruded entities in `outDimTags`. The entries in `numElements` give the number of elements in each layer. If the `height` vector is not empty, it provides the (cumulative) height of the different layers. If `recombine` is set, recombine the mesh in the layers. A second boundary layer can be created from the same entities if `second` is set. If `viewIndex` is >= 0, use the corresponding view to either specify the normals (if the view contains a vector field) or scale the normals (if the view is scalar).

Input: `dimTags` (vector of pairs of integers), `numElements = [1]` (vector of integers), `heights = []` (vector of doubles), `recombine = False` (boolean), `second = False` (boolean), `viewIndex = -1` (integer)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (aneurysm.py, naca_boundary_layer_2d.py, naca_boundary_layer_3d.py, tube_boundary_layer.py)

`gmsh/model/geo/translate`

Translate the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation along (`dx`, `dy`, `dz`).

Input: `dimTags` (vector of pairs of integers), `dx` (double), `dy` (double), `dz` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t2.cpp), Python (t2.py)

`gmsh/model/geo/rotate`

Rotate the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation by `angle` radians around the axis of revolution defined by the point (`x`, `y`, `z`) and the direction (`ax`, `ay`, `az`).

Input: `dimTags` (vector of pairs of integers), `x` (double), `y` (double), `z` (double), `ax` (double), `ay` (double), `az` (double), `angle` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t2.cpp), Python (t2.py)

`gmsh/model/geo/dilate`

Scale the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation by factors `a`, `b` and `c` along the three coordinate axes; use (`x`, `y`, `z`) as the center of the homothetic transformation.

Input: `dimTags` (vector of pairs of integers), `x` (double), `y` (double), `z` (double), `a` (double), `b` (double), `c` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/mirror`

Mirror the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation, with respect to the plane of equation `a` * x + `b` * y + `c` * z + `d` = 0.

Input: `dimTags` (vector of pairs of integers), `a` (double), `b` (double), `c` (double), `d` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/symmetrize`

Mirror the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation, with respect to the plane of equation `a` * x + `b` * y + `c` * z + `d` = 0. (This is a synonym for `mirror`, which will be deprecated in a future release.)

Input: `dimTags` (vector of pairs of integers), `a` (double), `b` (double), `c` (double), `d` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/copy`

Copy the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation; the new entities are returned in `outDimTags`.

Input: `dimTags` (vector of pairs of integers)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t2.cpp), Python (t2.py)

`gmsh/model/geo/remove`

Remove the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD representation, provided that they are not on the boundary of higher-dimensional entities. If `recursive` is true, remove all the entities on their boundaries, down to dimension 0.

Input: `dimTags` (vector of pairs of integers), `recursive` = `False` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t6.cpp), Python (t6.py)

`gmsh/model/geo/removeAllDuplicates`

Remove all duplicate entities in the built-in CAD representation (different entities at the same geometrical location).

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/splitCurve`

Split the curve of tag `tag` in the built-in CAD representation, on the specified control points `pointTags`. This feature is only available for lines, splines and b-splines. Return the tag(s) `curveTags` of the newly created curve(s).

Input: `tag` (integer), `pointTags` (vector of integers)

Output: `curveTags` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/getMaxTag`
Get the maximum tag of entities of dimension `dim` in the built-in CAD representation.

Input: `dim` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/setMaxTag`
Set the maximum tag `maxTag` for entities of dimension `dim` in the built-in CAD representation.

Input: `dim` (integer), `maxTag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/addPhysicalGroup`
Add a physical group of dimension `dim`, grouping the entities with tags `tags` in the built-in CAD representation. Return the tag of the physical group, equal to `tag` if `tag` is positive, or a new tag if `tag` < 0. Set the name of the physical group if `name` is not empty.

Input: `dim` (integer), `tags` (vector of integers), `tag = -1` (integer), `name = ""` (string)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t5.cpp), Python (t5.py)

`gmsh/model/geo/removePhysicalGroups`
Remove the physical groups `dimTags` (given as a vector of (dim, tag) pairs) from the built-in CAD representation. If `dimTags` is empty, remove all groups.

Input: `dimTags = []` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/synchronize`

Synchronize the built-in CAD representation with the current Gmsh model. This can be called at any time, but since it involves a non trivial amount of processing, the number of synchronization points should normally be minimized. Without synchronization the entities in the built-in CAD representation are not available to any function outside of the built-in CAD kernel functions.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t3.cpp, t5.cpp, t6.cpp, ...), Python (t1.py, t2.py, t3.py, t5.py, t6.py, ...)

6.7 Namespace `gmsh/model/geo/mesh`: built-in CAD kernel meshing constraints

`gmsh/model/geo/mesh/setSize`

Set a mesh size constraint on the entities `dimTags` (given as a vector of (dim, tag) pairs) in the built-in CAD kernel representation. Currently only entities of dimension 0 (points) are handled.

Input: `dimTags` (vector of pairs of integers), `size` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t2.cpp, t15.cpp), Python (t2.py, t15.py)

`gmsh/model/geo/mesh/setTransfiniteCurve`

Set a transfinite meshing constraint on the curve `tag` in the built-in CAD kernel representation, with `numNodes` nodes distributed according to `meshType` and `coef`. Currently supported types are `"Progression"` (geometrical progression with power `coef`) and `"Bump"` (refinement toward both extremities of the curve).

Input: `tag` (integer), `nPoints` (integer), `meshType = "Progression"` (string), `coef = 1.` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t6.cpp), Python (t6.py)

`gmsh/model/geo/mesh/setTransfiniteSurface`

Set a transfinite meshing constraint on the surface `tag` in the built-in CAD kernel representation. `arrangement` describes the arrangement of the triangles when the surface is not flagged as recombined: currently supported values are `"Left"`, `"Right"`, `"AlternateLeft"` and `"AlternateRight"`. `cornerTags` can be used to specify the (3 or 4) corners of the transfinite interpolation explicitly; specifying the corners explicitly is mandatory if the surface has more that 3 or 4 points on its boundary.

Input: `tag` (integer), `arrangement = "Left"` (string), `cornerTags = []` (vector of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t6.cpp), Python (t6.py)

`gmsh/model/geo/mesh/setTransfiniteVolume`
Set a transfinite meshing constraint on the surface `tag` in the built-in CAD kernel representation. `cornerTags` can be used to specify the (6 or 8) corners of the transfinite interpolation explicitly.

Input: `tag` (integer), `cornerTags = []` (vector of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/mesh/setRecombine`
Set a recombination meshing constraint on the entity of dimension `dim` and tag `tag` in the built-in CAD kernel representation. Currently only entities of dimension 2 (to recombine triangles into quadrangles) are supported; `angle` specifies the threshold angle for the simple recombination algorithm.

Input: `dim` (integer), `tag` (integer), `angle = 45.` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t6.cpp), Python (t6.py)

`gmsh/model/geo/mesh/setSmoothing`
Set a smoothing meshing constraint on the entity of dimension `dim` and tag `tag` in the built-in CAD kernel representation. `val` iterations of a Laplace smoother are applied.

Input: `dim` (integer), `tag` (integer), `val` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/mesh/setReverse`
Set a reverse meshing constraint on the entity of dimension `dim` and tag `tag` in the built-in CAD kernel representation. If `val` is true, the mesh orientation will be reversed with respect to the natural mesh orientation (i.e. the orientation consistent with the orientation of the geometry). If `val` is false, the mesh is left as-is.

Input: `dim` (integer), `tag` (integer), `val = True` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/mesh/setAlgorithm`
Set the meshing algorithm on the entity of dimension `dim` and tag `tag` in the built-in CAD kernel representation. Currently only supported for `dim` == 2.

Input: `dim` (integer), `tag` (integer), `val` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/geo/mesh/setSizeFromBoundary`
Force the mesh size to be extended from the boundary, or not, for the entity of dimension `dim` and tag `tag` in the built-in CAD kernel representation. Currently only supported for `dim` == 2.

Input: `dim` (integer), `tag` (integer), `val` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

6.8 Namespace `gmsh/model/occ`: OpenCASCADE CAD kernel functions

`gmsh/model/occ/addPoint`
Add a geometrical point in the OpenCASCADE CAD representation, at coordinates (`x`, `y`, `z`). If `meshSize` is > 0, add a meshing constraint at that point. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the point. (Note that the point will be added in the current model only after `synchronize` is called. This behavior holds for all the entities added in the occ module.)

Input: `x` (double), `y` (double), `z` (double), `meshSize = 0.` (double), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp), Python (t19.py, bspline_bezier_patches.py, bspline_bezier_trimmed.py, bspline_filling.py, circle_arc.py, ...)

`gmsh/model/occ/addLine`
Add a straight line segment in the OpenCASCADE CAD representation, between the two points with tags `startTag` and `endTag`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the line.

Input: `startTag` (integer), `endTag` (integer), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (crack.py, naca_boundary_layer_2d.py, naca_boundary_layer_3d.py, relocate_nodes.py, stl_to_brep.py)

`gmsh/model/occ/addCircleArc`

Add a circle arc in the OpenCASCADE CAD representation, between the two points with tags `startTag` and `endTag`, with middle point `middleTag`. If `center` is true, the middle point is the center of the circle; otherwise the circle goes through the middle point. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the circle arc.

Input: `startTag` (integer), `middleTag` (integer), `endTag` (integer), `tag = -1` (integer), `center = True` (boolean)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (circle_arc.py, naca_boundary_layer_2d.py, naca_boundary_layer_3d.py)

`gmsh/model/occ/addCircle`

Add a circle of center (`x`, `y`, `z`) and radius `r` in the OpenCASCADE CAD representation. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. If `angle1` and `angle2` are specified, create a circle arc between the two angles. If a vector `zAxis` of size 3 is provided, use it as the normal to the circle plane (z-axis). If a vector `xAxis` of size 3 is provided in addition to `zAxis`, use it to define the x-axis. Return the tag of the circle.

Input: `x` (double), `y` (double), `z` (double), `r` (double), `tag = -1` (integer), `angle1 = 0.` (double), `angle2 = 2*pi` (double), `zAxis = []` (vector of doubles), `xAxis = []` (vector of doubles)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp), Python (t19.py, bspline_bezier_trimmed.py, closest_point.py, prim_axis.py, trimmed.py)

`gmsh/model/occ/addEllipseArc`

Add an ellipse arc in the OpenCASCADE CAD representation, between the two points `startTag` and `endTag`, and with center `centerTag` and major axis point `majorTag`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the ellipse arc. Note that OpenCASCADE does not allow creating ellipse arcs with the major radius smaller than the minor radius.

Input: `startTag` (integer), `centerTag` (integer), `majorTag` (integer), `endTag` (integer), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/addEllipse`

Add an ellipse of center (`x`, `y`, `z`) and radii `r1` and `r2` (with `r1 >= r2`) along the x- and y-axes, respectively, in the OpenCASCADE CAD representation. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. If `angle1` and `angle2` are specified, create an ellipse arc between the two angles. If a vector `zAxis` of size 3 is provided, use it as the normal to the ellipse plane (z-axis). If a vector `xAxis` of size 3 is provided in addition to `zAxis`, use it to define the x-axis. Return the tag of the ellipse.

Input: `x` (double), `y` (double), `z` (double), `r1` (double), `r2` (double), `tag = -1` (integer), `angle1 = 0.` (double), `angle2 = 2*pi` (double), `zAxis = []` (vector of doubles), `xAxis = []` (vector of doubles)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (prim_axis.py)

`gmsh/model/occ/addSpline`

Add a spline (C2 b-spline) curve in the OpenCASCADE CAD representation, going through the points `pointTags`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Create a periodic curve if the first and last points are the same. Return the tag of the spline curve. If the `tangents` vector contains 6 entries, use them as concatenated x, y, z components of the initial and final tangents of the b-spline; if it contains 3 times as many entries as the number of points, use them as concatenated x, y, z components of the tangents at each point, unless the norm of the tangent is zero.

Input: `pointTags` (vector of integers), `tag = -1` (integer), `tangents = []` (vector of doubles)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp), Python (t19.py, naca_boundary_layer_2d.py, naca_boundary_layer_3d.py, pipe.py, spline.py, ...)

`gmsh/model/occ/addBSpline`

Add a b-spline curve of degree `degree` in the OpenCASCADE CAD representation, with `pointTags` control points. If `weights`, `knots` or `multiplicities` are not provided, default parameters are computed automatically. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Create a periodic curve if the first and last points are the same. Return the tag of the b-spline curve.

Input: `pointTags` (vector of integers), `tag = -1` (integer), `degree = 3` (integer), `weights = []` (vector of doubles), `knots = []` (vector of doubles), `multiplicities = []` (vector of integers)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (bspline_filling.py, spline.py)

`gmsh/model/occ/addBezier`

Add a Bezier curve in the OpenCASCADE CAD representation, with `pointTags` control points. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the Bezier curve.

Input: `pointTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (spline.py)

`gmsh/model/occ/addWire`

Add a wire (open or closed) in the OpenCASCADE CAD representation, formed by the curves `curveTags`. Note that an OpenCASCADE wire can be made of curves that share geometrically identical (but topologically different) points. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the wire.

Input: `curveTags` (vector of integers), `tag = -1` (integer), `checkClosed = False` (boolean)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp), Python (t19.py, bspline_bezier_trimmed.py, bspline_filling.py, pipe.py, trimmed.py)

`gmsh/model/occ/addCurveLoop`

Add a curve loop (a closed wire) in the OpenCASCADE CAD representation, formed by the curves `curveTags`. `curveTags` should contain tags of curves forming a closed loop. Negative tags can be specified for compatibility with the built-in kernel, but are simply ignored: the wire is oriented according to the orientation of its first curve. Note that an OpenCASCADE curve loop can be made of curves that share geometrically identical (but topologically different) points. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the curve loop.

Input: `curveTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp), Python (t19.py, naca_boundary_layer_2d.py, relocate_nodes.py, stl_to_brep.py, surface_filling.py)

`gmsh/model/occ/addRectangle`

Add a rectangle in the OpenCASCADE CAD representation, with lower left corner at (`x`, `y`, `z`) and upper right corner at (`x + dx`, `y + dy`, `z`). If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Round the corners if `roundedRadius` is nonzero. Return the tag of the rectangle.

Input: `x` (double), `y` (double), `z` (double), `dx` (double), `dy` (double), `tag = -1` (integer), `roundedRadius = 0.` (double)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t17.cpp, t20.cpp, t21.cpp, x6.cpp), Python (t17.py, t20.py, t21.py, tri.py, x6.py, ...)

`gmsh/model/occ/addDisk`

Add a disk in the OpenCASCADE CAD representation, with center (`xc`, `yc`, `zc`) and radius `rx` along the x-axis and `ry` along the y-axis (`rx >= ry`). If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. If a vector `zAxis` of size 3 is provided, use it as the normal to the disk (z-axis). If a vector `xAxis` of size 3 is provided in addition to `zAxis`, use it to define the x-axis. Return the tag of the disk.

Input: `xc` (double), `yc` (double), `zc` (double), `rx` (double), `ry` (double), `tag = -1` (integer), `zAxis = []` (vector of doubles), `xAxis = []` (vector of doubles)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp), Python (t19.py, pipe.py, poisson.py, prim_axis.py)

`gmsh/model/occ/addPlaneSurface`

Add a plane surface in the OpenCASCADE CAD representation, defined by one or more curve loops (or closed wires) `wireTags`. The first curve loop defines the exterior contour; additional curve loop define holes. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the surface.

Input: `wireTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (naca_boundary_layer_2d.py, stl_to_brep.py)

`gmsh/model/occ/addSurfaceFilling`

Add a surface in the OpenCASCADE CAD representation, filling the curve loop `wireTag`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the surface. If `pointTags` are provided, force the surface to pass through the given points. The other optional arguments are `degree` (the degree of the energy criterion to minimize for computing the deformation of the surface), `numPointsOnCurves` (the average number of points for discretisation of the bounding curves), `numIter` (the maximum number of iterations of the optimization process), `anisotropic` (improve performance when the ratio of the length along the two parametric coordinates of the surface is high), `tol2d` (tolerance to the constraints in the parametric plane of the surface), `tol3d` (the maximum distance allowed between the support surface and the constraints), `tolAng` (the maximum angle allowed between the normal of the surface and the constraints), `tolCurv` (the maximum difference of curvature allowed between the surface and the constraint), `maxDegree` (the highest degree which the polynomial defining the filling surface can have) and, `maxSegments` (the largest number of segments which the filling surface can have).

Input: `wireTag` (integer), `tag = -1` (integer), `pointTags = []` (vector of integers), `degree = 3` (integer), `numPointsOnCurves = 15` (integer), `numIter = 2` (integer), `anisotropic = False` (boolean), `tol2d = 0.00001` (double), `tol3d = 0.0001` (double), `tolAng = 0.01` (double), `tolCurv = 0.1` (double), `maxDegree = 8` (integer), `maxSegments = 9` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (relocate_nodes.py, surface_filling.py)

`gmsh/model/occ/addBSplineFilling`

Add a BSpline surface in the OpenCASCADE CAD representation, filling the curve loop `wireTag`. The curve loop should be made of 2, 3 or 4 curves. The optional `type` argument specifies the type of filling: `"Stretch"` creates the flattest patch, `"Curved"` (the default) creates the most rounded patch, and `"Coons"` creates a rounded patch with less depth than `"Curved"`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the surface.

Input: `wireTag` (integer), `tag = -1` (integer), `type = ""` (string)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (bspline_filling.py, surface_filling.py)

`gmsh/model/occ/addBezierFilling`

Add a Bezier surface in the OpenCASCADE CAD representation, filling the curve loop `wireTag`. The curve loop should be made of 2, 3 or 4 Bezier curves. The optional `type` argument specifies the type of filling: `"Stretch"` creates the flattest patch, `"Curved"` (the default) creates the most rounded patch, and `"Coons"` creates a rounded patch with less depth than `"Curved"`. If `tag` is positive, set the tag

explicitly; otherwise a new tag is selected automatically. Return the tag of the surface.

Input: `wireTag` (integer), `tag = -1` (integer), `type = ""` (string)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/addBSplineSurface`

Add a b-spline surface of degree `degreeU` x `degreeV` in the OpenCASCADE CAD representation, with `pointTags` control points given as a single vector [Pu1v1, ... Pu`numPointsU`v1, Pu1v2, ...]. If `weights`, `knotsU`, `knotsV`, `multiplicitiesU` or `multiplicitiesV` are not provided, default parameters are computed automatically. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. If `wireTags` is provided, trim the b-spline patch using the provided wires: the first wire defines the external contour, the others define holes. If `wire3D` is set, consider wire curves as 3D curves and project them on the b-spline surface; otherwise consider the wire curves as defined in the parametric space of the surface. Return the tag of the b-spline surface.

Input: `pointTags` (vector of integers), `numPointsU` (integer), `tag = -1` (integer), `degreeU = 3` (integer), `degreeV = 3` (integer), `weights = []` (vector of doubles), `knotsU = []` (vector of doubles), `knotsV = []` (vector of doubles), `multiplicitiesU = []` (vector of integers), `multiplicitiesV = []` (vector of integers), `wireTags = []` (vector of integers), `wire3D = False` (boolean)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (bspline_bezier_patches.py, bspline_bezier_trimmed.py, terrain_bspline.py)

`gmsh/model/occ/addBezierSurface`

Add a Bezier surface in the OpenCASCADE CAD representation, with `pointTags` control points given as a single vector [Pu1v1, ... Pu`numPointsU`v1, Pu1v2, ...]. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. If `wireTags` is provided, trim the Bezier patch using the provided wires: the first wire defines the external contour, the others define holes. If `wire3D` is set, consider wire curves as 3D curves and project them on the Bezier surface; otherwise consider the wire curves as defined in the parametric space of the surface. Return the tag of the Bezier surface.

Input: `pointTags` (vector of integers), `numPointsU` (integer), `tag = -1` (integer), `wireTags = []` (vector of integers), `wire3D = False` (boolean)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (bspline_bezier_patches.py)

`gmsh/model/occ/addTrimmedSurface`

Trim the surface `surfaceTag` with the wires `wireTags`, replacing any existing trimming curves. The first wire defines the external contour, the others define holes. If `wire3D` is set, consider wire curves as 3D curves and project them on the surface; otherwise consider the wire curves as defined in the parametric space of the surface. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the trimmed surface.

Input: `surfaceTag` (integer), `wireTags = []` (vector of integers), `wire3D = False` (boolean), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (trimmed.py)

`gmsh/model/occ/addSurfaceLoop`

Add a surface loop (a closed shell) in the OpenCASCADE CAD representation, formed by `surfaceTags`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the surface loop. Setting `sewing` allows one to build a shell made of surfaces that share geometrically identical (but topologically different) curves.

Input: `surfaceTags` (vector of integers), `tag = -1` (integer), `sewing = False` (boolean)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (stl_to_brep.py)

`gmsh/model/occ/addVolume`

Add a volume (a region) in the OpenCASCADE CAD representation, defined by one or more surface loops `shellTags`. The first surface loop defines the exterior boundary; additional surface loop define holes. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the volume.

Input: `shellTags` (vector of integers), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (stl_to_brep.py)

`gmsh/model/occ/addSphere`

Add a sphere of center (`xc`, `yc`, `zc`) and radius `r` in the OpenCASCADE CAD representation. The optional `angle1` and `angle2` arguments define the polar angle opening (from -Pi/2 to Pi/2). The optional `angle3` argument defines the azimuthal opening (from 0 to 2*Pi). If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the sphere.

Input: `xc` (double), `yc` (double), `zc` (double), `radius` (double), `tag = -1` (integer), `angle1 = -pi/2` (double), `angle2 = pi/2` (double), `angle3 = 2*pi` (double)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp, t18.cpp, x5.cpp), Python (t16.py, t18.py, x5.py, boolean.py, extend_field.py, ...)

`gmsh/model/occ/addBox`

Add a parallelepipedic box in the OpenCASCADE CAD representation, defined by a point (`x`, `y`, `z`) and the extents along the x-, y- and z-axes. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the box.

Input: `x` (double), `y` (double), `z` (double), `dx` (double), `dy` (double), `dz` (double), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp, t18.cpp, x4.cpp, x5.cpp, x7.cpp), Python (t16.py, t18.py, x4.py, x5.py, x7.py, ...)

`gmsh/model/occ/addCylinder`

Add a cylinder in the OpenCASCADE CAD representation, defined by the center (`x`, `y`, `z`) of its first circular face, the 3 components (`dx`, `dy`, `dz`) of the vector defining its axis and its radius `r`. The optional `angle` argument defines the angular opening (from 0 to 2*Pi). If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the cylinder.

Input: `x` (double), `y` (double), `z` (double), `dx` (double), `dy` (double), `dz` (double), `r` (double), `tag = -1` (integer), `angle = 2*pi` (double)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (boolean.py, cylinderFFD.py, gui.py, tube_boundary_layer.py)

`gmsh/model/occ/addCone`

Add a cone in the OpenCASCADE CAD representation, defined by the center (`x`, `y`, `z`) of its first circular face, the 3 components of the vector (`dx`, `dy`, `dz`) defining its axis and the two radii `r1` and `r2` of the faces (these radii can be zero). If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. `angle` defines the optional angular opening (from 0 to 2*Pi). Return the tag of the cone.

Input: `x` (double), `y` (double), `z` (double), `dx` (double), `dy` (double), `dz` (double), `r1` (double), `r2` (double), `tag = -1` (integer), `angle = 2*pi` (double)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x1.cpp), Python (x1.py)

`gmsh/model/occ/addWedge`

Add a right angular wedge in the OpenCASCADE CAD representation, defined by the right-angle point (`x`, `y`, `z`) and the 3 extends along the x-, y- and z-axes (`dx`, `dy`, `dz`). If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. The optional argument `ltx` defines the top extent along the x-axis. If a vector `zAxis` of size 3 is provided, use it to define the z-axis. Return the tag of the wedge.

Input: `x` (double), `y` (double), `z` (double), `dx` (double), `dy` (double), `dz` (double), `tag = -1` (integer), `ltx = 0.` (double), `zAxis = []` (vector of doubles)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (prim_axis.py)

`gmsh/model/occ/addTorus`

Add a torus in the OpenCASCADE CAD representation, defined by its center (`x`, `y`, `z`) and its 2 radii `r` and `r2`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. The optional argument `angle` defines the angular opening (from 0 to 2*Pi). If a vector `zAxis` of size 3 is provided, use it to define the z-axis. Return the tag of the torus.

Input: `x` (double), `y` (double), `z` (double), `r1` (double), `r2` (double), `tag = -1` (integer), `angle = 2*pi` (double), `zAxis = []` (vector of doubles)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (prim_axis.py, step_header_data.py)

`gmsh/model/occ/addThruSections`

Add a volume (if the optional argument `makeSolid` is set) or surfaces in the OpenCASCADE CAD representation, defined through the open or closed wires `wireTags`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. The new entities are returned in `outDimTags` as a vector of (dim, tag) pairs. If the optional argument `makeRuled` is set, the surfaces created on the boundary are forced to be ruled surfaces. If `maxDegree` is positive, set the maximal degree of resulting surface. The optional argument `continuity` allows to specify the continuity of the resulting shape (`"C0"`, `"G1"`, `"C1"`, `"G2"`, `"C2"`, `"C3"`, `"CN"`). The optional argument `parametrization` sets the parametrization type (`"ChordLength"`, `"Centripetal"`, `"IsoParametric"`). The optional argument `smoothing` determines if smoothing is applied.

Input: `wireTags` (vector of integers), `tag = -1` (integer), `makeSolid = True` (boolean), `makeRuled = False` (boolean), `maxDegree = -1` (integer),

`continuity = ""` (string), `parametrization = ""` (string), `smoothing = False` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp), Python (t19.py)

`gmsh/model/occ/addThickSolid`
Add a hollowed volume in the OpenCASCADE CAD representation, built from an initial volume `volumeTag` and a set of faces from this volume `excludeSurfaceTags`, which are to be removed. The remaining faces of the volume become the walls of the hollowed solid, with thickness `offset`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically.

Input: `volumeTag` (integer), `excludeSurfaceTags` (vector of integers), `offset` (double), `tag = -1` (integer)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/extrude`
Extrude the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation, using a translation along (`dx`, `dy`, `dz`). Return extruded entities in `outDimTags`. If the `numElements` vector is not empty, also extrude the mesh: the entries in `numElements` give the number of elements in each layer. If the `height` vector is not empty, it provides the (cumulative) height of the different layers, normalized to 1. If `recombine` is set, recombine the mesh in the layers.

Input: `dimTags` (vector of pairs of integers), `dx` (double), `dy` (double), `dz` (double), `numElements = []` (vector of integers), `heights = []` (vector of doubles), `recombine = False` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (naca_boundary_layer_3d.py)

`gmsh/model/occ/revolve`
Extrude the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation, using a rotation of `angle` radians around the axis of revolution defined by the point (`x`, `y`, `z`) and the direction (`ax`, `ay`, `az`). Return extruded entities in `outDimTags`. If the `numElements` vector is not empty, also extrude the mesh: the entries in `numElements` give the number of elements in each layer. If the `height` vector is not empty, it provides the (cumulative) height of the different layers, normalized to 1. When the mesh is extruded the angle should be strictly smaller than 2*Pi. If `recombine` is set, recombine the mesh in the layers.

Input: `dimTags` (vector of pairs of integers), `x` (double), `y` (double), `z` (double), `ax` (double), `ay` (double), `az` (double), `angle` (double), `numElements = []` (vector of integers), `heights = []` (vector of doubles), `recombine = False` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (naca_boundary_layer_3d.py)

`gmsh/model/occ/addPipe`

Add a pipe in the OpenCASCADE CAD representation, by extruding the entities `dimTags` (given as a vector of (dim, tag) pairs) along the wire `wireTag`. The type of sweep can be specified with `trihedron` (possible values: "DiscreteTrihedron", "CorrectedFrenet", "Fixed", "Frenet", "ConstantNormal", "Darboux", "GuideAC", "GuidePlan", "GuideACWithContact", "GuidePlanWithContact"). If `trihedron` is not provided, "DiscreteTrihedron" is assumed. Return the pipe in `outDimTags`.

Input: `dimTags` (vector of pairs of integers), `wireTag` (integer), `trihedron = ""` (string)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp), Python (t19.py, pipe.py)

`gmsh/model/occ/fillet`

Fillet the volumes `volumeTags` on the curves `curveTags` with radii `radii`. The `radii` vector can either contain a single radius, as many radii as `curveTags`, or twice as many as `curveTags` (in which case different radii are provided for the begin and end points of the curves). Return the filleted entities in `outDimTags` as a vector of (dim, tag) pairs. Remove the original volume if `removeVolume` is set.

Input: `volumeTags` (vector of integers), `curveTags` (vector of integers), `radii` (vector of doubles), `removeVolume = True` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp), Python (t19.py)

`gmsh/model/occ/chamfer`

Chamfer the volumes `volumeTags` on the curves `curveTags` with distances `distances` measured on surfaces `surfaceTags`. The `distances` vector can either contain a single distance, as many distances as `curveTags` and `surfaceTags`, or twice as many as `curveTags` and `surfaceTags` (in which case the first in each pair is measured on the corresponding surface in `surfaceTags`, the other on the other adjacent surface). Return the chamfered entities in `outDimTags`. Remove the original volume if `removeVolume` is set.

Input: `volumeTags` (vector of integers), `curveTags` (vector of integers), `surfaceTags` (vector of integers), `distances` (vector of doubles), `removeVolume = True` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/fuse`

Compute the boolean union (the fusion) of the entities `objectDimTags` and `toolDimTags` (vectors of (dim, tag) pairs) in the OpenCASCADE CAD representation. Return the resulting entities in `outDimTags`. If `tag` is positive, try to set the tag explicitly (only valid if the boolean operation results in a single entity). Remove the object if `removeObject` is set. Remove the tool if `removeTool` is set.

Input: `objectDimTags` (vector of pairs of integers), `toolDimTags` (vector of pairs of integers), `tag = -1` (integer), `removeObject = True` (boolean), `removeTool = True` (boolean)

Output: `outDimTags` (vector of pairs of integers), `outDimTagsMap` (vector of vectors of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x5.cpp), Python (x5.py, boolean.py, gui.py, tube_boundary_layer.py)

`gmsh/model/occ/intersect`

Compute the boolean intersection (the common parts) of the entities `objectDimTags` and `toolDimTags` (vectors of (dim, tag) pairs) in the OpenCASCADE CAD representation. Return the resulting entities in `outDimTags`. If `tag` is positive, try to set the tag explicitly (only valid if the boolean operation results in a single entity). Remove the object if `removeObject` is set. Remove the tool if `removeTool` is set.

Input: `objectDimTags` (vector of pairs of integers), `toolDimTags` (vector of pairs of integers), `tag = -1` (integer), `removeObject = True` (boolean), `removeTool = True` (boolean)

Output: `outDimTags` (vector of pairs of integers), `outDimTagsMap` (vector of vectors of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (boolean.py, gui.py)

`gmsh/model/occ/cut`

Compute the boolean difference between the entities `objectDimTags` and `toolDimTags` (given as vectors of (dim, tag) pairs) in the OpenCASCADE CAD representation. Return the resulting entities in `outDimTags`. If `tag` is positive, try to set the tag explicitly (only valid if the boolean operation results in a single entity). Remove the object if `removeObject` is set. Remove the tool if `removeTool` is set.

Input: `objectDimTags` (vector of pairs of integers), `toolDimTags` (vector of pairs of integers), `tag = -1` (integer), `removeObject = True` (boolean), `removeTool = True` (boolean)

Output: `outDimTags` (vector of pairs of integers), `outDimTagsMap` (vector of vectors of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp), Python (t16.py, boolean.py, extend_field.py, gui.py, spherical_surf.py)

`gmsh/model/occ/fragment`

Compute the boolean fragments (general fuse) resulting from the intersection of the entities `objectDimTags` and `toolDimTags` (given as vectors of (dim, tag) pairs) in the OpenCASCADE CAD representation, making all interfaces conformal. When applied to entities of different dimensions, the lower dimensional entities will be automatically embedded in the higher dimensional entities if they are not on their boundary. Return the resulting entities in `outDimTags`. If `tag` is positive, try to set the tag explicitly (only valid if the boolean operation results in a single entity). Remove the object if `removeObject` is set. Remove the tool if `removeTool` is set.

Input: `objectDimTags` (vector of pairs of integers), `toolDimTags` (vector of pairs of integers), `tag = -1` (integer), `removeObject = True` (boolean), `removeTool = True` (boolean)

Output: `outDimTags` (vector of pairs of integers), `outDimTagsMap` (vector of vectors of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp, t18.cpp, t20.cpp, t21.cpp), Python (t16.py, t18.py, t20.py, t21.py, bspline_bezier_patches.py, ...)

`gmsh/model/occ/translate`

Translate the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation along (`dx`, `dy`, `dz`).

Input: `dimTags` (vector of pairs of integers), `dx` (double), `dy` (double), `dz` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp, t20.cpp), Python (t19.py, t20.py)

`gmsh/model/occ/rotate`

Rotate the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation by `angle` radians around the axis of revolution defined by the point (`x`, `y`, `z`) and the direction (`ax`, `ay`, `az`).

Input: `dimTags` (vector of pairs of integers), `x` (double), `y` (double), `z` (double), `ax` (double), `ay` (double), `az` (double), `angle` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp, t20.cpp), Python (t19.py, t20.py, naca_boundary_layer_2d.py, naca_boundary_layer_3d.py, pipe.py)

`gmsh/model/occ/dilate`

Scale the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation by factors `a`, `b` and `c` along the three coordinate axes; use (`x`, `y`, `z`) as the center of the homothetic transformation.

Input: `dimTags` (vector of pairs of integers), `x` (double), `y` (double), `z` (double), `a` (double), `b` (double), `c` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/mirror`

Mirror the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation, with respect to the plane of equation `a` * x + `b` * y + `c` * z + `d` = 0.

Input: `dimTags` (vector of pairs of integers), `a` (double), `b` (double), `c` (double), `d` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/symmetrize`

Mirror the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation, with respect to the plane of equation `a` * x + `b` * y + `c` * z + `d` = 0. (This is a deprecated synonym for `mirror`.)

Input: `dimTags` (vector of pairs of integers), `a` (double), `b` (double), `c` (double), `d` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/affineTransform`

Apply a general affine transformation matrix `affineTransform` (16 entries of a 4x4 matrix, by row; only the 12 first can be provided for convenience) to the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation.

Input: `dimTags` (vector of pairs of integers), `affineTransform` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/copy`

Copy the entities `dimTags` in the OpenCASCADE CAD representation; the new entities are returned in `outDimTags`.

Input: `dimTags` (vector of pairs of integers)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp, t20.cpp), Python (t19.py, t20.py)

`gmsh/model/occ/remove`

Remove the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation, provided that they are not on the boundary of higher-dimensional entities. If `recursive` is true, remove all the entities on their boundaries, down to dimension 0.

Input: `dimTags` (vector of pairs of integers), `recursive = False` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t19.cpp, t20.cpp), Python (t19.py, t20.py, pipe.py, trimmed.py, tube_boundary_layer.py)

`gmsh/model/occ/removeAllDuplicates`

Remove all duplicate entities in the OpenCASCADE CAD representation (different entities at the same geometrical location) after intersecting (using boolean fragments) all highest dimensional entities.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (bspline_bezier_patches.py, hybrid_order.py, stl_to_mesh.py)

`gmsh/model/occ/healShapes`

Apply various healing procedures to the entities `dimTags` (given as a vector of (dim, tag) pairs), or to all the entities in the model if `dimTags` is empty, in the OpenCASCADE CAD representation. Return the healed entities in `outDimTags`.

Input: `dimTags = []` (vector of pairs of integers), `tolerance = 1e-8` (double), `fixDegenerated = True` (boolean), `fixSmallEdges = True` (boolean), `fixSmallFaces = True` (boolean), `sewFaces = True` (boolean), `makeSolids = True` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (bspline_bezier_patches.py, heal.py)

`gmsh/model/occ/convertToNURBS`

Convert the entities `dimTags` to NURBS.

Input: `dimTags` (vector of pairs of integers)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/importShapes`

Import BREP, STEP or IGES shapes from the file `fileName` in the OpenCASCADE CAD representation. The imported entities are returned in `outDimTags`, as a vector of (dim, tag) pairs. If the optional argument `highestDimOnly` is set, only import the highest dimensional entities in the file. The optional argument `format` can be used to force the format of the file (currently "brep", "step" or "iges").

Input: `fileName` (string), `highestDimOnly = True` (boolean), `format = ""` (string)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t20.cpp), Python (t20.py)

`gmsh/model/occ/importShapesNativePointer`

Imports an OpenCASCADE `shape` by providing a pointer to a native OpenCASCADE `TopoDS_Shape` object (passed as a pointer to void). The imported entities are returned in `outDimTags` as a vector of (dim, tag) pairs. If the optional argument `highestDimOnly` is set, only import the highest dimensional entities in `shape`. In Python, this function can be used for integration with PythonOCC, in which the SwigPyObject pointer of `TopoDS_Shape` must be passed as an int to `shape`, i.e., `shape = int(pythonocc_shape.this)`. Warning: this function is unsafe, as providing an invalid pointer will lead to undefined behavior.

Input: `shape` (pointer), `highestDimOnly = True` (boolean)

Output: `outDimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/getEntities`

Get all the OpenCASCADE entities. If `dim` is >= 0, return only the entities of the specified dimension (e.g. points if `dim` == 0). The entities are returned as a vector of (dim, tag) pairs.

Input: `dim = -1` (integer)

Output: `dimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t20.cpp), Python (t20.py, bspline_bezier_patches.py, naca_boundary_layer_3d.py, tube_boundary_layer.py)

`gmsh/model/occ/getEntitiesInBoundingBox`

Get the OpenCASCADE entities in the bounding box defined by the two points (`xmin`, `ymin`, `zmin`) and (`xmax`, `ymax`, `zmax`). If `dim` is >= 0, return only the entities of the specified dimension (e.g. points if `dim` == 0).

Input: `xmin` (double), `ymin` (double), `zmin` (double), `xmax` (double), `ymax` (double), `zmax` (double), `dim = -1` (integer)

Output: `dimTags` (vector of pairs of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/getBoundingBox`

Get the bounding box (`xmin`, `ymin`, `zmin`), (`xmax`, `ymax`, `zmax`) of the OpenCASCADE entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `xmin` (double), `ymin` (double), `zmin` (double), `xmax` (double), `ymax` (double), `zmax` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t20.cpp), Python (t20.py, naca_boundary_layer_3d.py)

`gmsh/model/occ/getCurveLoops`

Get the tags `curveLoopTags` of the curve loops making up the surface of tag `surfaceTag`, as well as the tags `curveTags` of the curves making up each curve loop.

Input: `surfaceTag` (integer)

Output: `curveLoopTags` (vector of integers), `curveTags` (vector of vectors of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/getSurfaceLoops`

Get the tags `surfaceLoopTags` of the surface loops making up the volume of tag `volumeTag`, as well as the tags `surfaceTags` of the surfaces making up each surface loop.

Input: `volumeTag` (integer)

Output: `surfaceLoopTags` (vector of integers), `surfaceTags` (vector of vectors of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/getMass`
Get the mass of the OpenCASCADE entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `mass` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (step_assembly.py, volume.py)

`gmsh/model/occ/getCenterOfMass`
Get the center of mass of the OpenCASCADE entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `x` (double), `y` (double), `z` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/getMatrixOfInertia`
Get the matrix of inertia (by row) of the OpenCASCADE entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: `mat` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/getMaxTag`
Get the maximum tag of entities of dimension `dim` in the OpenCASCADE CAD representation.

Input: `dim` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/setMaxTag`
Set the maximum tag `maxTag` for entities of dimension `dim` in the OpenCASCADE CAD representation.

Input: `dim` (integer), `maxTag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/model/occ/synchronize`
Synchronize the OpenCASCADE CAD representation with the current Gmsh model. This can be called at any time, but since it involves a non trivial amount of processing, the number of synchronization points should normally be minimized. Without synchronization the entities in the OpenCASCADE CAD representation are not available to any function outside of the OpenCASCADE CAD kernel functions.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp, t17.cpp, t18.cpp, t19.cpp, t20.cpp, ...), Python (t16.py, t17.py, t18.py, t19.py, t20.py, ...)

6.9 Namespace `gmsh/model/occ/mesh`: OpenCASCADE CAD kernel meshing constraints

`gmsh/model/occ/mesh/setSize`
Set a mesh size constraint on the entities `dimTags` (given as a vector of (dim, tag) pairs) in the OpenCASCADE CAD representation. Currently only entities of dimension 0 (points) are handled.

Input: `dimTags` (vector of pairs of integers), `size` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (naca_boundary_layer_3d.py)

6.10 Namespace `gmsh/view`: post-processing view functions

`gmsh/view/add`
Add a new post-processing view, with name `name`. If `tag` is positive use it (and remove the view with that tag if it already exists), otherwise associate a new tag. Return the view tag.

Input: `name` (string), `tag = -1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t4.cpp, x3.cpp, x4.cpp, x5.cpp), Python (t4.py, x3.py, x4.py, x5.py, adapt_mesh.py, ...)

`gmsh/view/remove`

Remove the view with tag `tag`.

Input: `tag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (plugin.py)

`gmsh/view/getIndex`

Get the index of the view with tag `tag` in the list of currently loaded views. This dynamic index (it can change when views are removed) is used to access view options.

Input: `tag` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (adapt_mesh.py)

`gmsh/view/getTags`

Get the tags of all views.

Input: -

Output: `tags` (vector of integers)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t8.cpp, t9.cpp), Python (t8.py, t9.py, plugin.py)

`gmsh/view/addModelData`

Add model-based post-processing data to the view with tag `tag`. `modelName` identifies the model the data is attached to. `dataType` specifies the type of data, currently either `"NodeData"`, `"ElementData"` or `"ElementNodeData"`. `step` specifies the identifier (`>=` 0) of the data in a sequence. `tags` gives the tags of the nodes or elements in the mesh to which the data is associated. `data` is a vector of the same length as `tags`: each entry is the vector of double precision numbers representing the data associated with the corresponding tag. The optional `time` argument associate a time value with the data. `numComponents` gives the number of data components (1 for scalar data, 3 for vector data, etc.) per entity; if negative, it is automatically inferred (when possible) from the input data. `partition` allows one to specify data in several sub-sets.

Input: `tag` (integer), `step` (integer), `modelName` (string), `dataType` (string), `tags` (vector of sizes), `data` (vector of vectors of doubles), `time` = `0.` (double), `numComponents` = `-1` (integer), `partition` = `0` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (adapt_mesh.py, plugin.py, poisson.py, view.py)

`gmsh/view/addHomogeneousModelData`
Add homogeneous model-based post-processing data to the view with tag `tag`. The arguments have the same meaning as in `addModelData`, except that `data` is supposed to be homogeneous and is thus flattened in a single vector. For data types that can lead to different data sizes per tag (like "ElementNodeData"), the data should be padded.

Input: `tag` (integer), `step` (integer), `modelName` (string), `dataType` (string), `tags` (vector of sizes), `data` (vector of doubles), `time` = `0.` (double), `numComponents` = `-1` (integer), `partition` = `0` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x4.cpp), Python (x4.py, copy_mesh.py, view_element_size.py, view_renumbering.py)

`gmsh/view/getModelData`
Get model-based post-processing data from the view with tag `tag` at step `step`. Return the `data` associated to the nodes or the elements with tags `tags`, as well as the `dataType` and the number of components `numComponents`.

Input: `tag` (integer), `step` (integer)

Output: `dataType` (string), `tags` (vector of sizes), `data` (vector of vectors of doubles), `time` (double), `numComponents` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (get_data_perf.py, mesh_quality.py, plugin.py)

`gmsh/view/getHomogeneousModelData`
Get homogeneous model-based post-processing data from the view with tag `tag` at step `step`. The arguments have the same meaning as in `getModelData`, except that `data` is returned flattened in a single vector, with the appropriate padding if necessary.

Input: `tag` (integer), `step` (integer)

Output: `dataType` (string), `tags` (vector of sizes), `data` (vector of doubles), `time` (double), `numComponents` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (get_data_perf.py)

`gmsh/view/addListData`

Add list-based post-processing data to the view with tag `tag`. List-based datasets are independent from any model and any mesh. `dataType` identifies the data by concatenating the field type (`"S"` for scalar, `"V"` for vector, `"T"` for tensor) and the element type (`"P"` for point, `"L"` for line, `"T"` for triangle, `"S"` for tetrahedron, `"I"` for prism, `"H"` for hexaHedron, `"Y"` for pyramid). For example `dataType` should be `"ST"` for a scalar field on triangles. `numEle` gives the number of elements in the data. `data` contains the data for the `numEle` elements, concatenated, with node coordinates followed by values per node, repeated for each step: [e1x1, ..., e1xn, e1y1, ..., e1yn, e1z1, ..., e1zn, e1v1..., e1vN, e2x1, ...].

Input: `tag` (integer), `dataType` (string), `numEle` (integer), `data` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x3.cpp, x5.cpp), Python (x3.py, x5.py, normals.py, view_adaptive_to_mesh.py, view_combine.py, ...)

`gmsh/view/getListData`

Get list-based post-processing data from the view with tag `tag`. Return the types `dataTypes`, the number of elements `numElements` for each data type and the `data` for each data type. If `returnAdaptive` is set, return the data obtained after adaptive refinement, if available.

Input: `tag` (integer), `returnAdaptive = False` (boolean)

Output: `dataType` (vector of strings), `numElements` (vector of integers), `data` (vector of vectors of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (plugin.py, view_adaptive_to_mesh.py, volume.py)

`gmsh/view/addListDataString`

Add a string to a list-based post-processing view with tag `tag`. If `coord` contains 3 coordinates the string is positioned in the 3D model space (`"3D string"`); if it contains 2 coordinates it is positioned in the 2D graphics viewport (`"2D string"`). `data` contains one or more (for multistep views) strings. `style` contains key-value pairs of styling parameters, concatenated. Available keys are `"Font"` (possible values: `"Times-Roman"`, `"Times-Bold"`, `"Times-Italic"`, `"Times-BoldItalic"`, `"Helvetica"`, `"Helvetica-Bold"`, `"Helvetica-Oblique"`, `"Helvetica-BoldOblique"`, `"Courier"`, `"Courier-Bold"`, `"Courier-Oblique"`, `"Courier-BoldOblique"`, `"Symbol"`, `"ZapfDingbats"`, `"Screen"`), `"FontSize"` and `"Align"` (possible values: `"Left"` or `"BottomLeft"`, `"Center"` or `"BottomCenter"`, `"Right"` or `"BottomRight"`, `"TopLeft"`, `"TopCenter"`, `"TopRight"`, `"CenterLeft"`, `"CenterCenter"`, `"CenterRight"`).

Input: `tag` (integer), `coord` (vector of doubles), `data` (vector of strings), `style = []` (vector of strings)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t4.cpp, x3.cpp), Python (t4.py, x3.py)

`gmsh/view/getListDataStrings`

Get list-based post-processing data strings (2D strings if `dim` == 2, 3D strings if `dim` = 3) from the view with tag `tag`. Return the coordinates in `coord`, the strings in `data` and the styles in `style`.

Input: `tag` (integer), `dim` (integer)

Output: `coord` (vector of doubles), `data` (vector of strings), `style` (vector of strings)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/view/setInterpolationMatrices`

Set interpolation matrices for the element family `type` ("Line", "Triangle", "Quadrangle", "Tetrahedron", "Hexahedron", "Prism", "Pyramid") in the view `tag`. The approximation of the values over an element is written as a linear combination of `d` basis functions f_i(u, v, w) = sum_(j = 0, ..., `d` - 1) `coef`[i][j] u^`exp`[j][0] v^`exp`[j][1] w^`exp`[j][2], i = 0, ..., `d`-1, with u, v, w the coordinates in the reference element. The `coef` matrix (of size `d` x `d`) and the `exp` matrix (of size `d` x 3) are stored as vectors, by row. If `dGeo` is positive, use `coefGeo` and `expGeo` to define the interpolation of the x, y, z coordinates of the element in terms of the u, v, w coordinates, in exactly the same way. If `d` < 0, remove the interpolation matrices.

Input: `tag` (integer), `type` (string), `d` (integer), `coef` (vector of doubles), `exp` (vector of doubles), `dGeo` = `0` (integer), `coefGeo` = `[]` (vector of doubles), `expGeo` = `[]` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x3.cpp), Python (x3.py, view_adaptive_to_mesh.py, view_list_isoparametric.py, view_list_subparametric.py, view_list_superparametric.py)

`gmsh/view/addAlias`

Add a post-processing view as an `alias` of the reference view with tag `refTag`. If `copyOptions` is set, copy the options of the reference view. If `tag` is positive use it (and remove the view with that tag if it already exists), otherwise associate a new tag. Return the view tag.

Input: `refTag` (integer), `copyOptions` = `False` (boolean), `tag` = `-1` (integer)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (view_combine.py)

`gmsh/view/combine`

Combine elements (if `what` == "elements") or steps (if `what` == "steps") of all views (`how` == "all"), all visible views (`how` == "visible") or all views having the same name (`how` == "name"). Remove original views if `remove` is set.

Input: `what` (string), `how` (string), `remove = True` (boolean), `copyOptions = True` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (view_combine.py)

`gmsh/view/probe`

Probe the view `tag` for its `values` at point (`x`, `y`, `z`). If no match is found, `value` is returned empty. Return only the value at step `step` is `step` is positive. Return only values with `numComp` if `numComp` is positive. Return the gradient of the `values` if `gradient` is set. If `distanceMax` is zero, only return a result if an exact match inside an element in the view is found; if `distanceMax` is positive and an exact match is not found, return the value at the closest node if it is closer than `distanceMax`; if `distanceMax` is negative and an exact match is not found, always return the value at the closest node. The distance to the match is returned in `distance`. Return the result from the element described by its coordinates if `xElementCoord`, `yElementCoord` and `zElementCoord` are provided. If `dim` is >= 0, return only matches from elements of the specified dimension.

Input: `tag` (integer), `x` (double), `y` (double), `z` (double), `step = -1` (integer), `numComp = -1` (integer), `gradient = False` (boolean), `distanceMax = 0.` (double), `xElemCoord = []` (vector of doubles), `yElemCoord = []` (vector of doubles), `zElemCoord = []` (vector of doubles), `dim = -1` (integer)

Output: `values` (vector of doubles), `distance` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x3.cpp), Python (x3.py)

`gmsh/view/write`

Write the view to a file `fileName`. The export format is determined by the file extension. Append to the file if `append` is set.

Input: `tag` (integer), `fileName` (string), `append = False` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (x3.cpp, x4.cpp), Python (x3.py, x4.py, adapt_mesh.py, normals.py, plugin.py, ...)

`gmsh/view/setVisibilityPerWindow`
Set the global visibility of the view `tag` per window to `value`, where `windowIndex` identifies the window in the window list.

Input: `tag` (integer), `value` (integer), `windowIndex = 0` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

6.11 Namespace `gmsh/view/option`: view option handling functions

`gmsh/view/option/setNumber`
Set the numerical option `name` to value `value` for the view with tag `tag`.

Input: `tag` (integer), `name` (string), `value` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t8.cpp, t9.cpp, x3.cpp, x5.cpp), Python (t8.py, t9.py, x3.py, x5.py, view_adaptive_to_mesh.py, ...)

`gmsh/view/option/getNumber`
Get the `value` of the numerical option `name` for the view with tag `tag`.

Input: `tag` (integer), `name` (string)

Output: `value` (double)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t8.cpp, x3.cpp), Python (t8.py, x3.py)

`gmsh/view/option/setString`
Set the string option `name` to value `value` for the view with tag `tag`.

Input: `tag` (integer), `name` (string), `value` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t4.cpp, t8.cpp), Python (t4.py, t8.py)

`gmsh/view/option/getString`
Get the `value` of the string option `name` for the view with tag `tag`.

Input: `tag` (integer), `name` (string)

Output: `value` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/view/option/setColor`
Set the color option `name` to the RGBA value (`r`, `g`, `b`, `a`) for the view with tag `tag`, where where `r`, `g`, `b` and `a` should be integers between 0 and 255.

Input: `tag` (integer), `name` (string), `r` (integer), `g` (integer), `b` (integer), `a = 255` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/view/option/getColor`
Get the `r`, `g`, `b`, `a` value of the color option `name` for the view with tag `tag`.

Input: `tag` (integer), `name` (string)

Output: `r` (integer), `g` (integer), `b` (integer), `a` (integer)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/view/option/copy`
Copy the options from the view with tag `refTag` to the view with tag `tag`.

Input: `refTag` (integer), `tag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

6.12 Namespace `gmsh/plugin`: plugin functions

`gmsh/plugin/setNumber`
Set the numerical option `option` to the value `value` for plugin `name`. Plugins available in the official Gmsh release are listed in the "Gmsh plugins" chapter of the Gmsh reference manual.

Input: `name` (string), `option` (string), `value` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t9.cpp, t21.cpp), Python (t9.py, t21.py, adapt_mesh.py, crack3d.py, crack.py, ...)

`gmsh/plugin/setString`
Set the string option `option` to the value `value` for plugin `name`. Plugins available in the official Gmsh release are listed in the "Gmsh plugins" chapter of the Gmsh reference manual.

Input: `name` (string), `option` (string), `value` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t9.cpp), Python (t9.py)

`gmsh/plugin/run`

Run the plugin `name`. Return the tag of the created view (if any). Plugins available in the official Gmsh release are listed in the "Gmsh plugins" chapter of the Gmsh reference manual.

Input: `name` (string)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t9.cpp, t21.cpp), Python (t9.py, t21.py, adapt_mesh.py, crack3d.py, crack.py, ...)

6.13 Namespace `gmsh/graphics`: graphics functions

`gmsh/graphics/draw`

Draw all the OpenGL scenes.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t8.cpp, t13.cpp, t21.cpp), Python (t3.py, t8.py, t13.py, t21.py, split_window.py)

6.14 Namespace `gmsh/fltk`: FLTK graphical user interface functions

`gmsh/fltk/initialize`

Create the FLTK graphical user interface. Can only be called in the main thread.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t8.cpp, t13.cpp, t21.cpp), Python (t3.py, t8.py, t13.py, t21.py, custom_gui.py, ...)

`gmsh/fltk/finalize`

Close the FLTK graphical user interface. Can only be called in the main thread.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/fltk/wait`

Wait at most `time` seconds for user interface events and return. If `time` < 0, wait indefinitely. First automatically create the user interface if it has not yet been initialized. Can only be called in the main thread.

Input: `time = -1.` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t13.cpp, t21.cpp), Python (t3.py, t13.py, t21.py, custom_gui.py, prepro.py, ...)

`gmsh/fltk/update`

Update the user interface (potentially creating new widgets and windows). First automatically create the user interface if it has not yet been initialized. Can only be called in the main thread: use `awake("update")` to trigger an update of the user interface from another thread.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (custom_gui.py, prepro.py)

`gmsh/fltk/awake`

Awake the main user interface thread and process pending events, and optionally perform an action (currently the only `action` allowed is "update").

Input: `action = ""` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (custom_gui.py)

`gmsh/fltk/lock`

Block the current thread until it can safely modify the user interface.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (custom_gui.py)

`gmsh/fltk/unlock`

Release the lock that was set using lock.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (custom_gui.py)

`gmsh/fltk/run`

Run the event loop of the graphical user interface, i.e. repeatedly call `wait()`. First automatically create the user interface if it has not yet been initialized. Can only be called in the main thread.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t1.cpp, t2.cpp, t4.cpp, t5.cpp, t6.cpp, ...), Python (t1.py, t2.py, t4.py, t5.py, t6.py, ...)

`gmsh/fltk/isAvailable`

Check if the user interface is available (e.g. to detect if it has been closed).

Input: -

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t13.cpp, t21.cpp), Python (t3.py, t13.py, t21.py, custom_gui.py, prepro.py, ...)

`gmsh/fltk/selectEntities`

Select entities in the user interface. Return the selected entities as a vector of (dim, tag) pairs. If `dim` is >= 0, return only the entities of the specified dimension (e.g. points if `dim` == 0).

Input: `dim = -1` (integer)

Output: `dimTags` (vector of pairs of integers)

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (prepro.py)

`gmsh/fltk/selectElements`
Select elements in the user interface.

Input: -

Output: `elementTags` (vector of sizes)

Return: integer

Language-specific definition:
C++, C, Python, Julia

Examples: Python (select_elements.py)

`gmsh/fltk/selectViews`
Select views in the user interface.

Input: -

Output: `viewTags` (vector of integers)

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/fltk/splitCurrentWindow`
Split the current window horizontally (if `how` == "h") or vertically (if `how` == "v"), using ratio `ratio`. If `how` == "u", restore a single window.

Input: `how = "v"` (string), `ratio = 0.5` (double)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (split_window.py)

`gmsh/fltk/setCurrentWindow`
Set the current window by speficying its index (starting at 0) in the list of all windows. When new windows are created by splits, new windows are appended at the end of the list.

Input: `windowIndex = 0` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (split_window.py)

`gmsh/fltk/setStatusMessage`
Set a status message in the current window. If `graphics` is set, display the message inside the graphic window instead of the status bar.

Input: `message` (string), `graphics = False` (boolean)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (prepro.py, select_elements.py)

`gmsh/fltk/showContextWindow`
Show context window for the entity of dimension `dim` and tag `tag`.

Input: `dim` (integer), `tag` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (prepro.py)

`gmsh/fltk/openTreeItem`
Open the `name` item in the menu tree.

Input: `name` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (prepro.py)

`gmsh/fltk/closeTreeItem`
Close the `name` item in the menu tree.

Input: `name` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

6.15 Namespace `gmsh/parser`: parser functions

`gmsh/parser/getNames`
Get the names of the variables in the Gmsh parser matching the `search` regular expression. If `search` is empty, return all the names.

Input: `search = ""` (string)

Output: `names` (vector of strings)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/parser/setNumber`
Set the value of the number variable `name` in the Gmsh parser. Create the variable if it does not exist; update the value if the variable exists.

Input: `name` (string), `value` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/parser/setString`

Set the value of the string variable `name` in the Gmsh parser. Create the variable if it does not exist; update the value if the variable exists.

Input: `name` (string), `value` (vector of strings)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/parser/getNumber`

Get the value of the number variable `name` from the Gmsh parser. Return an empty vector if the variable does not exist.

Input: `name` (string)

Output: `value` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/parser/getString`

Get the value of the string variable `name` from the Gmsh parser. Return an empty vector if the variable does not exist.

Input: `name` (string)

Output: `value` (vector of strings)

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/parser/clear`

Clear all the Gmsh parser variables, or remove a single variable if `name` is given.

Input: `name = ""` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/parser/parse`

Parse the file `fileName` with the Gmsh parser.

Input: `fileName` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

6.16 Namespace `gmsh/onelab`: ONELAB server functions

`gmsh/onelab/set`

Set one or more parameters in the ONELAB database, encoded in `format`.

Input: `data` (string), `format = "json"` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t13.cpp, t21.cpp), Python (t3.py, t13.py, t21.py, custom_gui.py, onelab_test.py, ...)

`gmsh/onelab/get`

Get all the parameters (or a single one if `name` is specified) from the ONELAB database, encoded in `format`.

Input: `name = ""` (string), `format = "json"` (string)

Output: `data` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (onelab_run_auto.py, onelab_test.py, prepro.py)

`gmsh/onelab/getNames`

Get the names of the parameters in the ONELAB database matching the `search` regular expression. If `search` is empty, return all the names.

Input: `search = ""` (string)

Output: `names` (vector of strings)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (prepro.py)

`gmsh/onelab/setNumber`

Set the value of the number parameter `name` in the ONELAB database. Create the parameter if it does not exist; update the value if the parameter exists.

Input: `name` (string), `value` (vector of doubles)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (custom_gui.py, onelab_run.py, onelab_test.py)

`gmsh/onelab/setString`

Set the value of the string parameter `name` in the ONELAB database. Create the parameter if it does not exist; update the value if the parameter exists.

Input: `name` (string), `value` (vector of strings)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t13.cpp, t21.cpp), Python (t3.py, t13.py, t21.py, custom_gui.py, onelab_test.py, ...)

`gmsh/onelab/getNumber`

Get the value of the number parameter `name` from the ONELAB database. Return an empty vector if the parameter does not exist.

Input: `name` (string)

Output: `value` (vector of doubles)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t13.cpp, t21.cpp), Python (t3.py, t13.py, t21.py, custom_gui.py, prepro.py, ...)

`gmsh/onelab/getString`

Get the value of the string parameter `name` from the ONELAB database. Return an empty vector if the parameter does not exist.

Input: `name` (string)

Output: `value` (vector of strings)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t3.cpp, t13.cpp, t21.cpp), Python (t3.py, t13.py, t21.py, custom_gui.py, prepro.py, ...)

`gmsh/onelab/getChanged`

Check if any parameters in the ONELAB database used by the client `name` have been changed.

Input: `name` (string)

Output: -

Return: integer

Language-specific definition:
C++, C, Python, Julia

`gmsh/onelab/setChanged`

Set the changed flag to value `value` for all the parameters in the ONELAB database used by the client `name`.

Input: `name` (string), `value` (integer)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

`gmsh/onelab/clear`
Clear the ONELAB database, or remove a single parameter if `name` is given.

Input: `name = ""` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (onelab_test.py)

`gmsh/onelab/run`
Run a ONELAB client. If `name` is provided, create a new ONELAB client with name `name` and executes `command`. If not, try to run a client that might be linked to the processed input files.

Input: `name = ""` (string), `command = ""` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: Python (onelab_run.py, onelab_run_auto.py)

6.17 Namespace `gmsh/logger`: information logging functions

`gmsh/logger/write`
Write a `message`. `level` can be "info", "warning" or "error".

Input: `message` (string), `level = "info"` (string)

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t7.cpp, t8.cpp, t9.cpp, t13.cpp, t16.cpp, ...), Python (t8.py, t9.py, x5.py, custom_gui.py, terrain_stl.py)

`gmsh/logger/start`
Start logging messages.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp), Python (t16.py)

`gmsh/logger/get`
Get logged messages.

Input: -

Output: `log` (vector of strings)

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp), Python (t16.py)

`gmsh/logger/stop`
Stop logging messages.

Input: -

Output: -

Return: -

Language-specific definition:
C++, C, Python, Julia

Examples: C++ (t16.cpp), Python (t16.py)

`gmsh/logger/getWallTime`
Return wall clock time.

Input: -

Output: -

Return: double

Language-specific definition:
C++, C, Python, Julia

Examples: Python (import_perf.py)

`gmsh/logger/getCpuTime`
Return CPU time.

Input: -

Output: -

Return: double

Language-specific definition:
C++, C, Python, Julia

`gmsh/logger/getLastError`
Return last error message, if any.

Input: -

Output: `error` (string)

Return: -

Language-specific definition:
C++, C, Python, Julia

7 Gmsh options

This chapter lists all the Gmsh options. Options can be specified in script files (see Section 5.1 [General scripting commands], page 91) or using the API (see Section 6.2 [Namespace gmsh/option], page 128): see Section 2.3 [t3], page 21 for an example. They can also be specified on the command line using the `-setnumber` and `-setstring` switches: see Chapter 4 [Gmsh command-line interface], page 85. Many options can also be changed interactively in the GUI (see Chapter 3 [Gmsh graphical user interface], page 79): to see which option corresponds to which widget in the GUI, leave your mouse on the widget and a tooltip with the option name will appear. Note that some options can affect the GUI in real time: loading a script file that sets `General.GraphicsWidth` for example (see Section 7.1 [General options], page 223) will change the width of the graphic window at runtime.

Gmsh's default behavior is to save some of these options in a per-user "session resource" file (cf. "Saved in: `General.SessionFileName`" in the option descriptions below) every time Gmsh is shut down. This permits for example to automatically remember the size and location of the windows or which fonts to use. A second set of options can be saved (automatically or manually with the 'File->Save Options As Default' menu) in a per-user "option" file (cf. "Saved in: `General.OptionsFileName`" in the descriptions below), automatically loaded by Gmsh every time it starts up. Finally, other options are only saved to disk manually, either by explicitly saving an option file with 'File->Export', or when saving per-model options with 'File->Save Model Options' (cf. "Saved in: `-`" in the lists below). Per-model options are saved in a file name matching the model file, but with an extra '`.opt`' extension appended: the option file will be automatically opened after Gmsh opens the model file.

Gmsh will attempt to save and load the session and option files first in the `$GMSH_HOME` directory, then in `$APPDATA` (on Windows) or `$HOME` (on other OSes), then in `$TMP`, and finally in `$TEMP`, in that order. If none of these variables are defined, Gmsh will try to save and load the files from the current working directory.

To reset all options to their default values, either delete the `General.SessionFileName` and `General.OptionsFileName` files by hand, use 'Help->Restore All Options to Default Settings', or click on 'Restore all options to default settings' button in the 'Tools->Options->General->Advanced' window.

7.1 General options

`General.AxesFormatX`
: Number format for X-axis (in standard C form)
Default value: `"%.3g"`
Saved in: `General.OptionsFileName`

`General.AxesFormatY`
: Number format for Y-axis (in standard C form)
Default value: `"%.3g"`
Saved in: `General.OptionsFileName`

`General.AxesFormatZ`
: Number format for Z-axis (in standard C form)
Default value: `"%.3g"`
Saved in: `General.OptionsFileName`

`General.AxesLabelX`
: X-axis label
Default value: `""`
Saved in: `General.OptionsFileName`

`General.AxesLabelY`
Y-axis label
Default value: `""`
Saved in: `General.OptionsFileName`

`General.AxesLabelZ`
Z-axis label
Default value: `""`
Saved in: `General.OptionsFileName`

`General.BackgroundImageFileName`
Background image file in JPEG, PNG or PDF format
Default value: `""`
Saved in: `General.OptionsFileName`

`General.BuildInfo`
Gmsh build information (read-only)
Default value: `"Version: 4.12.0-git-6e2db1a37; License: GNU General Public License; Build OS: MacOSARM-sdk; Build date: 20231110; Build host: MacBook-Pro-65.local; Build options: 64Bit ALGLIB[contrib] ANN[contrib] Bamg Blossom Cairo Cgns DIntegration Dlopen DomHex Eigen[contrib] Fltk GMP Gmm[contrib] Hxt Jpeg Kbipack MathEx[contrib] Med Mesh Metis[contrib] Mmg Mpeg Netgen ONELAB ONELABMetamodel OpenCASCADE OpenCASCADE-CAF OpenGL OpenMP[Homebrew] OptHom Parser Plugins Png Post QuadMeshingTools QuadTri Solver TetGen/BR TouchBar Voro++[contrib] WinslowUntangler Zlib; FLTK version: 1.4.0; OCC version: 7.8.0; MED version: 4.1.1; Packaged by: geuzaine; Web site: https://gmsh.info; Issue tracker: https://gitlab.onelab.info/gmsh/gmsh/issues"`
Saved in: `-`

`General.BuildOptions`
Gmsh build options (read-only)
Default value: `"64Bit ALGLIB[contrib] ANN[contrib] Bamg Blossom Cairo Cgns DIntegration Dlopen DomHex Eigen[contrib] Fltk GMP Gmm[contrib] Hxt Jpeg Kbipack MathEx[contrib] Med Mesh Metis[contrib] Mmg Mpeg Netgen ONELAB ONELABMetamodel OpenCASCADE OpenCASCADE-CAF OpenGL OpenMP[Homebrew] OptHom Parser Plugins Png Post QuadMeshingTools QuadTri Solver TetGen/BR TouchBar Voro++[contrib] WinslowUntangler Zlib"`
Saved in: `-`

`General.DefaultFileName`
Default project file name
Default value: `"untitled.geo"`
Saved in: `General.OptionsFileName`

`General.Display`
X server to use (only for Unix versions)
Default value: `""`
Saved in: `-`

`General.ErrorFileName`
File into which the log is saved if a fatal error occurs
Default value: `".gmsh-errors"`
Saved in: `General.OptionsFileName`

`General.ExecutableFileName`
File name of the Gmsh executable (read-only)
Default value: `""`
Saved in: `General.SessionFileName`

`General.FileName`
Current project file name (read-only)
Default value: `""`
Saved in: `-`

`General.FltkTheme`
FLTK user interface theme (try e.g. plastic or gtk+)
Default value: `""`
Saved in: `General.SessionFileName`

`General.GraphicsFont`
Font used in the graphic window
Default value: `"Helvetica"`
Saved in: `General.OptionsFileName`

`General.GraphicsFontEngine`
Set graphics font engine (Native, StringTexture, Cairo)
Default value: `"Native"`
Saved in: `General.OptionsFileName`

`General.GraphicsFontTitle`
Font used in the graphic window for titles
Default value: `"Helvetica"`
Saved in: `General.OptionsFileName`

`General.OptionsFileName`
Option file created with 'Tools->Options->Save'; automatically read on startup
Default value: `".gmsh-options"`
Saved in: `General.SessionFileName`

`General.RecentFile0`
Most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.RecentFile1`
2nd most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.RecentFile2`
3rd most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.RecentFile3`
4th most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.RecentFile4`
5th most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.RecentFile5`
6th most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.RecentFile6`
7th most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.RecentFile7`
8th most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.RecentFile8`
9th most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.RecentFile9`
10th most recent opened file
Default value: `"untitled.geo"`
Saved in: `General.SessionFileName`

`General.SessionFileName`
Option file into which session specific information is saved; automatically read on startup
Default value: `".gmshrc"`
Saved in: `-`

`General.ScriptingLanguages`
Language(s) in which scripting commands generated by the GUI are written
Default value: `"geo"`
Saved in: `General.OptionsFileName`

`General.TextEditor`
System command to launch a text editor
Default value: `"open -t '%s'"`
Saved in: `General.OptionsFileName`

`General.TmpFileName`
Temporary file used by the geometry module
Default value: `".gmsh-tmp"`
Saved in: `General.SessionFileName`

`General.Version`
Gmsh version (read-only)
Default value: `"4.12.0-git-6e2db1a37"`
Saved in: `-`

`General.WatchFilePattern`
Pattern of files to merge as they become available
Default value: `""`
Saved in: `-`

`General.AbortOnError`
Abort on error? (0: no, 1: abort meshing, 2: throw an exception unless in interactive mode, 3: throw an exception always, 4: exit)

Default value: 0
Saved in: General.OptionsFileName

General.AlphaBlending
Enable alpha blending (transparency) in post-processing views
Default value: 1
Saved in: General.OptionsFileName

General.Antialiasing
Use multisample antialiasing (will slow down rendering)
Default value: 0
Saved in: General.OptionsFileName

General.ArrowHeadRadius
Relative radius of arrow head
Default value: 0.12
Saved in: General.OptionsFileName

General.ArrowStemLength
Relative length of arrow stem
Default value: 0.56
Saved in: General.OptionsFileName

General.ArrowStemRadius
Relative radius of arrow stem
Default value: 0.02
Saved in: General.OptionsFileName

General.Axes
Axes (0: none, 1: simple axes, 2: box, 3: full grid, 4: open grid, 5: ruler)
Default value: 0
Saved in: General.OptionsFileName

General.AxesMikado
Mikado axes style
Default value: 0
Saved in: General.OptionsFileName

General.AxesAutoPosition
Position the axes automatically
Default value: 1
Saved in: General.OptionsFileName

General.AxesForceValue
Force values on axes (otherwise use natural coordinates)
Default value: 0
Saved in: General.OptionsFileName

General.AxesMaxX
Maximum X-axis coordinate
Default value: 1
Saved in: General.OptionsFileName

General.AxesMaxY
Maximum Y-axis coordinate
Default value: 1
Saved in: General.OptionsFileName

`General.AxesMaxZ`
Maximum Z-axis coordinate
Default value: `1`
Saved in: `General.OptionsFileName`

`General.AxesMinX`
Minimum X-axis coordinate
Default value: `0`
Saved in: `General.OptionsFileName`

`General.AxesMinY`
Minimum Y-axis coordinate
Default value: `0`
Saved in: `General.OptionsFileName`

`General.AxesMinZ`
Minimum Z-axis coordinate
Default value: `0`
Saved in: `General.OptionsFileName`

`General.AxesTicsX`
Number of tics on the X-axis
Default value: `5`
Saved in: `General.OptionsFileName`

`General.AxesTicsY`
Number of tics on the Y-axis
Default value: `5`
Saved in: `General.OptionsFileName`

`General.AxesTicsZ`
Number of tics on the Z-axis
Default value: `5`
Saved in: `General.OptionsFileName`

`General.AxesValueMaxX`
Maximum X-axis forced value
Default value: `1`
Saved in: `General.OptionsFileName`

`General.AxesValueMaxY`
Maximum Y-axis forced value
Default value: `1`
Saved in: `General.OptionsFileName`

`General.AxesValueMaxZ`
Maximum Z-axis forced value
Default value: `1`
Saved in: `General.OptionsFileName`

`General.AxesValueMinX`
Minimum X-axis forced value
Default value: `0`
Saved in: `General.OptionsFileName`

`General.AxesValueMinY`
Minimum Y-axis forced value
Default value: `0`
Saved in: `General.OptionsFileName`

`General.AxesValueMinZ`
Minimum Z-axis forced value
Default value: `0`
Saved in: `General.OptionsFileName`

`General.BackgroundGradient`
Draw background gradient (0: none, 1: vertical, 2: horizontal, 3: radial)
Default value: `1`
Saved in: `General.OptionsFileName`

`General.BackgroundImage3D`
Create background image in the 3D model (units = model units) or as 2D background (units = pixels)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.BackgroundImagePage`
Page to render in the background image (for multi-page PDFs)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.BackgroundImagePositionX`
X position of background image (for 2D background: < 0: measure from right window edge; >= 1e5: centered)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.BackgroundImagePositionY`
Y position of background image (for 2D background: < 0: measure from bottom window edge; >= 1e5: centered)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.BackgroundImageWidth`
Width of background image (0: actual width if height = 0, natural scaling if not; -1: graphic window width)
Default value: `-1`
Saved in: `General.OptionsFileName`

`General.BackgroundImageHeight`
Height of background image (0: actual height if width = 0, natural scaling if not; -1: graphic window height)
Default value: `-1`
Saved in: `General.OptionsFileName`

`General.BoundingBoxSize`
Overall bounding box size (read-only)
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Camera`
Enable camera view mode
Default value: `0`
Saved in: `General.OptionsFileName`

`General.CameraAperture`
Camera aperture in degrees
Default value: `40`
Saved in: `General.OptionsFileName`

`General.CameraEyeSeparationRatio`
Eye separation ratio in % for stereo rendering
Default value: `1.5`
Saved in: `General.OptionsFileName`

`General.CameraFocalLengthRatio`
Camera Focal length ratio
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Clip0A`
First coefficient in equation for clipping plane 0 ('A' in 'AX+BY+CZ+D=0')
Default value: `1`
Saved in: `-`

`General.Clip0B`
Second coefficient in equation for clipping plane 0 ('B' in 'AX+BY+CZ+D=0')
Default value: `0`
Saved in: `-`

`General.Clip0C`
Third coefficient in equation for clipping plane 0 ('C' in 'AX+BY+CZ+D=0')
Default value: `0`
Saved in: `-`

`General.Clip0D`
Fourth coefficient in equation for clipping plane 0 ('D' in 'AX+BY+CZ+D=0')
Default value: `0`
Saved in: `-`

`General.Clip1A`
First coefficient in equation for clipping plane 1
Default value: `0`
Saved in: `-`

`General.Clip1B`
Second coefficient in equation for clipping plane 1
Default value: `1`
Saved in: `-`

`General.Clip1C`
Third coefficient in equation for clipping plane 1
Default value: `0`
Saved in: `-`

`General.Clip1D`
Fourth coefficient in equation for clipping plane 1
Default value: `0`
Saved in: `-`

`General.Clip2A`
First coefficient in equation for clipping plane 2
Default value: `0`
Saved in: `-`

`General.Clip2B`
Second coefficient in equation for clipping plane 2
Default value: `0`
Saved in: `-`

`General.Clip2C`
Third coefficient in equation for clipping plane 2
Default value: `1`
Saved in: `-`

`General.Clip2D`
Fourth coefficient in equation for clipping plane 2
Default value: `0`
Saved in: `-`

`General.Clip3A`
First coefficient in equation for clipping plane 3
Default value: `-1`
Saved in: `-`

`General.Clip3B`
Second coefficient in equation for clipping plane 3
Default value: `0`
Saved in: `-`

`General.Clip3C`
Third coefficient in equation for clipping plane 3
Default value: `0`
Saved in: `-`

`General.Clip3D`
Fourth coefficient in equation for clipping plane 3
Default value: `1`
Saved in: `-`

`General.Clip4A`
First coefficient in equation for clipping plane 4
Default value: `0`
Saved in: `-`

`General.Clip4B`
Second coefficient in equation for clipping plane 4
Default value: `-1`
Saved in: `-`

`General.Clip4C`
Third coefficient in equation for clipping plane 4
Default value: `0`
Saved in: `-`

`General.Clip4D`
Fourth coefficient in equation for clipping plane 4
Default value: `1`
Saved in: `-`

`General.Clip5A`
First coefficient in equation for clipping plane 5
Default value: `0`
Saved in: `-`

`General.Clip5B`
: Second coefficient in equation for clipping plane 5
Default value: `0`
Saved in: `-`

`General.Clip5C`
: Third coefficient in equation for clipping plane 5
Default value: `-1`
Saved in: `-`

`General.Clip5D`
: Fourth coefficient in equation for clipping plane 5
Default value: `1`
Saved in: `-`

`General.ClipFactor`
: Near and far clipping plane distance factor (decrease value for better z-buffer resolution)
Default value: `5`
Saved in: `-`

`General.ClipOnlyDrawIntersectingVolume`
: Only draw layer of elements that intersect the clipping plane
Default value: `0`
Saved in: `General.OptionsFileName`

`General.ClipOnlyVolume`
: Only clip volume elements
Default value: `0`
Saved in: `General.OptionsFileName`

`General.ClipPositionX`
: Horizontal position (in pixels) of the upper left corner of the clipping planes window
Default value: `650`
Saved in: `General.SessionFileName`

`General.ClipPositionY`
: Vertical position (in pixels) of the upper left corner of the clipping planes window
Default value: `150`
Saved in: `General.SessionFileName`

`General.ClipWholeElements`
: Clip whole elements
Default value: `0`
Saved in: `General.OptionsFileName`

`General.ColorScheme`
: Default color scheme for graphics (0: light, 1: default, 2: grayscale, 3: dark)
Default value: `1`
Saved in: `General.SessionFileName`

`General.ConfirmOverwrite`
: Ask confirmation before overwriting files?
Default value: `1`
Saved in: `General.OptionsFileName`

`General.ContextPositionX`
Horizontal position (in pixels) of the upper left corner of the contextual windows
Default value: `650`
Saved in: `General.SessionFileName`

`General.ContextPositionY`
Vertical position (in pixels) of the upper left corner of the contextual windows
Default value: `150`
Saved in: `General.SessionFileName`

`General.DetachedMenu`
Should the menu window be detached from the graphic window?
Default value: `0`
Saved in: `General.SessionFileName`

`General.DetachedProcess`
On Windows, should processes created by Gmsh be detached?
Default value: `1`
Saved in: `General.OptionsFileName`

`General.DisplayBorderFactor`
Border factor for model display (0: model fits window size exactly)
Default value: `0.2`
Saved in: `General.OptionsFileName`

`General.DoubleBuffer`
Use a double buffered graphic window (on Unix, should be set to 0 when working on a remote host without GLX)
Default value: `1`
Saved in: `General.OptionsFileName`

`General.DrawBoundingBoxes`
Draw bounding boxes
Default value: `0`
Saved in: `General.OptionsFileName`

`General.ExpertMode`
Enable expert mode (to disable all the messages meant for inexperienced users)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.ExtraPositionX`
Horizontal position (in pixels) of the upper left corner of the generic extra window
Default value: `650`
Saved in: `General.SessionFileName`

`General.ExtraPositionY`
Vertical position (in pixels) of the upper left corner of the generic extra window
Default value: `350`
Saved in: `General.SessionFileName`

`General.ExtraHeight`
Height (in pixels) of the generic extra window
Default value: `100`
Saved in: `General.SessionFileName`

`General.ExtraWidth`
: Width (in pixels) of the generic extra window
Default value: `100`
Saved in: `General.SessionFileName`

`General.FastRedraw`
: Draw simplified model while rotating, panning and zooming
Default value: `0`
Saved in: `General.OptionsFileName`

`General.FieldPositionX`
: Horizontal position (in pixels) of the upper left corner of the field window
Default value: `650`
Saved in: `General.SessionFileName`

`General.FieldPositionY`
: Vertical position (in pixels) of the upper left corner of the field window
Default value: `550`
Saved in: `General.SessionFileName`

`General.FieldHeight`
: Height (in pixels) of the field window
Default value: `320`
Saved in: `General.SessionFileName`

`General.FieldWidth`
: Width (in pixels) of the field window
Default value: `420`
Saved in: `General.SessionFileName`

`General.FileChooserPositionX`
: Horizontal position (in pixels) of the upper left corner of the file chooser windows
Default value: `200`
Saved in: `General.SessionFileName`

`General.FileChooserPositionY`
: Vertical position (in pixels) of the upper left corner of the file chooser windows
Default value: `200`
Saved in: `General.SessionFileName`

`General.FltkColorScheme`
: FLTK user interface color theme (0: standard, 1:dark)
Default value: `0`
Saved in: `General.SessionFileName`

`General.FltkRefreshRate`
: FLTK user interface maximum refresh rate, per second (0: no limit)
Default value: `5`
Saved in: `General.OptionsFileName`

`General.FontSize`
: Size of the font in the user interface, in pixels (-1: automatic)
Default value: `-1`
Saved in: `General.OptionsFileName`

`General.GraphicsFontSize`
: Size of the font in the graphic window, in pixels
Default value: `15`
Saved in: `General.OptionsFileName`

`General.GraphicsFontSizeTitle`
Size of the font in the graphic window for titles, in pixels
Default value: `18`
Saved in: `General.OptionsFileName`

`General.GraphicsHeight`
Height (in pixels) of the graphic window
Default value: `600`
Saved in: `General.SessionFileName`

`General.GraphicsPositionX`
Horizontal position (in pixels) of the upper left corner of the graphic window
Default value: `50`
Saved in: `General.SessionFileName`

`General.GraphicsPositionY`
Vertical position (in pixels) of the upper left corner of the graphic window
Default value: `50`
Saved in: `General.SessionFileName`

`General.GraphicsWidth`
Width (in pixels) of the graphic window
Default value: `800`
Saved in: `General.SessionFileName`

`General.HighOrderToolsPositionX`
Horizontal position (in pixels) of the upper left corner of the high-order tools window
Default value: `650`
Saved in: `General.SessionFileName`

`General.HighOrderToolsPositionY`
Vertical position (in pixels) of the upper left corner of the high-order tools window
Default value: `150`
Saved in: `General.SessionFileName`

`General.HighResolutionGraphics`
Use high-resolution OpenGL graphics (e.g. for Macs with retina displays)
Default value: `1`
Saved in: `General.OptionsFileName`

`General.InitialModule`
Module launched on startup (0: automatic, 1: geometry, 2: mesh, 3: solver, 4: post-processing)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.InputScrolling`
Enable numerical input scrolling in user interface (moving the mouse to change numbers)
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Light0`
Enable light source 0
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Light0X`
X position of light source 0
Default value: `0.65`
Saved in: `General.OptionsFileName`

`General.Light0Y`
Y position of light source 0
Default value: `0.65`
Saved in: `General.OptionsFileName`

`General.Light0Z`
Z position of light source 0
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Light0W`
Divisor of the X, Y and Z coordinates of light source 0 (W=0 means infinitely far source)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light1`
Enable light source 1
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light1X`
X position of light source 1
Default value: `0.5`
Saved in: `General.OptionsFileName`

`General.Light1Y`
Y position of light source 1
Default value: `0.3`
Saved in: `General.OptionsFileName`

`General.Light1Z`
Z position of light source 1
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Light1W`
Divisor of the X, Y and Z coordinates of light source 1 (W=0 means infinitely far source)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light2`
Enable light source 2
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light2X`
X position of light source 2
Default value: `0.5`
Saved in: `General.OptionsFileName`

`General.Light2Y`
Y position of light source 2
Default value: `0.3`
Saved in: `General.OptionsFileName`

`General.Light2Z`
Z position of light source 2
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Light2W`
Divisor of the X, Y and Z coordinates of light source 2 (W=0 means infinitely far source)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light3`
Enable light source 3
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light3X`
X position of light source 3
Default value: `0.5`
Saved in: `General.OptionsFileName`

`General.Light3Y`
Y position of light source 3
Default value: `0.3`
Saved in: `General.OptionsFileName`

`General.Light3Z`
Z position of light source 3
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Light3W`
Divisor of the X, Y and Z coordinates of light source 3 (W=0 means infinitely far source)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light4`
Enable light source 4
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light4X`
X position of light source 4
Default value: `0.5`
Saved in: `General.OptionsFileName`

`General.Light4Y`
Y position of light source 4
Default value: `0.3`
Saved in: `General.OptionsFileName`

`General.Light4Z`
Z position of light source 4
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Light4W`
Divisor of the X, Y and Z coordinates of light source 4 (W=0 means infinitely far source)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light5`
Enable light source 5
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Light5X`
X position of light source 5
Default value: `0.5`
Saved in: `General.OptionsFileName`

`General.Light5Y`
Y position of light source 5
Default value: `0.3`
Saved in: `General.OptionsFileName`

`General.Light5Z`
Z position of light source 5
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Light5W`
Divisor of the X, Y and Z coordinates of light source 5 (W=0 means infinitely far source)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.LineWidth`
Display width of lines (in pixels)
Default value: `1`
Saved in: `General.OptionsFileName`

`General.ManipulatorPositionX`
Horizontal position (in pixels) of the upper left corner of the manipulator window
Default value: `650`
Saved in: `General.SessionFileName`

`General.ManipulatorPositionY`
Vertical position (in pixels) of the upper left corner of the manipulator window
Default value: `150`
Saved in: `General.SessionFileName`

`General.MaxX`
Maximum model coordinate along the X-axis (read-only)
Default value: `0`
Saved in: `-`

`General.MaxY`
: Maximum model coordinate along the Y-axis (read-only)
Default value: `0`
Saved in: `-`

`General.MaxZ`
: Maximum model coordinate along the Z-axis (read-only)
Default value: `0`
Saved in: `-`

`General.MenuWidth`
: Width (in pixels) of the menu tree
Default value: `200`
Saved in: `General.SessionFileName`

`General.MenuHeight`
: Height (in pixels) of the (detached) menu tree
Default value: `200`
Saved in: `General.SessionFileName`

`General.MenuPositionX`
: Horizontal position (in pixels) of the (detached) menu tree
Default value: `400`
Saved in: `General.SessionFileName`

`General.MenuPositionY`
: Vertical position (in pixels) of the (detached) menu tree
Default value: `400`
Saved in: `General.SessionFileName`

`General.MessageFontSize`
: Size of the font in the message window, in pixels (-1: automatic)
Default value: `-1`
Saved in: `General.OptionsFileName`

`General.MessageHeight`
: Height (in pixels) of the message console when it is visible (should be > 0)
Default value: `300`
Saved in: `General.SessionFileName`

`General.MinX`
: Minimum model coordinate along the X-axis (read-only)
Default value: `0`
Saved in: `-`

`General.MinY`
: Minimum model coordinate along the Y-axis (read-only)
Default value: `0`
Saved in: `-`

`General.MinZ`
: Minimum model coordinate along the Z-axis (read-only)
Default value: `0`
Saved in: `-`

`General.MouseHoverMeshes`
: Enable mouse hover on meshes
Default value: `0`
Saved in: `General.OptionsFileName`

`General.MouseSelection`
Enable mouse selection
Default value: `1`
Saved in: `General.OptionsFileName`

`General.MouseInvertZoom`
Invert mouse wheel zoom direction
Default value: `0`
Saved in: `General.OptionsFileName`

`General.NativeFileChooser`
Use the native file chooser?
Default value: `1`
Saved in: `General.SessionFileName`

`General.NonModalWindows`
Force all control windows to be on top of the graphic window ("non-modal")
Default value: `1`
Saved in: `General.SessionFileName`

`General.NoPopup`
Disable interactive dialog windows in scripts (and use default values instead)
Default value: `0`
Saved in: `General.OptionsFileName`

`General.NumThreads`
Maximum number of threads used by Gmsh when compiled with OpenMP support (0: use system default, i.e. OMP_NUM_THREADS)
Default value: `1`
Saved in: `General.OptionsFileName`

`General.OptionsPositionX`
Horizontal position (in pixels) of the upper left corner of the option window
Default value: `650`
Saved in: `General.SessionFileName`

`General.OptionsPositionY`
Vertical position (in pixels) of the upper left corner of the option window
Default value: `150`
Saved in: `General.SessionFileName`

`General.Orthographic`
Orthographic projection mode (0: perspective projection)
Default value: `1`
Saved in: `General.OptionsFileName`

`General.PluginPositionX`
Horizontal position (in pixels) of the upper left corner of the plugin window
Default value: `650`
Saved in: `General.SessionFileName`

`General.PluginPositionY`
Vertical position (in pixels) of the upper left corner of the plugin window
Default value: `550`
Saved in: `General.SessionFileName`

`General.PluginHeight`
: Height (in pixels) of the plugin window
Default value: `320`
Saved in: `General.SessionFileName`

`General.PluginWidth`
: Width (in pixels) of the plugin window
Default value: `420`
Saved in: `General.SessionFileName`

`General.PointSize`
: Display size of points (in pixels)
Default value: `3`
Saved in: `General.OptionsFileName`

`General.PolygonOffsetAlwaysOn`
: Always apply polygon offset, instead of trying to detect when it is required
Default value: `0`
Saved in: `General.OptionsFileName`

`General.PolygonOffsetFactor`
: Polygon offset factor (offset = factor * DZ + r * units)
Default value: `0.5`
Saved in: `General.OptionsFileName`

`General.PolygonOffsetUnits`
: Polygon offset units (offset = factor * DZ + r * units)
Default value: `1`
Saved in: `General.OptionsFileName`

`General.ProgressMeterStep`
: Increment (in percent) of the progress meter bar
Default value: `10`
Saved in: `General.OptionsFileName`

`General.QuadricSubdivisions`
: Number of subdivisions used to draw points or lines as spheres or cylinders
Default value: `6`
Saved in: `General.OptionsFileName`

`General.RotationX`
: First Euler angle (used if Trackball=0)
Default value: `0`
Saved in: `-`

`General.RotationY`
: Second Euler angle (used if Trackball=0)
Default value: `0`
Saved in: `-`

`General.RotationZ`
: Third Euler angle (used if Trackball=0)
Default value: `0`
Saved in: `-`

`General.RotationCenterGravity`
: Rotate around the (pseudo) center of mass instead of (RotationCenterX, RotationCenterY, RotationCenterZ)

Default value: 1
Saved in: General.OptionsFileName

General.RotationCenterX
X coordinate of the center of rotation
Default value: 0
Saved in: -

General.RotationCenterY
Y coordinate of the center of rotation
Default value: 0
Saved in: -

General.RotationCenterZ
Z coordinate of the center of rotation
Default value: 0
Saved in: -

General.SaveOptions
Automatically save current options in General.OptionsFileName (1) or per model (2)when the graphical user interface is closed?
Default value: 0
Saved in: General.SessionFileName

General.SaveSession
Automatically save session specific information in General.SessionFileName when the graphical user interface is closed?
Default value: 1
Saved in: General.SessionFileName

General.ScaleX
X-axis scale factor
Default value: 1
Saved in: -

General.ScaleY
Y-axis scale factor
Default value: 1
Saved in: -

General.ScaleZ
Z-axis scale factor
Default value: 1
Saved in: -

General.Shininess
Material shininess
Default value: 0.4
Saved in: General.OptionsFileName

General.ShininessExponent
Material shininess exponent (between 0 and 128)
Default value: 40
Saved in: General.OptionsFileName

General.ShowModuleMenu
Show the standard Gmsh menu in the tree
Default value: 1
Saved in: General.OptionsFileName

`General.ShowOptionsOnStartup`
Show option window on startup
Default value: `0`
Saved in: `General.OptionsFileName`

`General.ShowMessagesOnStartup`
Show message window on startup
Default value: `0`
Saved in: `General.OptionsFileName`

`General.SmallAxes`
Display the small axes
Default value: `1`
Saved in: `General.OptionsFileName`

`General.SmallAxesPositionX`
X position (in pixels) of small axes (< 0: measure from right window edge; >= 1e5: centered)
Default value: `-60`
Saved in: `General.OptionsFileName`

`General.SmallAxesPositionY`
Y position (in pixels) of small axes (< 0: measure from bottom window edge; >= 1e5: centered)
Default value: `-40`
Saved in: `General.OptionsFileName`

`General.SmallAxesSize`
Size (in pixels) of small axes
Default value: `30`
Saved in: `General.OptionsFileName`

`General.StatisticsPositionX`
Horizontal position (in pixels) of the upper left corner of the statistic window
Default value: `650`
Saved in: `General.SessionFileName`

`General.StatisticsPositionY`
Vertical position (in pixels) of the upper left corner of the statistic window
Default value: `150`
Saved in: `General.SessionFileName`

`General.Stereo`
Use stereo rendering
Default value: `0`
Saved in: `General.OptionsFileName`

`General.SystemMenuBar`
Use the system menu bar on macOS?
Default value: `1`
Saved in: `General.SessionFileName`

`General.Terminal`
Should information be printed on the terminal (if available)?
Default value: `0`
Saved in: `General.OptionsFileName`

`General.Tooltips`
Show tooltips in the user interface
Default value: `1`
Saved in: `General.OptionsFileName`

`General.Trackball`
Use trackball rotation mode
Default value: `1`
Saved in: `General.OptionsFileName`

`General.TrackballHyperbolicSheet`
Use hyperbolic sheet away from trackball center for z-rotations
Default value: `1`
Saved in: `General.OptionsFileName`

`General.TrackballQuaternion0`
First trackball quaternion component (used if General.Trackball=1)
Default value: `0`
Saved in: `-`

`General.TrackballQuaternion1`
Second trackball quaternion component (used if General.Trackball=1)
Default value: `0`
Saved in: `-`

`General.TrackballQuaternion2`
Third trackball quaternion component (used if General.Trackball=1)
Default value: `0`
Saved in: `-`

`General.TrackballQuaternion3`
Fourth trackball quaternion component (used if General.Trackball=1)
Default value: `1`
Saved in: `-`

`General.TranslationX`
X-axis translation (in model units)
Default value: `0`
Saved in: `-`

`General.TranslationY`
Y-axis translation (in model units)
Default value: `0`
Saved in: `-`

`General.TranslationZ`
Z-axis translation (in model units)
Default value: `0`
Saved in: `-`

`General.VectorType`
Default vector display type (for normals, etc.)
Default value: `4`
Saved in: `General.OptionsFileName`

`General.Verbosity`
Level of information printed on the terminal and the message console (0: silent except for fatal errors, 1: +errors, 2: +warnings, 3: +direct, 4: +information, 5:

+status, 99: +debug)
Default value: 5
Saved in: General.OptionsFileName

General.VisibilityPositionX
Horizontal position (in pixels) of the upper left corner of the visibility window
Default value: 650
Saved in: General.SessionFileName

General.VisibilityPositionY
Vertical position (in pixels) of the upper left corner of the visibility window
Default value: 150
Saved in: General.SessionFileName

General.ZoomFactor
Middle mouse button zoom acceleration factor
Default value: 4
Saved in: General.OptionsFileName

General.Color.Background
Background color
Default value: {255,255,255}
Saved in: General.OptionsFileName

General.Color.BackgroundGradient
Background gradient color
Default value: {208,215,255}
Saved in: General.OptionsFileName

General.Color.Foreground
Foreground color
Default value: {85,85,85}
Saved in: General.OptionsFileName

General.Color.Text
Text color
Default value: {0,0,0}
Saved in: General.OptionsFileName

General.Color.Axes
Axes color
Default value: {0,0,0}
Saved in: General.OptionsFileName

General.Color.SmallAxes
Small axes color
Default value: {0,0,0}
Saved in: General.OptionsFileName

General.Color.AmbientLight
Ambient light color
Default value: {25,25,25}
Saved in: General.OptionsFileName

General.Color.DiffuseLight
Diffuse light color
Default value: {255,255,255}
Saved in: General.OptionsFileName

`General.Color.SpecularLight`
Specular light color
Default value: `{255,255,255}`
Saved in: `General.OptionsFileName`

7.2 Print options

`Print.ParameterCommand`
Command parsed when the print parameter is changed
Default value: `"Mesh.Clip=1; View.Clip=1; General.ClipWholeElements=1; General.ClipOD=Print.Parameter; SetChanged;"`
Saved in: `General.OptionsFileName`

`Print.Parameter`
Current value of the print parameter
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.ParameterFirst`
First value of print parameter in loop
Default value: `-1`
Saved in: `General.OptionsFileName`

`Print.ParameterLast`
Last value of print parameter in loop
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.ParameterSteps`
Number of steps in loop over print parameter
Default value: `10`
Saved in: `General.OptionsFileName`

`Print.Background`
Print background (gradient and image)?
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.CompositeWindows`
Composite all window tiles in the same output image (for bitmap output only)
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.DeleteTemporaryFiles`
Delete temporary files used during printing
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.EpsBestRoot`
Try to minimize primitive splitting in BSP tree sorted PostScript/PDF output
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.EpsCompress`
Compress PostScript/PDF output using zlib
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.EpsLineWidthFactor`
Width factor for lines in PostScript/PDF output
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.EpsOcclusionCulling`
Cull occluded primitives (to reduce PostScript/PDF file size)
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.EpsPointSizeFactor`
Size factor for points in PostScript/PDF output
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.EpsPS3Shading`
Enable PostScript Level 3 shading
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.EpsQuality`
PostScript/PDF quality (0: bitmap, 1: vector (simple sort), 2: vector (accurate sort), 3: vector (unsorted)
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.Format`
File format (10: automatic)
Default value: `10`
Saved in: `General.OptionsFileName`

`Print.GeoLabels`
Save labels in unrolled Gmsh geometries
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.GeoOnlyPhysicals`
Only save entities that belong to physical groups
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.GifDither`
Apply dithering to GIF output
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.GifInterlace`
Interlace GIF output
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.GifSort`
Sort the colormap in GIF output
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.GifTransparent`
Output transparent GIF image
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.Height`
Height of printed image; use (possibly scaled) current height if < 0
Default value: `-1`
Saved in: `General.OptionsFileName`

`Print.JpegQuality`
JPEG quality (between 1 and 100)
Default value: `100`
Saved in: `General.OptionsFileName`

`Print.JpegSmoothing`
JPEG smoothing (between 0 and 100)
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.PgfTwoDim`
Output PGF format for two dimensions. Mostly irrelevant if 'PgfExportAxis=0'. Default '1' (yes).
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.PgfExportAxis`
Include axis in export pgf code (not in the png). Default '0' (no).
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.PgfHorizontalBar`
Use a horizontal color bar in the pgf output. Default '0' (no).
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.PostElementary`
Save elementary region tags in mesh statistics exported as post-processing views
Default value: `1`
Saved in: `General.OptionsFileName`

`Print.PostElement`
Save element tags in mesh statistics exported as post-processing views
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.PostGamma`
Save Gamma quality measure in mesh statistics exported as post-processing views
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.PostEta`
Save Eta quality measure in mesh statistics exported as post-processing views
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.PostSICN`
Save SICN (signed inverse condition number) quality measure in mesh statistics exported as post-processing views

Default value: 0
Saved in: General.OptionsFileName

Print.PostSIGE
Save SIGE (signed inverse gradient error) quality measure in mesh statistics exported as post-processing views
Default value: 0
Saved in: General.OptionsFileName

Print.PostDisto
Save Disto quality measure in mesh statistics exported as post-processing views
Default value: 0
Saved in: General.OptionsFileName

Print.TexAsEquation
Print all TeX strings as equations
Default value: 0
Saved in: General.OptionsFileName

Print.TexForceFontSize
Force font size of TeX strings to fontsize in the graphic window
Default value: 0
Saved in: General.OptionsFileName

Print.TexWidthInMm
Width of tex graphics in mm (use 0 for the natural width inferred from the image width in pixels)
Default value: 150
Saved in: General.OptionsFileName

Print.Text
Print text strings?
Default value: 1
Saved in: General.OptionsFileName

Print.X3dCompatibility
Produce highly compatible X3D output (no scale bar)
Default value: 0
Saved in: General.OptionsFileName

Print.X3dPrecision
Precision of X3D output
Default value: 1e-09
Saved in: General.OptionsFileName

Print.X3dRemoveInnerBorders
Remove inner borders in X3D output
Default value: 0
Saved in: General.OptionsFileName

Print.X3dTransparency
Transparency for X3D output
Default value: 0
Saved in: General.OptionsFileName

Print.X3dSurfaces
Save surfaces in CAD X3D output (0: no, 1: yes in a single X3D object,2: one X3D object per geometrical surface, 3: one X3D object perphysical surface)

Default value: `1`
Saved in: `General.OptionsFileName`

`Print.X3dEdges`
Save edges in CAD X3D output (0: no, 1: yes in a single X3D object,2: one X3D object per geometrical edge, 3: one X3D object perphysical edge)
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.X3dVertices`
Save vertices in CAD X3D output (0: no, 1: yes)
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.X3dVolumes`
Save separate volumes in CAD X3D output (0: no, 1: yes)
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.X3dColorize`
Apply colors to faces (0: no, 1: yes)
Default value: `0`
Saved in: `General.OptionsFileName`

`Print.Width`
Width of printed image; use (possibly scaled) current width if < 0)
Default value: `-1`
Saved in: `General.OptionsFileName`

7.3 Geometry options

`Geometry.DoubleClickedPointCommand`
Command parsed when double-clicking on a point, or 'ONELAB' to edit associated ONELAB parameters
Default value: `"ONELAB"`
Saved in: `General.OptionsFileName`

`Geometry.DoubleClickedCurveCommand`
Command parsed when double-clicking on a curve, or 'ONELAB' to edit associated ONELAB parameters
Default value: `"ONELAB"`
Saved in: `General.OptionsFileName`

`Geometry.DoubleClickedSurfaceCommand`
Command parsed when double-clicking on a surface, or 'ONELAB' to edit associated ONELAB parameters
Default value: `"ONELAB"`
Saved in: `General.OptionsFileName`

`Geometry.DoubleClickedVolumeCommand`
Command parsed when double-clicking on a volume, or 'ONELAB' to edit associated ONELAB parameters
Default value: `"ONELAB"`
Saved in: `General.OptionsFileName`

`Geometry.OCCTargetUnit`
Length unit to which coordinates from STEP and IGES files are converted to when imported by OpenCASCADE, e.g. 'M' for meters (leave empty to use the default

OpenCASCADE behavior); the option should be set before importing the STEP or IGES file
Default value: ""
Saved in: General.OptionsFileName

Geometry.PipeDefaultTrihedron
Default trihedron type when creating pipes
Default value: "DiscreteTrihedron"
Saved in: General.OptionsFileName

Geometry.AutoCoherence
Should all duplicate entities be automatically removed with the built-in geometry kernel? If Geometry.AutoCoherence = 2, also remove degenerate entities. The option has no effect with the OpenCASCADE kernel
Default value: 1
Saved in: General.OptionsFileName

Geometry.Clip
Enable clipping planes? (Plane[i]=2^i, i=0,...,5)
Default value: 0
Saved in: -

Geometry.CopyMeshingMethod
Copy meshing method (unstructured or transfinite) when duplicating geometrical entities with built-in geometry kernel?
Default value: 0
Saved in: General.OptionsFileName

Geometry.Curves
Display geometry curves?
Default value: 1
Saved in: General.OptionsFileName

Geometry.CurveLabels
Display curve labels?
Default value: 0
Saved in: General.OptionsFileName

Geometry.CurveSelectWidth
Display width of selected curves (in pixels)
Default value: 3
Saved in: General.OptionsFileName

Geometry.CurveType
Display curves as solid color segments (0) or 3D cylinders (1)
Default value: 0
Saved in: General.OptionsFileName

Geometry.CurveWidth
Display width of lines (in pixels)
Default value: 2
Saved in: General.OptionsFileName

Geometry.DoubleClickedEntityTag
Tag of last double-clicked geometrical entity
Default value: 0
Saved in: -

`Geometry.ExactExtrusion`
Use exact extrusion formula in interpolations (set to 0 to allow geometrical transformations of extruded entities)
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.ExtrudeReturnLateralEntities`
Add lateral entities in lists returned by extrusion commands?
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.ExtrudeSplinePoints`
Number of control points for splines created during extrusion
Default value: `5`
Saved in: `General.OptionsFileName`

`Geometry.FirstEntityTag`
First tag (>= 1) of entities when creating a model
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.FirstPhysicalTag`
First tag (>= 1) of physicall groups when creating a model
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.HighlightOrphans`
Highlight orphan and boundary entities?
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.LabelType`
Type of entity label (0: description, 1: elementary entity tag, 2: physical group tag, 3: elementary name, 4: physical name)
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.Light`
Enable lighting for the geometry
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.LightTwoSide`
Light both sides of surfaces (leads to slower rendering)
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.MatchGeomAndMesh`
Matches geometries and meshes
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.MatchMeshScaleFactor`
Rescaling factor for the mesh to correspond to size of the geometry
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.MatchMeshTolerance`
Tolerance for matching mesh and geometry
Default value: `1e-06`
Saved in: `General.OptionsFileName`

`Geometry.Normals`
Display size of normal vectors (in pixels)
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.NumSubEdges`
Number of subdivisions (per control point or pole) used to draw curves
Default value: `40`
Saved in: `General.OptionsFileName`

`Geometry.OCCAutoEmbed`
Automatically embed points, curves and faces in higher dimensional entities if they are marked as 'internal' by OpenCASCADE
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.OCCAutoFix`
Automatically fix orientation of wires, faces, shells and volumes when creating new entities with the OpenCASCADE kernel
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.OCCBooleanPreserveNumbering`
Try to preserve the numbering of entities through OpenCASCADE boolean operations
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.OCCBoundsUseStl`
Use STL mesh for computing bounds of OpenCASCADE shapes (more accurate, but slower)
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OCCDisableStl`
Disable STL creation in OpenCASCADE kernel
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OCCFixDegenerated`
Fix degenerated edges/faces when importing STEP, IGES and BRep models with the OpenCASCADE kernel
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OCCFixSmallEdges`
Fix small edges when importing STEP, IGES and BRep models with the OpenCASCADE kernel
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OCCFixSmallFaces`
Fix small faces when importing STEP, IGES and BRep models with the OpenCASCADE kernel
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OCCExportOnlyVisible`
Only consider visible shapes when exporting STEP or BREP models with the OpenCASCADE kernel
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OCCImportLabels`
Import labels and colors when importing STEP models with the OpenCASCADE kernel
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.OCCMakeSolids`
Fix shells and make solids when importing STEP, IGES and BRep models with the OpenCASCADE kernel
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OCCParallel`
Use multi-threaded OpenCASCADE boolean operators
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OCCFastUnbind`
Use fast (i.e. without recursive checks on boundaries) unbinding of entities in geometrical transformations (1), as well as in boolean operations (2)
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.OCCScaling`
Scale STEP, IGES and BRep models by the given factor when importing them with the OpenCASCADE kernel
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.OCCSewFaces`
Sew faces when importing STEP, IGES and BRep models with the OpenCASCADE kernel
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OCCThruSectionsDegree`
Maximum degree of surfaces generated by thrusections with the OpenCASCADE kernel, if not explicitly specified (default OCC value if negative)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Geometry.OCCUnionUnify`
Try to unify faces and edges (remove internal seams) which lie on the same geometry after performing a boolean union with the OpenCASCADE kernel
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.OCCUseGenericClosestPoint`
Use generic algrithm to compute point projections in the OpenCASCADE kernel (less robust, but significally faster in some configurations)
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OffsetX`
Model display offset along X-axis (in model coordinates)
Default value: `0`
Saved in: `-`

`Geometry.OffsetY`
Model display offset along Y-axis (in model coordinates)
Default value: `0`
Saved in: `-`

`Geometry.OffsetZ`
Model display offset along Z-axis (in model coordinates)
Default value: `0`
Saved in: `-`

`Geometry.OldCircle`
Use old circle description (compatibility option for old Gmsh geometries)
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OldRuledSurface`
Use old 3-sided ruled surface interpolation (compatibility option for old Gmsh geometries)
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.OldNewReg`
Use old newreg definition for geometrical transformations (compatibility option for old Gmsh geometries)
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.OrientedPhysicals`
Use sign of elementary entity in physical definition as orientation indicator
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.Points`
Display geometry points?
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.PointLabels`
Display points labels?
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.PointSelectSize`
Display size of selected points (in pixels)
Default value: `6`
Saved in: `General.OptionsFileName`

`Geometry.PointSize`
Display size of points (in pixels)
Default value: `4`
Saved in: `General.OptionsFileName`

`Geometry.PointType`
Display points as solid color dots (0) or 3D spheres (1)
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.ReparamOnFaceRobust`
Use projection for reparametrization of a point classified on GEdge on a GFace
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.ScalingFactor`
Global geometry scaling factor
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.SnapPoints`
Snap points on curves if their evaluation using the parametrization is larger than the geometrical tolerance (currently only with the OpenCASCADE kernel)
Default value: `1`
Saved in: `General.OptionsFileName`

`Geometry.SnapX`
Snapping grid spacing along the X-axis
Default value: `0.1`
Saved in: `General.OptionsFileName`

`Geometry.SnapY`
Snapping grid spacing along the Y-axis
Default value: `0.1`
Saved in: `General.OptionsFileName`

`Geometry.SnapZ`
Snapping grid spacing along the Z-axis
Default value: `0.1`
Saved in: `General.OptionsFileName`

`Geometry.Surfaces`
Display geometry surfaces?
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.SurfaceLabels`
Display surface labels?
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.SurfaceType`
Surface display type (0: cross, 1: wireframe, 2: solid). Wireframe and solid are not available with the built-in geometry kernel.
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.Tangents`
Display size of tangent vectors (in pixels)
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.Tolerance`
Geometrical tolerance
Default value: `1e-08`
Saved in: `General.OptionsFileName`

`Geometry.ToleranceBoolean`
Geometrical tolerance for boolean operations
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.Transform`
Transform model display coordinates (0: no, 1: scale)
Default value: `0`
Saved in: `-`

`Geometry.TransformXX`
Element (1,1) of the 3x3 model display transformation matrix
Default value: `1`
Saved in: `-`

`Geometry.TransformXY`
Element (1,2) of the 3x3 model display transformation matrix
Default value: `0`
Saved in: `-`

`Geometry.TransformXZ`
Element (1,3) of the 3x3 model display transformation matrix
Default value: `0`
Saved in: `-`

`Geometry.TransformYX`
Element (2,1) of the 3x3 model display transformation matrix
Default value: `0`
Saved in: `-`

`Geometry.TransformYY`
Element (2,2) of the 3x3 model display transformation matrix
Default value: `1`
Saved in: `-`

`Geometry.TransformYZ`
Element (2,3) of the 3x3 model display transformation matrix
Default value: `0`
Saved in: `-`

`Geometry.TransformZX`
Element (3,1) of the 3x3 model display transformation matrix
Default value: `0`
Saved in: `-`

`Geometry.TransformZY`
Element (3,2) of the 3x3 model display transformation matrix
Default value: `0`
Saved in: `-`

`Geometry.TransformZZ`
Element (3,3) of the 3x3 model display transformation matrix
Default value: `1`
Saved in: `-`

`Geometry.Volumes`
Display geometry volumes?
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.VolumeLabels`
Display volume labels?
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.VolumeType`
Volume display type (0: sphere, 1: diamond)
Default value: `0`
Saved in: `General.OptionsFileName`

`Geometry.Color.Points`
Normal geometry point color
Default value: `{90,90,90}`
Saved in: `General.OptionsFileName`

`Geometry.Color.Curves`
Normal geometry curve color
Default value: `{0,0,255}`
Saved in: `General.OptionsFileName`

`Geometry.Color.Surfaces`
Normal geometry surface color
Default value: `{128,128,128}`
Saved in: `General.OptionsFileName`

`Geometry.Color.Volumes`
Normal geometry volume color
Default value: `{200,200,0}`
Saved in: `General.OptionsFileName`

`Geometry.Color.Selection`
Selected geometry color
Default value: `{255,0,0}`
Saved in: `General.OptionsFileName`

`Geometry.Color.HighlightZero`
Highlight 0 color
Default value: `{255,0,0}`
Saved in: `General.OptionsFileName`

`Geometry.Color.HighlightOne`
Highlight 1 color
Default value: `{255,150,0}`
Saved in: `General.OptionsFileName`

`Geometry.Color.HighlightTwo`
Highlight 2 color
Default value: `{255,255,0}`
Saved in: `General.OptionsFileName`

`Geometry.Color.Tangents`
Tangent geometry vectors color
Default value: `{255,255,0}`
Saved in: `General.OptionsFileName`

`Geometry.Color.Normals`
Normal geometry vectors color
Default value: `{255,0,0}`
Saved in: `General.OptionsFileName`

`Geometry.Color.Projection`
Projection surface color
Default value: `{0,255,0}`
Saved in: `General.OptionsFileName`

7.4 Mesh options

`Mesh.Algorithm`
2D mesh algorithm (1: MeshAdapt, 2: Automatic, 3: Initial mesh only, 5: Delaunay, 6: Frontal-Delaunay, 7: BAMG, 8: Frontal-Delaunay for Quads, 9: Packing of Parallelograms, 11: Quasi-structured Quad)
Default value: `6`
Saved in: `General.OptionsFileName`

`Mesh.Algorithm3D`
3D mesh algorithm (1: Delaunay, 3: Initial mesh only, 4: Frontal, 7: MMG3D, 9: R-tree, 10: HXT)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.AlgorithmSwitchOnFailure`
Switch meshing algorithm on failure? (Currently only for 2D Delaunay-based algorithms, switching to MeshAdapt)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.AngleSmoothNormals`
Threshold angle below which normals are not smoothed
Default value: `30`
Saved in: `General.OptionsFileName`

`Mesh.AngleToleranceFacetOverlap`
Consider connected facets as overlapping when the dihedral angle between the facets is smaller than the user's defined tolerance (in degrees)
Default value: `0.1`
Saved in: `General.OptionsFileName`

`Mesh.AnisoMax`
Maximum anisotropy of the mesh
Default value: `1e+33`
Saved in: `General.OptionsFileName`

`Mesh.AllowSwapAngle`
Threshold angle (in degrees) between faces normals under which we allow an edge swap
Default value: `10`
Saved in: `General.OptionsFileName`

`Mesh.BdfFieldFormat`
Field format for Nastran BDF files (0: free, 1: small, 2: large)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.Binary`
Write mesh files in binary format (if possible)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.BoundaryLayerFanElements`
Number of elements (per Pi radians) for 2D boundary layer fans
Default value: `5`
Saved in: `General.OptionsFileName`

`Mesh.CgnsImportOrder`
Order of the mesh to be created by coarsening CGNS structured zones (1 to 4)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.CgnsImportIgnoreBC`
Ignore information in ZoneBC structures when reading a CGNS file
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.CgnsImportIgnoreSolution`
Ignore solution when reading a CGNS file
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.CgnsConstructTopology`
Reconstruct the model topology (BREP) after reading a CGNS file
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.CgnsExportCPEX0045`
Use the CPEX0045 convention when exporting a high-order mesh to CGNS
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.CgnsExportStructured`
Export transfinite meshes as structured CGNS grids
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.CheckSurfaceNormalValidity`
Check surface mesh validity according to the geometry normal
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.Clip`
Enable clipping planes? (Plane[i]=2^i, i=0,...,5)
Default value: `0`
Saved in: `-`

`Mesh.ColorCarousel`
Mesh coloring (0: by element type, 1: by elementary entity, 2: by physical group, 3: by mesh partition)

Default value: 1
Saved in: General.OptionsFileName

Mesh.CompoundClassify
How are surface mesh elements classified on compounds? (0: on the new discrete surface, 1: on the original geometrical surfaces - incompatible with e.g. high-order meshing)
Default value: 1
Saved in: General.OptionsFileName

Mesh.CompoundMeshSizeFactor
Mesh size factor applied to compound parts
Default value: 0.5
Saved in: General.OptionsFileName

Mesh.CpuTime
CPU time (in seconds) for the generation of the current mesh (read-only)
Default value: 0
Saved in: -

Mesh.CreateTopologyMsh2
Attempt to (re)create the model topology when reading MSH2 files
Default value: 0
Saved in: General.OptionsFileName

Mesh.DrawSkinOnly
Draw only the skin of 3D meshes?
Default value: 0
Saved in: General.OptionsFileName

Mesh.Dual
Display the dual mesh obtained by barycentric subdivision
Default value: 0
Saved in: General.OptionsFileName

Mesh.ElementOrder
Element order (1: first order elements)
Default value: 1
Saved in: General.OptionsFileName

Mesh.Explode
Element shrinking factor (between 0 and 1)
Default value: 1
Saved in: General.OptionsFileName

Mesh.FirstElementTag
First tag (>= 1) of mesh elements when generating or renumbering a mesh
Default value: 1
Saved in: General.OptionsFileName

Mesh.FirstNodeTag
First tag (>= 1) of mesh nodes when generating or renumbering a mesh
Default value: 1
Saved in: General.OptionsFileName

Mesh.FlexibleTransfinite
Allow transfinite constraints to be modified for recombination (e.g. Blossom) or by global mesh size factor

Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.Format`
Mesh output format (1: msh, 2: unv, 10: auto, 16: vtk, 19: vrml, 21: mail, 26: pos stat, 27: stl, 28: p3d, 30: mesh, 31: bdf, 32: cgns, 33: med, 34: diff, 38: ir3, 39: inp, 40: ply2, 41: celum, 42: su2, 47: tochnog, 49: neu, 50: matlab)
Default value: `10`
Saved in: `General.OptionsFileName`

`Mesh.Hexahedra`
Display mesh hexahedra?
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderDistCAD`
Try to optimize distance to CAD in high-order optimizer?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderFixBoundaryNodes`
Fix all (1) or periodic (2) boundary nodes during high-order optimization?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderIterMax`
Maximum number of iterations in high-order optimization pass
Default value: `100`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderNumLayers`
Number of layers around a problematic element to consider for high-order optimization, or number of element layers to consider in the boundary layer mesh for high-order fast curving
Default value: `6`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderOptimize`
Optimize high-order meshes? (0: none, 1: optimization, 2: elastic+optimization, 3: elastic, 4: fast curving)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderPassMax`
Maximum number of high-order optimization passes (moving barrier)
Default value: `25`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderPeriodic`
Force location of nodes for periodic meshes using periodicity transform (0: assume identical parametrisations, 1: invert parametrisations, 2: compute closest point
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderPoissonRatio`
Poisson ratio of the material used in the elastic smoother for high-order meshes (between -1.0 and 0.5, excluded)

Default value: `0.33`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderSavePeriodic`
Save high-order nodes in periodic section of MSH files?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderPrimSurfMesh`
Try to fix flipped surface mesh elements in high-order optimizer?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderThresholdMin`
Minimum threshold for high-order element optimization
Default value: `0.1`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderThresholdMax`
Maximum threshold for high-order element optimization
Default value: `2`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderFastCurvingNewAlgo`
Curve boundary layer with new "fast curving" algorithm (experimental)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderCurveOuterBL`
Curve also the outer surface of the boundary layer in the fast curving algorithm (0 = do not curve, 1 = curve according to boundary, 2 = curve without breaking outer elements)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderMaxRho`
Maximum min/max ratio of edge/face size for the detection of BL element columns in the fast curving algorithm
Default value: `0.3`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderMaxAngle`
Maximum angle between layers of BL elements for the detection of columns in the fast curving algorithm
Default value: `0.174533`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderMaxInnerAngle`
Maximum angle between edges/faces within layers of BL triangles/tets for the detection of columns in the fast curving algorithm
Default value: `0.523599`
Saved in: `General.OptionsFileName`

`Mesh.HighOrderSkipQualityCheck`
Skip element quality check after high-order mesh generation
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.IgnoreParametrization`
Skip parametrization section when reading meshes in the MSH4 format
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.IgnorePeriodicity`
Skip periodic node section and skip periodic boundary alignment step when reading meshes in the MSH2 format
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.LabelSampling`
Label sampling rate (display one label every 'LabelSampling' elements)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.LabelType`
Type of element label (0: node/element tag, 1: elementary entity tag, 2: physical entity tag, 3: partition, 4: coordinates)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.LcIntegrationPrecision`
Accuracy of evaluation of the LC field for 1D mesh generation
Default value: `1e-09`
Saved in: `General.OptionsFileName`

`Mesh.Light`
Enable lighting for the mesh
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.LightLines`
Enable lighting for mesh edges (0: no, 1: surfaces, 2: surfaces+volumes
Default value: `2`
Saved in: `General.OptionsFileName`

`Mesh.LightTwoSide`
Light both sides of surfaces (leads to slower rendering)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.Lines`
Display mesh lines (1D elements)?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.LineLabels`
Display mesh line labels?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.LineWidth`
Display width of mesh lines (in pixels)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.MaxIterDelaunay3D`
: Maximum number of point insertion iterations in 3D Delaunay mesher (0: unlimited)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MaxNumThreads1D`
: Maximum number of threads for 1D meshing (0: use General.NumThreads)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MaxNumThreads2D`
: Maximum number of threads for 2D meshing (0: use General.NumThreads)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MaxNumThreads3D`
: Maximum number of threads for 3D meshing (0: use General.NumThreads)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MaxRetries`
: Maximum number of times meshing is retried on curves and surfaces with a pending mesh
Default value: `10`
Saved in: `General.OptionsFileName`

`Mesh.MeshOnlyVisible`
: Mesh only visible entities (experimental)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MeshOnlyEmpty`
: Mesh only entities that have no existing mesh
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MeshSizeExtendFromBoundary`
: Extend computation of mesh element sizes from the boundaries into the interior (0: never; 1: for surfaces and volumes; 2: for surfaces and volumes, but use smallest surface element edge length instead of longest length in 3D Delaunay; -2: only for surfaces; -3: only for volumes)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.MeshSizeFactor`
: Factor applied to all mesh element sizes
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.MeshSizeMin`
: Minimum mesh element size
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MeshSizeMax`
Maximum mesh element size
Default value: `1e+22`
Saved in: `General.OptionsFileName`

`Mesh.MeshSizeFromCurvature`
Automatically compute mesh element sizes from curvature, using the value as the target number of elements per 2 * Pi radians
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MeshSizeFromCurvatureIsotropic`
Force isotropic curvature estimation when the mesh size is computed from curvature
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MeshSizeFromPoints`
Compute mesh element sizes from values given at geometry points
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.MeshSizeFromParametricPoints`
Compute mesh element sizes from values given at geometry points defining parametric curves
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MetisAlgorithm`
METIS partitioning algorithm 'ptype' (1: Recursive, 2: K-way)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.MetisEdgeMatching`
METIS edge matching type 'ctype' (1: Random, 2: Sorted Heavy-Edge)
Default value: `2`
Saved in: `General.OptionsFileName`

`Mesh.MetisMaxLoadImbalance`
METIS maximum load imbalance 'ufactor' (-1: default, i.e. 30 for K-way and 1 for Recursive)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.MetisObjective`
METIS objective type 'objtype' (1: min. edge-cut, 2: min. communication volume)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.MetisMinConn`
METIS minimize maximum connectivity of partitions 'minconn' (-1: default)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.MetisRefinementAlgorithm`
METIS algorithm for k-way refinement 'rtype' (1: FM-based cut, 2: Greedy, 3: Two-sided node FM, 4: One-sided node FM)
Default value: `2`
Saved in: `General.OptionsFileName`

`Mesh.MinimumLineNodes`
Minimum number of nodes used to mesh (straight) lines
Default value: `2`
Saved in: `General.OptionsFileName`

`Mesh.MinimumCircleNodes`
Minimum number of nodes used to mesh circles and ellipses
Default value: `7`
Saved in: `General.OptionsFileName`

`Mesh.MinimumCurveNodes`
Minimum number of nodes used to mesh curves other than lines, circles and ellipses
Default value: `3`
Saved in: `General.OptionsFileName`

`Mesh.MinimumElementsPerTwoPi`
[Deprecated]
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MshFileVersion`
Version of the MSH file format to use
Default value: `4.1`
Saved in: `General.OptionsFileName`

`Mesh.MedFileMinorVersion`
Minor version of the MED file format to use (-1: use minor version of the MED library)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.MedImportGroupsOfNodes`
Import groups of nodes (0: no; 1: create geometrical point for each node)?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.MedSingleModel`
Import MED meshes in the current model, even if several MED mesh names exist
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.NbHexahedra`
Number of hexahedra in the current mesh (read-only)
Default value: `0`
Saved in: `-`

`Mesh.NbNodes`
Number of nodes in the current mesh (read-only)
Default value: `0`
Saved in: `-`

`Mesh.NbPartitions`
Number of partitions
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.NbPrisms`
Number of prisms in the current mesh (read-only)
Default value: `0`
Saved in: `-`

`Mesh.NbPyramids`
Number of pyramids in the current mesh (read-only)
Default value: `0`
Saved in: `-`

`Mesh.NbTrihedra`
Number of trihedra in the current mesh (read-only)
Default value: `0`
Saved in: `-`

`Mesh.NbQuadrangles`
Number of quadrangles in the current mesh (read-only)
Default value: `0`
Saved in: `-`

`Mesh.NbTetrahedra`
Number of tetrahedra in the current mesh (read-only)
Default value: `0`
Saved in: `-`

`Mesh.NbTriangles`
Number of triangles in the current mesh (read-only)
Default value: `0`
Saved in: `-`

`Mesh.NewtonConvergenceTestXYZ`
Force inverse surface mapping algorithm (Newton-Raphson) to converge in real coordinates (experimental)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.Nodes`
Display mesh nodes?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.NodeLabels`
Display mesh node labels?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.NodeSize`
Display size of mesh nodes (in pixels)
Default value: `4`
Saved in: `General.OptionsFileName`

`Mesh.NodeType`
Display mesh nodes as solid color dots (0) or 3D spheres (1)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.Normals`
Display size of normal vectors (in pixels)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.NumSubEdges`
Number of edge subdivisions used to draw high-order mesh elements
Default value: `2`
Saved in: `General.OptionsFileName`

`Mesh.OldInitialDelaunay2D`
Use old initial 2D Delaunay code
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.Optimize`
Optimize the mesh to improve the quality of tetrahedral elements
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.OptimizeThreshold`
Optimize tetrahedra that have a quality below ...
Default value: `0.3`
Saved in: `General.OptionsFileName`

`Mesh.OptimizeNetgen`
Optimize the mesh using Netgen to improve the quality of tetrahedral elements
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.PartitionHexWeight`
Weight of hexahedral element for METIS load balancing (-1: automatic)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionLineWeight`
Weight of line element for METIS load balancing (-1: automatic)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionPrismWeight`
Weight of prismatic element (wedge) for METIS load balancing (-1: automatic)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionPyramidWeight`
Weight of pyramidal element for METIS load balancing (-1: automatic)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionQuadWeight`
Weight of quadrangle for METIS load balancing (-1: automatic)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionTrihedronWeight`
Weight of trihedron element for METIS load balancing (-1: automatic)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.PartitionTetWeight`
Weight of tetrahedral element for METIS load balancing (-1: automatic)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionTriWeight`
Weight of triangle element for METIS load balancing (-1: automatic)
Default value: `-1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionCreateTopology`
Create boundary representation of partitions
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionCreatePhysicals`
Create physical groups for partitions, based on existing physical groups
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionCreateGhostCells`
Create ghost cells, i.e. create for each partition a ghost entity containing elements connected to neighboring partitions by at least one node.
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.PartitionSplitMeshFiles`
Write one file for each mesh partition
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.PartitionTopologyFile`
Write a .pro file with the partition topology
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.PartitionOldStyleMsh2`
Write partitioned meshes in MSH2 format using old style (i.e. by not referencing new partitioned entities, except on partition boundaries), for backward compatibility
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.PartitionConvertMsh2`
When reading partitioned meshes in MSH2 format, create new partition entities
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.PreserveNumberingMsh2`
Preserve element numbering in MSH2 format (will break meshes with multiple physical groups for a single elementary entity)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.Prisms`
Display mesh prisms?
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.Pyramids`
Display mesh pyramids?
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.QuadqsSizemapMethod`
Size map method in QuadQuasiStructured. 0: default, 1: cross-field,2: cross-field + CAD small features adaptation,3: from background mesh (e.g. sizes in current triangulation),4: cross-field + CAD small features adaptation (clamped by background mesh)
Default value: `3`
Saved in: `General.OptionsFileName`

`Mesh.QuadqsTopologyOptimizationMethods`
Topology optimization methods in QuadQuasiStructured. 0: default (all),100: pattern-based CAD faces,010: disk quadrangulation remeshing,001: cavity remeshing,xxx: combination of multiple methods (e.g. 111 for all)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.QuadqsRemeshingBoldness`
Controls how much cavity remeshing is allowed to distort the quad mesh. From 0 (no quality decrease during remeshing) to 1 (quality can tend to 0 during remeshing).
Default value: `0.66`
Saved in: `General.OptionsFileName`

`Mesh.QuadqsScalingOnTriangulation`
Ratio on the edge length between the triangulation and the quadrangulation. Use a small ratio (e.g. 0.5) to get a background triangulation finer than the quad mesh. Useful to get a more accurate cross-field.
Default value: `0.75`
Saved in: `General.OptionsFileName`

`Mesh.Quadrangles`
Display mesh quadrangles?
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.QualityInf`
Only display elements whose quality measure is greater than QualityInf
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.QualitySup`
Only display elements whose quality measure is smaller than QualitySup
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.QualityType`
Type of quality measure (0: SICN~signed inverse condition number, 1: SIGE~signed inverse gradient error, 2: gamma~vol/sum_face/max_edge, 3: Disto~minJ/maxJ
Default value: `2`
Saved in: `General.OptionsFileName`

`Mesh.RadiusInf`
Only display elements whose longest edge is greater than RadiusInf
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.RadiusSup`
Only display elements whose longest edge is smaller than RadiusSup
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.RandomFactor`
Random factor used in the 2D meshing algorithm (should be increased if RandomFactor * size(triangle)/size(model) approaches machine accuracy)
Default value: `1e-09`
Saved in: `General.OptionsFileName`

`Mesh.RandomFactor3D`
Random factor used in the 3D meshing algorithm
Default value: `1e-12`
Saved in: `General.OptionsFileName`

`Mesh.RandomSeed`
Seed of pseudo-random number generator
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.ReadGroupsOfElements`
Read groups of elements in UNV meshes (this will discard the elementary entity tags inferred from the element section)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.RecombinationAlgorithm`
Mesh recombination algorithm (0: simple, 1: blossom, 2: simple full-quad, 3: blossom full-quad)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.RecombineAll`
Apply recombination algorithm to all surfaces, ignoring per-surface spec
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.RecombineOptimizeTopology`
Number of topological optimization passes (removal of diamonds, ...) of recombined surface meshes
Default value: `5`
Saved in: `General.OptionsFileName`

`Mesh.RecombineNodeRepositioning`
Allow repositioning of nodes during recombination of surface meshes
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.RecombineMinimumQuality`
Minimum quality for quadrangle generated by recombination
Default value: `0.01`
Saved in: `General.OptionsFileName`

`Mesh.Recombine3DAll`
Apply recombination3D algorithm to all volumes, ignoring per-volume spec (experimental)

Default value: 0
Saved in: General.OptionsFileName

Mesh.Recombine3DLevel
3d recombination level (0: hex, 1: hex+prisms, 2: hex+prism+pyramids) (experimental)
Default value: 0
Saved in: General.OptionsFileName

Mesh.Recombine3DConformity
3d recombination conformity type (0: nonconforming, 1: trihedra, 2: pyramids+trihedra, 3:pyramids+hexSplit+trihedra, 4:hexSplit+trihedra)(experimental)
Default value: 0
Saved in: General.OptionsFileName

Mesh.RefineSteps
Number of refinement steps in the MeshAdapt-based 2D algorithms
Default value: 10
Saved in: General.OptionsFileName

Mesh.Renumber
Renumber nodes and elements in a continuous sequence after mesh generation
Default value: 1
Saved in: General.OptionsFileName

Mesh.ReparamMaxTriangles
Maximum number of triangles in a single parametrization patch
Default value: 250000
Saved in: General.OptionsFileName

Mesh.SaveAll
Save all elements, even if they don't belong to physical groups (for some mesh formats, this removes physical groups altogether)
Default value: 0
Saved in: -

Mesh.SaveElementTagType
Type of the element tag saved in mesh formats that don't support saving physical or partition ids (1: elementary, 2: physical, 3: partition)
Default value: 1
Saved in: General.OptionsFileName

Mesh.SaveGroupsOfElements
Save groups of elements for each physical group (for UNV and INP mesh format) if value is positive; if negative, save groups of elements for physical groups of dimension dim if the (dim+1)^th least significant digit of -Mesh.SaveGroupsOfElements is 1 (for example: -100 will only savesurfaces, while -1010 will save volumes and curves), and for INP skip saving elements of dimension dim altogether if the (dim+1)^th least significant digit of -Mesh.SaveGroupsOfElements is 0
Default value: 1
Saved in: General.OptionsFileName

Mesh.SaveGroupsOfNodes
Save groups of nodes for each physical group (for UNV, INP and Tochnog mesh formats) if value is positive; if negative, save groups of nodes for physical groups of dimension dim if the (dim+1)^th least significant digit of -Mesh.SaveGroupsOfNodes is 1 (for example: -100 will only save surfaces, while -1010 will save volumes and

curves); for INP, save groups of nodes for all entities of dimension dim if the (dim+1)^th least significant digit of -Mesh.SaveGroupsOfNodes is 2
Default value: 0
Saved in: General.OptionsFileName

Mesh.SaveParametric
Save parametric coordinates of nodes
Default value: 0
Saved in: General.OptionsFileName

Mesh.SaveWithoutOrphans
Don't save orphan entities (not connected to any highest dimensional entity in the model) in MSH4 files
Default value: 0
Saved in: General.OptionsFileName

Mesh.SaveTopology
Save model topology in MSH2 output files (this is always saved in MSH3 and above)
Default value: 0
Saved in: General.OptionsFileName

Mesh.ScalingFactor
Global scaling factor applied to the saved mesh
Default value: 1
Saved in: General.OptionsFileName

Mesh.SecondOrderIncomplete
Create incomplete second order elements? (8-node quads, 20-node hexas, etc.)
Default value: 0
Saved in: General.OptionsFileName

Mesh.SecondOrderLinear
Should second order nodes (as well as nodes generated with subdivision algorithms) simply be created by linear interpolation?
Default value: 0
Saved in: General.OptionsFileName

Mesh.Smoothing
Number of smoothing steps applied to the final mesh
Default value: 1
Saved in: General.OptionsFileName

Mesh.SmoothCrossField
Apply n barycentric smoothing passes to the 3D cross field
Default value: 0
Saved in: General.OptionsFileName

Mesh.CrossFieldClosestPoint
Use closest point to compute 2D crossfield
Default value: 1
Saved in: General.OptionsFileName

Mesh.SmoothNormals
Smooth the mesh normals?
Default value: 0
Saved in: General.OptionsFileName

`Mesh.SmoothRatio`
Ratio between mesh sizes at nodes of a same edge (used in BAMG)
Default value: `1.8`
Saved in: `General.OptionsFileName`

`Mesh.StlAngularDeflection`
Maximum angular deflection when creating STL representations of entities (currently only used with the OpenCASCADE kernel)
Default value: `0.3`
Saved in: `General.OptionsFileName`

`Mesh.StlLinearDeflection`
Maximum relative linear deflection when creating STL representation of entities (currently only used with the OpenCASCADE kernel)
Default value: `0.001`
Saved in: `General.OptionsFileName`

`Mesh.StlLinearDeflectionRelative`
Compute the linear deflection for STL representations relative to the length of curves (currently only used with the OpenCASCADE kernel)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.StlOneSolidPerSurface`
Create one solid per surface when exporting STL files? (0: single solid, 1: one solid per face, 2: one solid per physical surface)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.StlRemoveDuplicateTriangles`
Remove duplicate triangles when importing STL files?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.SubdivisionAlgorithm`
Mesh subdivision algorithm (0: none, 1: all quadrangles, 2: all hexahedra, 3: barycentric)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.SurfaceEdges`
Display edges of surface mesh?
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.SurfaceFaces`
Display faces of surface mesh?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.SurfaceLabels`
Display surface mesh element labels?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.SwitchElementTags`
Invert elementary and physical tags when reading the mesh
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.Tangents`
Display size of tangent vectors (in pixels)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.Tetrahedra`
Display mesh tetrahedra?
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.ToleranceEdgeLength`
Skip a model edge in mesh generation if its length is less than user's defined tolerance
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.ToleranceInitialDelaunay`
Tolerance for initial 3D Delaunay mesher
Default value: `1e-12`
Saved in: `General.OptionsFileName`

`Mesh.ToleranceReferenceElement`
Tolerance for classifying a point inside a reference element (of size 1)
Default value: `1e-06`
Saved in: `General.OptionsFileName`

`Mesh.Triangles`
Display mesh triangles?
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.Trihedra`
Display mesh trihedra?
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.TransfiniteTri`
Use alternative transfinite arrangement when meshing 3-sided surfaces
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.UnvStrictFormat`
Use strict format specification for UNV files, with 'D' for exponents (instead of 'E' as used by some tools)
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.VolumeEdges`
Display edges of volume mesh?
Default value: `1`
Saved in: `General.OptionsFileName`

`Mesh.VolumeFaces`
Display faces of volume mesh?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.VolumeLabels`
Display volume mesh element labels?
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.Voronoi`
Display the voronoi diagram
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.ZoneDefinition`
Method for defining a zone (0: single zone, 1: by partition, 2: by physical)
Default value: `0`
Saved in: `General.OptionsFileName`

`Mesh.Color.Nodes`
Mesh node color
Default value: `{0,0,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.NodesSup`
Second order mesh node color
Default value: `{255,0,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Lines`
Mesh line color
Default value: `{0,0,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Triangles`
Mesh triangle color (if Mesh.ColorCarousel=0)
Default value: `{160,150,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Quadrangles`
Mesh quadrangle color (if Mesh.ColorCarousel=0)
Default value: `{130,120,225}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Tetrahedra`
Mesh tetrahedron color (if Mesh.ColorCarousel=0)
Default value: `{160,150,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Hexahedra`
Mesh hexahedron color (if Mesh.ColorCarousel=0)
Default value: `{130,120,225}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Prisms`
Mesh prism color (if Mesh.ColorCarousel=0)
Default value: `{232,210,23}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Pyramids`
Mesh pyramid color (if Mesh.ColorCarousel=0)
Default value: `{217,113,38}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Trihedra`
Mesh trihedron color (if Mesh.ColorCarousel=0)
Default value: `{20,255,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Tangents`
Tangent mesh vector color
Default value: `{255,255,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Normals`
Normal mesh vector color
Default value: `{255,0,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Zero`
Color 0 in color carousel
Default value: `{255,120,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.One`
Color 1 in color carousel
Default value: `{0,255,132}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Two`
Color 2 in color carousel
Default value: `{255,160,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Three`
Color 3 in color carousel
Default value: `{0,255,192}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Four`
Color 4 in color carousel
Default value: `{255,200,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Five`
Color 5 in color carousel
Default value: `{0,216,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Six`
Color 6 in color carousel
Default value: `{255,240,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Seven`
Color 7 in color carousel
Default value: `{0,176,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Eight`
Color 8 in color carousel
Default value: `{228,255,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Nine`
Color 9 in color carousel
Default value: `{0,116,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Ten`
Color 10 in color carousel
Default value: `{188,255,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Eleven`
Color 11 in color carousel
Default value: `{0,76,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Twelve`
Color 12 in color carousel
Default value: `{148,255,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Thirteen`
Color 13 in color carousel
Default value: `{24,0,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Fourteen`
Color 14 in color carousel
Default value: `{108,255,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Fifteen`
Color 15 in color carousel
Default value: `{84,0,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Sixteen`
Color 16 in color carousel
Default value: `{68,255,0}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Seventeen`
Color 17 in color carousel
Default value: `{104,0,255}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Eighteen`
Color 18 in color carousel
Default value: `{0,255,52}`
Saved in: `General.OptionsFileName`

`Mesh.Color.Nineteen`
Color 19 in color carousel
Default value: `{184,0,255}`
Saved in: `General.OptionsFileName`

7.5 Solver options

`Solver.Executable0`
System command to launch solver 0
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Executable1`
System command to launch solver 1
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Executable2`
System command to launch solver 2
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Executable3`
System command to launch solver 3
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Executable4`
System command to launch solver 4
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Executable5`
System command to launch solver 5
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Executable6`
System command to launch solver 6
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Executable7`
System command to launch solver 7
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Executable8`
System command to launch solver 8
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Executable9`
System command to launch solver 9
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Name0`
Name of solver 0
Default value: `"GetDP"`
Saved in: `General.SessionFileName`

`Solver.Name1`
Name of solver 1
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Name2`
Name of solver 2
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Name3`
Name of solver 3
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Name4`
Name of solver 4
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Name5`
Name of solver 5
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Name6`
Name of solver 6
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Name7`
Name of solver 7
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Name8`
Name of solver 8
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Name9`
Name of solver 9
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Extension0`
File extension for solver 0
Default value: `".pro"`
Saved in: `General.SessionFileName`

`Solver.Extension1`
File extension for solver 1
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Extension2`
File extension for solver 2
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Extension3`
File extension for solver 3
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Extension4`
File extension for solver 4
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Extension5`
File extension for solver 5
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Extension6`
File extension for solver 6
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Extension7`
File extension for solver 7
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Extension8`
File extension for solver 8
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.Extension9`
File extension for solver 9
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.OctaveInterpreter`
Name of the Octave interpreter (used to run .m files)
Default value: `"octave"`
Saved in: `General.SessionFileName`

`Solver.PythonInterpreter`
Name of the Python interpreter (used to run .py files if they are not executable)
Default value: `"python"`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin0`
Command to login to a remote host to launch solver 0
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin1`
Command to login to a remote host to launch solver 1
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin2`
Command to login to a remote host to launch solver 2
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin3`
Command to login to a remote host to launch solver 3
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin4`
Command to login to a remote host to launch solver 4
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin5`
Command to login to a remote host to launch solver 5
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin6`
Command to login to a remote host to launch solver 6
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin7`
Command to login to a remote host to launch solver 7
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin8`
Command to login to a remote host to launch solver 8
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.RemoteLogin9`
Command to login to a remote host to launch solver 9
Default value: `""`
Saved in: `General.SessionFileName`

`Solver.SocketName`
Base name of socket (UNIX socket if the name does not contain a colon, TCP/IP otherwise, in the form 'host:baseport'; the actual name/port is constructed by appending the unique client id. If baseport is 0 or is not provided, the port is chosen automatically (recommended))
Default value: `".gmshsock"`
Saved in: `General.OptionsFileName`

`Solver.AlwaysListen`
Always listen to incoming connection requests?
Default value: `0`
Saved in: `General.OptionsFileName`

`Solver.AutoArchiveOutputFiles`
Automatically archive output files after each computation
Default value: `0`
Saved in: `General.OptionsFileName`

`Solver.AutoCheck`
Automatically check model every time a parameter is changed
Default value: `1`
Saved in: `General.OptionsFileName`

`Solver.AutoLoadDatabase`
Automatically load the ONELAB database when launching a solver
Default value: `0`
Saved in: `General.OptionsFileName`

`Solver.AutoSaveDatabase`
Automatically save the ONELAB database after each computation
Default value: `1`
Saved in: `General.OptionsFileName`

`Solver.AutoMesh`
Automatically mesh (0: never; 1: if geometry changed, but use existing mesh on disk if available; 2: if geometry changed; -1: the geometry script creates the mesh)
Default value: `2`
Saved in: `General.OptionsFileName`

`Solver.AutoMergeFile`
Automatically merge result files
Default value: `1`
Saved in: `General.OptionsFileName`

`Solver.AutoShowViews`
Automcatically show newly merged results (0: none; 1: all; 2: last one)
Default value: `2`
Saved in: `General.OptionsFileName`

`Solver.AutoShowLastStep`
Automatically show the last step in newly merged results, if there are more than 2 steps
Default value: `1`
Saved in: `General.OptionsFileName`

`Solver.Plugins`
Enable default solver plugins?
Default value: `0`
Saved in: `General.OptionsFileName`

`Solver.ShowInvisibleParameters`
Show all parameters, even those marked invisible
Default value: `0`
Saved in: `General.OptionsFileName`

`Solver.Timeout`
Time (in seconds) before closing the socket if no connection is happening
Default value: `5`
Saved in: `General.OptionsFileName`

7.6 Post-processing options

`PostProcessing.DoubleClickedGraphPointCommand`
Command parsed when double-clicking on a graph data point (e.g. Merge Sprintf('file_%g.pos', PostProcessing.GraphPointX);)
Default value: `""`
Saved in: `General.OptionsFileName`

`PostProcessing.GraphPointCommand`
Synonym for 'DoubleClickedGraphPointCommand'
Default value: `""`
Saved in: `General.OptionsFileName`

`PostProcessing.AnimationDelay`
Delay (in seconds) between frames in automatic animation mode
Default value: `0.1`
Saved in: `General.OptionsFileName`

`PostProcessing.AnimationCycle`
Cycle through time steps (0) or views (1) for animations
Default value: `0`
Saved in: `General.OptionsFileName`

`PostProcessing.AnimationStep`
Step increment for animations
Default value: `1`
Saved in: `General.OptionsFileName`

`PostProcessing.Binary`
Write post-processing files in binary format (if possible)
Default value: `0`
Saved in: `General.OptionsFileName`

`PostProcessing.CombineRemoveOriginal`
Remove original views after a Combine operation
Default value: `1`
Saved in: `General.OptionsFileName`

`PostProcessing.CombineCopyOptions`
Copy options during Combine operation
Default value: `1`
Saved in: `General.OptionsFileName`

`PostProcessing.DoubleClickedGraphPointX`
Abscissa of last double-clicked graph point
Default value: `0`
Saved in: `-`

`PostProcessing.DoubleClickedGraphPointY`
Ordinate of last double-clicked graph point
Default value: `0`
Saved in: `-`

`PostProcessing.DoubleClickedView`
Index of last double-clicked view
Default value: `0`
Saved in: `-`

`PostProcessing.ForceElementData`
Try to force saving datasets as ElementData
Default value: `0`
Saved in: `General.OptionsFileName`

`PostProcessing.ForceNodeData`
Try to force saving datasets as NodeData
Default value: `0`
Saved in: `General.OptionsFileName`

`PostProcessing.Format`
: Default file format for post-processing views (0: ASCII view, 1: binary view, 2: parsed view, 3: STL triangulation, 4: raw text, 5: Gmsh mesh, 6: MED file, 10: automatic)
Default value: `10`
Saved in: `General.OptionsFileName`

`PostProcessing.GraphPointX`
: Synonym for 'DoubleClickedGraphPointX'
Default value: `0`
Saved in: `-`

`PostProcessing.GraphPointY`
: Synonym for 'DoubleClickedGraphPointY'
Default value: `0`
Saved in: `-`

`PostProcessing.HorizontalScales`
: Display value scales horizontally
Default value: `1`
Saved in: `General.OptionsFileName`

`PostProcessing.Link`
: Post-processing view links (0: apply next option changes to selected views, 1: force same options for all selected views)
Default value: `0`
Saved in: `General.OptionsFileName`

`PostProcessing.NbViews`
: Current number of views merged (read-only)
Default value: `0`
Saved in: `-`

`PostProcessing.Plugins`
: Enable default post-processing plugins?
Default value: `1`
Saved in: `General.OptionsFileName`

`PostProcessing.SaveInterpolationMatrices`
: Save the interpolation matrices when exporting model-based data
Default value: `1`
Saved in: `General.OptionsFileName`

`PostProcessing.SaveMesh`
: Save the mesh when exporting model-based data
Default value: `1`
Saved in: `General.OptionsFileName`

`PostProcessing.Smoothing`
: Apply (non-reversible) smoothing to post-processing view when merged
Default value: `0`
Saved in: `General.OptionsFileName`

7.7 Post-processing view options

Options related to post-processing views take two forms.

1. options that should apply to all views can be set through '`View.string`', *before any view is loaded*;

2. options that should apply only to the *n*-th view take the form '`View[n].string`' ($n = 0$, 1, 2, ...), *after the n-th view is loaded*.

`View.Attributes`
Optional string attached to the view. If the string contains 'AlwaysVisible', the view will not be hidden when new ones are merged.
Default value: `""`
Saved in: `General.OptionsFileName`

`View.AxesFormatX`
Number format for X-axis (in standard C form)
Default value: `"%.3g"`
Saved in: `General.OptionsFileName`

`View.AxesFormatY`
Number format for Y-axis (in standard C form)
Default value: `"%.3g"`
Saved in: `General.OptionsFileName`

`View.AxesFormatZ`
Number format for Z-axis (in standard C form)
Default value: `"%.3g"`
Saved in: `General.OptionsFileName`

`View.AxesLabelX`
X-axis label
Default value: `""`
Saved in: `General.OptionsFileName`

`View.AxesLabelY`
Y-axis label
Default value: `""`
Saved in: `General.OptionsFileName`

`View.AxesLabelZ`
Z-axis label
Default value: `""`
Saved in: `General.OptionsFileName`

`View.DoubleClickedCommand`
Command parsed when double-clicking on the view
Default value: `""`
Saved in: `General.OptionsFileName`

`View.FileName`
Default post-processing view file name
Default value: `""`
Saved in: `-`

`View.Format`
Number format (in standard C form)
Default value: `"%.3g"`
Saved in: `General.OptionsFileName`

`View.GeneralizedRaiseX`
Generalized elevation of the view along X-axis (in model coordinates, using formula possibly containing x, y, z, s[tep], t[ime], v0, ... v8)
Default value: `"v0"`
Saved in: `General.OptionsFileName`

`View.GeneralizedRaiseY`
: Generalized elevation of the view along Y-axis (in model coordinates, using formula possibly containing x, y, z, s[tep], t[ime], v0, ... v8)
Default value: `"v1"`
Saved in: `General.OptionsFileName`

`View.GeneralizedRaiseZ`
: Generalized elevation of the view along Z-axis (in model coordinates, using formula possibly containing x, y, z, s[tep], t[ime], v0, ... v8)
Default value: `"v2"`
Saved in: `General.OptionsFileName`

`View.Group`
: Group to which this view belongs
Default value: `""`
Saved in: `General.OptionsFileName`

`View.Name`
: Default post-processing view name
Default value: `""`
Saved in: `-`

`View.Stipple0`
: First stippling pattern
Default value: `"1*0x1F1F"`
Saved in: `General.OptionsFileName`

`View.Stipple1`
: Second stippling pattern
Default value: `"1*0x3333"`
Saved in: `General.OptionsFileName`

`View.Stipple2`
: Third stippling pattern
Default value: `"1*0x087F"`
Saved in: `General.OptionsFileName`

`View.Stipple3`
: Fourth stippling pattern
Default value: `"1*0xCCCF"`
Saved in: `General.OptionsFileName`

`View.Stipple4`
: Fifth stippling pattern
Default value: `"2*0x1111"`
Saved in: `General.OptionsFileName`

`View.Stipple5`
: Sixth stippling pattern
Default value: `"2*0x0F0F"`
Saved in: `General.OptionsFileName`

`View.Stipple6`
: Seventh stippling pattern
Default value: `"1*0xCFFF"`
Saved in: `General.OptionsFileName`

`View.Stipple7`
Eighth stippling pattern
Default value: `"2*0x0202"`
Saved in: `General.OptionsFileName`

`View.Stipple8`
Ninth stippling pattern
Default value: `"2*0x087F"`
Saved in: `General.OptionsFileName`

`View.Stipple9`
Tenth stippling pattern
Default value: `"1*0xFFFF"`
Saved in: `General.OptionsFileName`

`View.AbscissaRangeType`
Ascissa scale range type (1: default, 2: custom)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.AdaptVisualizationGrid`
Use adaptive visualization grid (for high-order elements)?
Default value: `0`
Saved in: `General.OptionsFileName`

`View.AngleSmoothNormals`
Threshold angle below which normals are not smoothed
Default value: `30`
Saved in: `General.OptionsFileName`

`View.ArrowSizeMax`
Maximum display size of arrows (in pixels)
Default value: `60`
Saved in: `General.OptionsFileName`

`View.ArrowSizeMin`
Minimum display size of arrows (in pixels)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.AutoPosition`
Position the scale or 2D plot automatically (0: manual, 1: automatic, 2: top left, 3: top right, 4: bottom left, 5: bottom right, 6: top, 7: bottom, 8: left, 9: right, 10: full, 11: top third, 12: in model coordinates)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.Axes`
Axes (0: none, 1: simple axes, 2: box, 3: full grid, 4: open grid, 5: ruler)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.AxesMikado`
Mikado axes style
Default value: `0`
Saved in: `General.OptionsFileName`

`View.AxesAutoPosition`
Position the axes automatically
Default value: `1`
Saved in: `General.OptionsFileName`

`View.AxesMaxX`
Maximum X-axis coordinate
Default value: `1`
Saved in: `General.OptionsFileName`

`View.AxesMaxY`
Maximum Y-axis coordinate
Default value: `1`
Saved in: `General.OptionsFileName`

`View.AxesMaxZ`
Maximum Z-axis coordinate
Default value: `1`
Saved in: `General.OptionsFileName`

`View.AxesMinX`
Minimum X-axis coordinate
Default value: `0`
Saved in: `General.OptionsFileName`

`View.AxesMinY`
Minimum Y-axis coordinate
Default value: `0`
Saved in: `General.OptionsFileName`

`View.AxesMinZ`
Minimum Z-axis coordinate
Default value: `0`
Saved in: `General.OptionsFileName`

`View.AxesTicsX`
Number of tics on the X-axis
Default value: `5`
Saved in: `General.OptionsFileName`

`View.AxesTicsY`
Number of tics on the Y-axis
Default value: `5`
Saved in: `General.OptionsFileName`

`View.AxesTicsZ`
Number of tics on the Z-axis
Default value: `5`
Saved in: `General.OptionsFileName`

`View.Boundary`
Draw the 'N minus b'-dimensional boundary of the element (N: element dimension, b: option value)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.CenterGlyphs`
Center glyphs (arrows, numbers, etc.)? (0: left, 1: centered, 2: right)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.Clip`
Enable clipping planes? (Plane[i]=2^i, i=0,...,5)
Default value: `0`
Saved in: `-`

`View.Closed`
Close the subtree containing this view
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ColormapAlpha`
Colormap alpha channel value (used only if != 1)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.ColormapAlphaPower`
Colormap alpha channel power
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ColormapBeta`
Colormap beta parameter (gamma = 1-beta)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ColormapBias`
Colormap bias
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ColormapCurvature`
Colormap curvature or slope coefficient
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ColormapInvert`
Invert the color values, i.e., replace x with (255-x) in the colormap?
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ColormapNumber`
Default colormap number (0: black, 1: vis5d, 2: jet, 3: lucie, 4: rainbow, 5: emc2000, 6: incadescent, 7: hot, 8: pink, 9: grayscale, 10: french, 11: hsv, 12: spectrum, 13: bone, 14: spring, 15: summer, 16: autumm, 17: winter, 18: cool, 19: copper, 20: magma, 21: inferno, 22: plasma, 23: viridis, 24: turbo)
Default value: `2`
Saved in: `General.OptionsFileName`

`View.ColormapRotation`
Incremental colormap rotation
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ColormapSwap`
: Swap the min/max values in the colormap?
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ComponentMap0`
: Forced component 0 (if View.ForceNumComponents > 0)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ComponentMap1`
: Forced component 1 (if View.ForceNumComponents > 0)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.ComponentMap2`
: Forced component 2 (if View.ForceNumComponents > 0)
Default value: `2`
Saved in: `General.OptionsFileName`

`View.ComponentMap3`
: Forced component 3 (if View.ForceNumComponents > 0)
Default value: `3`
Saved in: `General.OptionsFileName`

`View.ComponentMap4`
: Forced component 4 (if View.ForceNumComponents > 0)
Default value: `4`
Saved in: `General.OptionsFileName`

`View.ComponentMap5`
: Forced component 5 (if View.ForceNumComponents > 0)
Default value: `5`
Saved in: `General.OptionsFileName`

`View.ComponentMap6`
: Forced component 6 (if View.ForceNumComponents > 0)
Default value: `6`
Saved in: `General.OptionsFileName`

`View.ComponentMap7`
: Forced component 7 (if View.ForceNumComponents > 0)
Default value: `7`
Saved in: `General.OptionsFileName`

`View.ComponentMap8`
: Forced component 8 (if View.ForceNumComponents > 0)
Default value: `8`
Saved in: `General.OptionsFileName`

`View.CustomAbscissaMax`
: User-defined maximum abscissa value
Default value: `0`
Saved in: `-`

`View.CustomAbscissaMin`
: User-defined minimum abscissa value
Default value: `0`
Saved in: `-`

`View.CustomMax`
: User-defined maximum value to be displayed
Default value: `0`
Saved in: `-`

`View.CustomMin`
: User-defined minimum value to be displayed
Default value: `0`
Saved in: `-`

`View.DisplacementFactor`
: Displacement amplification
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawHexahedra`
: Display post-processing hexahedra?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawLines`
: Display post-processing lines?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawPoints`
: Display post-processing points?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawPrisms`
: Display post-processing prisms?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawPyramids`
: Display post-processing pyramids?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawTrihedra`
: Display post-processing trihedra?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawQuadrangles`
: Display post-processing quadrangles?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawScalars`
: Display scalar values?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawSkinOnly`
: Draw only the skin of 3D scalar views?
Default value: `0`
Saved in: `General.OptionsFileName`

`View.DrawStrings`
Display post-processing annotation strings?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawTensors`
Display tensor values?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawTetrahedra`
Display post-processing tetrahedra?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawTriangles`
Display post-processing triangles?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.DrawVectors`
Display vector values?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.Explode`
Element shrinking factor (between 0 and 1)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.ExternalView`
Index of the view used to color vector fields (-1: self)
Default value: `-1`
Saved in: `General.OptionsFileName`

`View.FakeTransparency`
Use fake transparency (cheaper than the real thing, but incorrect)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ForceNumComponents`
Force number of components to display (see View.ComponentMapN for mapping)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.GeneralizedRaiseFactor`
Generalized raise amplification factor
Default value: `1`
Saved in: `General.OptionsFileName`

`View.GeneralizedRaiseView`
Index of the view used for generalized raise (-1: self)
Default value: `-1`
Saved in: `General.OptionsFileName`

`View.GlyphLocation`
Glyph (arrow, number, etc.) location (1: center of gravity, 2: node)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.Height`
Height (in pixels) of the scale or 2D plot
Default value: `200`
Saved in: `General.OptionsFileName`

`View.IntervalsType`
Type of interval display (1: iso, 2: continuous, 3: discrete, 4: numeric)
Default value: `2`
Saved in: `General.OptionsFileName`

`View.Light`
Enable lighting for the view
Default value: `1`
Saved in: `General.OptionsFileName`

`View.LightLines`
Light element edges
Default value: `1`
Saved in: `General.OptionsFileName`

`View.LightTwoSide`
Light both sides of surfaces (leads to slower rendering)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.LineType`
Display lines as solid color segments (0), 3D cylinders (1) or tapered cylinders (2)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.LineWidth`
Display width of lines (in pixels)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.MaxRecursionLevel`
Maximum recursion level for adaptive views
Default value: `0`
Saved in: `General.OptionsFileName`

`View.Max` Maximum value in the view (read-only)
Default value: `0`
Saved in: `-`

`View.MaxVisible`
Maximum value in the visible parts of the view, taking current time step and tensor display type into account (read-only)
Default value: `0`
Saved in: `-`

`View.MaxX`
Maximum view coordinate along the X-axis (read-only)
Default value: `0`
Saved in: `-`

`View.MaxY`
Maximum view coordinate along the Y-axis (read-only)
Default value: `0`
Saved in: `-`

`View.MaxZ`
: Maximum view coordinate along the Z-axis (read-only)
Default value: `0`
Saved in: `-`

`View.Min` Minimum value in the view (read-only)
Default value: `0`
Saved in: `-`

`View.MinVisible`
: Minimum value in the visible parts of the view, taking current time step and tensor display type into account (read-only)
Default value: `0`
Saved in: `-`

`View.MinX`
: Minimum view coordinate along the X-axis (read-only)
Default value: `0`
Saved in: `-`

`View.MinY`
: Minimum view coordinate along the Y-axis (read-only)
Default value: `0`
Saved in: `-`

`View.MinZ`
: Minimum view coordinate along the Z-axis (read-only)
Default value: `0`
Saved in: `-`

`View.NbIso`
: Number of intervals
Default value: `10`
Saved in: `General.OptionsFileName`

`View.NbTimeStep`
: Number of time steps in the view (do not change this!)
Default value: `1`
Saved in: `-`

`View.NormalRaise`
: Elevation of the view along the normal (in model coordinates)
Default value: `0`
Saved in: `-`

`View.Normals`
: Display size of normal vectors (in pixels)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.OffsetX`
: Translation of the view along X-axis (in model coordinates)
Default value: `0`
Saved in: `-`

`View.OffsetY`
: Translation of the view along Y-axis (in model coordinates)
Default value: `0`
Saved in: `-`

`View.OffsetZ`
Translation of the view along Z-axis (in model coordinates)
Default value: `0`
Saved in: `-`

`View.PointSize`
Display size of points (in pixels)
Default value: `3`
Saved in: `General.OptionsFileName`

`View.PointType`
Display points as solid color dots (0), 3D spheres (1), scaled dots (2) or scaled spheres (3)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.PositionX`
X position (in pixels) of the scale or 2D plot (< 0: measure from right edge; >= 1e5: centered)
Default value: `100`
Saved in: `General.OptionsFileName`

`View.PositionY`
Y position (in pixels) of the scale or 2D plot (< 0: measure from bottom edge; >= 1e5: centered)
Default value: `50`
Saved in: `General.OptionsFileName`

`View.RaiseX`
Elevation of the view along X-axis (in model coordinates)
Default value: `0`
Saved in: `-`

`View.RaiseY`
Elevation of the view along Y-axis (in model coordinates)
Default value: `0`
Saved in: `-`

`View.RaiseZ`
Elevation of the view along Z-axis (in model coordinates)
Default value: `0`
Saved in: `-`

`View.RangeType`
Value scale range type (1: default, 2: custom, 3: per time step)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.Sampling`
Element sampling rate (draw one out every 'Sampling' elements)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.SaturateValues`
Saturate the view values to custom min and max (1: true, 0: false)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ScaleType`
Value scale type (1: linear, 2: logarithmic, 3: double logarithmic)
Default value: `1`
Saved in: `General.OptionsFileName`

`View.ShowElement`
Show element boundaries?
Default value: `0`
Saved in: `General.OptionsFileName`

`View.ShowScale`
Show value scale?
Default value: `1`
Saved in: `General.OptionsFileName`

`View.ShowTime`
Time display mode (0: none, 1: time series, 2: harmonic data, 3: automatic, 4: step data, 5: multi-step data, 6: real eigenvalues, 7: complex eigenvalues)
Default value: `3`
Saved in: `General.OptionsFileName`

`View.SmoothNormals`
Smooth the normals?
Default value: `0`
Saved in: `General.OptionsFileName`

`View.Stipple`
Stipple curves in 2D and line plots?
Default value: `0`
Saved in: `General.OptionsFileName`

`View.Tangents`
Display size of tangent vectors (in pixels)
Default value: `0`
Saved in: `General.OptionsFileName`

`View.TargetError`
Target representation error for adaptive views
Default value: `0.0001`
Saved in: `General.OptionsFileName`

`View.TensorType`
Tensor display type (1: Von-Mises, 2: maximum eigenvalue, 3: minimum eigenvalue, 4: eigenvectors, 5: ellipse, 6: ellipsoid, 7: frame (box), 8: frame (vectors))
Default value: `1`
Saved in: `General.OptionsFileName`

`View.TimeStep`
Current time step displayed
Default value: `0`
Saved in: `-`

`View.Time`
Current time displayed (if positive, sets the time step corresponding the given time value)
Default value: `0`
Saved in: `-`

`View.TransformXX`
Element (1,1) of the 3x3 coordinate transformation matrix
Default value: `1`
Saved in: `-`

`View.TransformXY`
Element (1,2) of the 3x3 coordinate transformation matrix
Default value: `0`
Saved in: `-`

`View.TransformXZ`
Element (1,3) of the 3x3 coordinate transformation matrix
Default value: `0`
Saved in: `-`

`View.TransformYX`
Element (2,1) of the 3x3 coordinate transformation matrix
Default value: `0`
Saved in: `-`

`View.TransformYY`
Element (2,2) of the 3x3 coordinate transformation matrix
Default value: `1`
Saved in: `-`

`View.TransformYZ`
Element (2,3) of the 3x3 coordinate transformation matrix
Default value: `0`
Saved in: `-`

`View.TransformZX`
Element (3,1) of the 3x3 coordinate transformation matrix
Default value: `0`
Saved in: `-`

`View.TransformZY`
Element (3,2) of the 3x3 coordinate transformation matrix
Default value: `0`
Saved in: `-`

`View.TransformZZ`
Element (3,3) of the 3x3 coordinate transformation matrix
Default value: `1`
Saved in: `-`

`View.Type`
Type of plot (1: 3D, 2: 2D space, 3: 2D time, 4: 2D)
Default value: `1`
Saved in: `-`

`View.UseGeneralizedRaise`
Use generalized raise?
Default value: `0`
Saved in: `General.OptionsFileName`

`View.VectorType`
Vector display type (1: segment, 2: arrow, 3: pyramid, 4: 3D arrow, 5: displacement, 6: comet)

Default value: 4
Saved in: General.OptionsFileName

View.Visible
Is the view visible?
Default value: 1
Saved in: -

View.Width
Width (in pixels) of the scale or 2D plot
Default value: 300
Saved in: General.OptionsFileName

View.Color.Points
Point color
Default value: {0,0,0}
Saved in: General.OptionsFileName

View.Color.Lines
Line color
Default value: {0,0,0}
Saved in: General.OptionsFileName

View.Color.Triangles
Triangle color
Default value: {0,0,0}
Saved in: General.OptionsFileName

View.Color.Quadrangles
Quadrangle color
Default value: {0,0,0}
Saved in: General.OptionsFileName

View.Color.Tetrahedra
Tetrahedron color
Default value: {0,0,0}
Saved in: General.OptionsFileName

View.Color.Hexahedra
Hexahedron color
Default value: {0,0,0}
Saved in: General.OptionsFileName

View.Color.Prisms
Prism color
Default value: {0,0,0}
Saved in: General.OptionsFileName

View.Color.Pyramids
Pyramid color
Default value: {0,0,0}
Saved in: General.OptionsFileName

View.Color.Trihedra
Trihedron color
Default value: {0,0,0}
Saved in: General.OptionsFileName

`View.Color.Tangents`
Tangent vector color
Default value: `{255,255,0}`
Saved in: `General.OptionsFileName`

`View.Color.Normals`
Normal vector color
Default value: `{255,0,0}`
Saved in: `General.OptionsFileName`

`View.Color.Text2D`
2D text color
Default value: `{0,0,0}`
Saved in: `General.OptionsFileName`

`View.Color.Text3D`
3D text color
Default value: `{0,0,0}`
Saved in: `General.OptionsFileName`

`View.Color.Axes`
Axes color
Default value: `{0,0,0}`
Saved in: `General.OptionsFileName`

`View.Color.Background2D`
Bacground color for 2D plots
Default value: `{255,255,255}`
Saved in: `General.OptionsFileName`

`View.ColorTable`
Color table used to draw the view
Saved in: `General.OptionsFileName`

8 Gmsh mesh size fields

This chapter lists all the Gmsh mesh size fields (see Section 1.2.2 [Specifying mesh element sizes], page 10). Fields can be specified in script files (see Section 5.3.1 [Mesh element sizes], page 113) or using the API (see Section 6.5 [Namespace gmsh/model/mesh/field], page 171). See Section 2.10 [t10], page 38 for an example on how to use fields.

`AttractorAnisoCurve`

Compute the distance to the given curves and specify the mesh size independently in the direction normal and parallel to the nearest curve. For efficiency each curve is replaced by a set of Sampling points, to which the distance is actually computed.

Options:

`CurvesList`
Tags of curves in the geometric model
Type: list
Default value: `{}`

`DistMax` Maxmium distance, above this distance from the curves, prescribe the maximum mesh sizes
Type: float
Default value: `0.5`

`DistMin` Minimum distance, below this distance from the curves, prescribe the minimum mesh sizes
Type: float
Default value: `0.1`

`Sampling` Number of sampling points on each curve
Type: integer
Default value: `20`

`SizeMaxNormal`
Maximum mesh size in the direction normal to the closest curve
Type: float
Default value: `0.5`

`SizeMaxTangent`
Maximum mesh size in the direction tangeant to the closest curve
Type: float
Default value: `0.5`

`SizeMinNormal`
Minimum mesh size in the direction normal to the closest curve
Type: float
Default value: `0.05`

`SizeMinTangent`
Minimum mesh size in the direction tangeant to the closest curve
Type: float
Default value: `0.5`

`AutomaticMeshSizeField`

Compute a mesh size field that is quite automatic Takes into account surface curvatures and closeness of objects

Options:

`features` Enable computation of local feature size (thin channels)
Type: boolean
Default value: `1`

`gradation`
Maximum growth ratio for the edges lengths
Type: float
Default value: `1.1`

`hBulk` Default size where it is not prescribed
Type: float
Default value: `-1`

`hMax` Maximum size
Type: float
Default value: `-1`

`hMin` Minimum size
Type: float
Default value: `-1`

`nPointsPerCircle`
Number of points per circle (adapt to curvature of surfaces)
Type: integer
Default value: `20`

`nPointsPerGap`
Number of layers of elements in thin layers
Type: integer
Default value: `0`

`p4estFileToLoad`
p4est file containing the size field
Type: string
Default value: `""`

`smoothing`
Enable size smoothing (should always be true)
Type: boolean
Default value: `1`

`Ball` Return VIn inside a spherical ball, and VOut outside. The ball is defined by

||dX||^2 < R^2 &&
dX = (X - XC)^2 + (Y-YC)^2 + (Z-ZC)^2

If Thickness is > 0, the mesh size is interpolated between VIn and VOut in a layer around the ball of the prescribed thickness.

Options:

`Radius` Radius
Type: float
Default value: `0`

`Thickness`
: Thickness of a transition layer outside the ball
Type: float
Default value: `0`

`VIn`
: Value inside the ball
Type: float
Default value: `1e+22`

`VOut`
: Value outside the ball
Type: float
Default value: `1e+22`

`XCenter`
: X coordinate of the ball center
Type: float
Default value: `0`

`YCenter`
: Y coordinate of the ball center
Type: float
Default value: `0`

`ZCenter`
: Z coordinate of the ball center
Type: float
Default value: `0`

`BoundaryLayer`
: Insert a 2D boundary layer mesh next to some curves in the model.

Options:

`AnisoMax`
: Threshold angle for creating a mesh fan in the boundary layer
Type: float
Default value: `10000000000`

`Beta`
: Beta coefficient of the Beta Law
Type: float
Default value: `1.01`

`BetaLaw`
: Use Beta Law instead of geometric progression
Type: integer
Default value: `0`

`CurvesList`
: Tags of curves in the geometric model for which a boundary layer is needed
Type: list
Default value: `{}`

`ExcludedSurfacesList`
: Tags of surfaces in the geometric model where the boundary layer should not be constructed
Type: list
Default value: `{}`

`FanPointsList`
: Tags of points in the geometric model for which a fan is created
Type: list
Default value: `{}`

`FanPointsSizesList`
Number of elements in the fan for each fan point. If not present default value Mesh.BoundaryLayerFanElements
Type: list
Default value: `{}`

`IntersectMetrics`
Intersect metrics of all surfaces
Type: integer
Default value: `0`

`NbLayers` Number of Layers in theBeta Law
Type: integer
Default value: `10`

`PointsList`
Tags of points in the geometric model for which a boundary layer ends
Type: list
Default value: `{}`

`Quads` Generate recombined elements in the boundary layer
Type: integer
Default value: `0`

`Ratio` Size ratio between two successive layers
Type: float
Default value: `1.1`

`Size` Mesh size normal to the curve
Type: float
Default value: `0.1`

`SizeFar` Mesh size far from the curves
Type: float
Default value: `1`

`SizesList`
Mesh size normal to the curve, per point (overwrites Size when defined)
Type: list_double
Default value: `{}`

`Thickness`
Maximal thickness of the boundary layer
Type: float
Default value: `0.01`

`Box` Return VIn inside the box, and VOut outside. The box is defined by

Xmin <= x <= XMax &&
YMin <= y <= YMax &&
ZMin <= z <= ZMax

If Thickness is > 0, the mesh size is interpolated between VIn and VOut in a layer around the box of the prescribed thickness.

Options:

`Thickness`
: Thickness of a transition layer outside the box
Type: float
Default value: `0`

`VIn`
: Value inside the box
Type: float
Default value: `1e+22`

`VOut`
: Value outside the box
Type: float
Default value: `1e+22`

`XMax`
: Maximum X coordinate of the box
Type: float
Default value: `0`

`XMin`
: Minimum X coordinate of the box
Type: float
Default value: `0`

`YMax`
: Maximum Y coordinate of the box
Type: float
Default value: `0`

`YMin`
: Minimum Y coordinate of the box
Type: float
Default value: `0`

`ZMax`
: Maximum Z coordinate of the box
Type: float
Default value: `0`

`ZMin`
: Minimum Z coordinate of the box
Type: float
Default value: `0`

`Constant` Return VIn when inside the entities (and on their boundary if IncludeBoundary is set), and VOut outside.

Options:

`CurvesList`
: Curve tags
Type: list
Default value: `{}`

`IncludeBoundary`
: Include the boundary of the entities
Type: boolean
Default value: `1`

`PointsList`
: Point tags
Type: list
Default value: `{}`

`SurfacesList`
Surface tags
Type: list
Default value: `{}`

`VIn` Value inside the entities
Type: float
Default value: `1e+22`

`VOut` Value outside the entities
Type: float
Default value: `1e+22`

`VolumesList`
Volume tags
Type: list
Default value: `{}`

`Curvature`
Compute the curvature of Field[InField]:

F = div(norm(grad(Field[InField])))

Options:

`Delta` Step of the finite differences
Type: float
Default value: `0.0003464101615137755`

`InField` Input field tag
Type: integer
Default value: `1`

`Cylinder` Return VIn inside a frustrated cylinder, and VOut outside. The cylinder is defined by

||dX||^2 < R^2 &&
(X-X0).A < ||A||^2
dX = (X - X0) - ((X - X0).A)/(||A||^2) . A

Options:

`Radius` Radius
Type: float
Default value: `0`

`VIn` Value inside the cylinder
Type: float
Default value: `1e+22`

`VOut` Value outside the cylinder
Type: float
Default value: `1e+22`

`XAxis` X component of the cylinder axis
Type: float
Default value: `0`

`XCenter` X coordinate of the cylinder center
Type: float
Default value: `0`

`YAxis` Y component of the cylinder axis
Type: float
Default value: `0`

`YCenter` Y coordinate of the cylinder center
Type: float
Default value: `0`

`ZAxis` Z component of the cylinder axis
Type: float
Default value: `1`

`ZCenter` Z coordinate of the cylinder center
Type: float
Default value: `0`

`Distance` Compute the distance to the given points, curves or surfaces. For efficiency, curves and surfaces are replaced by a set of points (sampled according to Sampling), to which the distance is actually computed.

Options:

`CurvesList`
Tags of curves in the geometric model
Type: list
Default value: `{}`

`PointsList`
Tags of points in the geometric model
Type: list
Default value: `{}`

`Sampling` Linear (i.e. per dimension) number of sampling points to discretize each curve and surface
Type: integer
Default value: `20`

`SurfacesList`
Tags of surfaces in the geometric model (only OpenCASCADE and discrete surfaces are currently supported)
Type: list
Default value: `{}`

`Extend` Compute an extension of the mesh sizes from the given boundary curves (resp. surfaces) inside the surfaces (resp. volumes) being meshed. If the mesh size on the boundary, computed as the local average length of the edges of the boundary elements, is denoted by SizeBnd, the extension is computed as:

F = f * SizeBnd + (1 - f) * SizeMax, if d < DistMax

F = SizeMax, if d >= DistMax

where d denotes the distance to the boundary and f = ((DistMax - d) / DistMax)^Power.

Options:

`CurvesList`
Tags of curves in the geometric model
Type: list
Default value: `{}`

`DistMax` Maximum distance of the size extension
Type: float
Default value: `1`

`Power` Power exponent used to interpolate the mesh size
Type: float
Default value: `1`

`SizeMax` Mesh size outside DistMax
Type: float
Default value: `1`

`SurfacesList`
Tags of surfaces in the geometric model
Type: list
Default value: `{}`

`ExternalProcess`
This Field is experimental
Call an external process that received coordinates triple (x,y,z) as binary double precision numbers on stdin and is supposed to write the field value on stdout as a binary double precision number.
NaN,NaN,NaN is sent as coordinate to indicate the end of the process.

Example of client (python2):
import os
import struct
import math
import sys
if sys.platform == "win32" :
import msvcrt
msvcrt.setmode(0, os.O_BINARY)
msvcrt.setmode(1, os.O_BINARY)
while(True):
xyz = struct.unpack("ddd", os.read(0,24))
if math.isnan(xyz[0]):
break
f = 0.001 + xyz[1]*0.009
os.write(1,struct.pack("d",f))

Example of client (python3):
import struct
import sys
import math

```
while(True):
xyz = struct.unpack("ddd", sys.stdin.buffer.read(24))
if math.isnan(xyz[0]):
break
f = 0.001 + xyz[1]*0.009
sys.stdout.buffer.write(struct.pack("d",f))
sys.stdout.flush()
```

Example of client (c, unix):

```
#include <unistd.h>
int main(int argc, char **argv) {
double xyz[3];
while(read(STDIN_FILENO, &xyz, 3*sizeof(double)) == 3*sizeof(double)) {
if (xyz[0] != xyz[0]) break; //nan
double f = 0.001 + 0.009 * xyz[1];
write(STDOUT_FILENO, &f, sizeof(double));
}
return 0;
}
```

Example of client (c, windows):

```
#include <stdio.h>
#include <io.h>
#include <fcntl.h>
int main(int argc, char **argv) {
double xyz[3];
setmode(fileno(stdin),O_BINARY);
setmode(fileno(stdout),O_BINARY);
while(read(fileno(stdin), &xyz, 3*sizeof(double)) == 3*sizeof(double)) {
if (xyz[0] != xyz[0])
break;
double f = f = 0.01 + 0.09 * xyz[1];
write(fileno(stdout), &f, sizeof(double));
}
}
```

Options:

`CommandLine`
: Command line to launch
Type: string
Default value: `""`

`Frustum` Interpolate mesh sizes on a extended cylinder frustrum defined by inner (R1i and R2i) and outer (R1o and R2o) radii and two endpoints P1 and P2.The field value F for a point P is given by :

```
u = P1P . P1P2 / ||P1P2||
r = || P1P - u*P1P2 ||
Ri = (1 - u) * R1i + u * R2i
Ro = (1 - u) * R1o + u * R2o
```

v = (r - Ri) / (Ro - Ri)
F = (1 - v) * ((1 - u) * v1i + u * v2i) + v * ((1 - u) * v1o + u * v2o)
with (u, v) in [0, 1] x [0, 1].

Options:

`InnerR1` Inner radius of Frustum at endpoint 1
Type: float
Default value: `0`

`InnerR2` Inner radius of Frustum at endpoint 2
Type: float
Default value: `0`

`InnerV1` Mesh size at point 1, inner radius
Type: float
Default value: `0.1`

`InnerV2` Mesh size at point 2, inner radius
Type: float
Default value: `0.1`

`OuterR1` Outer radius of Frustum at endpoint 1
Type: float
Default value: `1`

`OuterR2` Outer radius of Frustum at endpoint 2
Type: float
Default value: `1`

`OuterV1` Mesh size at point 1, outer radius
Type: float
Default value: `1`

`OuterV2` Mesh size at point 2, outer radius
Type: float
Default value: `1`

`X1` X coordinate of endpoint 1
Type: float
Default value: `0`

`X2` X coordinate of endpoint 2
Type: float
Default value: `0`

`Y1` Y coordinate of endpoint 1
Type: float
Default value: `0`

`Y2` Y coordinate of endpoint 2
Type: float
Default value: `0`

`Z1` Z coordinate of endpoint 1
Type: float
Default value: `1`

`Z2` Z coordinate of endpoint 2
Type: float
Default value: `0`

`Gradient` Compute the finite difference gradient of Field[InField]:

F = (Field[InField](X + Delta/2) - Field[InField](X - Delta/2)) / Delta

Options:

`Delta` Finite difference step
Type: float
Default value: `0.0003464101615137755`

`InField` Input field tag
Type: integer
Default value: `1`

`Kind` Component of the gradient to evaluate: 0 for X, 1 for Y, 2 for Z, 3 for the norm
Type: integer
Default value: `3`

`IntersectAniso`
Take the intersection of 2 anisotropic fields according to Alauzet.

Options:

`FieldsList`
Field indices
Type: list
Default value: `{}`

`Laplacian`
Compute finite difference the Laplacian of Field[InField]:

F = G(x+d,y,z) + G(x-d,y,z) +
G(x,y+d,z) + G(x,y-d,z) +
G(x,y,z+d) + G(x,y,z-d) - 6 * G(x,y,z),

where G = Field[InField] and d = Delta.

Options:

`Delta` Finite difference step
Type: float
Default value: `0.0003464101615137755`

`InField` Input field tag
Type: integer
Default value: `1`

`LonLat` Evaluate Field[InField] in geographic coordinates (longitude, latitude):

F = Field[InField](atan(y / x), asin(z / sqrt(x^2 + y^2 + z^2))

Options:

`FromStereo`
If = 1, the mesh is in stereographic coordinates: xi = 2Rx/(R+z), eta = 2Ry/(R+z)
Type: integer
Default value: `0`

`InField` Tag of the field to evaluate
Type: integer
Default value: `1`

`RadiusStereo`
Radius of the sphere of the stereograpic coordinates
Type: float
Default value: `6371000`

`MathEval` Evaluate a mathematical expression. The expression can contain x, y, z for spatial coordinates, F0, F1, ... for field values, and mathematical functions.

Options:

`F` Mathematical function to evaluate.
Type: string
Default value: `"F2 + Sin(z)"`

`MathEvalAniso`
Evaluate a metric expression. The expressions can contain x, y, z for spatial coordinates, F0, F1, ... for field values, and mathematical functions.

Options:

`M11` Element 11 of the metric tensor
Type: string
Default value: `"F2 + Sin(z)"`

`M12` Element 12 of the metric tensor
Type: string
Default value: `"F2 + Sin(z)"`

`M13` Element 13 of the metric tensor
Type: string
Default value: `"F2 + Sin(z)"`

`M22` Element 22 of the metric tensor
Type: string
Default value: `"F2 + Sin(z)"`

`M23` Element 23 of the metric tensor
Type: string
Default value: `"F2 + Sin(z)"`

`M33` Element 33 of the metric tensor
Type: string
Default value: `"F2 + Sin(z)"`

`Max` Take the maximum value of a list of fields.

Options:

`FieldsList`
Field indices
Type: list
Default value: `{}`

`MaxEigenHessian`
Compute the maximum eigenvalue of the Hessian matrix of Field[InField], with the gradients evaluated by finite differences:

F = max(eig(grad(grad(Field[InField]))))

Options:

`Delta` Step used for the finite differences
Type: float
Default value: `0.0003464101615137755`

`InField` Input field tag
Type: integer
Default value: `1`

`Mean` Return the mean value

F = (G(x + delta, y, z) + G(x - delta, y, z) +
G(x, y + delta, z) + G(x, y - delta, z) +
G(x, y, z + delta) + G(x, y, z - delta) +
G(x, y, z)) / 7,

where G = Field[InField].

Options:

`Delta` Distance used to compute the mean value
Type: float
Default value: `0.0003464101615137755`

`InField` Input field tag
Type: integer
Default value: `1`

`Min` Take the minimum value of a list of fields.

Options:

`FieldsList`
Field indices
Type: list
Default value: `{}`

`MinAniso` Take the intersection of a list of possibly anisotropic fields.

Options:

`FieldsList`
Field indices
Type: list
Default value: `{}`

`Octree` Pre compute another field on an octree to speed-up evalution.

Options:

`InField` Id of the field to represent on the octree
Type: integer
Default value: `1`

`Param` Evaluate Field[InField] in parametric coordinates:

F = Field[InField](FX,FY,FZ)

See the MathEval Field help to get a description of valid FX, FY and FZ expressions.

Options:

`FX` X component of parametric function
Type: string
Default value: `""`

`FY` Y component of parametric function
Type: string
Default value: `""`

`FZ` Z component of parametric function
Type: string
Default value: `""`

`InField` Input field tag
Type: integer
Default value: `1`

`PostView` Evaluate the post processing view with index ViewIndex, or with tag ViewTag if ViewTag is positive.

Options:

`CropNegativeValues`
return MAX_LC instead of a negative value (this option is needed for backward compatibility with the BackgroundMesh option
Type: boolean
Default value: `1`

`UseClosest`
Use value at closest node if no exact match is found
Type: boolean
Default value: `1`

`ViewIndex`
Post-processing view index
Type: integer
Default value: `0`

`ViewTag` Post-processing view tag
Type: integer
Default value: `-1`

`Restrict` Restrict the application of a field to a given list of geometrical points, curves, surfaces or volumes (as well as their boundaries if IncludeBoundary is set).

Options:

`CurvesList`
Curve tags
Type: list
Default value: `{}`

`InField` Input field tag
Type: integer
Default value: `1`

`IncludeBoundary`
Include the boundary of the entities
Type: boolean
Default value: `1`

`PointsList`
Point tags
Type: list
Default value: `{}`

`SurfacesList`
Surface tags
Type: list
Default value: `{}`

`VolumesList`
Volume tags
Type: list
Default value: `{}`

`Structured`
Linearly interpolate between data provided on a 3D rectangular structured grid.

The format of the input file is:

Ox Oy Oz
Dx Dy Dz
nx ny nz

v(0,0,0) v(0,0,1) v(0,0,2) ...
v(0,1,0) v(0,1,1) v(0,1,2) ...
v(0,2,0) v(0,2,1) v(0,2,2) ...
... ...
v(1,0,0) ... ...

where O are the coordinates of the first node, D are the distances between nodes in each direction, n are the numbers of nodes in each direction, and v are the values on each node.

Options:

`FileName` Name of the input file
Type: path
Default value: `""`

`OutsideValue`
Value of the field outside the grid (only used if the "SetOutsideValue" option is true).
Type: float
Default value: `1e+22`

`SetOutsideValue`
True to use the "OutsideValue" option. If False, the last values of the grid are used.
Type: boolean
Default value: `0`

`TextFormat`
True for ASCII input files, false for binary files (4 bite signed integers for n, double precision floating points for v, D and O)
Type: boolean
Default value: `0`

`Threshold`

Return F = SizeMin if Field[InField] <= DistMin, F = SizeMax if Field[InField] >= DistMax, and the interpolation between SizeMin and SizeMax if DistMin < Field[InField] < DistMax.

Options:

`DistMax` Value after which the mesh size will be SizeMax
Type: float
Default value: `10`

`DistMin` Value up to which the mesh size will be SizeMin
Type: float
Default value: `1`

`InField` Tag of the field computing the input value, usually a distance
Type: integer
Default value: `0`

`Sigmoid` True to interpolate between SizeMin and LcMax using a sigmoid, false to interpolate linearly

Type: boolean
Default value: `0`

`SizeMax` Mesh size when value > DistMax
Type: float
Default value: `1`

`SizeMin` Mesh size when value < DistMin
Type: float
Default value: `0.1`

`StopAtDistMax`
True to not impose mesh size outside DistMax (i.e., F = a very big value if Field[InField] > DistMax)
Type: boolean
Default value: `0`

9 Gmsh plugins

This chapter lists all the plugins that are bundled in the official Gmsh distribution. Plugins are available in the GUI (by right-clicking on a view button, or by clicking on the black arrow next to the view button, and then selecting the 'Plugin' submenu), in the scripting language (see Section 5.4 [Post-processing scripting commands], page 119) and in the API (see Section 6.12 [Namespace gmsh/plugin], page 211). See Section 2.9 [t9], page 36 for an example on how to use plugins.

`Plugin(AnalyseMeshQuality)`

Plugin(AnalyseMeshQuality) analyses the quality of the elements of a given dimension in the current model. Depending on the input parameters it computes the minimum of the Jacobian determinant (J), the IGE quality measure (Inverse Gradient Error) and/or the ICN quality measure (Condition Number). Statistics are printed and, if requested, a model-based post-processing view is created for each quality measure. The plugin can optionally hide elements by comparing the measure to a prescribed threshold.

J is faster to compute but gives information only on element validity while the other measures also give information on element quality. The IGE measure is related to the error on the gradient of the finite element solution. It is the scaled Jacobian for quads and hexes and a new measure for triangles and tetrahedra. The ICN measure is related to the condition number of the stiffness matrix. (See the article `"Efficient computation of the minimum of shape quality measures on curvilinear finite elements"` for details.)

Parameters:

- 'JacobianDeterminant': compute J?

- 'IGEMeasure': compute IGE?

- 'ICNMeasure': compute ICN?

- 'HidingThreshold': hide all elements for which min(mu) is strictly greater than (if 'ThresholdGreater' == 1) or less than (if 'ThresholdGreater' == 0) the threshold, where mu is ICN if 'ICNMeasure' == 1, IGE if 'IGEMeasure' == 1 or min(J)/max(J) if 'JacobianDeterminant' == 1.

- 'CreateView': create a model-based view of min(J)/max(J), min(IGE) and/or min(ICN)?

- 'Recompute': force recomputation (set to 1 if the mesh has changed).

- 'DimensionOfElements': analyse elements of the given dimension if equal to 1, 2 or 3; analyse 2D and 3D elements if equal to 4; or analyse elements of the highest dimension if equal to -1. Numeric options:

`JacobianDeterminant`
Default value: `0`

`IGEMeasure`
Default value: `0`

`ICNMeasure`
Default value: `0`

`HidingThreshold`
Default value: `99`

`ThresholdGreater`
Default value: `1`

`CreateView`
Default value: `0`

`Recompute`
Default value: `0`

`DimensionOfElements`
Default value: `-1`

`Plugin(Annotate)`
Plugin(Annotate) adds the text string 'Text', in font 'Font' and size 'FontSize', in the view 'View'. The string is aligned according to 'Align'.

If 'ThreeD' is equal to 1, the plugin inserts the string in model coordinates at the position ('X','Y','Z'). If 'ThreeD' is equal to 0, the plugin inserts the string in screen coordinates at the position ('X','Y').

If 'View' < 0, the plugin is run on the current view.

Plugin(Annotate) is executed in-place for list-based datasets or creates a new list-based view for other datasets. String options:

`Text` Default value: `"My Text"`

`Font` Default value: `"Helvetica"`

`Align` Default value: `"Left"`

Numeric options:

`X` Default value: `50`

`Y` Default value: `30`

`Z` Default value: `0`

`ThreeD` Default value: `0`

`FontSize` Default value: `14`

`View` Default value: `-1`

`Plugin(BoundaryAngles)`
Plugin(BoundaryAngles) computes the (interior) angles between the line elements on the boundary of all surfaces. The angles, computed modulo 2*Pi, are stored in a new post-processing view, one for each surface. The plugin currently only works for planar surfaces.Available options:- Visible (1=True, 0 = False, Default = 1): Visibility of the Views in the GUI - Save (1=True, 0 = False, Default = 0): Save the Views on disk ?- Remove (1=True, 0 = False, Default = 0): Remove the View from the memory after execution?- Filename (Default = 'Angles_Surface'): Root name for the Views (in case of save / Visibility)- Dir (Default = ''): Output directory (possibly nested) String options:

`Filename` Default value: `"Angles_Surface"`

`Dir` Default value: `""`

Numeric options:

`View` Default value: `-1`

`Save` Default value: `0`

`Visible` Default value: `0`

`Remove` Default value: `0`

`Plugin(Bubbles)`

Plugin(Bubbles) constructs a geometry consisting of 'bubbles' inscribed in the Voronoi of an input triangulation. 'ShrinkFactor' allows to change the size of the bubbles. The plugin expects a triangulation in the 'z = 0' plane to exist in the current model.

Plugin(Bubbles) creates one '.geo' file. String options:

`OutputFile`
Default value: `"bubbles.geo"`

Numeric options:

`ShrinkFactor`
Default value: `0`

`Plugin(Crack)`

Plugin(Crack) creates a crack around the orientable, manifold physical group 'PhysicalGroup' of dimension 'Dimension' (1 or 2), embedded in a mesh of dimension 'Dimension' + 1.The plugin duplicates the nodes and the elements on the crack and stores them in a new discrete curve ('Dimension' = 1) or surface ('Dimension' = 2). The elements touching the crack on the positive side are modified to use the newly generated nodes.If 'OpenBoundaryPhysicalGroup' is given (> 0), its nodes are duplicated and the crack will be left open on that (part of the) boundary. Otherwise, the lips of the crack are sealed, i.e., its nodes are not duplicated. If 'AuxiliaryPhysicalGroup' is given (> 0), its elements are considered in addition to those in 'PhysicalGroup' for the logic that groups the elements into the positive and negative side of the crack. However, the nodes in 'AuxiliaryPhysicalGroup' are not duplicated (unless they are also in 'PhysicalGroup'). This can be useful to treat corner cases in non-trivial geometries. For 1D cracks, 'NormalX', 'NormalY' and 'NormalZ' provide the reference normal of the surface in which the crack is supposed to be embedded. If 'NewPhysicalGroup' is positive, use it as the tag of the newly created curve or surface; otherwise use 'PhysicalGroup'. Numeric options:

`Dimension`
Default value: `1`

`PhysicalGroup`
Default value: `1`

`OpenBoundaryPhysicalGroup`
Default value: `0`

`AuxiliaryPhysicalGroup`
Default value: `0`

`NormalX` Default value: `0`

`NormalY` Default value: `0`

`NormalZ` Default value: `1`

`NewPhysicalGroup`
Default value: `0`

`DebugView`
Default value: `0`

`Plugin(Curl)`
Plugin(Curl) computes the curl of the field in the view 'View'.

If 'View' < 0, the plugin is run on the current view.

Plugin(Curl) creates one new list-based view. Numeric options:

`View` Default value: `-1`

`Plugin(CurvedBndDist)`
Plugin(CurvedBndDist) ...

`Plugin(CutBox)`
Plugin(CutBox) cuts the view 'View' with a rectangular box defined by the 4 points ('X0','Y0','Z0') (origin), ('X1','Y1','Z1') (axis of U), ('X2','Y2','Z2') (axis of V) and ('X3','Y3','Z3') (axis of W).

The number of points along U, V, W is set with the options 'NumPointsU', 'NumPointsV' and 'NumPointsW'.

If 'ConnectPoints' is zero, the plugin creates points; otherwise, the plugin generates hexahedra, quadrangles, lines or points depending on the values of 'NumPointsU', 'NumPointsV' and 'NumPointsW'.

If 'Boundary' is zero, the plugin interpolates the view inside the box; otherwise the plugin interpolates the view at its boundary.

If 'View' < 0, the plugin is run on the current view.

Plugin(CutBox) creates one new list-based view. Numeric options:

`X0` Default value: `0`

`Y0` Default value: `0`

`Z0` Default value: `0`

`X1` Default value: `1`

`Y1` Default value: `0`

`Z1` Default value: `0`

`X2` Default value: `0`

`Y2` Default value: `1`

`Z2` Default value: `0`

`X3` Default value: `0`

`Y3` Default value: `0`

`Z3` Default value: `1`

`NumPointsU`
Default value: `20`

`NumPointsV`
Default value: `20`

`NumPointsW`
Default value: `20`

`ConnectPoints`
Default value: `1`

`Boundary` Default value: `1`

`View` Default value: `-1`

`Plugin(CutGrid)`

Plugin(CutGrid) cuts the view 'View' with a rectangular grid defined by the 3 points ('X0','Y0','Z0') (origin), ('X1','Y1','Z1') (axis of U) and ('X2','Y2','Z2') (axis of V).

The number of points along U and V is set with the options 'NumPointsU' and 'NumPointsV'.

If 'ConnectPoints' is zero, the plugin creates points; otherwise, the plugin generates quadrangles, lines or points depending on the values of 'NumPointsU' and 'NumPointsV'.

If 'View' < 0, the plugin is run on the current view.

Plugin(CutGrid) creates one new list-based view. Numeric options:

`X0` Default value: `0`

`Y0` Default value: `0`

`Z0` Default value: `0`

`X1` Default value: `1`

`Y1` Default value: `0`

`Z1` Default value: `0`

`X2` Default value: `0`

`Y2` Default value: `1`

`Z2` Default value: `0`

`NumPointsU`
Default value: `20`

`NumPointsV`
Default value: `20`

`ConnectPoints`
Default value: `1`

`View` Default value: `-1`

`Plugin(CutMesh)`

Plugin(CutMesh) cuts the mesh of the current GModel with the zero value of the levelset defined with the view 'View'.Sub-elements are created in the new model (polygons in 2D and polyhedra in 3D) and border elements are created on the zero-levelset.

If 'Split' is nonzero, the plugin splits the meshalong the edges of the cut elements in the positive side.

If 'SaveTri' is nonzero, the sub-elements are saved as simplices.

Plugin(CutMesh) creates one new GModel. Numeric options:

`View` Default value: `-1`

`Split` Default value: `0`

`SaveTri` Default value: `0`

`Plugin(CutParametric)`

Plugin(CutParametric) cuts the view 'View' with the parametric function ('X'(u,v), 'Y'(u,v), 'Z'(u,v)), using 'NumPointsU' values of the parameter u in ['MinU', 'MaxU'] and 'NumPointsV' values of the parameter v in ['MinV', 'MaxV'].

If 'ConnectPoints' is set, the plugin creates surface or line elements; otherwise, the plugin generates points.

If 'View' < 0, the plugin is run on the current view.

Plugin(CutParametric) creates one new list-based view. String options:

`X` Default value: `"2 * Cos(u) * Sin(v)"`

`Y` Default value: `"4 * Sin(u) * Sin(v)"`

`Z` Default value: `"0.1 + 0.5 * Cos(v)"`

Numeric options:

`MinU` Default value: `0`

`MaxU` Default value: `6.2832`

`NumPointsU`
Default value: `180`

`MinV` Default value: `0`

`MaxV` Default value: `6.2832`

`NumPointsV`
Default value: `180`

`ConnectPoints`
Default value: `0`

`View` Default value: `-1`

`Plugin(CutPlane)`

Plugin(CutPlane) cuts the view 'View' with the plane 'A'*X + 'B'*Y + 'C'*Z + 'D' = 0.

If 'ExtractVolume' is nonzero, the plugin extracts the elements on one side of the plane (depending on the sign of 'ExtractVolume').

If 'View' < 0, the plugin is run on the current view.

Plugin(CutPlane) creates one new list-based view. Numeric options:

`A` Default value: `1`

`B` Default value: `0`

`C` Default value: `0`

`D` Default value: `-0.01`

`ExtractVolume`
Default value: `0`

`RecurLevel`
Default value: `3`

`TargetError`
Default value: `0.0001`

`View` Default value: `-1`

`Plugin(CutSphere)`
Plugin(CutSphere) cuts the view 'View' with the sphere (X-'Xc')^2 + (Y-'Yc')^2 + (Z-'Zc')^2 = 'R'^2.

If 'ExtractVolume' is nonzero, the plugin extracts the elements inside (if 'ExtractVolume' < 0) or outside (if 'ExtractVolume' > 0) the sphere.

If 'View' < 0, the plugin is run on the current view.

Plugin(CutSphere) creates one new list-based view. Numeric options:

`Xc` Default value: `0`

`Yc` Default value: `0`

`Zc` Default value: `0`

`R` Default value: `0.25`

`ExtractVolume`
Default value: `0`

`RecurLevel`
Default value: `3`

`TargetError`
Default value: `0.0001`

`View` Default value: `-1`

`Plugin(DiscretizationError)`
Plugin(DiscretizationError) computes the error between the mesh and the geometry. It does so by supersampling the elements and computing the distance between the supersampled points dans their projection on the geometry. Numeric options:

`SuperSamplingNodes`
Default value: `10`

`Plugin(Distance)`
Plugin(Distance) computes distances to entities in a mesh.

If 'PhysicalPoint', 'PhysicalLine' and 'PhysicalSurface' are 0, the distance is computed to all the boundaries. Otherwise the distance is computed to the given physical group.

If 'DistanceType' is 0, the plugin computes the geometrical Euclidean distance using the naive O(N^2) algorithm. If 'DistanceType' > 0, the plugin computes an approximate distance by solving a PDE with a diffusion constant equal to 'DistanceType' time the maximum size of the bounding box of the mesh as in [Legrand et al. 2006].

Positive 'MinScale' and 'MaxScale' scale the distance function.

Plugin(Distance) creates one new list-based view. Numeric options:

`PhysicalPoint`
Default value: `0`

`PhysicalLine`
Default value: `0`

`PhysicalSurface`
Default value: `0`

`DistanceType`
Default value: `0`

`MinScale` Default value: `0`

`MaxScale` Default value: `0`

`Plugin(Divergence)`
Plugin(Divergence) computes the divergence of the field in the view 'View'.

If 'View' < 0, the plugin is run on the current view.

Plugin(Divergence) creates one new list-based view. Numeric options:

`View` Default value: `-1`

`Plugin(Eigenvalues)`
Plugin(Eigenvalues) computes the three real eigenvalues of each tensor in the view 'View'.

If 'View' < 0, the plugin is run on the current view.

Plugin(Eigenvalues) creates three new list-based scalar views. Numeric options:

`View` Default value: `-1`

`Plugin(Eigenvectors)`
Plugin(Eigenvectors) computes the three (right) eigenvectors of each tensor in the view 'View' and sorts them according to the value of the associated eigenvalues.

If 'ScaleByEigenvalues' is set, each eigenvector is scaled by its associated eigenvalue.

The plugin gives an error if the eigenvectors are complex.

If 'View' < 0, the plugin is run on the current view.

Plugin(Eigenvectors) creates three new list-based vector view. Numeric options:

`ScaleByEigenvalues`
Default value: `1`

`View` Default value: `-1`

`Plugin(ExtractEdges)`

Plugin(ExtractEdges) extracts sharp edges from a triangular mesh.

Plugin(ExtractEdges) creates one new view. Numeric options:

`Angle` Default value: `40`

`IncludeBoundary`
Default value: `1`

`Plugin(ExtractElements)`

Plugin(ExtractElements) extracts some elements from the view 'View'. If 'MinVal' != 'MaxVal', it extracts the elements whose 'TimeStep'-th values (averaged by element) are comprised between 'MinVal' and 'MaxVal'. If 'Visible' != 0, it extracts visible elements.

If 'View' < 0, the plugin is run on the current view.

Plugin(ExtractElements) creates one new list-based view. Numeric options:

`MinVal` Default value: `0`

`MaxVal` Default value: `0`

`TimeStep` Default value: `0`

`Visible` Default value: `1`

`Dimension`
Default value: `-1`

`View` Default value: `-1`

`Plugin(FieldFromAmplitudePhase)`

Plugin(FieldFromAmplitudePhase) builds a complex field 'u' from amplitude 'a' (complex) and phase 'phi' given in two different 'Views' u = a * exp(k*phi), with k the wavenumber.

The result is to be interpolated in a sufficiently fine mesh: 'MeshFile'.

Plugin(FieldFromAmplitudePhase) generates one new view. String options:

`MeshFile` Default value: `"fine.msh"`

Numeric options:

`Wavenumber`
Default value: `5`

`AmplitudeView`
Default value: `0`

`PhaseView`
Default value: `1`

`Plugin(GaussPoints)`
Given an input mesh, Plugin(GaussPoints) creates a list-based view containing the Gauss points for a given polynomial 'Order'.

If 'PhysicalGroup' is nonzero, the plugin only creates points for the elements belonging to the group. Numeric options:

`Order` Default value: `0`

`Dimension`
Default value: `2`

`PhysicalGroup`
Default value: `0`

`Plugin(Gradient)`
Plugin(Gradient) computes the gradient of the field in the view 'View'.

If 'View' `<` 0, the plugin is run on the current view.

Plugin(Gradient) creates one new list-based view. Numeric options:

`View` Default value: `-1`

`Plugin(HarmonicToTime)`
Plugin(HarmonicToTime) takes the values in the time steps 'RealPart' and 'ImaginaryPart' of the view 'View', and creates a new view containing

'View'['RealPart'] * cos(p) `+-` 'View'['ImaginaryPart'] * sin(p)
with
p = 2*Pi*k/'NumSteps', k = 0, ..., 'NumSteps'-1
and 'NumSteps' the total number of time steps
over 'NumPeriods' periods at frequency 'Frequency' [Hz].
The '`+`' sign is used if 'TimeSign'`>`0, the '-' sign otherwise.

If 'View' `<` 0, the plugin is run on the current view.

Plugin(HarmonicToTime) creates one new list-based view. Numeric options:

`RealPart` Default value: `0`

`ImaginaryPart`
Default value: `1`

`NumSteps` Default value: `20`

`TimeSign` Default value: `-1`

`Frequency`
Default value: `1`

`NumPeriods`
Default value: `1`

`View` Default value: `-1`

`Plugin(HomologyComputation)`

Plugin(HomologyComputation) computes representative chains of basis elements of (relative) homology and cohomology spaces.

Define physical groups in order to specify the computation domain and the relative subdomain. Otherwise the whole mesh is the domain and the relative subdomain is empty.

Plugin(HomologyComputation) creates new views, one for each basis element. The resulting basis chains of desired dimension together with the mesh are saved to the given file. String options:

`DomainPhysicalGroups`
Default value: `""`

`SubdomainPhysicalGroups`
Default value: `""`

`ReductionImmunePhysicalGroups`
Default value: `""`

`DimensionOfChainsToSave`
Default value: `"0, 1, 2, 3"`

`Filename` Default value: `"homology.msh"`

Numeric options:

`ComputeHomology`
Default value: `1`

`ComputeCohomology`
Default value: `0`

`HomologyPhysicalGroupsBegin`
Default value: `-1`

`CohomologyPhysicalGroupsBegin`
Default value: `-1`

`CreatePostProcessingViews`
Default value: `1`

`ReductionOmit`
Default value: `1`

`ReductionCombine`
Default value: `3`

`PostProcessSimplify`
Default value: `1`

`ReductionHeuristic`
Default value: `1`

`Plugin(HomologyPostProcessing)`

Plugin(HomologyPostProcessing) operates on representative basis chains of homology and cohomology spaces. Functionality:

1. (co)homology basis transformation:
'TransformationMatrix': Integer matrix of the transformation.

'PhysicalGroupsOfOperatedChains': (Co)chains of a (co)homology space basis to be transformed.
Results a new (co)chain basis that is an integer combination of the given basis.

2. Make basis representations of a homology space and a cohomology space compatible:
'PhysicalGroupsOfOperatedChains': Chains of a homology space basis.
'PhysicalGroupsOfOperatedChains2': Cochains of a cohomology space basis.
Results a new basis for the homology space such that the incidence matrix of the new basis and the basis of the cohomology space is the identity matrix.

Options:
'PhysicalGroupsToTraceResults': Trace the resulting (co)chains to the given physical groups.
'PhysicalGroupsToProjectResults': Project the resulting (co)chains to the complement of the given physical groups.
'NameForResultChains': Post-processing view name prefix for the results.
'ApplyBoundaryOperatorToResults': Apply boundary operator to the resulting chains.

String options:

`TransformationMatrix`
Default value: `"1, 0; 0, 1"`

`PhysicalGroupsOfOperatedChains`
Default value: `"1, 2"`

`PhysicalGroupsOfOperatedChains2`
Default value: `""`

`PhysicalGroupsToTraceResults`
Default value: `""`

`PhysicalGroupsToProjectResults`
Default value: `""`

`NameForResultChains`
Default value: `"c"`

Numeric options:

`ApplyBoundaryOperatorToResults`
Default value: `0`

`Plugin(Integrate)`

Plugin(Integrate) integrates a scalar field over all the elements of the view 'View' (if 'Dimension' < 0), or over all elements of the prescribed dimension (if 'Dimension' > 0). If the field is a vector field, the circulation/flux of the field over line/surface elements is calculated.

If 'View' < 0, the plugin is run on the current view.

If 'OverTime' = i > -1 , the plugin integrates the scalar view over time (using the trapezoidal rule) instead of over space, starting at step i. If 'Visible' = 1, the plugin only integrates over visible entities.

Plugin(Integrate) creates one new list-based view. Numeric options:

`View` Default value: `-1`

`OverTime` Default value: `-1`

`Dimension`
Default value: `-1`

`Visible` Default value: `1`

`Plugin(Invisible)`

Plugin(Invisible) deletes (if 'DeleteElements' is set) or reverses (if 'ReverseElements' is set) all the invisible elements in the current model. If the bounding box defined by 'XMin' < x < 'XMax, 'YMin' < y < 'YMax and 'ZMin' < z < 'ZMax' is not empty, mark all elements outside the bounding box as invisible prior to deleting or inverting the elements. Numeric options:

`DeleteElements`
Default value: `1`

`ReverseElements`
Default value: `0`

`XMin` Default value: `0`

`YMin` Default value: `0`

`ZMin` Default value: `0`

`XMax` Default value: `0`

`YMax` Default value: `0`

`ZMax` Default value: `0`

`Plugin(Isosurface)`

Plugin(Isosurface) extracts the isosurface of value 'Value' from the view 'View', and draws the 'OtherTimeStep'-th step of the view 'OtherView' on this isosurface.

If 'ExtractVolume' is nonzero, the plugin extracts the isovolume with values greater (if 'ExtractVolume' > 0) or smaller (if 'ExtractVolume' < 0) than the isosurface 'Value'.

If 'OtherTimeStep' < 0, the plugin uses, for each time step in 'View', the corresponding time step in 'OtherView'. If 'OtherView' < 0, the plugin uses 'View' as the value source.

If 'View' < 0, the plugin is run on the current view.

Plugin(Isosurface) creates as many list-based views as there are time steps in 'View'. Numeric options:

`Value` Default value: `0`

`ExtractVolume`
Default value: `0`

`RecurLevel`
Default value: `3`

`TargetError`
Default value: `0.0001`

`View` Default value: `-1`

`OtherTimeStep`
Default value: `-1`

`OtherView`
Default value: `-1`

`Plugin(Lambda2)`
Plugin(Lambda2) computes the eigenvalues Lambda(1,2,3) of the tensor (S_ik S_kj + Om_ik Om_kj), where S_ij = 0.5 (ui,j + uj,i) and Om_ij = 0.5 (ui,j - uj,i) are respectively the symmetric and antisymmetric parts of the velocity gradient tensor.

Vortices are well represented by regions where Lambda(2) is negative.

If 'View' contains tensor elements, the plugin directly uses the tensors as the values of the velocity gradient tensor; if 'View' contains vector elements, the plugin uses them as the velocities from which to derive the velocity gradient tensor.

If 'View' < 0, the plugin is run on the current view.

Plugin(Lambda2) creates one new list-based view. Numeric options:

`Eigenvalue`
Default value: `2`

`View` Default value: `-1`

`Plugin(LongitudeLatitude)`
Plugin(LongituteLatitude) projects the view 'View' in longitude-latitude.

If 'View' < 0, the plugin is run on the current view.

Plugin(LongituteLatitude) is executed in place. Numeric options:

`View` Default value: `-1`

`Plugin(MakeSimplex)`
Plugin(MakeSimplex) decomposes all non-simplectic elements (quadrangles, prisms, hexahedra, pyramids) in the view 'View' into simplices (triangles, tetrahedra).

If 'View' < 0, the plugin is run on the current view.

Plugin(MakeSimplex) is executed in-place. Numeric options:

`View` Default value: `-1`

`Plugin(MathEval)`
Plugin(MathEval) creates a new view using data from the time step 'TimeStep' in the view 'View'.

If only 'Expression0' is given (and 'Expression1', ..., 'Expression8' are all empty), the plugin creates a scalar view. If 'Expression0', 'Expression1' and/or 'Expression2' are given (and 'Expression3', ..., 'Expression8' are all empty) the plugin creates a vector view. Otherwise the plugin creates a tensor view.

In addition to the usual mathematical functions (Exp, Log, Sqrt, Sin, Cos, Fabs, etc.) and operators (+, -, *, /, ^), all expressions can contain:

- the symbols v0, v1, v2, ..., vn, which represent the n components in 'View';

- the symbols w0, w1, w2, ..., wn, which represent the n components of 'OtherView', at time step 'OtherTimeStep';

- the symbols x, y and z, which represent the three spatial coordinates.

If 'TimeStep' < 0, the plugin extracts data from all the time steps in the view.

If 'View' < 0, the plugin is run on the current view.

Plugin(MathEval) creates one new view.If 'PhysicalRegion' < 0, the plugin is run on all physical regions.If 'Dimension' > 0, only search for elements of the given dimension.

Plugin(MathEval) creates one new list-based view. String options:

`Expression0`
Default value: `"Sqrt(v0^2+v1^2+v2^2)"`

`Expression1`
Default value: `""`

`Expression2`
Default value: `""`

`Expression3`
Default value: `""`

`Expression4`
Default value: `""`

`Expression5`
Default value: `""`

`Expression6`
Default value: `""`

`Expression7`
Default value: `""`

`Expression8`
Default value: `""`

Numeric options:

`TimeStep` Default value: `-1`

`View` Default value: `-1`

`OtherTimeStep`
Default value: `-1`

`OtherView`
Default value: `-1`

`ForceInterpolation`
Default value: `0`

`PhysicalRegion`
Default value: `-1`

`Dimension`
Default value: `-1`

`Plugin(MeshSizeFieldView)`
Plugin(MeshSizeFieldView) evaluates the mesh size field 'MeshSizeField' on specified 'Component' (0 for scalar) of the post-processing view 'View'. Numeric options:

`MeshSizeField`
Default value: `0`

`View` Default value: `-1`

`Component`
Default value: `0`

`Plugin(MeshSubEntities)`
Plugin(MeshSubEntities) creates mesh elements for the entities of dimension 'OutputDimension' (0 for vertices, 1 for edges, 2 for faces) of the 'InputPhysicalGroup' of dimension 'InputDimension'. The plugin creates new elements belonging to 'OutputPhysicalGroup'. Numeric options:

`InputDimension`
Default value: `1`

`InputPhysicalGroup`
Default value: `1`

`OuputDimension`
Default value: `0`

`OuputPhysicalGroup`
Default value: `2000`

`Plugin(MeshVolume)`
Plugin(MeshVolume) computes the volume of the mesh.

Only the elements in the physical group 'PhysicalGroup' of dimension 'Dimension' are taken into account, unless 'PhysicalGroup' is negative, in which case all the elements of the given 'Dimension' are considered. If 'Dimension' is negative, all the elements are considered.

Plugin(MeshVolume) creates one new list-based view. Numeric options:

`PhysicalGroup`
Default value: `-1`

`Dimension`
Default value: `3`

`Plugin(MinMax)`
Plugin(MinMax) computes the min/max of a view.

If 'View' < 0, the plugin is run on the current view. If 'OverTime' = 1, the plugin calculates the min/max over space and time. If 'Argument' = 1, the plugin calculates

the min/max and the argmin/argmax. If 'Visible' = 1, the plugin is only applied to visible entities.

Plugin(MinMax) creates two new list-based views. Numeric options:

`View` Default value: `-1`

`OverTime` Default value: `0`

`Argument` Default value: `0`

`Visible` Default value: `1`

`Plugin(ModifyComponents)`

Plugin(ModifyComponents) modifies the components of the 'TimeStep'-th time step in the view 'View', using the expressions provided in 'Expression0', ..., 'Expression8'. If an expression is empty, the corresponding component in the view is not modified.

The expressions can contain:

- the usual mathematical functions (Log, Sqrt, Sin, Cos, Fabs, ...) and operators (+, -, *, /, ^);

- the symbols x, y and z, to retrieve the coordinates of the current node;

- the symbols Time and TimeStep, to retrieve the current time and time step values;

- the symbols v0, v1, v2, ..., v8, to retrieve each component of the field in 'View' at the 'TimeStep'-th time step;

- the symbols w0, w1, w2, ..., w8, to retrieve each component of the field in 'OtherView' at the 'OtherTimeStep'-th time step. If 'OtherView' and 'View' are based on different spatial grids, or if their data types are different, 'OtherView' is interpolated onto 'View'.

If 'TimeStep' < 0, the plugin automatically loops over all the time steps in 'View' and evaluates the expressions for each one.

If 'OtherTimeStep' < 0, the plugin uses 'TimeStep' instead.

If 'View' < 0, the plugin is run on the current view.

If 'OtherView' < 0, the plugin uses 'View' instead.

Plugin(ModifyComponents) is executed in-place. String options:

`Expression0`
Default value: `"v0 * Sin(x)"`

`Expression1`
Default value: `""`

`Expression2`
Default value: `""`

`Expression3`
Default value: `""`

`Expression4`
Default value: `""`

`Expression5`
Default value: `""`

`Expression6`
Default value: `""`

`Expression7`
Default value: `""`

`Expression8`
Default value: `""`

Numeric options:

`TimeStep` Default value: `-1`

`View` Default value: `-1`

`OtherTimeStep`
Default value: `-1`

`OtherView`
Default value: `-1`

`ForceInterpolation`
Default value: `0`

`Plugin(ModulusPhase)`

Plugin(ModulusPhase) interprets the time steps 'realPart' and 'imaginaryPart' in the view 'View' as the real and imaginary parts of a complex field and replaces them with their corresponding modulus and phase.

If 'View' < 0, the plugin is run on the current view.

Plugin(ModulusPhase) is executed in-place. Numeric options:

`RealPart` Default value: `0`

`ImaginaryPart`
Default value: `1`

`View` Default value: `-1`

`Plugin(NearToFarField)`

Plugin(NearToFarField) computes the far field pattern from the near electric E and magnetic H fields on a surface enclosing the radiating device (antenna).

Parameters: the wavenumber, the angular discretisation (phi in [0, 2*Pi] and theta in [0, Pi]) of the far field sphere and the indices of the views containing the complex-valued E and H fields. If 'Normalize' is set, the far field is normalized to 1. If 'dB' is set, the far field is computed in dB. If 'NegativeTime' is set, E and H are assumed to have exp(-iwt) time dependency; otherwise they are assume to have exp(+iwt) time dependency. If 'MatlabOutputFile' is given the raw far field data is also exported in Matlab format.

Plugin(NearToFarField) creates one new view. String options:

`MatlabOutputFile`
Default value: `"farfield.m"`

Numeric options:

`Wavenumber`
Default value: `1`

`PhiStart` Default value: `0`

`PhiEnd` Default value: `6.28319`

`NumPointsPhi`
Default value: `60`

`ThetaStart`
Default value: `0`

`ThetaEnd` Default value: `3.14159`

`NumPointsTheta`
Default value: `30`

`EView` Default value: `0`

`HView` Default value: `1`

`Normalize`
Default value: `1`

`dB` Default value: `1`

`NegativeTime`
Default value: `0`

`RFar` Default value: `0`

`Plugin(NearestNeighbor)`

Plugin(NearestNeighbor) computes the distance from each point in 'View' to its nearest neighbor.

If 'View' < 0, the plugin is run on the current view.

Plugin(NearestNeighbor) is executed in-place. Numeric options:

`View` Default value: `-1`

`Plugin(NewView)`

Plugin(NewView) creates a new model-based view from the current mesh, with 'NumComp' field components, set to value 'Value'.

If 'ViewTag' is positive, force that tag for the created view. The view type is determined by 'Type' (NodeData or ElementData). In the case of an ElementData type, the view can be restricted to a specific physical group with a positive 'PhysicalGroup'. String options:

`Type` Default value: `"NodeData"`

Numeric options:

`NumComp` Default value: `1`

`Value` Default value: `0`

`ViewTag` Default value: `-1`

`PhysicalGroup`
Default value: `-1`

`Plugin(Particles)`

Plugin(Particles) computes the trajectory of particules in the force field given by the 'TimeStep'-th time step of a vector view 'View'.

The plugin takes as input a grid defined by the 3 points ('X0','Y0','Z0') (origin), ('X1','Y1','Z1') (axis of U) and ('X2','Y2','Z2') (axis of V).

The number of particles along U and V that are to be transported is set with the options 'NumPointsU' and 'NumPointsV'. The equation

A2 * d^2X(t)/dt^2 + A1 * dX(t)/dt + A0 * X(t) = F

is then solved with the initial conditions X(t=0) chosen as the grid, dX/dt(t=0)=0, and with F interpolated from the vector view.

Time stepping is done using a Newmark scheme with step size 'DT' and 'MaxIter' maximum number of iterations.

If 'View' < 0, the plugin is run on the current view.

Plugin(Particles) creates one new list-based view containing multi-step vector points. Numeric options:

`X0` Default value: `0`

`Y0` Default value: `0`

`Z0` Default value: `0`

`X1` Default value: `1`

`Y1` Default value: `0`

`Z1` Default value: `0`

`X2` Default value: `0`

`Y2` Default value: `1`

`Z2` Default value: `0`

`NumPointsU`
Default value: `10`

`NumPointsV`
Default value: `1`

`A2` Default value: `1`

`A1` Default value: `0`

`A0` Default value: `0`

`DT` Default value: `0.1`

`MaxIter` Default value: `100`

`TimeStep` Default value: `0`

`View` Default value: `-1`

`Plugin(Probe)`

Plugin(Probe) gets the value of the view 'View' at the point ('X','Y','Z').

If 'View' < 0, the plugin is run on the current view.

Plugin(Probe) creates one new view. Numeric options:

`X` Default value: `0`

`Y` Default value: `0`

`Z` Default value: `0`

`View` Default value: `-1`

`Plugin(Remove)`

Plugin(Remove) removes the marked items from the list-based view 'View'.

If 'View' < 0, the plugin is run on the current view.

Plugin(Remove) is executed in-place. Numeric options:

`Text2D` Default value: `1`

`Text3D` Default value: `1`

`Points` Default value: `0`

`Lines` Default value: `0`

`Triangles`
Default value: `0`

`Quadrangles`
Default value: `0`

`Tetrahedra`
Default value: `0`

`Hexahedra`
Default value: `0`

`Prisms` Default value: `0`

`Pyramids` Default value: `0`

`Scalar` Default value: `1`

`Vector` Default value: `1`

`Tensor` Default value: `1`

`View` Default value: `-1`

`Plugin(Scal2Tens)`

Plugin(Scal2Tens) converts some scalar fields into a tensor field. The number of components must be given (max. 9). The new view 'NameNewView' contains the new tensor field. If the number of a view is -1, the value of the corresponding component is 0. String options:

`NameNewView`
Default value: `"NewView"`

Numeric options:

`NumberOfComponents`
Default value: `9`

`View0` Default value: `-1`

`View1` Default value: `-1`

`View2` Default value: `-1`

`View3` Default value: `-1`

`View4` Default value: `-1`

`View5` Default value: `-1`

`View6` Default value: `-1`

`View7` Default value: `-1`

`View8` Default value: `-1`

`Plugin(Scal2Vec)`
Plugin(Scal2Vec) converts the scalar fields into a vectorial field. The new view 'NameNewView' contains it. If the number of a view is -1, the value of the corresponding component of the vector field is 0. String options:

`NameNewView`
Default value: `"NewView"`

Numeric options:

`ViewX` Default value: `-1`

`ViewY` Default value: `-1`

`ViewZ` Default value: `-1`

`Plugin(ShowNeighborElements)`
Plugin(ShowNeighborElements) sets visible some elements and a layer of elements around them, the other being set invisible. Numeric options:

`NumLayers`
Default value: `1`

`Element1` Default value: `0`

`Element2` Default value: `0`

`Element3` Default value: `0`

`Element4` Default value: `0`

`Element5` Default value: `0`

`Plugin(SimplePartition)`
Plugin(SimplePartition) partitions the current mesh into 'NumSlicesX', 'NumSlicesY' and 'NumSlicesZ' slices along the X-, Y- and Z-axis, respectively. The distribution of these slices is governed by 'MappingX', 'MappingY' and 'MappingZ', where 't' is a normalized absissa along each direction. (Setting 'MappingX' to 't' will thus lead to equidistant slices along the X-axis.) String options:

`MappingX` Default value: `"t"`

`MappingY` Default value: `"t"`

`MappingZ` Default value: `"t"`

Numeric options:

`NumSlicesX`
Default value: `4`

`NumSlicesY`
Default value: `1`

`NumSlicesZ`
Default value: `1`

`Plugin(Skin)`
Plugin(Skin) extracts the boundary (skin) of the current mesh (if 'FromMesh' = 1), or from the the view 'View' (in which case it creates a new view). If 'View' < 0 and 'FromMesh' = 0, the plugin is run on the current view.
If 'Visible' is set, the plugin only extracts the skin of visible entities. Numeric options:

`Visible` Default value: `1`

`FromMesh` Default value: `0`

`View` Default value: `-1`

`Plugin(Smooth)`
Plugin(Smooth) averages the values at the nodes of the view 'View'.

If 'View' < 0, the plugin is run on the current view.

Plugin(Smooth) is executed in-place. Numeric options:

`View` Default value: `-1`

`Plugin(SpanningTree)`
Plugin(SpanningTree) builds a tree spanning every vertex of a mesh and stores it directly in the model.
The tree is constructed by starting first on the curves, then on the surfaces and finally on the volumes.

Parameters
- PhysicalVolumes: list of the physical volumes upon which the tree must be built.
- PhysicalSurfaces: list of the physical surfaces upon which the tree must be built.
- PhysicalCurves: list of the physical curves upon which the tree must be built.
- OutputPhysical: physical tag of the generated tree (-1 will select a new tag automatically).

Note - Lists must be comma separated integers and spaces are ignored.
Remark - This plugin does not overwrite a physical group.Therefore, if an existing physical tag is used in OutputPhysical, the edges of the tree will be /added/ to the specified group. String options:

`PhysicalVolumes`
Default value: `""`

`PhysicalSurfaces`
Default value: `""`

`PhysicalCurves`
Default value: `""`

Numeric options:

`OutputPhysical`
Default value: `-1`

`Plugin(SphericalRaise)`
Plugin(SphericalRaise) transforms the coordinates of the elements in the view 'View' using the values associated with the 'TimeStep'-th time step.

Instead of elevating the nodes along the X, Y and Z axes as with the View['View'].RaiseX, View['View'].RaiseY and View['View'].RaiseZ options, the raise is applied along the radius of a sphere centered at ('Xc', 'Yc', 'Zc').

To produce a standard radiation pattern, set 'Offset' to minus the radius of the sphere the original data lives on.

If 'View' < 0, the plugin is run on the current view.

Plugin(SphericalRaise) is executed in-place. Numeric options:

`Xc` Default value: `0`

`Yc` Default value: `0`

`Zc` Default value: `0`

`Raise` Default value: `1`

`Offset` Default value: `0`

`TimeStep` Default value: `0`

`View` Default value: `-1`

`Plugin(StreamLines)`
Plugin(StreamLines) computes stream lines from the 'TimeStep'-th time step of a vector view 'View' and optionally interpolates the scalar view 'OtherView' on the resulting stream lines.

The plugin takes as input a grid defined by the 3 points ('X0','Y0','Z0') (origin), ('X1','Y1','Z1') (axis of U) and ('X2','Y2','Z2') (axis of V).

The number of points along U and V that are to be transported is set with the options 'NumPointsU' and 'NumPointsV'. The equation

dX(t)/dt = V(x,y,z)

is then solved with the initial condition X(t=0) chosen as the grid and with V(x,y,z) interpolated on the vector view.

The time stepping scheme is a RK44 with step size 'DT' and 'MaxIter' maximum number of iterations.

If 'TimeStep' < 0, the plugin tries to compute streamlines of the unsteady flow.

If 'View' < 0, the plugin is run on the current view.

Plugin(StreamLines) creates one new list-based view. This view contains multi-step vector points if 'OtherView' < 0, or single-step scalar lines if 'OtherView' >= 0. Numeric options:

`X0` Default value: `0`

`Y0` Default value: `0`

`Z0` Default value: `0`

`X1` Default value: `1`

`Y1` Default value: `0`

`Z1` Default value: `0`

`X2` Default value: `0`

`Y2` Default value: `1`

`Z2` Default value: `0`

`NumPointsU`
Default value: `10`

`NumPointsV`
Default value: `1`

`DT` Default value: `0.1`

`MaxIter` Default value: `100`

`TimeStep` Default value: `0`

`View` Default value: `-1`

`OtherView`
Default value: `-1`

`Plugin(Summation)`

Plugin(Summation) sums every time steps of 'Reference View' and (every) 'Other View X'and store the result in a new view.
If 'View 0' < 0 then the current view is selected.
If 'View 1...8' < 0 then this view is skipped.
Views can have different number of time steps
Warning: the Plugin assume that every views sharethe same mesh and that meshes do not move between time steps! String options:

`Resuling View Name`
Default value: `"default"`

Numeric options:

`View 0` Default value: `-1`

`View 1` Default value: `-1`

`View 2` Default value: `-1`

`View 3` Default value: `-1`

`View 4` Default value: `-1`

`View 5` Default value: `-1`

`View 6` Default value: `-1`

`View 7` Default value: `-1`

`Plugin(Tetrahedralize)`

Plugin(Tetrahedralize) tetrahedralizes the points in the view 'View'.

If 'View' < 0, the plugin is run on the current view.

Plugin(Tetrahedralize) creates one new list-based view. Numeric options:

`View` Default value: `-1`

`Plugin(Transform)`

Plugin(Transform) transforms the homogeneous node coordinates (x,y,z,1) of the elements in the view 'View' by the matrix

['A11' 'A12' 'A13' 'Tx']
['A21' 'A22' 'A23' 'Ty']
['A31' 'A32' 'A33' 'Tz'].

If 'SwapOrientation' is set, the orientation of the elements is reversed.

If 'View' < 0, the plugin is run on the current view.

Plugin(Transform) is executed in-place. Numeric options:

`A11` Default value: `1`

`A12` Default value: `0`

`A13` Default value: `0`

`A21` Default value: `0`

`A22` Default value: `1`

`A23` Default value: `0`

`A31` Default value: `0`

`A32` Default value: `0`

`A33` Default value: `1`

`Tx` Default value: `0`

`Ty` Default value: `0`

`Tz` Default value: `0`

`SwapOrientation`
Default value: `0`

`View` Default value: `-1`

`Plugin(Triangulate)`

Plugin(Triangulate) triangulates the points in the view 'View', assuming that all the points belong to a surface that can be projected one-to-one onto a plane.

If 'View' < 0, the plugin is run on the current view.

Plugin(Triangulate) creates one new list-based view. Numeric options:

`View` Default value: `-1`

`Plugin(VoroMetal)`
Plugin(VoroMetal) creates microstructures using Voronoi diagrams.

String options:

`SeedsFile`
Default value: `"seeds.txt"`

Numeric options:

`ComputeBestSeeds`
Default value: `0`

`ComputeMicrostructure`
Default value: `1`

`Plugin(Warp)`
Plugin(Warp) transforms the elements in the view 'View' by adding to their node coordinates the vector field stored in the 'TimeStep'-th time step of the view 'OtherView', scaled by 'Factor'.

If 'View' < 0, the plugin is run on the current view.

If 'OtherView' < 0, the vector field is taken as the field of surface normals multiplied by the 'TimeStep' value in 'View'. (The smoothing of the surface normals is controlled by the 'SmoothingAngle' parameter.)

Plugin(Warp) is executed in-place. Numeric options:

`Factor` Default value: `1`

`TimeStep` Default value: `0`

`SmoothingAngle`
Default value: `180`

`View` Default value: `-1`

`OtherView`
Default value: `-1`

10 Gmsh file formats

This chapter describes Gmsh's native "MSH" file format, used to store meshes and associated post-processing datasets. The MSH format exists in two flavors: ASCII and binary. The format has a version number that is independent of Gmsh's main version number.

(Remember that for small post-processing datasets you can also use human-readable "parsed" post-processing views, as described in Section 5.4 [Post-processing scripting commands], page 119. Such "parsed" views do not require an underlying mesh, and can therefore be easier to use in some cases.)

10.1 MSH file format

The MSH file format version 4 (current revision: version 4.1) contains one mandatory section giving information about the file (`$MeshFormat`), followed by several optional sections defining the physical group names (`$PhysicalName`), the elementary model entities (`$Entities`), the partitioned entities (`$PartitionedEntities`), the nodes (`$Nodes`), the elements (`$Elements`), the periodicity relations (`$Periodic`), the ghost elements (`$GhostElements`), the parametrizations (`$Parametrizations`) and the post-processing datasets (`$NodeData`, `$ElementData`, `$ElementNodeData`). The sections reflect the underlying Gmsh data model: `$Entities` store the boundary representation of the model geometrical entities, `$Nodes` and `$Elements` store mesh data classified on these entities, and `$NodeData`, `$ElementData`, `$ElementNodeData` store post-processing data (views). (See Chapter 6 [Gmsh application programming interface], page 125 and Section B.1 [Source code structure], page 377 for a more detailed description of the internal Gmsh data model.)

To represent a simple mesh, the minimal sections that should be present in the file are `$MeshFormat`, `$Nodes` and `$Elements`. Nodes are assumed to be defined before elements. To represent a mesh with the full topology (BRep) of the model and associated physical groups, an `$Entities` section should be present before the `$Nodes` section. Sections can be repeated in the same file, and post-processing sections can be put into separate files (e.g. one file per time step). Any section with an unrecognized header is stored by default as a model attribute: you can thus e.g. add comments in a '`.msh`' file by putting them inside a `$Comments`/`$EndComments` section. Unrocognized sections can be ignored altogether if the `Mesh.IgnoreUnknownSections` option is set.

All the node, element, entity and physical group tags (their global identification numbers) should be strictly positive. (Tag `0` is reserved for internal use.) Important note about efficiency: tags can be "sparse", i.e., do not have to constitute a continuous list of numbers (the format even allows them to not be ordered). However, using sparse node or element tags can lead to performance degradation. For meshes, sparse indexing can[1] force Gmsh to use a map instead of a vector to access nodes and elements. The performance hit is on speed. For post-processing datasets, which always use vectors to access data, the performance hit is on memory. A `$NodeData` with two nodes, tagged 1 and 1000000, will allocate a (mostly empty) vector of 1000000 elements. By default, for non-partitioned, single file meshes, Gmsh will create files with a continuous ordering of node and element tags, starting at 1. Detecting if the numbering is continuous can be done easily when reading a file by inspecting `numNodes`, `minNodeTag` and `maxNodeTag` in the `$Nodes` section; and `numElements`, `minElementTag` and `maxElementTag` in the `$Elements` section.

In binary mode (`Mesh.Binary=1` or `-bin` on the command line), all the numerical values (integer and floating point) not marked as ASCII in the format description below are written in binary form, using the type given between parentheses. The block structure of the `$Nodes` and `$Elements` sections allows to read integer and floating point data in each block in a single step (e.g. using `fread` in C).

[1] If the numbering is not too sparse, Gmsh will still use a vector.

The format is defined as follows:

```
$MeshFormat // same as MSH version 2
  version(ASCII double; currently 4.1)
    file-type(ASCII int; 0 for ASCII mode, 1 for binary mode)
    data-size(ASCII int; sizeof(size_t))
  < int with value one; only in binary mode, to detect endianness >
$EndMeshFormat

$PhysicalNames // same as MSH version 2
  numPhysicalNames(ASCII int)
  dimension(ASCII int) physicalTag(ASCII int) "name"(127 characters max)
  ...
$EndPhysicalNames

$Entities
  numPoints(size_t) numCurves(size_t)
    numSurfaces(size_t) numVolumes(size_t)
  pointTag(int) X(double) Y(double) Z(double)
    numPhysicalTags(size_t) physicalTag(int) ...
  ...
  curveTag(int) minX(double) minY(double) minZ(double)
    maxX(double) maxY(double) maxZ(double)
    numPhysicalTags(size_t) physicalTag(int) ...
    numBoundingPoints(size_t) pointTag(int; sign encodes orientation) ...
  ...
  surfaceTag(int) minX(double) minY(double) minZ(double)
    maxX(double) maxY(double) maxZ(double)
    numPhysicalTags(size_t) physicalTag(int) ...
    numBoundingCurves(size_t) curveTag(int; sign encodes orientation) ...
  ...
  volumeTag(int) minX(double) minY(double) minZ(double)
    maxX(double) maxY(double) maxZ(double)
    numPhysicalTags(size_t) physicalTag(int) ...
    numBoundngSurfaces(size_t) surfaceTag(int; sign encodes orientation) ...
  ...
$EndEntities

$PartitionedEntities
  numPartitions(size_t)
  numGhostEntities(size_t)
    ghostEntityTag(int) partition(int)
    ...
  numPoints(size_t) numCurves(size_t)
    numSurfaces(size_t) numVolumes(size_t)
  pointTag(int) parentDim(int) parentTag(int)
    numPartitions(size_t) partitionTag(int) ...
    X(double) Y(double) Z(double)
    numPhysicalTags(size_t) physicalTag(int) ...
  ...
  curveTag(int) parentDim(int) parentTag(int)
    numPartitions(size_t) partitionTag(int) ...
```

```
    minX(double) minY(double) minZ(double)
    maxX(double) maxY(double) maxZ(double)
    numPhysicalTags(size_t) physicalTag(int) ...
    numBoundingPoints(size_t) pointTag(int) ...
  ...
  surfaceTag(int) parentDim(int) parentTag(int)
    numPartitions(size_t) partitionTag(int) ...
    minX(double) minY(double) minZ(double)
    maxX(double) maxY(double) maxZ(double)
    numPhysicalTags(size_t) physicalTag(int) ...
    numBoundingCurves(size_t) curveTag(int) ...
  ...
  volumeTag(int) parentDim(int) parentTag(int)
    numPartitions(size_t) partitionTag(int) ...
    minX(double) minY(double) minZ(double)
    maxX(double) maxY(double) maxZ(double)
    numPhysicalTags(size_t) physicalTag(int) ...
    numBoundingSurfaces(size_t) surfaceTag(int) ...
  ...
$EndPartitionedEntities

$Nodes
  numEntityBlocks(size_t) numNodes(size_t)
    minNodeTag(size_t) maxNodeTag(size_t)
  entityDim(int) entityTag(int) parametric(int; 0 or 1)
    numNodesInBlock(size_t)
    nodeTag(size_t)
    ...
    x(double) y(double) z(double)
       < u(double; if parametric and entityDim >= 1) >
       < v(double; if parametric and entityDim >= 2) >
       < w(double; if parametric and entityDim == 3) >
    ...
  ...
$EndNodes

$Elements
  numEntityBlocks(size_t) numElements(size_t)
    minElementTag(size_t) maxElementTag(size_t)
  entityDim(int) entityTag(int) elementType(int; see below)
    numElementsInBlock(size_t)
    elementTag(size_t) nodeTag(size_t) ...
    ...
  ...
$EndElements

$Periodic
  numPeriodicLinks(size_t)
  entityDim(int) entityTag(int) entityTagMaster(int)
  numAffine(size_t) value(double) ...
  numCorrespondingNodes(size_t)
    nodeTag(size_t) nodeTagMaster(size_t)
```

```
    ...
  ...
$EndPeriodic

$GhostElements
  numGhostElements(size_t)
  elementTag(size_t) partitionTag(int)
    numGhostPartitions(size_t) ghostPartitionTag(int) ...
  ...
$EndGhostElements

$Parametrizations
  numCurveParam(size_t) numSurfaceParam(size_t)
  curveTag(int) numNodes(size_t)
    nodeX(double) nodeY(double) nodeZ(double) nodeU(double)
    ...
  ...
  surfaceTag(int) numNodes(size_t) numTriangles(size_t)
    nodeX(double) nodeY(double) nodeZ(double)
      nodeU(double) nodeV(double)
      curvMaxX(double) curvMaxY(double) curvMaxZ(double)
      curvMinX(double) curvMinY(double) curvMinZ(double)
    ...
    nodeIndex1(int) nodeIndex2(int) nodeIndex3(int)
    ...
  ...
$EndParametrizations

$NodeData
  numStringTags(ASCII int)
  stringTag(string) ...
  numRealTags(ASCII int)
  realTag(ASCII double) ...
  numIntegerTags(ASCII int)
  integerTag(ASCII int) ...
  nodeTag(int) value(double) ...
  ...
$EndNodeData

$ElementData
  numStringTags(ASCII int)
  stringTag(string) ...
  numRealTags(ASCII int)
  realTag(ASCII double) ...
  numIntegerTags(ASCII int)
  integerTag(ASCII int) ...
  elementTag(int) value(double) ...
  ...
$EndElementData

$ElementNodeData
  numStringTags(ASCII int)
```

```
    stringTag(string) ...
    numRealTags(ASCII int)
    realTag(ASCII double) ...
    numIntegerTags(ASCII int)
    integerTag(ASCII int) ...
    elementTag(int) numNodesPerElement(int) value(double) ...
    ...
$EndElementNodeData

$InterpolationScheme
  name(string)
  numElementTopologies(ASCII int)
  elementTopology
  numInterpolationMatrices(ASCII int)
  numRows(ASCII int) numColumns(ASCII int) value(ASCII double) ...
$EndInterpolationScheme
```

In the format description above, `elementType` is e.g.:

`1` 2-node line.

`2` 3-node triangle.

`3` 4-node quadrangle.

`4` 4-node tetrahedron.

`5` 8-node hexahedron.

`6` 6-node prism.

`7` 5-node pyramid.

`8` 3-node second order line (2 nodes associated with the vertices and 1 with the edge).

`9` 6-node second order triangle (3 nodes associated with the vertices and 3 with the edges).

`10` 9-node second order quadrangle (4 nodes associated with the vertices, 4 with the edges and 1 with the face).

`11` 10-node second order tetrahedron (4 nodes associated with the vertices and 6 with the edges).

`12` 27-node second order hexahedron (8 nodes associated with the vertices, 12 with the edges, 6 with the faces and 1 with the volume).

`13` 18-node second order prism (6 nodes associated with the vertices, 9 with the edges and 3 with the quadrangular faces).

`14` 14-node second order pyramid (5 nodes associated with the vertices, 8 with the edges and 1 with the quadrangular face).

`15` 1-node point.

`16` 8-node second order quadrangle (4 nodes associated with the vertices and 4 with the edges).

`17` 20-node second order hexahedron (8 nodes associated with the vertices and 12 with the edges).

`18` 15-node second order prism (6 nodes associated with the vertices and 9 with the edges).

`19` 13-node second order pyramid (5 nodes associated with the vertices and 8 with the edges).

`20` 9-node third order incomplete triangle (3 nodes associated with the vertices, 6 with the edges)

`21` 10-node third order triangle (3 nodes associated with the vertices, 6 with the edges, 1 with the face)

`22` 12-node fourth order incomplete triangle (3 nodes associated with the vertices, 9 with the edges)

`23` 15-node fourth order triangle (3 nodes associated with the vertices, 9 with the edges, 3 with the face)

`24` 15-node fifth order incomplete triangle (3 nodes associated with the vertices, 12 with the edges)

`25` 21-node fifth order complete triangle (3 nodes associated with the vertices, 12 with the edges, 6 with the face)

`26` 4-node third order edge (2 nodes associated with the vertices, 2 internal to the edge)

`27` 5-node fourth order edge (2 nodes associated with the vertices, 3 internal to the edge)

`28` 6-node fifth order edge (2 nodes associated with the vertices, 4 internal to the edge)

`29` 20-node third order tetrahedron (4 nodes associated with the vertices, 12 with the edges, 4 with the faces)

`30` 35-node fourth order tetrahedron (4 nodes associated with the vertices, 18 with the edges, 12 with the faces, 1 in the volume)

`31` 56-node fifth order tetrahedron (4 nodes associated with the vertices, 24 with the edges, 24 with the faces, 4 in the volume)

`92` 64-node third order hexahedron (8 nodes associated with the vertices, 24 with the edges, 24 with the faces, 8 in the volume)

`93` 125-node fourth order hexahedron (8 nodes associated with the vertices, 36 with the edges, 54 with the faces, 27 in the volume)

`...`

All the currently supported elements in the format are defined in GmshDefines.h. See Section 10.2 [Node ordering], page 356 for the ordering of the nodes.

The post-processing sections (`$NodeData`, `$ElementData`, `$ElementNodeData`) can contain `numStringTags` string tags, `numRealTags` real value tags and `numIntegerTags` integer tags. The default set of tags understood by Gmsh is as follows:

`stringTag`
: The first is interpreted as the name of the post-processing view and the second as the name of the interpolation scheme, as provided in the `$InterpolationScheme` section.

`realTag`
: The first is interpreted as a time value associated with the dataset.

`integerTag`
: The first is interpreted as a time step index (starting at 0), the second as the number of field components of the data in the view (1, 3 or 9), the third as the number of entities (nodes or elements) in the view, and the fourth as the partition index for the view data (0 for no partition).

In the `$InterpolationScheme` section:

`numElementTopologies`
: is the number of element topologies for which interpolation matrices are provided.

`elementTopology`
: is the id tag of a given element topology: 1 for points, 2 for lines, 3 for triangles, 4 for quadrangles, 5 for tetrahedra, 6 for pyramids, 7 for prisms, 8 for hexahedra, 9 for polygons and 10 for polyhedra.

`numInterpolationMatrices`
: is the number of interpolation matrices provided for the given element topology. Currently you should provide 2 matrices, i.e., the matrices that specify how to interpolate the data (they have the same meaning as in Section 5.4 [Post-processing scripting commands], page 119). The matrices are specified by 2 integers (`numRows` and `numColumns`) followed by the values, by row.

Here is a small example of a minimal ASCII MSH4.1 file, with a mesh consisting of two quadrangles and an associated nodal scalar dataset (the comments are not part of the actual file):

```
$MeshFormat
4.1 0 8     MSH4.1, ASCII
$EndMeshFormat
$Nodes
1 6 1 6     1 entity bloc, 6 nodes total, min/max node tags: 1 and 6
2 1 0 6     2D entity (surface) 1, no parametric coordinates, 6 nodes
1             node tag #1
2             node tag #2
3             etc.
4
5
6
0. 0. 0.      node #1 coordinates (0., 0., 0.)
1. 0. 0.      node #2 coordinates (1., 0., 0.)
1. 1. 0.      etc.
0. 1. 0.
2. 0. 0.
2. 1. 0.
$EndNodes
$Elements
1 2 1 2     1 entity bloc, 2 elements total, min/max element tags: 1 and 2
2 1 3 2     2D entity (surface) 1, element type 3 (4-node quad), 2 elements
1 1 2 3 4     quad tag #1, nodes 1 2 3 4
2 2 5 6 3     quad tag #2, nodes 2 5 6 3
$EndElements
$NodeData
1           1 string tag:
"My view"     the name of the view ("My view")
1           1 real tag:
0.0           the time value (0.0)
3           3 integer tags:
0             the time step (0; time steps always start at 0)
1             1-component (scalar) field
6             6 associated nodal values
1 0.0       value associated with node #1 (0.0)
```

```
2 0.1       value associated with node #2 (0.1)
3 0.2       etc.
4 0.0
5 0.2
6 0.4
$EndNodeData
```

The 4.1 revision of the format includes the following modifications with respect to the initial 4.0 version:

- All the `unsigned long` entries have been changed to `size_t`. All the entries designating counts which were previously encoded as `int` have also been changed to `size_t`. (This only impacts binary files.)
- The `$Entities` section is now optional.
- Integer and floating point data in the `$Nodes` section is not mixed anymore: all the tags are given first, followed by all the coordinates.
- The bounding box for point entities has been replaced simply by the 3 coordinates of the point (instead of the six bounding box values).
- The `entityDim` and `entityTag` values have been switched in the `$Nodes` and `$Elements` sections (for consistency with the ordering used elsewhere in the file and in the Chapter 6 [Gmsh application programming interface], page 125).
- The minimum and the maximum tag of nodes (resp. elements) have been added in the header of the `$Nodes` (resp. `$Elements`) section, to facilitate the detection of sparse or dense numberings when reading the file.
- The `$Periodic` section has been changed to always provide the number of values in the affine transform (which can be zero, if the transform is not provided).

The following changes are foreseen in a future revision of the MSH format:

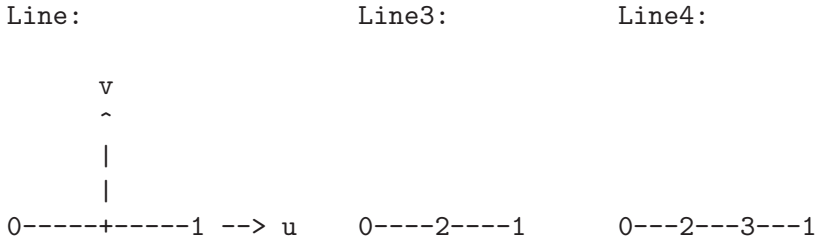
- The `$GhostElements`, `$NodeData`, `$ElementData` and `$ElementNodeData` will be reworked for greater IO efficiency, with separation of entries by type and a block structure with predictable sizes.
- Node and element tags in `$NodeData`, `$ElementData` and `$ElementNodeData` will be switched to `size_t`.

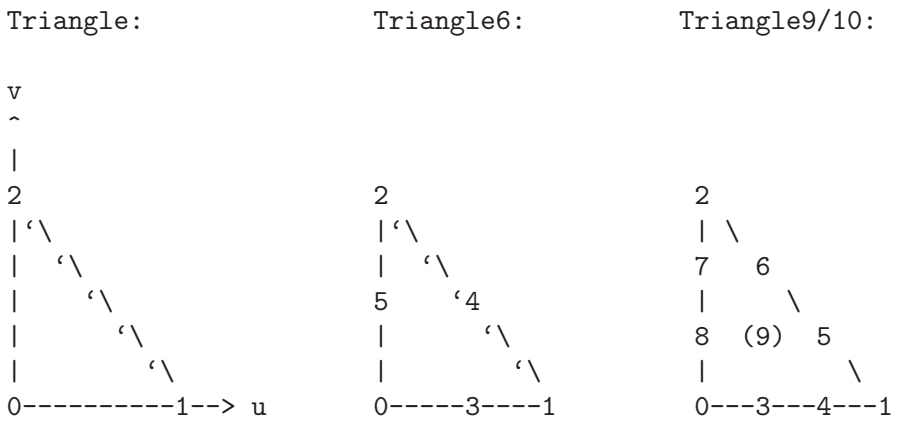
10.2 Node ordering

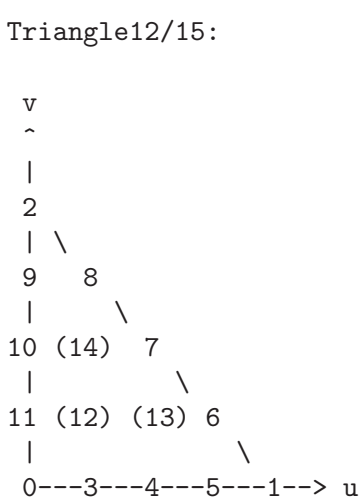
Historically, Gmsh first supported linear elements (lines, triangles, quadrangles, tetrahedra, prisms and hexahedra). Then, support for second and some third order elements has been added. Below we distinguish such "low order elements", which are hardcoded (i.e. they are explicitly defined in the code), and general "high-order elements", that have been coded in a more general fashion, theoretically valid for any order.

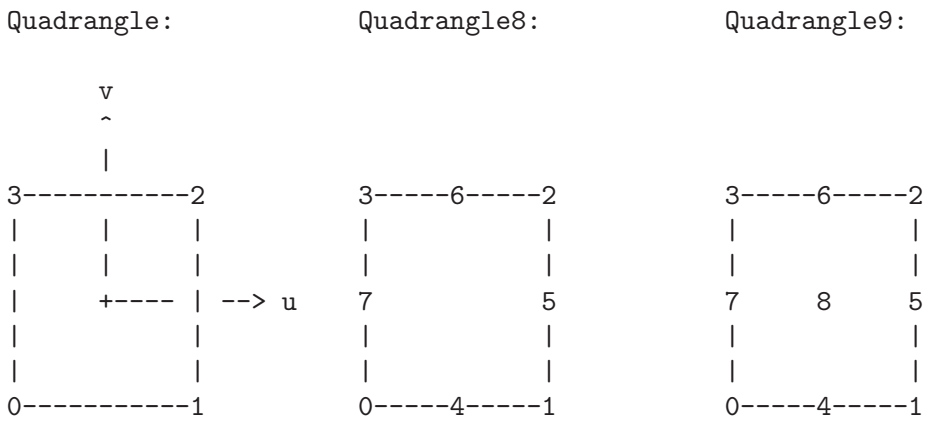
10.2.1 Low order elements

For all mesh and post-processing file formats, the reference elements are defined as follows.

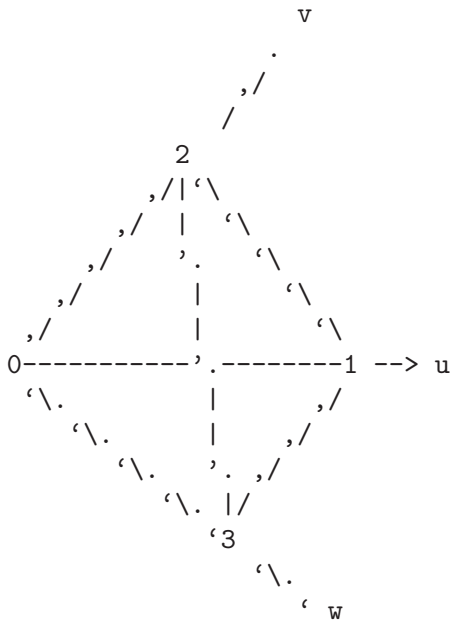



Triangle:
Triangle6:
Triangle9/10:
v
u

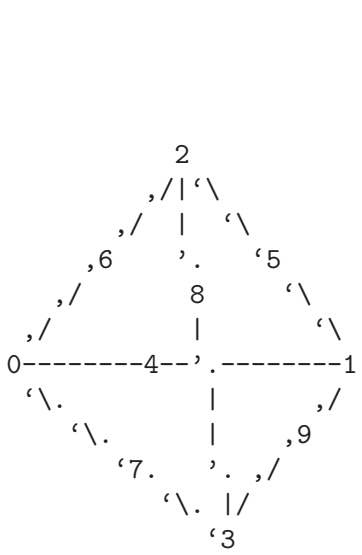

Triangle12/15:
v
u


Quadrangle:
Quadrangle8:
Quadrangle9:
v
u

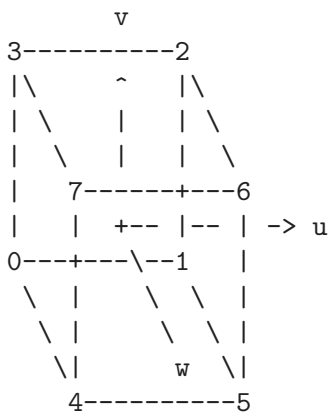
Tetrahedron:



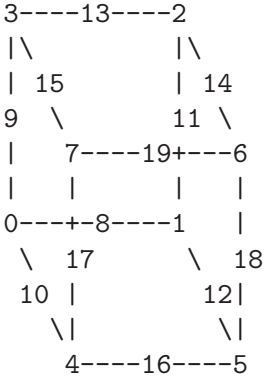
Tetrahedron10:



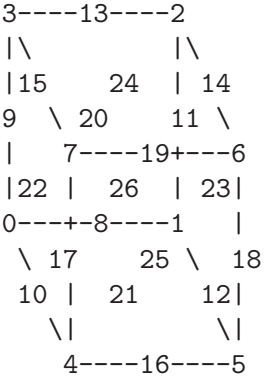
Hexahedron:



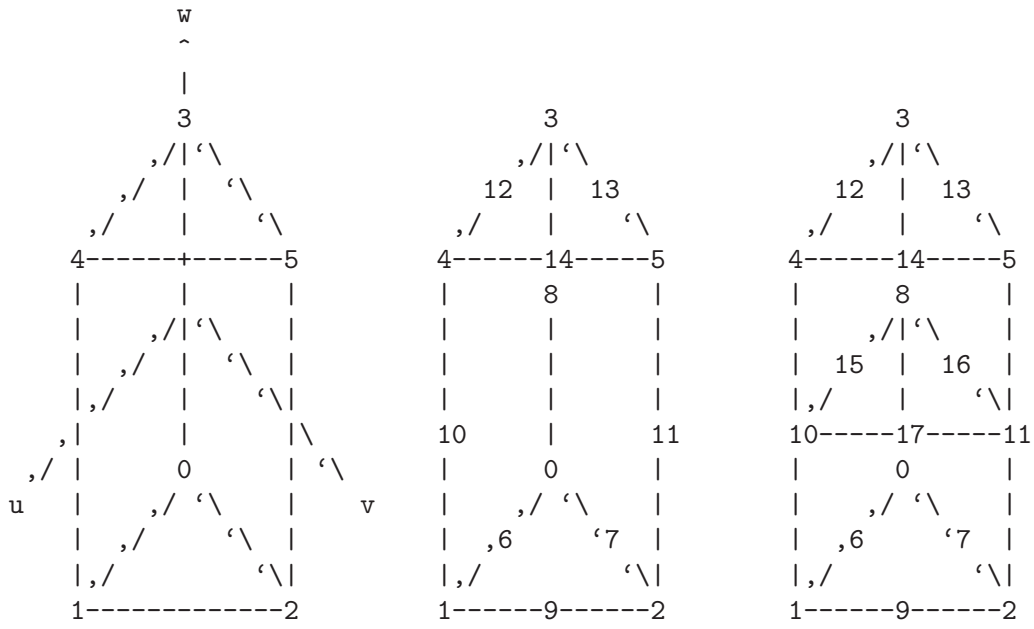
Hexahedron20:



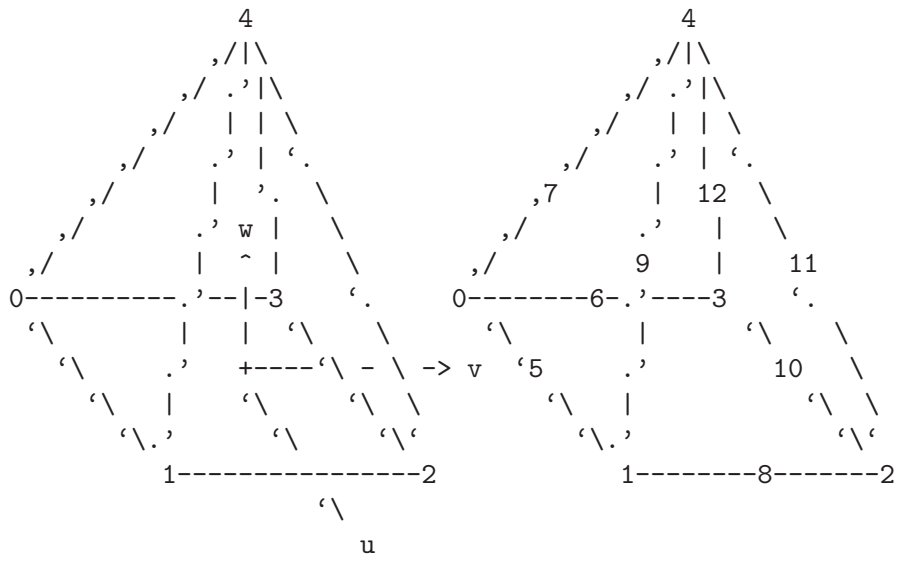
Hexahedron27:



Prism: Prism15: Prism18:



Pyramid: Pyramid13:



```
Pyramid14:

                4
              ,/|\
            ,/ .'|\
          ,/   | | \
        ,/    .' | '.
      ,7      |  12  \
    ,/       .'   |   \
  ,/         9    |    11
0--------6-.'----3    '.
  '\        |      '\    \
    '5     .' 13     10   \
      '\   |           '\  \
        '\.'             '\'
           1--------8-------2
                    '\
                      u
```

10.2.2 High-order elements

The node ordering of a higher order (possibly curved) element is compatible with the numbering of low order element (it is a generalization). We number nodes in the following order:

- the element principal or corner vertices;
- the internal nodes for each edge;
- the internal nodes for each face;
- the volume internal nodes.

The numbering for internal nodes is recursive, i.e. the numbering follows that of the nodes of an embedded edge/face/volume of lower order. The higher order nodes are assumed to be equispaced. Edges and faces are numbered following the lowest order template that generates a single high-order on this edge/face. Furthermore, an edge is oriented from the node with the lowest to the highest index. The orientation of a face is such that the computed normal points outward; the starting point is the node with the lowest index.

10.3 Legacy formats

This section describes Gmsh's older native file formats. Future versions of Gmsh will continue to support these formats, but we recommend that you do not use them in new applications.

10.3.1 MSH file format version 2 (Legacy)

The MSH file format version 2 is Gmsh's previous native mesh file format, now superseded by the format described in Section 10.1 [MSH file format], page 349. It is defined as follows:

```
$MeshFormat
version-number file-type data-size
$EndMeshFormat
$PhysicalNames
number-of-names
physical-dimension physical-tag "physical-name"
...
$EndPhysicalNames
$Nodes
```

```
number-of-nodes
node-number x-coord y-coord z-coord
...
$EndNodes
$Elements
number-of-elements
elm-number elm-type number-of-tags < tag > ... node-number-list
...
$EndElements
$Periodic
number-of-periodic-entities
<Affine value ...>
dimension entity-tag master-entity-tag
number-of-nodes
node-number master-node-number
...
$EndPeriodic
$NodeData
number-of-string-tags
< "string-tag" >
...
number-of-real-tags
< real-tag >
...
number-of-integer-tags
< integer-tag >
...
node-number value ...
...
$EndNodeData
$ElementData
number-of-string-tags
< "string-tag" >
...
number-of-real-tags
< real-tag >
...
number-of-integer-tags
< integer-tag >
...
elm-number value ...
...
$EndElementData
$ElementNodeData
number-of-string-tags
< "string-tag" >
...
number-of-real-tags
< real-tag >
...
number-of-integer-tags
< integer-tag >
```

```
...
elm-number number-of-nodes-per-element value ...
...
$EndElementNodeData
$InterpolationScheme
"name"
number-of-element-topologies
elm-topology
number-of-interpolation-matrices
num-rows num-columns value ...
...
$EndInterpolationScheme
```

where

version-number
: is a real number equal to 2.2

file-type
: is an integer equal to 0 in the ASCII file format.

data-size
: is an integer equal to the size of the floating point numbers used in the file (currently only *data-size* = sizeof(double) is supported).

number-of-nodes
: is the number of nodes in the mesh.

node-number
: is the number (index) of the *n*-th node in the mesh; *node-number* must be a positive (non-zero) integer. Note that the *node-number*s do not necessarily have to form a dense nor an ordered sequence.

x-coord y-coord z-coord
: are the floating point values giving the X, Y and Z coordinates of the *n*-th node.

number-of-elements
: is the number of elements in the mesh.

elm-number
: is the number (index) of the *n*-th element in the mesh; *elm-number* must be a positive (non-zero) integer. Note that the *elm-number*s do not necessarily have to form a dense nor an ordered sequence.

elm-type
: defines the geometrical type of the *n*-th element: see Section 10.1 [MSH file format], page 349.

number-of-tags
: gives the number of integer tags that follow for the *n*-th element. By default, the first *tag* is the tag of the physical entity to which the element belongs; the second is the tag of the elementary model entity to which the element belongs; the third is the number of mesh partitions to which the element belongs, followed by the partition ids (negative partition ids indicate ghost cells). A zero tag is equivalent to no tag. Gmsh and most codes using the MSH 2 format require at least the first two tags (physical and elementary tags).

node-number-list
: is the list of the node numbers of the *n*-th element. The ordering of the nodes is given in Section 10.2 [Node ordering], page 356.

number-of-string-tags
: gives the number of string tags that follow. By default the first *string-tag* is interpreted as the name of the post-processing view and the second as the name of the interpolation scheme. The interpolation scheme is provided in the `$InterpolationScheme` section (see below).

number-of-real-tags
: gives the number of real number tags that follow. By default the first *real-tag* is interpreted as a time value associated with the dataset.

number-of-integer-tags
: gives the number of integer tags that follow. By default the first *integer-tag* is interpreted as a time step index (starting at 0), the second as the number of field components of the data in the view (1, 3 or 9), the third as the number of entities (nodes or elements) in the view, and the fourth as the partition index for the view data (0 for no partition).

number-of-nodes-per-elements
: gives the number of node values for an element in an element-based view.

value
: is a real number giving the value associated with a node or an element. For `NodeData` (respectively `ElementData`) views, there are *ncomp* values per node (resp. per element), where *ncomp* is the number of field components. For `ElementNodeData` views, there are *ncomp* times *number-of-nodes-per-elements* values per element.

number-of-element-topologies
: is the number of element topologies for which interpolation matrices are provided

elm-topology
: is the id tag of a given element topology: 1 for points, 2 for lines, 3 for triangles, 4 for quadrangles, 5 for tetrahedra, 6 for pyramids, 7 for prisms, 8 for hexahedra, 9 for polygons and 10 for polyhedra.

number-of-interpolation-matrices
: is the number of interpolation matrices provided for the element topology *elm-topology*. Currently you should provide 2 matrices, i.e., the matrices that specify how to interpolate the data (they have the same meaning as in Section 5.4 [Post-processing scripting commands], page 119). The matrices are specified by 2 integers (*num-rows* and *num-columns*) followed by the values.

Below is a small example (a mesh consisting of two quadrangles with an associated nodal scalar dataset; the comments are not part of the actual file!):

```
$MeshFormat
2.2 0 8
$EndMeshFormat
$Nodes
6                   six mesh nodes:
1 0.0 0.0 0.0         node #1: coordinates (0.0, 0.0, 0.0)
2 1.0 0.0 0.0         node #2: coordinates (1.0, 0.0, 0.0)
3 1.0 1.0 0.0         etc.
4 0.0 1.0 0.0
5 2.0 0.0 0.0
6 2.0 1.0 0.0
$EndNodes
$Elements
2                   two elements:
```

```
1 3 2 99 2 1 2 3 4   quad #1: type 3, phys 99, ent 2, nodes 1 2 3 4
2 3 2 99 2 2 5 6 3   quad #2: type 3, phys 99, ent 2, nodes 2 5 6 3
$EndElements
$NodeData
1                   one string tag:
"My view"             the name of the view ("My view")
1                   one real tag:
0.0                   the time value (0.0)
3                   three integer tags:
0                     the time step (0; time steps always start at 0)
1                     1-component (scalar) field
6                     six associated nodal values
1 0.0               value associated with node #1 (0.0)
2 0.1               value associated with node #2 (0.1)
3 0.2               etc.
4 0.0
5 0.2
6 0.4
$EndNodeData
```

The binary file format is similar to the ASCII format described above:

```
$MeshFormat
version-number file-type data-size
one-binary
$EndMeshFormat
$Nodes
number-of-nodes
nodes-binary
$EndNodes
$Elements
number-of-elements
element-header-binary
elements-binary
element-header-binary
elements-binary
...
$EndElements

[ All other sections are identical to ASCII, except that
  node-number, elm-number, number-of-nodes-per-element
  and values are written in binary format. Beware that all the
  $End tags must start on a new line. ]
```

where

version-number
: is a real number equal to 2.2.

file-type
: is an integer equal to 1.

data-size
: has the same meaning as in the ASCII file format. Currently only *data-size* = sizeof(double) is supported.

one-binary
: is an integer of value 1 written in binary form. This integer is used for detecting if the computer on which the binary file was written and the computer on which the file is read are of the same type (little or big endian).

  Here is a pseudo C code to write *one-binary*:

```
int one = 1;
fwrite(&one, sizeof(int), 1, file);
```

number-of-nodes
: has the same meaning as in the ASCII file format.

nodes-binary
: is the list of nodes in binary form, i.e., a array of *number-of-nodes* * (4 + 3 * *data-size*) bytes. For each node, the first 4 bytes contain the node number and the next (3 * *data-size*) bytes contain the three floating point coordinates.

  Here is a pseudo C code to write *nodes-binary*:

```
for(i = 0; i < number_of_nodes; i++){
  fwrite(&num_i, sizeof(int), 1, file);
  double xyz[3] = {node_i_x, node_i_y, node_i_z};
  fwrite(xyz, sizeof(double), 3, file);
}
```

number-of-elements
: has the same meaning as in the ASCII file format.

element-header-binary
: is a list of 3 integers in binary form, i.e., an array of (3 * 4) bytes: the first four bytes contain the type of the elements that follow (same as *elm-type* in the ASCII format), the next four contain the number of elements that follow, and the last four contain the number of tags per element (same as *number-of-tags* in the ASCII format).

  Here is a pseudo C code to write *element-header-binary*:

```
int header[3] = {elm_type, num_elm_follow, num_tags};
fwrite(header, sizeof(int), 3, file);
```

elements-binary
: is a list of elements in binary form, i.e., an array of "number of elements that follow" * (4 + *number-of-tags* * 4 + *#node-number-list* * 4) bytes. For each element, the first four bytes contain the element number, the next (*number-of-tags* * 4) contain the tags, and the last (*#node-number-list* * 4) contain the node indices.

  Here is a pseudo C code to write *elements-binary* for triangles with the 2 standard tags (the physical group and elementary entity):

```
for(i = 0; i < number_of_triangles; i++){
  int data[6] = {num_i, physical, elementary,
                 node_i_1, node_i_2, node_i_3};
  fwrite(data, sizeof(int), 6, file);
}
```

10.3.2 MSH file format version 1 (Legacy)

The MSH file format version 1 is Gmsh's original native mesh file format, now superseded by the format described in Section 10.1 [MSH file format], page 349. It is defined as follows:

```
$NOD
number-of-nodes
```

```
node-number x-coord y-coord z-coord
...
$ENDNOD
$ELM
number-of-elements
elm-number elm-type reg-phys reg-elem number-of-nodes node-number-list
...
$ENDELM
```

where

number-of-nodes
: is the number of nodes in the mesh.

node-number
: is the number (index) of the *n*-th node in the mesh; *node-number* must be a positive (non-zero) integer. Note that the *node-number*s do not necessarily have to form a dense nor an ordered sequence.

x-coord y-coord z-coord
: are the floating point values giving the X, Y and Z coordinates of the *n*-th node.

number-of-elements
: is the number of elements in the mesh.

elm-number
: is the number (index) of the *n*-th element in the mesh; *elm-number* must be a positive (non-zero) integer. Note that the *elm-number*s do not necessarily have to form a dense nor an ordered sequence.

elm-type defines the geometrical type of the *n*-th element:

1	2-node line.
2	3-node triangle.
3	4-node quadrangle.
4	4-node tetrahedron.
5	8-node hexahedron.
6	6-node prism.
7	5-node pyramid.
8	3-node second order line (2 nodes associated with the vertices and 1 with the edge).
9	6-node second order triangle (3 nodes associated with the vertices and 3 with the edges).
10	9-node second order quadrangle (4 nodes associated with the vertices, 4 with the edges and 1 with the face).
11	10-node second order tetrahedron (4 nodes associated with the vertices and 6 with the edges).
12	27-node second order hexahedron (8 nodes associated with the vertices, 12 with the edges, 6 with the faces and 1 with the volume).
13	18-node second order prism (6 nodes associated with the vertices, 9 with the edges and 3 with the quadrangular faces).

`14` 14-node second order pyramid (5 nodes associated with the vertices, 8 with the edges and 1 with the quadrangular face).

`15` 1-node point.

`16` 8-node second order quadrangle (4 nodes associated with the vertices and 4 with the edges).

`17` 20-node second order hexahedron (8 nodes associated with the vertices and 12 with the edges).

`18` 15-node second order prism (6 nodes associated with the vertices and 9 with the edges).

`19` 13-node second order pyramid (5 nodes associated with the vertices and 8 with the edges).

See below for the ordering of the nodes.

reg-phys is the tag of the physical entity to which the element belongs; *reg-phys* must be a positive integer, or zero. If *reg-phys* is equal to zero, the element is considered not to belong to any physical entity.

reg-elem is the tag of the elementary entity to which the element belongs; *reg-elem* must be a positive (non-zero) integer.

number-of-nodes
is the number of nodes for the *n*-th element. This is redundant, but kept for backward compatibility.

node-number-list
is the list of the *number-of-nodes* node numbers of the *n*-th element. The ordering of the nodes is given in Section 10.2 [Node ordering], page 356.

10.3.3 POS ASCII file format (Legacy)

The POS ASCII file is Gmsh's old native post-processing format, now superseded by the format described in Section 10.1 [MSH file format], page 349. It is defined as follows:

```
$PostFormat
1.4 file-type data-size
$EndPostFormat
$View
view-name nb-time-steps
nb-scalar-points nb-vector-points nb-tensor-points
nb-scalar-lines nb-vector-lines nb-tensor-lines
nb-scalar-triangles nb-vector-triangles nb-tensor-triangles
nb-scalar-quadrangles nb-vector-quadrangles nb-tensor-quadrangles
nb-scalar-tetrahedra nb-vector-tetrahedra nb-tensor-tetrahedra
nb-scalar-hexahedra nb-vector-hexahedra nb-tensor-hexahedra
nb-scalar-prisms nb-vector-prisms nb-tensor-prisms
nb-scalar-pyramids nb-vector-pyramids nb-tensor-pyramids
nb-scalar-lines2 nb-vector-lines2 nb-tensor-lines2
nb-scalar-triangles2 nb-vector-triangles2 nb-tensor-triangles2
nb-scalar-quadrangles2 nb-vector-quadrangles2 nb-tensor-quadrangles2
nb-scalar-tetrahedra2 nb-vector-tetrahedra2 nb-tensor-tetrahedra2
nb-scalar-hexahedra2 nb-vector-hexahedra2 nb-tensor-hexahedra2
nb-scalar-prisms2 nb-vector-prisms2 nb-tensor-prisms2
nb-scalar-pyramids2 nb-vector-pyramids2 nb-tensor-pyramids2
```

```
nb-text2d nb-text2d-chars nb-text3d nb-text3d-chars
time-step-values
< scalar-point-value > ... < vector-point-value > ...
    < tensor-point-value > ...
< scalar-line-value > ... < vector-line-value > ...
    < tensor-line-value > ...
< scalar-triangle-value > ... < vector-triangle-value > ...
    < tensor-triangle-value > ...
< scalar-quadrangle-value > ... < vector-quadrangle-value > ...
    < tensor-quadrangle-value > ...
< scalar-tetrahedron-value > ... < vector-tetrahedron-value > ...
    < tensor-tetrahedron-value > ...
< scalar-hexahedron-value > ... < vector-hexahedron-value > ...
    < tensor-hexahedron-value > ...
< scalar-prism-value > ... < vector-prism-value > ...
    < tensor-prism-value > ...
< scalar-pyramid-value > ... < vector-pyramid-value > ...
    < tensor-pyramid-value > ...
< scalar-line2-value > ... < vector-line2-value > ...
    < tensor-line2-value > ...
< scalar-triangle2-value > ... < vector-triangle2-value > ...
    < tensor-triangle2-value > ...
< scalar-quadrangle2-value > ... < vector-quadrangle2-value > ...
    < tensor-quadrangle2-value > ...
< scalar-tetrahedron2-value > ... < vector-tetrahedron2-value > ...
    < tensor-tetrahedron2-value > ...
< scalar-hexahedron2-value > ... < vector-hexahedron2-value > ...
    < tensor-hexahedron2-value > ...
< scalar-prism2-value > ... < vector-prism2-value > ...
    < tensor-prism2-value > ...
< scalar-pyramid2-value > ... < vector-pyramid2-value > ...
    < tensor-pyramid2-value > ...
< text2d > ... < text2d-chars > ...
< text3d > ... < text3d-chars > ...
$EndView
```

where

file-type
: is an integer equal to 0 in the ASCII file format.

data-size
: is an integer equal to the size of the floating point numbers used in the file (usually, *data-size* = sizeof(double)).

view-name
: is a string containing the name of the view (max. 256 characters).

nb-time-steps
: is an integer giving the number of time steps in the view.

nb-scalar-points
nb-vector-points
...
: are integers giving the number of scalar points, vector points, ..., in the view.

nb-text2d
nb-text3d
: are integers giving the number of 2D and 3D text strings in the view.

nb-text2d-chars
nb-text3d-chars
: are integers giving the total number of characters in the 2D and 3D strings.

time-step-values
: is a list of *nb-time-steps* double precision numbers giving the value of the time (or any other variable) for which an evolution was saved.

scalar-point-value
vector-point-value
...
: are lists of double precision numbers giving the node coordinates and the values associated with the nodes of the *nb-scalar-points* scalar points, *nb-vector-points* vector points, ..., for each of the *time-step-values*.

  For example, *vector-triangle-value* is defined as:

```
coord1-node1 coord1-node2 coord1-node3
coord2-node1 coord2-node2 coord2-node3
coord3-node1 coord3-node2 coord3-node3
comp1-node1-time1 comp2-node1-time1 comp3-node1-time1
comp1-node2-time1 comp2-node2-time1 comp3-node2-time1
comp1-node3-time1 comp2-node3-time1 comp3-node3-time1
comp1-node1-time2 comp2-node1-time2 comp3-node1-time2
comp1-node2-time2 comp2-node2-time2 comp3-node2-time2
comp1-node3-time2 comp2-node3-time2 comp3-node3-time2
...
```

  The ordering of the nodes is given in Section 10.2 [Node ordering], page 356.

text2d
: is a list of 4 double precision numbers:

```
coord1 coord2 style index
```

  where *coord1* and *coord2* give the X-Y position of the 2D string in screen coordinates (measured from the top-left corner of the window) and where *index* gives the starting index of the string in *text2d-chars*. If *coord1* (respectively *coord2*) is negative, the position is measured from the right (respectively bottom) edge of the window. If *coord1* (respectively *coord2*) is larger than 99999, the string is centered horizontally (respectively vertically). If *style* is equal to zero, the text is aligned bottom-left and displayed using the default font and size. Otherwise, *style* is converted into an integer whose eight lower bits give the font size, whose eight next bits select the font (the index corresponds to the position in the font menu in the GUI), and whose eight next bits define the text alignment (0=bottom-left, 1=bottom-center, 2=bottom-right, 3=top-left, 4=top-center, 5=top-right, 6=center-left, 7=center-center, 8=center-right).

text2d-chars
: is a list of *nb-text2d-chars* characters. Substrings are separated with the null '\0' character.

text3d
: is a list of 5 double precision numbers

```
coord1 coord2 coord3 style index
```

  where *coord1*, *coord2* and *coord3* give the XYZ coordinates of the string in model (real world) coordinates, *index* gives the starting index of the string in *text3d-chars*, and *style* has the same meaning as in *text2d*.

text3d-chars
: is a list of *nb-text3d-chars* chars. Substrings are separated with the null '\0' character.

10.3.4 POS binary file format (Legacy)

The POS binary file format is the same as the POS ASCII file format described in Section 10.3.3 [POS ASCII file format (Legacy)], page 367, except that:

1. *file-type* equals 1.
2. all lists of floating point numbers and characters are written in binary format
3. there is an additional integer, of value 1, written before *time-step-values*. This integer is used for detecting if the computer on which the binary file was written and the computer on which the file is read are of the same type (little or big endian).

Here is a pseudo C code to write a post-processing file in binary format:

```
int one = 1;

fprintf(file, "$PostFormat\n");
fprintf(file, "%g %d %d\n", 1.4, 1, sizeof(double));
fprintf(file, "$EndPostFormat\n");
fprintf(file, "$View\n");
fprintf(file, "%s %d "
  "%d %d %d %d %d %d %d %d %d "
  "%d %d %d %d %d %d %d %d %d "
  "%d %d %d %d %d %d %d %d %d "
  "%d %d %d %d %d %d %d %d %d "
  "%d %d %d %d %d %d %d %d %d "
  "%d %d %d %d\n",
  view-name, nb-time-steps,
  nb-scalar-points, nb-vector-points, nb-tensor-points,
  nb-scalar-lines, nb-vector-lines, nb-tensor-lines,
  nb-scalar-triangles, nb-vector-triangles, nb-tensor-triangles,
  nb-scalar-quadrangles, nb-vector-quadrangles, nb-tensor-quadrangles,
  nb-scalar-tetrahedra, nb-vector-tetrahedra, nb-tensor-tetrahedra,
  nb-scalar-hexahedra, nb-vector-hexahedra, nb-tensor-hexahedra,
  nb-scalar-prisms, nb-vector-prisms, nb-tensor-prisms,
  nb-scalar-pyramids, nb-vector-pyramids, nb-tensor-pyramids,
  nb-scalar-lines2, nb-vector-lines2, nb-tensor-lines2,
  nb-scalar-triangles2, nb-vector-triangles2, nb-tensor-triangles2,
  nb-scalar-quadrangles2, nb-vector-quadrangles2,
  nb-tensor-quadrangles2,
  nb-scalar-tetrahedra2, nb-vector-tetrahedra2, nb-tensor-tetrahedra2,
  nb-scalar-hexahedra2, nb-vector-hexahedra2, nb-tensor-hexahedra2,
  nb-scalar-prisms2, nb-vector-prisms2, nb-tensor-prisms2,
  nb-scalar-pyramids2, nb-vector-pyramids2, nb-tensor-pyramids2,
  nb-text2d, nb-text2d-chars, nb-text3d, nb-text3d-chars);
fwrite(&one, sizeof(int), 1, file);
fwrite(time-step-values, sizeof(double), nb-time-steps, file);
fwrite(all-scalar-point-values, sizeof(double), ..., file);
...
fprintf(file, "\n$EndView\n");
```

In this pseudo-code, *all-scalar-point-values* is the array of double precision numbers containing all the *scalar-point-value* lists, put one after each other in order to form a long array of doubles. The principle is the same for all other kinds of values.

Appendix A Compiling the source code

Stable releases and source snapshots are available from https://gmsh.info/src/. You can also access the Git repository directly:

1. The first time you want to download the latest full source, type:

   ```
   git clone https://gitlab.onelab.info/gmsh/gmsh.git
   ```

2. To update your local version to the latest and greatest, go in the gmsh directory and type:

   ```
   git pull
   ```

Once you have the source code, you need to run CMake to configure your build (see the README.txt file in the top-level source directory for additional information on how to run CMake, as well as the Gmsh-compilation wiki page for more detailed instructions on how to compile Gmsh, including the compilation of common dependencies).

Each build can be configured using a series of options, to selectively enable optional modules or features. Here is the list of all the Gmsh-specific CMake options:

`ENABLE_3M`
: Enable proprietary 3M extension (default: OFF)

`ENABLE_ALGLIB`
: Enable ALGLIB (used by some mesh optimizers) (default: ON)

`ENABLE_ANN`
: Enable ANN (used for fast point search in mesh/post) (default: ON)

`ENABLE_BAMG`
: Enable Bamg 2D anisotropic mesh generator (default: ON)

`ENABLE_BLAS_LAPACK`
: Enable BLAS/Lapack for linear algebra (if Eigen if disabled) (default: OFF)

`ENABLE_BLOSSOM`
: Enable Blossom algorithm (needed for full quad meshing) (default: ON)

`ENABLE_BUILD_LIB`
: Enable 'lib' target for building static Gmsh library (default: OFF)

`ENABLE_BUILD_SHARED`
: Enable 'shared' target for building shared Gmsh library (default: OFF)

`ENABLE_BUILD_DYNAMIC`
: Enable dynamic Gmsh executable (linked with shared library) (default: OFF)

`ENABLE_BUILD_ANDROID`
: Enable Android NDK library target (experimental) (default: OFF)

`ENABLE_BUILD_IOS`
: Enable iOS library target (experimental) (default: OFF)

`ENABLE_CGNS`
: Enable CGNS import/export (experimental) (default: ON)

`ENABLE_CGNS_CPEX0045`
: Enable high-order CGNS import/export following CPEX0045 (experimental) (default: OFF)

`ENABLE_CAIRO`
: Enable Cairo to render fonts (experimental) (default: ON)

`ENABLE_PROFILE`
: Enable profiling compiler flags (default: OFF)

`ENABLE_DINTEGRATION`
: Enable discrete integration (needed for levelsets) (default: ON)

`ENABLE_DOMHEX`
: Enable experimental DOMHEX code (default: ON)

`ENABLE_EIGEN`
: Enable Eigen for linear algebra (instead of Blas/Lapack) (default: ON)

`ENABLE_FLTK`
: Enable FLTK graphical user interface (requires mesh/post) (default: ON)

`ENABLE_GEOMETRYCENTRAL`
: Enable geometry-central library (experimental) (default: ON)

`ENABLE_GETDP`
: Enable GetDP solver (linked as a library, experimental) (default: ON)

`ENABLE_GMM`
: Enable GMM linear solvers (simple alternative to PETSc) (default: ON)

`ENABLE_GMP`
: Enable GMP for Kbipack (advanced) (default: ON)

`ENABLE_GRAPHICS`
: Enable building graphics lib even without GUI (advanced) (default: OFF)

`ENABLE_HXT`
: Enable HXT library (for reparametrization and meshing) (default: ON)

`ENABLE_KBIPACK`
: Enable Kbipack (neeeded by homology solver) (default: ON)

`ENABLE_MATHEX`
: Enable Mathex expression parser (used by plugins and options) (default: ON)

`ENABLE_MED`
: Enable MED mesh and post file formats (default: ON)

`ENABLE_MESH`
: Enable mesh module (default: ON)

`ENABLE_METIS`
: Enable Metis mesh partitioner (default: ON)

`ENABLE_MMG`
: Enable Mmg mesh adaptation interface (default: ON)

`ENABLE_MPEG_ENCODE`
: Enable built-in MPEG movie encoder (default: ON)

`ENABLE_MPI`
: Enable MPI (experimental, not used for meshing) (default: OFF)

`ENABLE_MSVC_STATIC_RUNTIME`
: Enable static Visual C++ runtime (default: OFF)

`ENABLE_MUMPS`
: Enable MUMPS sparse direct linear solver (default: OFF)

`ENABLE_NETGEN`
: Enable Netgen 3D frontal mesh generator (default: ON)

`ENABLE_NUMPY`
: Enable fullMatrix and numpy array conversion for private API (default: OFF)

`ENABLE_PETSC4PY`
: Enable petsc4py wrappers for petsc matrices for private API (default: OFF)

`ENABLE_OCC`
: Enable OpenCASCADE CAD kernel (default: ON)

`ENABLE_OCC_CAF`
: Enable OpenCASCADE CAF module (for STEP/IGES attributes) (default: ON)

`ENABLE_OCC_STATIC`
: Link OpenCASCADE static instead of dynamic libraries (requires ENABLE_OCC) (default: OFF)

`ENABLE_OCC_TBB`
: Add TBB libraries in list of OCC libraries (default: OFF)

`ENABLE_ONELAB`
: Enable ONELAB solver interface (default: ON)

`ENABLE_ONELAB_METAMODEL`
: Enable ONELAB metamodels (experimental) (default: ON)

`ENABLE_OPENACC`
: Enable OpenACC (default: OFF)

`ENABLE_OPENMP`
: Enable OpenMP (default: ON)

`ENABLE_OPTHOM`
: Enable high-order mesh optimization tools (default: ON)

`ENABLE_OS_SPECIFIC_INSTALL`
: Enable OS-specific (e.g. app bundle) installation (default: OFF)

`ENABLE_OSMESA`
: Enable OSMesa for offscreen rendering (experimental) (default: OFF)

`ENABLE_P4EST`
: Enable p4est for enabling automatic mesh size field (experimental) (default: OFF)

`ENABLE_PACKAGE_STRIP`
: Strip symbols in install packages to reduce install size (default: ON)

`ENABLE_PARSER`
: Enable GEO file parser (required for .geo/.pos scripts) (default: ON)

`ENABLE_PETSC`
: Enable PETSc linear solvers (required for SLEPc) (default: OFF)

`ENABLE_PLUGINS`
: Enable post-processing plugins (default: ON)

`ENABLE_POST`
: Enable post-processing module (required by GUI) (default: ON)

`ENABLE_POPPLER`
: Enable Poppler for displaying PDF documents (experimental) (default: OFF)

`ENABLE_PRIVATE_API`
: Enable private API (default: OFF)

`ENABLE_PRO`
: Enable PRO extensions (default: ON)

`ENABLE_QUADMESHINGTOOLS`
: Enable QuadMeshingTools extensions (default: ON)

`ENABLE_QUADTRI`
: Enable QuadTri structured meshing extensions (default: ON)

`ENABLE_REVOROPT`
: Enable Revoropt (used for CVT remeshing) (default: OFF)

`ENABLE_RPATH`
: Use RPATH in dynamically linked targets (default: ON)

`ENABLE_SLEPC`
: Enable SLEPc eigensolvers (default: OFF)

`ENABLE_SOLVER`
: Enable built-in finite element solvers (required for reparametrization) (default: ON)

`ENABLE_SYSTEM_CONTRIB`
: Use system versions of contrib libraries, when possible (default: OFF)

`ENABLE_TCMALLOC`
: Enable libtcmalloc (fast malloc that does not release memory) (default: OFF)

`ENABLE_TESTS`
: Enable tests (default: ON)

`ENABLE_TOUCHBAR`
: Enable Apple Touch bar (default: ON)

`ENABLE_VISUDEV`
: Enable additional visualization capabilities for development purposes (default: OFF)

`ENABLE_VOROPP`
: Enable voro++ (for hex meshing, experimental) (default: ON)

`ENABLE_WINSLOWUNTANGLER`
: Enable WinslowUntangler extensions (requires ALGLIB) (default: ON)

`ENABLE_WRAP_JAVA`
: Generate SWIG Java wrappers for private API (default: OFF)

`ENABLE_WRAP_PYTHON`
: Generate SWIG Python wrappers for private API (not used by public API) (default: OFF)

`ENABLE_ZIPPER`
: Enable Zip file compression/decompression (default: OFF)

Appendix B Information for developers

Gmsh is written in C++, the scripting language is parsed using Lex and Yacc (actually, Flex and Bison), and the GUI relies on OpenGL for the 3D graphics and FLTK (`http://www.fltk.org`) for the widgets (menus, buttons, etc.). Gmsh's build system is based on CMake (`http://www.cmake.org`). Practical notes on how to compile Gmsh's source code are provided in Appendix A [Compiling the source code], page 373 (see also Appendix C [Frequently asked questions], page 379).

This section is for developers who would like to contribute directly to the Gmsh source code. Gmsh's official Git repository is located at `https://gitlab.onelab.info/gmsh/gmsh`. The wiki (`https://gitlab.onelab.info/gmsh/gmsh/wikis/Git-cheat-sheet`) contains instructions on how to create feature branches and submit merge requests.

B.1 Source code structure

Gmsh's code is structured in several subdirectories, roughly separated between the four core modules (src/geo, src/mesh, src/solver, src/post) and associated utilities (src/common, src/numeric) on one hand, and the graphics (src/graphics) and interface (src/fltk, src/parser, api) code on the other.

The geometry module is based on a model class (src/geo/GModel.h), and abstract entity classes for geometrical points (src/geo/GVertex.h), curves (src/geo/GEdge.h), surfaces (src/geo/GFace.h) and volumes (src/geo/GRegion.h). Concrete implementations of these classes are provided for each supported CAD kernel (e.g. src/geo/gmshVertex.h for points in Gmsh's built-in CAD kernel, or src/geo/OCCVertex.h for points from OpenCASCADE). All these elementary model entities derive from src/geo/GEntity.h. Physical groups are simply stored as integer tags in the entities.

A mesh is composed of elements: mesh points (src/geo/MPoint.h), lines (src/geo/MLine.h), triangles (src/geo/MTriangle.h), quadrangles (src/geo/MQuadrangle.h), tetrahedra (src/geo/MTetrahedron.h), etc. All the mesh elements are derived from src/geo/MElement.h, and are stored in the corresponding model entities: one mesh point per geometrical point, mesh lines in geometrical curves, triangles and quadrangles in surfaces, etc. The elements are defined in terms of their nodes (src/geo/MVertex.h). Each model entity stores only its internal nodes: nodes on boundaries or on embedded entities are stored in the associated bounding/embedded entity.

The post-processing module is based on the concept of views (src/post/PView.h) and abstract data containers (derived from src/post/PViewData.h). Data can be either mesh-based (src/post/PViewDataGModel.h), in which case the view is linked to one or more models, or list-based (src/post/PViewDataList.h), in which case all the relevant geometrical information is self-contained in the view.

B.2 Coding style

If you plan to contribute code to the Gmsh project, here are some easy rules to make the code easy to read/debug/maintain:

- See `https://gitlab.onelab.info/gmsh/gmsh/wikis/Git-cheat-sheet` for instructions on how to contribute to Gmsh's Git source code repository. All branches are tested; make sure that all tests pass and that your code does not produce any warnings before submitting merge requests.
- Follow the style used in the existing code when adding something new: indent using 2 spaces (never use tabs!), put 1 space after commas, put opening braces for functions on a separate line, opening braces for loops and tests on the same line, etc. You can use the `clang-format` tool to apply these rules automatically (the rules are defined in the .clang-format file.)

- Always use the `Msg::` class to print information or errors
- Use memory checking tools to detect memory leaks and other nasty memory problems. For example, on Linux you can use `valgrind --leak-check=full gmsh file.geo -3`.

B.3 Adding a new option

To add a new option in Gmsh:

1. create the option in the `CTX` class (src/common/Context.h if it's a classical option, or in the `PViewOptions` class (src/post/PViewOptions.h) if it's a post-processing view-dependent option;
2. in src/common/DefaultOptions.h, give a name (for the parser to be able to access it), a reference to a handling routine (i.e. `opt_XXX`) and a default value for this option;
3. create the handling routine `opt_XXX` in src/common/Options.cpp (and add the prototype in src/common/Options.h);
4. optional: create the associated widget in src/fltk/optionWindow.h;

Appendix C Frequently asked questions

C.1 The basics

1. What is Gmsh?

   Gmsh is an automatic three-dimensional finite element mesh generator with built-in pre- and post-processing facilities. With Gmsh you can create or import 1D, 2D and 3D geometrical models, mesh them, launch external finite element solvers and visualize solutions. Gmsh can be used either as a stand-alone program (graphical or not) or as a library to integrate in C++, C, Python, Julia or Fortran codes.

2. What are the terms and conditions of use?

   Gmsh is distributed under the terms of the GNU General Public License, with an exception to allow for easier linking with external libraries. See Appendix F [License], page 413 for more information.

3. What does 'Gmsh' mean?

   Nothing... The name was derived from a previous version called "msh" (a shortcut for "mesh"), with the "g" prefix added to differentiate it. The default mesh file format used by Gmsh still uses the '`.msh`' extension.

   In English people tend to pronounce 'Gmsh' as "gee-mesh".

4. Can I embed 'Gmsh' in my own software?

   Yes, using the Gmsh API (see Chapter 6 [Gmsh application programming interface], page 125). See [Copying conditions], page 3 for the licensing constraints.

5. Where can I find more information?

   `https://gmsh.info` is the primary location to obtain information about Gmsh. There you will for example find the complete reference manual and the bug tracking database.

C.2 Installation problems

1. Which OSes does Gmsh run on?

   Gmsh runs on Windows, macOS, Linux and most Unix variants. Gmsh is also available as part of the ONELAB package on Android and iOS tablets and phones.

2. Are there additional requirements to run Gmsh?

   You should have the OpenGL libraries installed on your system, and in the path of the library loader. A free replacement for OpenGL can be found at `http://www.mesa3d.org`.

3. How do I compile Gmsh from the source code?

   You need cmake (`http://www.cmake.org`) and a C++ compiler. See Appendix A [Compiling the source code], page 373 for more information.

4. Where does Gmsh save its configuration files?

   Gmsh will attempt to save temporary files and persistent configuration options first in the `$GMSH_HOME` directory, then in `$APPDATA` (on Windows) or `$HOME` (on other OSes), then in `$TMP`, and finally in `$TEMP`, in that order. If none of these variables are defined, Gmsh will try to save/load its configuration files from the current working directory.

C.3 General questions

1. Gmsh (from a binary distribution) complains about missing libraries.

   On Windows, if your system complains about missing '`OPENGL32.DLL`' or '`GLU32.DLL`' libraries, then OpenGL is not properly installed on your machine. You can download OpenGL from Microsoft's web site, or directly from `http://www.opengl.org`.

On Unix try 'ldd gmsh' (or 'otool -L gmsh' on macOS) to check if all the required shared libraries are installed on your system. If not, install them. If it still doesn't work, recompile Gmsh from the source code.

2. Gmsh keeps re-displaying its graphics when other windows partially hide the graphical window.

   Disable opaque move in your window manager.

3. The graphics display very slowly.

   Are you are executing Gmsh from a remote host (via the network) without GLX? You should turn double buffering off (with the '-nodb' command-line switch).

4. There is an ugly "ghost triangulation" in the vector PostScript/PDF files generated by Gmsh!

   No, there isn't. This "ghost triangulation" is due to the fact that most PostScript previewers nowadays antialias the graphic primitives when they display the page on screen. (For example, in gv, you can disable antialising with the 'State->Antialias' menu.) You should not see this ghost triangulation in the printed output (on paper).

5. How can I save GIF, JPEG, ..., images?

   Just choose the appropriate format in 'File->Export'. By default Gmsh guesses the format from the file extension, so you can just type '`myfile.jpg`' in the dialog and Gmsh will automatically create a JPEG image file.

6. How save high-resolution images?

   You can specify the dimension in the dialog (e.g. set the width of the image to 5000 pixels; leaving one dimension negative will rescale using the natural aspect ratio), or through the `Print.Width` and `Print.Height` options. The maximum image size is graphics hardware dependent.

7. How can I save MPEG, AVI, ..., animations?

   You can create simple MPEG animations by choosing MPEG as the format in 'File->Export': this allows you to loop over time steps or post-processing data sets, or to change parameters according to `Print.Parameter`. To create fully customized animations or to use different output formats (AVI, MP4, etc.) you should write a script. Have a look at Section 2.8 [t8], page 33 or examples/post_processing/anim.script for some examples.

8. Can I change values in input fields with the mouse in the GUI?

   Yes: dragging the mouse in a numeric input field slides the value! The left button moves one step per pixel, the middle by '10*step', and the right button by '100*step'.

9. Can I copy messages to the clipboard?

   Yes: selecting the content of an input field, or lines in the message console ('Tools->Message Console'), copies the selected text to the clipboard.

10. Graphical rendering or entity selection is very slow on Linux.

    The issue is most probably linked with your graphics card driver. Try setting the environment variable `LIBGL_ALWAYS_SOFTWARE=true` to force software rendering.

C.4 Geometry module

1. Does Gmsh support trimmed NURBS surfaces?

   Yes, but only with the OpenCASCADE kernel.

2. Gmsh is very slow when I use many transformations (Translate, Rotate, Symmetry, Extrude, etc.) with the built-in CAD kernel. What's wrong?

   The default behavior of Gmsh is to check and suppress all duplicate entities (points, curves and surfaces) each time a transformation command is issued with the built-in CAD kernel.

This can slow down things a lot if many transformations are performed. There are two solutions to this problem:

- you may save the serialized ("unrolled") geometry in another file (using `gmsh file.geo -0` or exporting to ".geo_unrolled"), and use this new file for subsequent computations;
- or you may set the `Geometry.AutoCoherence` option to 0. This will prevent any automatic duplicate check/replacement. If you still need to remove the duplicates entities, simply add `Coherence;` at strategic locations in your '`.geo`' files (e.g. before the creation of curve loops, etc.).

3. Why is my ".geo_unrolled" file incomplete?

   "Unrolled GEO" files can only fully represent geometries created with the built-in geometry kernel. If you want to serialize a geometry created with the OpenCASCADE geometry kernel, you should use the native OpenCASCADE ".brep" format.

4. How can I display only selected parts of my model?

   Use 'Tools->Visibility'. This allows you to select elementary entities and physical groups, as well as mesh elements, in a variety of ways (in a list or tree browser, by tag, interactively, or per window).

5. Can I edit STEP/IGES/BRep models?

   Yes: with the OpenCASCADE kernel (`SetFactory("OpenCASCADE");`), load the file (`Merge "file.step";` or `ShapeFromFile("file.step");`) and add the relevant scripting commands after that to delete parts, create new parts or apply boolean operators. See e.g. examples/boolean/import.geo.

6. Why are there surfaces missing when I export a STEP as an unrolled '`.geo`' file?

   You should *not* export STEP models as '`.geo`' files. By design, Gmsh never translates from one CAD format to another. The "unrolled GEO" feature is there for unrolling complex GEO scripts writted with the built-in geometry kernel. While it can indeed export a limited subset of geometrical entities created by other CAD kernels (e.g. OpenCASCADE), this feature is available for debugging purposes.

7. How can I build modular geometries?

   Define common geometrical objects and options in separate files or using `Macro`, reusable in all your problem definition structures. Or use the features of your language of choice and the Gmsh API.

8. Some files take much more time to load with Gmsh 4 compared to Gmsh 3: what's happening?

   In Gmsh 4, some operations (`Color`, `Show`, `Hide`, `BoundingBox`, `Boundary`, `PointsOf`, `Periodic`, `In` embedding constraints, ..) are now applied directly on the internal Gmsh model, instead of being handled at the level of the CAD kernel. This implies a synchronization between the CAD kernel and the Gmsh model. To minimize the number of synchronizations (which can become costly for large models), you should always create your geometry first; and use these commands once the geometry has been created.

C.5 Mesh module

1. What should I do when the 2D unstructured algorithm fails?

   Verify that the curves in the model do not self-intersect. If '`Mesh.RandomFactor` * size of triangle / size of model' approaches machine accuracy, increase `Mesh.RandomFactor`.

   If everything fails file a bug report with the version of your operating system and the full geometry.

2. What should I do when the 3D unstructured algorithm fails?

   Verify that the surfaces in your model do not self-intersect or partially overlap. If they don't, try the other 3D algorithms ('Tool->Options->Mesh->General->3D algorithm') or try to adapt the mesh element sizes in your input file so that the surface mesh better matches the geometrical details of the model.

   If nothing works, file a bug report with the version of your operating system and the full geometry.

3. How can I only save tetrahedral elements (not triangles and lines)?

   By default, if physical groups are defined, the output mesh only contains those elements that belong to physical entities. So to save only 3D elements, simply define one (or more) physical volume(s) and don't define any physical surfaces, physical curves or physical points.

4. How can I remove mesh nodes for geometrical construction points (centers of spheres, etc.) from output mesh file?

   By default Gmsh saves all the geometrical entities and their associated mesh. In particular, since each geometry point is meshed with a point element, defined by a mesh node, the output file will contain one 0-D mesh element and one mesh node for each geometry point. To remove such elements/nodes from the mesh, simply define physical groups for the entities you want to save (see previous question).

5. My 2D meshes of IGES files present gaps between surfaces

   IGES files do not contain the topology of the model, and tolerance problems can thus appear when the OpenCASCADE importer cannot identify two (close) curves as actually being identical.

   The best solution is to *not use IGES and use STEP* instead. If you really have to use IGES, check that you don't have duplicate curves (e.g. by displaying their tags in the GUI with 'Tools->Options->Geometry->Visibility->Curve labels'). If there are duplicates, try to change the geometrical tolerance and sew the faces (see options in 'Tools->Options->Geometry->General').

6. The quality of the elements generated by the 3D algorithm is very bad.

   Use 'Optimize quality' in the mesh menu.

7. Non-recombined 3D extruded meshes sometimes fail.

   The swapping algorithm is not very clever. Try to change the surface mesh a bit, or recombine your mesh to generate prisms or hexahedra instead of tetrahedra.

8. Does Gmsh automatically couple unstructured tetrahedral meshes and structured hexahedral meshed using pyramids?

   Yes, but only if pyramids need to be created on a single side of the quadrangular surface mesh.

9. Can I explicitly assign region tags to extruded layers?

   No, this feature has been removed in Gmsh 2.0. You must use the standard entity tag instead.

10. Did you remove the elliptic mesh generator in Gmsh 2.0?

    Yes. You can achieve the same result by using the transfinite algorithm with smoothing (e.g., with `Mesh.Smoothing = 10`).

11. Does Gmsh support curved elements?

    Yes, just choose the appropriate order in the mesh menu after the mesh is completed. High-order optimization tools are also available in the mesh menu. You can select the order on the command line with e.g. `-order 2`, and activcate high-order optimization with `-optimize_ho`.

12. Can I import an existing surface mesh in Gmsh and use it to build a 3D mesh?

    Yes, you can import a surface mesh in any one of the supported mesh file formats, define a volume, and mesh it. For an example see examples/simple_geo/sphere-discrete.geo.

13. How do I define boundary conditions or material properties in Gmsh?

    By design, Gmsh does not try to incorporate every possible definition of boundary conditions or material properties—this is a job best left to the solver. Instead, Gmsh provides a simple mechanism to tag groups of elements, and it is up to the solver to interpret these tags as boundary conditions, materials, etc. Associating tags with elements in Gmsh is done by defining physical groups (Physical Points, Physical Curves, Physical Surfaces and Physical Volumes). See the reference manual as well as the tutorials (in particular Section 2.1 [t1], page 15) for a detailed description and some examples.

    The Gmsh API can be used to build sophisticated interactive workflows where the definition of boundary conditions and material properties can be fully tailored to your preferred solver. For an example see examples/api/prepro.py.

14. How can I display only the mesh associated with selected geometrical entities?

    See "How can I display only selected parts of my model?".

15. How can I "explore" a mesh (for example, to see inside a complex structure)?

    You can use 'Tools->Clipping' to clip the region of interest. You can define up to 6 clipping planes in Gmsh (i.e., enough to define a "cube" inside your model) and each plane can clip either the geometry, the mesh, the post-processing views, or any combination of the above. The clipping planes are defined using the four coefficients A,B,C,D of the equation A*x+B*y+C*y+D=0, which can be adjusted interactively by dragging the mouse in the input fields.

16. What is the signification of SICN, Gamma and SIGE in Tools->Statistics?

    They measure the quality of the tetrahedra in a mesh:

    - SICN: signed inverse condition number
    - Gamma: inscribed radius / circumscribed radius
    - SIGE: signed inverse error on the gradient of FE solution

    For the exact definitions, see src/geo/MElement.cpp. The graphs plot the the number of elements vs. the quality measure.

17. How can I save a mesh file with a given (e.g. older) MSH file format version?

    - In the GUI: open 'File->Export', enter your '`filename.msh`' and then pick the version in the dropdown menu.
    - On the command line: use the `-format` option (e.g. `gmsh file.geo -format msh2 -2`).
    - In a '`.geo`' script: add the line `Mesh.MshFileVersion = x.y;` for any version number `x.y`. You can also save this in your default options.
    - In the API: `gmsh::option::setNumber("Mesh.MshFileVersion", x.y)`.

    As an alternative method, you can also not specify the format explicitly, and just choose a filename with the `.msh2` or `.msh4` extension.

18. Why isn't neighboring element information stored in the MSH file?

    Each numerical method has its own requirements: it might need neighboring elements connected by a node, an edge or a face; it might require a single layer or multiple layers; it should include elements of lower dimension (boundaries) or not, go across geometrical entities or mesh partitions or not, etc. Given the number of possibilities, generating the appropriate information is thus best performed in the numerical solver itself. The Gmsh API makes these computations easy: see tutorial Section 2.28 [x7], page 75 and examples/api/neighbors.py.

19. Could mesh edges/faces be stored in the MSH file?

    Edge/faces can be easily generated from the information already available in the file (i.e. nodes and elements), or through the Gmsh API: see tutorial Section 2.28 [x7], page 75, examples/api/edges.cpp and examples/api/faces.cpp.

C.6 Solver module

1. How do I integrate my own solver with Gmsh?

   Gmsh uses the ONELAB interface (`http://www.onelab.info`) to interact with external solvers. See Section 1.3 [Solver module], page 12.

2. Can I launch Gmsh from my solver (instead of launching my solver from Gmsh) in order to monitor a solution?

   Using the Gmsh API, you can directly embed Gmsh in your own solver, use ONELAB for interactive parameter definition and modification, and create visualization data on the fly. See e.g. prepro.py, custom_gui.py, custom_gui.cpp.

   Another (rather crude) approach if to launch the Gmsh app everytime you want to visualize something (a simple C program showing how to do this is given in utils/misc/callgmsh.c).

   Yet another approach is to modify your program so that it can communicate with Gmsh through ONELAB over a socket. Select 'Always listen to incoming connection requests' in the Gmsh solver option panel (or run gmsh with the `-listen` command line switch), and Gmsh will always listen for your program on the given socket (or on the `Solver.SocketName` if no socket is specified).

C.7 Post-processing module

1. How do I compute a section of a plot?

   Use 'Tools->Plugins->Cut Plane'.

2. Can I save an isosurface to a file?

   Yes: first run 'Tools->Plugins->Isosurface' to extract the isosurface, then use 'View->Export' to save the new view.

3. Can Gmsh generate isovolumes?

   Yes, with the CutMap plugin (set the ExtractVolume option to -1 or 1 to extract the negative or positive levelset).

4. How do I animate my plots?

   If the views contain multiple time steps, you can press the 'play' button at the bottom of the graphic window, or change the time step by hand in the view option panel. You can also use the left and right arrow keys on your keyboard to change the time step in all visible views in real time.

   If you want to loop through different views instead of time steps, you can use the 'Loop through views instead of time steps' option in the view option panel, or use the up and down arrow keys on your keyboard.

5. How do I visualize a deformed mesh?

   Load a vector view containing the displacement field, and set 'Vector display' to 'Displacement' in 'View->Options->Aspect'. If the displacement is too small (or too large), you can scale it with the 'Displacement factor' option. (Remember that you can drag the mouse in all numeric input fields to slide the value!)

   Another option is to use the 'General transformation expressions' (in View->Options->Offset) on a scalar view, with the displacement map selected as the data source.

6. Can I visualize a field on a deformed mesh?

   Yes, there are several ways to do that.

   The easiest is to load two views: the first one containing a displacement field (a vector view that will be used to deform the mesh), and the second one containing the field you want to display (this view has to contain the same number of elements as the displacement view). You should then set 'Vector display' to 'Displacement' in the first view, as well as set 'Data source' to point to the second view. (You might want to make the second view invisible, too. If you want to amplify or decrease the amount of deformation, just modify the 'Displacement factor' option.)

   Another solution is to use the 'General transformation expressions' (in 'View->Options->Offset') on the field you want to display, with the displacement map selected as the data source.

   And yet another solution is to use the Warp plugin.

7. Can I color the arrows representing a vector field with data from a scalar field?

   Yes: load both the vector and the scalar fields (the two views must have the same number of elements) and, in the vector field options, select the scalar view in 'Data source'.

8. Can I color isovalue surfaces with data from another scalar view?

   Yes, using either the CutMap plugin (with the 'dView' option) or the Evaluate plugin.

9. Is there a way to save animations?

   You can save simple MPEG animations directly from the 'File->Export' menu. For other formats you should write a script. Have a look at Section 2.8 [t8], page 33 or examples/post_processing/anim.script for some examples.

10. Is there a way to visualize only certain components of vector/tensor fields?

    Yes, by using either the "Force field" options in 'Tools->Options->View->Visibility', or by using 'Tools->Plugins->MathEval'.

11. Can I do arithmetic operations on a view? Can I perform operations involving different views?

    Yes, with the Evaluate plugin.

12. Some plugins seem to create empty views. What's wrong?

    There can be several reasons:

    - the plugin might be written for specific element types only (for example, only for scalar triangles or tetrahedra). In that case, you should transform your view before running the plugin (you can use `Plugin(DecomposeinSimplex)` to transform all quads, hexas, prisms and pyramids into triangles and tetrahedra).
    - the plugin might expect a mesh while all you provide is a point cloud. In 2D, you can use `Plugin(Triangulate)` to transform a point cloud into a triangulated surface. In 3D you can use `Plugin(Tetrahedralize)`.
    - the input parameters are out of range.

    In any case, you can automatically remove all empty views with 'View->Remove->Empty Views' in the GUI, or with `Delete Empty Views;` in a script.

13. How can I see "inside" a complicated post-processing view?

    Use 'Tools->Clipping'.

    When viewing 3D scalar fields, you can also modify the colormap ('Tools->Options->View->Map') to make the iso-surfaces "transparent": either by holding *Ctrl* while dragging the mouse to draw the alpha channel by hand, or by using the `a`, *Ctrl*+`a`, *p* and *Ctrl*+*p* keyboard shortcuts.

Yet another (destructive) option is to use the ExtractVolume option in the CutSphere or CutPlane plugins.

14. I am loading a valid 3D scalar view but Gmsh does not display anything!

    If your dataset is constant per element make sure you don't use the 'Iso-values' interval type in 'Tools->Options->View->Range'.

Appendix D Version history

4.12.2 (January 21, 2024): small bug fixes.

4.12.1 (January 11, 2024): small bug fixes.

4.12.0 (December 21, 2023): new high-order mesh optimisation mode for periodic meshes; new element qualities available through API; new IGES export; new volume glyph; OCC curve loops can now be oriented based on the sign of the first curve; better mesh node visualization; added suppport for model attributes in MSH2 files; new mesh renumbering capabilities in the API; new GAMBIT mesh reader; replaced Geometry.OCCSafeUnbind with more flexible Geometry.OCCFastUnbind (which can be set for boolean operations as well); added support for editing STEP headers; small bug fixes.

* New API functions: model/getEntitiesForPhysicalName, mesh/computeRenumbering, mesh/getVisibility.

* Incompatible API changes: new optional argument to occ/addCircleArc, mesh/renumberNodes, mesh/renumberElements and view/getListData; new optional "interruptible" argument to gmsh.initialize() in Python

4.11.1 (December 21, 2022): Mesh.TransfiniteTri improvements; small bug fixes.

4.11.0 (November 6, 2022): new Fortran API; improved copying ("Duplicata") of multiple shapes with OCC; reduced default order for OCC surface filling; arbitrary string attributes can now be stored in models and MSH files; new Radioss export; added ability to specify spline tangents with OCC; new option Mesh.SaveWithoutOrphans to prune orphan entities (e.g. geometrical construction points) from MSH4 files; major overhaul of the reference manual; new official macOS ARM builds; small bug fixes.

* New API functions: model/getAttributeNames, model/getAttribute, model/setAttribute, model/removeAttribute

* Incompatible API changes: new argument to mesh/computeHomology; new optional arguments to occ/addSpline and occ/addThruSections

4.10.5 (July 1, 2022): small bug fixes.

4.10.4 (June 19, 2022): improved graphical window tooltips; small bug fixes.

* New API function: mesh/removeDuplicateElements

4.10.3 (May 26, 2022): small bug fixes.

* New API function: fltk/finalize

4.10.2 (May 13, 2022): fixed regression introduced in 4.9 for recombined meshes with boundary layers; new Geometry.OCCSafeUnbind option to disable boolean optimization introduced in 4.10.0 (for backward compatibility); new HealShapes command in .geo files; simplified calculation of OCC STL bounding boxes;

generalized Crack plugin; small bug fixes.

4.10.1 (May 1, 2022): small bug fixes.

4.10.0 (April 25, 2022): more flexible homology/cohomology workflow in the API; "Attractor" field is now just a synonym for the newer (and more efficient) "Distance" field; periodic bsplines now use the same default multiplicities in OCC as in the built-in kernel; model/isInside now also handles discrete entities; speed-up repeated simple boolean operations; C++ api now throws std::runtime_error on errors; small bug fixes.

* New API functions: geo/addGeometry, geo/addPointOnGeometry, mesh/addHomologyRequest, mesh/clearHomologyRequests, mesh/setVisibility, mesh/getElementQualities

* Incompatible API changes: additional const qualifiers in C API; removed mesh/computeCohomology; new arguments to occ/getCurveLoops and occ/getSurfaceLoops; changed arguments of mesh/computeHomology; new optional arguments to occ/addCircle, occ/addEllipse, occ/addDisk, occ/addTorus, occ/addWedge, model/addPhysicalGroup, model/geo/addPhysicalGroup, mesh/removeDuplicateNodes and mesh/setRecombine.

4.9.5 (February 21, 2022): dynamic Gmsh library now also only exports public symbols on macOS and Linux, like it does on Windows; better handling of max. thread settings; small bug fixes.

* New API function: mesh/getDuplicateNodes

4.9.4 (February 3, 2022): improved BSpline filling; new options Mesh.MinimumLineNodes, Mesh.RecombineNodeRepositioning, Mesh.RecombineMinimumQuality and Mesh.StlLinearDeflectionRelative; updated bundled Eigen; small bug fixes.

* New API functions: gmsh/isInitialized, occ/convertToNURBS, occ/getCurveLoops, occ/getSurfaceLoops, mesh/importStl, parser/getNames, parser/setNumber, parser/setString, parser/getNumber, parser/getString, parser/clear, parser/parse, onelab/getChanged, onelab/setChanged

4.9.3 (January 4, 2022): improved handling of degenerate curves in periodic surfaces and boundary layer extrusion; extended Mesh.SaveGroupsOfElements capabilities for INP export; extended Mesh.MeshSizeExtendFromBoundary + new "Extend" mesh size field to enable alternative mesh size extensions from boundary; enhanced X3D output; moved all kernel sources to src/ subdirectory; renamed demos/ as examples/ and tutorial/ as tutorials/; small bug fixes.

4.9.2 (December 23, 2021): faster projection on OCC entities; extended Mesh.SaveGroupsOfNodes capabilities for INP export; improved transfinite meshing of surfaces with boundary on periodic seam.

4.9.1 (December 18, 2021): relax tolerance on curve parametrization match for periodic meshing; enable extruded boundary layers on generic model entities; activate IncludeBoundary by default in Restrict field; downgraded compiler for

official Linux releases to gcc 6 to improve compatibility with older systems; small bug fixes (view tag generation with zero tag, model/setTag).

4.9.0 (December 3, 2021): new initial 2D meshing algorithm; new quasi-structured quad algorithm; improved handling of imperfect curve reparametrization on surfaces in 2D periodic meshing algorithm; mesh renumbering now also renumbers dependent post-processing views; the mesh size callback is now per-model and its returned value is not gathered with the other size constraints in a global min reduction anymore: instead the callback takes as additional argument the mesh size lc that would be prescribed in the absence of the callback, which allows to perform any desired modification (the old behavior can be achieved by returning min(lc, value)); OCC STL representation is now generated using relative deflection tolerance; new TransformMesh command in .geo files; new behavior of Mesh.SaveGroupsOf{Nodes,Elements} in UNV and INP exports; partitioned MSH4 files now contain the full partition topology (i.e. all partition entities); fixed metric calculation with Eigen (for anisotropic mesh generation); official binary builds now support OpenMP parallelization and are 64 bit only (build OS upgraded to Windows 10, macOS 10.15 and Linux glibc 2.24); new experimental Fortran API; new API functions to handle view options by tag instead of by index; color options in the API can now be specified as in .geo files, in the form "Category.Color.Option"; small bug fixes.

* New API functions: model/setTag, mesh/reverse, mesh/affineTransform, mesh/getMaxNodeTag, mesh/getMaxElementTag, mesh/getSizes, mesh/getPeriodic, mesh/getAllEdges, mesh/getAllFaces, mesh/addEdge, mesh/addFace, mesh/getNumberOfPartitions, field/list, field/getType, field/getNumber, field/getNumbers, field/getString, view/option/setNumber, view/option/getNumber, view/option/setString, view/option/getString, view/option/setColor, view/option/getColor, view/option/copy.

* Incompatible API changes: new arguments to mesh/getNode, mesh/getElement and view/probe; additional argument to the mesh size callback function provided to mesh/setSizeCallback; new optional arguments to gmsh/initialize, model/isInside, mesh/partition and occ/addSurfaceFilling; renamed mesh/preallocateBasisFunctionsOrientationForElements as mesh/preallocateBasisFunctionsOrientation, mesh/getNumberOfKeysForElements as mesh/getNumberOfKeys, and mesh/getBasisFunctionsOrientationForElements as mesh/getBasisFunctionsOrientation; renamed mesh/getKeysForElements as mesh/getKeys and mesh/getInformationForElements as mesh/getKeysInformation, and modified their arguments; modified arguments to mesh/getKeysForElement; removed mesh/getLocalMultipliersForHcurl0; renamed view/copyOptions as view/option/copy.

4.8.4 (April 28, 2021): set current model in gmsh/model/add; small bug fixes.

4.8.3 (April 6, 2021): better handling of errors in inverse surface mapping; fixed Mesh.MedFileMinorVersion for MED 4; small bug fixes.

4.8.2 (March 27, 2021): fixed regression in OCC transforms; fixed cwrap API.

4.8.1 (March 21, 2021): improved performance when transforming many OCC entities; fixed regression in high-order meshing of surfaces with singular

parametrizations; small bug fixes.

4.8.0 (March 2, 2021): new interactive and fully parametrizable definition of boundary conditions, materials, etc. through ONELAB variables; new API functions for creating trimmed BSpline/Bezier patches, perform raw triangulations and tetrehedralizations, get upward adjacencies, and create extruded boundary layers and automatic curve loops in built-in kernel; improved performance of high-order meshing of OCC models; improved handling of high resolution displays; new structured CGNS exporter; new transfinite Beta law; added support for embedded curves in HXT; added automatic conversion from partitioned MSH2 files to new partitioned entities; element groups can now be imported from UNV files; fixed order of Gauss quadrature for quads and hexas; code modernization (C++11); further uniformization of option names to match the documented terminology (Mesh.Point -> Mesh.Node, ...; old names are still accepted, but deprecated); deprecated Mesh.MinimumElementsPerTwoPi: set value directly to Mesh.MeshSizeFromCurvature instead; Python and Julia APIs now also define "snake case" aliases for all camelCase function names; small bug fixes and improvements.

* New API functions: model/getFileName, model/setFileName, model/getAdjacencies, model/getSecondDerivative, mesh/getEdges, mesh/getFaces, mesh/createEdges, mesh/createFaces, mesh/removeConstraints, mesh/getEmbedded, mesh/triangulate, mesh/tetrahedralize, geo/addCurveLoops, fltk/setStatusMessage, fltk/showContextWindow, fltk/openTreeItem, fltk/closeTreeItem, onelab/getNames.

* Incompatible API changes: new optional arguments to mesh/classifySurfaces, occ/addBSplineSurface, occ/addBezierSurface, occ/addPipe and view/probe; renamed mesh/getEdgeNumber as mesh/getEdges.

4.7.1 (November 16, 2020): small bug fixes and improvements.

4.7.0 (November 5, 2020): API errors now throw exceptions with the last error message (instead of an integer error code); API functions now print messages on the terminal by default, and throw exceptions on all errors unless in interactive mode; new API functions to retrieve "homogeneous" model-based data (for improved Python performance), to set interpolation matrices for high-order datasets, to assign "automatic" transfinite meshing constraints and to pass native (C++, C, Python or Julia) mesh size callback; added option to save high-order periodic nodes info; added support for scripted window splitting; improved VTK reader; new MatrixOfInertia command; added support for Unicode command line arguments on Windows; uniformized commands, options and field option names to match the documented terminology (CharacteristicLength -> MeshSize, geometry Line -> Curve, ...; old names are still accepted, but deprecated); improved handling of complex periodic cases; removed bundled Mmg3D and added support for stock Mmg 5; Gmsh now requires C++11 and CMake 3.1, and uses Eigen by default instead of Blas/Lapack for dense linear algebra; small bug fixes.

* New API functions: model/setVisibilityPerWindow, mesh/setSizeCallback, mesh/removeSizeCallback, mesh/setTransfiniteAutomatic, geo/addPhysicalGroup, geo/removePhysicalGroups, view/setInterpolationMatrices,

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  view/setVisibilityPerWindow, fltk/splitCurrentWindow, fltk/setCurrentWindow,
  logger/getLastError.

* Incompatible API changes: new optional argument to geo/addCurveLoop.

4.6.0 (June 22, 2020): new options to only generate initial 2D or 3D meshes
(without node insertion), and to only mesh non-meshed entities; added ability to
only remesh parts of discrete models; added support for mesh size fields and
embedded points and surfaces in HXT; improved reparametrization and partitioning
code; new OCC API functions to reduce the number of synchronizations for complex
models; new OCC spline surface interfaces; new functions and options to control
the first tag of entities, nodes and elements; fixed duplicated entities in STEP
output; improved mesh subdivision and high-order pipeline; MED output now
preserves node and element tags; small bug fixes.

* New API functions: model/getParametrizationBounds, model/isInside,
  model/getClosestPoint, model/reparametrizeOnSurface, mesh/rebuildElementCache,
  mesh/getBasisFunctionsOrientationForElements,
  mesh/getBasisFunctionsOrientationForElement, mesh/getNumberOfOrientations,
  mesh/preallocateBasisFunctionsOrientationForElements,
  mesh/setSizeAtParametricPoints, geo/setMaxTag, geo/getMaxTag,
  occ/addBSplineFilling, occ/addBezierFilling, occ/addBSplineSurface,
  occ/addBezierSurface, occ/setMaxTag, occ/getMaxTag, occ/getEntities,
  occ/getEntitiesInBoundingBox, occ/getBoundingBox,
  view/addHomogeneousModelData.

* Incompatible API changes: new optional arguments to mesh/clear,
  mesh/createTopology, mesh/createGeometry, occ/addThruSections,
  mesh/getPeriodicNodes; new arguments to mesh/getBasisFunctions; removed
  mesh/preallocateBasisFunctions, mesh/precomputeBasisFunctions and
  mesh/getBasisFunctionsForElements; renamed occ/setMeshSize as
  occ/mesh/setSize.

4.5.6 (March 30, 2020): better calculation of OCC bounding boxes using STL; API
tutorials; small bug fixes.

* New API functions: view/addListDataString, view/getListDataStrings.

4.5.5 (March 21, 2020): tooltips in GUI to help discovery of scripting options;
fixed MED IO of high-order elements; fixed OCC attribute search by bounding box;
fix parsing of mac-encoded scripts; new RecombineMesh command; added support for
extrusion of mixed-dimension entities with OCC; small bug fixes.

4.5.4 (February 29, 2020): periodic mesh optimization now ensures that the
master mesh is not modified; code cleanup; small bug fixes.

4.5.3 (February 22, 2020): improved positioning of corresponding nodes on
periodic entities; improved LaTeX output; improved curve splitting in
reparametrization; new binary PLY reader; small compilation fixes.

* New API functions: mesh/getEdgeNumber, mesh/getLocalMultipliersForHcurl0.
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4.5.2 (January 30, 2020): periodic meshes now obey reorientation constraints; physical group definitions now follow compound meshing constraints; small bug fixes and improvements.

* New API function: geo/splitCurve.

4.5.1 (December 28, 2019): new Min and Max commands in .geo files; Mesh.MinimumCirclePoints now behaves the same with all geometry kernels; fixed issue with UTF16-encoded home directories on Windows.

4.5.0 (December 21, 2019): changed default 2D meshing algorithm to Frontal-Delaunay; new compound Spline/BSpline commands; new MeshSizeFromBoundary command; new CGNS importer/exporter; new X3D exporter for geometries and meshes; improved surface mesh reclassification; new separate option to govern curvature adapted meshes (Mesh.MinimumElementsPerTwoPi and "-clcurv val"); improved handling of anisotropic surface meshes in 3D Delaunay; improved high-order periodic meshing; improved 2D boolean unions; file chooser type is now changeable at runtime; FLTK GUI can now be created and destroyed at will through the API; fixed regression in MeshAdapt for non-periodic surfaces with singularities; combining views now copies options; added API support for mesh compounds, per-surface mesh algorithm and mesh size from boundary; renamed plugin AnalyseCurvedMesh to AnalyseMeshQuality; fixed regression for built-in kernel BSplines on non-flat geometries (Sphere, PolarSphere); small fixes and improvements.

* New API functions: model/getCurrent, model/getParametrization, mesh/computeCrossField, mesh/setNode, mesh/getElementsByCoordinates, mesh/getLocalCoordinatesInElement, mesh/getNumberOfKeysForElements, mesh/setAlgorithm, mesh.setSizeFromBoundary, mesh/setComound, geo/addCompoundSpline, geo/addCompoundBSpline, fltk/isAvailable.

* Incompatible API changes: removed mesh/smooth (now handled by mesh/optimize like all other mesh optimizers); renamed logger/time to logger/getWallTime and logger/cputime to logger/getCpuTime; new arguments to mesh/optimize, mesh/getElementProperties and occ/healShapes; added optional argument to mesh/classifySurfaces and view/combine.

4.4.1 (July 25, 2019): small improvements (transfinite with degenerate curves, renumbering for some mesh formats, empty MSH file sections, tunable accuracy of compound meshes) and bug fixes (ellipse < pi, orientation and reclassification of compound parts, serendip pyramids, periodic MeshAdapt robustness, invalidate cache after mesh/addNodes).

4.4.0 (July 1, 2019): new STL remeshing workflow (with new ClassifySurfaces command in .geo files); added API support for color options, mesh optimization, recombination, smoothing and shape healing; exposed additional METIS options; improved support for periodic entities (multiple curves with the same start/end points, legacy MSH2 format, periodic surfaces with embedded entities); added mesh renumbering also after interactive mesh modifications; improved support for OpenCASCADE ellipse arcs; new interactive filter in visibility window; flatter GUI; small bug fixes.

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* New API functions: option/setColor, option/getColor, mesh/optimize,
  mesh/recombine, mesh/smooth, mesh/clear, mesh/getNodesByElementType,
  occ/healShapes.

* Incompatible API changes: mesh/getJacobians and mesh/getBasisFunctions now
  take integration points explicitly; mesh/setNodes and mesh/setElements have
  been replaced by mesh/addNodes and mesh/addElements; added optional arguments
  to mesh/classifySurfaces and occ/addSurfaceLoop; changed arguments of
  occ/addEllipseArc to follow geo/addEllipseArc.

4.3.0 (April 19, 2019): improved meshing of surfaces with singular
parametrizations; added API support for aliasing and combining views, copying
view options, setting point coordinates, extruding built-in CAD entities along
normals and retrieving mass, center of mass and inertia from OpenCASCADE CAD
entities; fixed regression introduced in 4.1.4 that could lead to
non-deterministic 2D meshes; small bug fixes.

* New API functions: model/setCoordinates, occ/getMass, occ/getCenterOfMass,
  occ/getMatrixOfInertia, view/addAlias, view/copyOptions, view/combine

* Incompatible API changes: added optional arguments to mesh/getNodes and
  mesh/getElementByCoordinates.

4.2.3 (April 3, 2019): added STL export by physical surface; added ability to
remove embedded entities; added handling of boundary entities in
addDiscreteEntity; small bug fixes.

* New API functions: mesh/getKeysForElements, mesh/getInformationForElements,
  mesh/removeEmbedded.

4.2.2 (March 13, 2019): fixed regression in reading of extruded meshes; added
ability to export one solid per surface in STL format.

4.2.1 (March 7, 2019): fixed regression for STEP files without global compound
shape; added support for reading IGES labels and colors; improved search for
shared library in Python and Julia modules; improved Plugin(MeshVolume); updates
to the reference manual.

4.2.0 (March 5, 2019): new MSH4.1 revision of the MSH file format, with support
for size_t node and element tags (see the reference manual for detailed
changes); added support for reading STEP labels and colors with OCC CAF; changed
default "Geometry.OCCTargetUnit" value to none (i.e. use STEP file coordinates
as-is, without conversion); improved high-order mesh optimization; added ability
to import groups of nodes from MED files; enhanced Plugin(Distance) and
Plugin(SimplePartition); removed unmaintained plugins; removed default
dependency on PETSc; small improvements and bug fixes.

* New API functions: model/setEntityName, model/getEntityName,
  model/removeEntityName.

* Incompatible API changes: changed type of node and element tags from int to
  size_t to support (very) large meshes; changed logger/start,
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  mesh/getPeriodicNodes and mesh/setElementsByType.

4.1.5 (February 14, 2019): improved OpenMP parallelization, STL remeshing, mesh
partitioning and high-order mesh optimization; bug fixes.

* New API function: mesh/classifySurfces.

4.1.4 (February 3, 2019): improved ghost cell I/O; small improvements and bug
fixes.

* New API functions: mesh/relocateNodes, mesh/getElementType,
  mesh/setElementsByType, mesh/getElementEdgeNodes, mesh/getElementFaceNodes,
  mesh/getGhostElements, mesh/splitQuadrangles.

4.1.3 (January 23, 2019): improved quad meshing; new options for automatic
full-quad meshes; save nodesets also for physical points (Abaqus, Tochnog);
small bug fixes.

* New API functions: model/removePhysicalName, model/getPartitions,
  mesh/unpartition.

4.1.2 (January 21, 2019): fixed full-quad subdivision if Mesh.SecondOrderLinear
is set; fixed packing of parallelograms regression in 4.1.1.

4.1.1 (January 20, 2019): added support for general affine transformations with
OpenCASCADE kernel; improved handling of boolean tolerance (snap vertices);
faster crossfield calculation by default (e.g. for Frontal-Delauany for quads
algorithm); fixed face vertices for PyramidN; renamed ONELAB "Action" and
"Button" parameters "ONELAB/Action" and "ONELAB/Button"; added support for
actions on any ONELAB button; added API functions for selections in user
interface.

* New API functions: occ/affineTransform, fltk/selectEntities,
  fltk/selectElements, fltk/selectViews.

4.1.0 (January 13, 2019): improved ONELAB and Fltk support in API; improved
renumbering of mesh nodes/elements; major code refactoring.

* New API functions: fltk/update, fltk/awake, fltk/lock, fltk/unlock,
  onelab/setNumber, onelab/getNumber, onelab/setString, onelab/getString,
  onelab/clear, onelab/write, logger/time, logger/cputime.

* Incompatible API changes: changed onelab/get.

4.0.7 (December 9, 2018): fixed small memory leaks; removed unused code.

4.0.6 (November 25, 2018): moved private API wrappers to utils/wrappers;
improved Gmsh 3 compatibility for high-order periodic meshes; fixed '-v 0' not
being completely silent; fixed rendering of image textures on some OSes; small
compilation fixes.

4.0.5 (November 17, 2018): new automatic hybrid mesh generation (pyramid layer)
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when 3D Delaunay algorithm is applied to a volume with quadrangles on boundary; improved robustness of 2D MeshAdapt algorithm; bug fixes.

4.0.4 (October 19, 2018): fixed physical names regression in 4.0.3.

4.0.3 (October 18, 2018): bug fixes.

* New API function: model/removePhysicalGroups.

4.0.2 (September 26, 2018): added support for creating MED files with specific MED (minor) version; small bug fixes.

4.0.1 (September 7, 2018): renumber mesh nodes/elements by default; new SendToServer command for nodal views; small bug fixes.

* New API functions: model/setVisibility, model/getVisibility, model/setColor, model/getColor.

4.0.0 (August 22, 2018): new C++, C, Python and Julia API; new MSH4 format; new mesh partitioning code based on Metis 5; new 3D tetrahedralization algorithm as default; new workflow for remeshing (compound entities as meshing constraints, CreateGeometry for mesh reparametrization); added support for general BSplines, fillets and chamfers with OpenCASCADE kernel and changed default BSpline parameters with the built-in kernel to match OpenCASCADE's; STEP files are now be default interpreted in MKS units (see Geometry.OCCTargetUnit); improved meshing of surfaces with singular parametrizations (spheres, etc.); uniformized entity naming conventions (line/curve, vertex/node, etc.); generalized handling of "all" entities in geo file (using {:} notation); added support for creating LSDYNA mesh files; removed old CAD creation factory (GModelFactory), old reparametrization code (G{Edge, Face, Region}Compound) and old partitioning code (Metis 4 and Chaco); various cleanups, bug fixes and enhancements.

3.0.6 (November 5, 2017): improved meshing of spheres; improved handling of mesh size constraints with OpenCASCADE kernel; implemented "Coherence" for OpenCASCADE kernel (shortcut for BooleanFragments); added GAMBIT Neutral File export; small improvements and bug fixes.

3.0.5 (September 6, 2017): bug fixes.

3.0.4 (July 28, 2017): moved vorometal code to plugin; OpenMP improvements; bug fixes.

3.0.3 (June 27, 2017): new element quality measures; Block->Box; minor fixes.

3.0.2 (May 13, 2017): improved handling of meshing constraints and entity numbering after boolean operations; improved handling of fast coarseness transitions in MeshAdapt; new TIKZ export; small bug fixes.

3.0.1 (April 14, 2017): fixed OpenCASCADE plane surfaces with holes.

3.0.0 (April 13, 2017): new constructive solid geometry features and boolean operations using OpenCASCADE; improved graphical user interface for interactive,

parametric geometry construction; new or modified commands in .geo files: SetFactory, Circle, Ellipse, Wire, Surface, Sphere, Block, Torus, Rectangle, Disk, Cylinder, Cone, Wedge, ThickSolid, ThruSections, Ruled ThruSections, Fillet, Extrude, BooleanUnion, BooleanIntersection, BooleanDifference, BooleanFragments, ShapeFromFile, Recursive Delete, Unique; "Surface" replaces the deprecated "Ruled Surface" command; faster 3D tetrahedral mesh optimization enabled by default; major code refactoring and numerous bug fixes.

2.16.0 (January 3, 2017): small improvements (list functions, second order hexes for MED, GUI) and bug fixes.

2.15.0 (December 4, 2016): fixed several regressions (multi-file partitioned grid export, mesh subdivision, old compound mesher); improved 2D boundary layer field & removed non-functional 3D boundary layer field; faster rendering of large meshes.

2.14.1 (October 30, 2016): fixed regression in periodic meshes; small bug fixes and code cleanups.

2.14.0 (October 9, 2016): new Tochnog file format export; added ability to remove last command in scripts generated interactively; ONELAB 1.3 with usability and performance improvements; faster "Coherence Mesh".

2.13.2 (August 18, 2016)): small improvements (scale labels, periodic and high-order meshes) and bug fixes.

2.13.1 (July 15, 2016): small bug fixes.

2.13.0 (July 11, 2016): new ONELAB 1.2 protocol with native support for lists; new experimental 3D boundary recovery code and 3D refinement algorithm; better adaptive visualization of quads and hexahedra; fixed several regressions introduced in 2.12.

2.12.0 (March 5, 2016): improved interactive definition of physical groups and handling of ONELAB clients; improved full quad algorithm; added support for list of strings, trihedra elements and X3D format; improved message console; new colormaps; various bugs fixes and small improvements all over.

2.11.0 (November 7, 2015): new Else/ElseIf commands; new OptimizeMesh command; Plugin(ModifyComponents) replaces Plugin(ModifyComponent); new VTK and X3D outputs; separate 0/Ctrl+0 shortcuts for geometry/full model reload; small bug fixes in homology solver, handling of embedded entities, and Plugin(Crack).

2.10.1 (July 30, 2015): minor fixes.

2.10.0 (July 21, 2015): improved periodic meshing constraints; new Physical specification with both label and numeric id; images can now be used as glyphs in post-processing views, using text annotations with the ‘file://’ prefix; Views can be grouped and organized in subtrees; improved visibility browser navigation; geometrical entities and post-processing views can now react to double-clicks, via new generic DoubleClicked options; new Get/SetNumber and Get/SetString for direct access to ONELAB variables; small bug fixes and code

cleanups.

2.9.3 (April 18, 2015): updated versions of PETSc/SLEPc and OpenCASCADE/OCE libraries used in official binary builds; new Find() command; miscellaneous code cleanups and small fixes.

2.9.2 (March 31, 2015): added support for extrusion of embedded points/curves; improved hex-dominant algorithm; fixed crashes in quad algorithm; fix regression in MED reader introduced in 2.9.0; new dark interface mode.

2.9.1 (March 18, 2015): minor bug fixes.

2.9.0 (March 12, 2015): improved robustness of spatial searches (extruded meshes, geometry coherence); improved reproductibility of 2D and 3D meshes; added support for high resolution ("retina") graphics; interactive graph point commands; on-the-fly creation of onelab clients in scripts; general periodic meshes using afine transforms; scripted selection of entities in bounding boxes; extended string and list handling functions; many small improvements and bug fixes.

2.8.5 (Jul 9, 2014): improved stability and error handling, better Coherence function, updated onelab API version and inline parameter definitions, new background image modes, more robust Triangulate/Tetrahedralize plugins, new PGF output, improved support for string~index variable names in parser, small improvements and bug fixes all over the place.

2.8.4 (Feb 7, 2014): better reproductibility of 2D meshes; new mandatory 'Name' attribute to define onelab variables in DefineConstant[] & co; new -setnumber/-setstring command line arguments; small improvements and bug fixes.

2.8.3 (Sep 27, 2013): new quick access menu and multiple view selection in GUI; enhanced animation creation; many small enhancements and bug fixes.

2.8.2 (Jul 16, 2013): improved high order tools interface; minor bug fixes.

2.8.1 (Jul 11, 2013): improved compound surfaces and transfinite arrangements.

2.8.0 (Jul 8, 2013): improved Delaunay point insertion; fixed mesh orientation of plane surfaces; fixed mesh size prescribed at embedded points; improved display of vectors at COG; new experimental text string display engines; improved fullscreen mode; access time/step in transformations; new experimental features: AdaptMesh and Surface In Volume; accept unicode file paths on Windows; compilation and bug fixes.

2.7.1 (May 11, 2013): improved Delaunay point insertion; updated onelab; better Abaqus and UNV export; small bug and compilation fixes.

2.7.0 (Mar 9, 2013): new single-window GUI, with dynamically customizable widget tree; faster STEP/BRep import; arbitrary size image export; faster 2D Delaunay/Frontal algorithms; full option viewer/editor; many bug fixes.

2.6.1 (Jul 15, 2012): minor improvements and bug fixes.

2.6.0 (Jun 19, 2012): new quadrilateral meshing algorithms (Blossom and Delaunay-Frontal for quads); new solver module based on ONELAB project (requires FLTK 1.3); new tensor field visualization modes (eigenvectors, ellipsoid, etc.); added support for interpolation schemes in .msh file; added support for MED3 format; rescale viewport around visible entities (shift+1:1 in GUI); unified post-processing field export; new experimental stereo+camera visualization mode; added experimental BAMG & Mmg3D support for anisotropic mesh generation; new OCC cut & merge algorithm imported from Salome; new ability to connect extruded meshes to tetrahedral grids using pyramids; new homology solver; Abaqus (INP) mesh export; new Python and Java wrappers; bug fixes and small improvements all over the place.

2.5.0 (Oct 15, 2010): new compound geometrical entities (for remeshing and/or trans-patch meshing); improved mesh reclassification tool; new client/server visualization mode; new ability to watch a pattern of files to merge; new integrated MPEG export; new option to force the type of views dynamically; bumped mesh version format to 2.2 (small change in the meaning of the partition tags; this only affects partitioned (i.e. parallel) meshes); renamed several post-processing plugins (as well as plugin options) to make them easier to understand; many bug fixes and usability improvements all over the place.

2.4.2 (Sep 21, 2009): solver code refactoring + better IDE integration.

2.4.1 (Sep 1, 2009): fixed surface mesh orientation bug introduced in 2.4.0; mesh and graphics code refactoring, small usability enhancements and bug fixes.

2.4.0 (Aug 22, 2009): switched build system to CMake; optionally copy transfinite mesh constraints during geometry transformations; bumped mesh version format to 2.1 (small change in the $PhysicalNames section, where the group dimension is now required); ported most plugins to the new post-processing API; switched from MathEval to MathEx and Flu_Tree_Browser to Fl_Tree; small bug fixes and improvements all over the place.

2.3.1 (Mar 18, 2009): removed GSL dependency (Gmsh now simply uses Blas and Lapack); new per-window visibility; added support for composite window printing and background images; fixed string option affectation in parser; fixed surface mesh orientation for OpenCASCADE models; fixed random triangle orientations in Delaunay and Frontal algorithms.

2.3.0 (Jan 23, 2009): major graphics and GUI code refactoring; new full-quad/hexa subdivision algorithm; improved automatic transfinite corner selection (now also for volumes); improved visibility browser; new automatic adaptive visualization for high-order simplices; modified arrow size, clipping planes and transform options; many improvements and bug fixes all over the place.

2.2.6 (Nov 21, 2008): better transfinite smoothing and automatic corner selection; fixed high order meshing crashes on Windows and Linux; new uniform mesh refinement (thanks Brian!); fixed various other small bugs.

2.2.5 (Oct 25, 2008): Gmsh now requires FLTK 1.1.7 or above; various small

improvements (STL and VTK mesh I/O, Netgen upgrade, Visual C++ support, Fields, Mesh.{Msh,Stl,...}Binary changed to Mesh.Binary) and bug fixes (pyramid interpolation, Chaco crashes).

2.2.4 (Aug 14, 2008): integrated Metis and Chaco mesh partitioners; variables can now be deleted in geo files; added support for point datasets in model-based postprocessing views; small bug fixes.

2.2.3 (Jul 14, 2008): enhanced clipping interface; API cleanup; fixed various bugs (Plugin(Integrate), high order meshes, surface info crash).

2.2.2 (Jun 20, 2008): added geometrical transformations on volumes; fixed bug in high order mesh generation.

2.2.1 (Jun 15, 2008): various small improvements (adaptive views, GUI, code cleanup) and bug fixes (high order meshes, Netgen interface).

2.2.0 (Apr 19, 2008): new model-based post-processing backend; added MED I/O for mesh and post-processing; fixed BDF vertex ordering for 2nd order elements; replaced Mesh.ConstrainedBackgroundMesh with Mesh.CharacteristicLength{FromPoints,ExtendFromBoundary}; new Fields interface; control windows are now non-modal by default; new experimental 2D frontal algorithm; fixed various bugs.

2.1.1 (Mar 1, 2008): small bug fixes (second order meshes, combine views, divide and conquer crash, ...).

2.1.0 (Feb 23, 2008): new post-processing database; complete rewrite of post-processing drawing code; improved surface mesh algorithms; improved STEP/IGES/BREP support; new 3D mesh optimization algorithm; new default native file choosers; fixed 'could not find extruded vertex' in extrusions; many improvements and bug fixes all over the place.

2.0.8 (Jul 13, 2007): unused vertices are not saved in mesh files anymore; new plugin GUI; automatic GUI font size selection; renamed Plugin(DecomposeInSimplex) into Plugin(MakeSimplex); reintroduced enhanced Plugin(SphericalRaise); clarified meshing algo names; new option to save groups of nodes in UNV meshes; new background mesh infrastructure; many small improvements and small bug fixes.

2.0.7 (Apr 3, 2007): volumes can now be defined from external CAD surfaces; Delaunay/Tetgen algorithm is now used by default when available; re-added support for Plot3D structured mesh format; added ability to export external CAD models as GEO files (this only works for the limited set of geometrical primitives available in the GEO language, of course--so trying to convert e.g. a trimmed NURBS from a STEP file into a GEO file will fail); "lateral" entities are now added at the end of the list returned by extrusion commands; fixed various bugs.

2.0.0 (Feb 5, 2007): new geometry and mesh databases, with support for STEP and IGES import via OpenCASCADE; complete rewrite of geometry and mesh drawing code; complete rewrite of mesh I/O layer (with new native binary MSH format and

support for import/export of I-deas UNV, Nastran BDF, STL, Medit MESH and VRML 1.0 files); added support for incomplete second order elements; new 2D and 3D meshing algorithms; improved integration of Netgen and TetGen algorithms; removed anisotropic meshing algorithm (as well as attractors); removed explicit region number specification in extrusions; option changes in the graphical interface are now applied instantaneously; added support for offscreen rendering using OSMesa; added support for SVG output; added string labels for Physical entities; lots of other improvements all over the place.

1.65 (May 15, 2006): new Plugin(ExtractEdges); fixed compilation errors with gcc4.1; replaced Plugin(DisplacementRaise) and Plugin(SphericalRaise) with the more flexible Plugin(Warp); better handling of discrete curves; new Status command in parser; added option to renumber nodes in .msh files (to avoid holes in the numbering sequence); fixed 2 special cases in quad->prism extrusion; fixed saving of 2nd order hexas with negative volume; small bug fixes and cleanups.

1.64 (Mar 18, 2006): Windows versions do no depend on Cygwin anymore; various bug fixes and cleanups.

1.63 (Feb 01, 2006): post-processing views can now be exported as meshes; improved background mesh handling (a lot faster, and more accurate); improved support for input images; new Plugin(ExtractElements); small bug fixes and enhancements.

1.62 (Jan 15, 2006): new option to draw color gradients in the background; enhanced perspective projection mode; new "lasso" selection mode (same as "lasso" zoom, but in selection mode); new "invert selection" button in the visibility browser; new snapping grid when adding points in the GUI; nicer normal smoothing; new extrude syntax (old syntax still available, but deprecated); various small bug fixes and enhancements.

1.61 (Nov 29, 2005): added support for second order (curved) elements in post-processor; new version (1.4) of post-processing file formats; new stippling options for 2D plots; removed limit on allowed number of files on command line; all "Combine" operations are now available in the parser; changed View.ArrowLocation into View.GlyphLocation; optimized memory usage when loading many (>1000) views; optimized loading and drawing of line meshes and 2D iso views; optimized handling of meshes with large number of physical entities; optimized vertex array creation for large post-processing views on Windows/Cygwin; removed Discrete Line and Discrete Surface commands (the same functionality can now be obtained by simply loading a mesh in .msh format); fixed coloring by mesh partition; added option to light wireframe meshes and views; new "mesh statistics" export format; new full-quad recombine option; new Plugin(ModulusPhase); hexas and prisms are now always saved with positive volume; improved interactive entity selection; new experimental Tetgen integration; new experimental STL remeshing algorithm; various small bug fixes and improvements.

1.60 (Mar 15, 2005): added support for discrete curves; new Window menu on Mac OS X; generalized all octree-based plugins (CutGrid, StreamLines, Probe, etc.) to handle all element types (and not only scalar and vector

triangles+tetrahedra); generalized Plugin(Evaluate), Plugin(Extract) and Plugin(Annotate); enhanced clipping plane interface; new grid/axes/rulers for 3D post-processing views (renamed the AbscissaName, NbAbscissa and AbscissaFormat options to more general names in the process); better automatic positioning of 2D graphs; new manipulator dialog to specify rotations, translations and scalings "by hand"; various small enhancements and bug fixes.

1.59 (Feb 06, 2005): added support for discrete (triangulated) surfaces, either in STL format or with the new "Discrete Surface" command; added STL and Text output format for post-processing views and STL output format for surface meshes; all levelset-based plugins can now also compute isovolumes; generalized Plugin(Evaluate) to handle external view data (based on the same or on a different mesh); generalized Plugin(CutGrid); new plugins (Eigenvalues, Gradient, Curl, Divergence); changed default colormap to match Matlab's "Jet" colormap; new transformation matrix option for views (for non-destructive rotations, symmetries, etc.); improved solver interface to keep the GUI responsive during solver calls; new C++ and Python solver examples; simplified Tools->Visibility GUI; transfinite lines with "Progression" now allow negative line numbers to reverse the progression; added ability to retrieve Gmsh's version number in the parser (to help write backward compatible scripts); fixed white space in unv mesh output; fixed various small bugs.

1.58 (Jan 01, 2005): fixed UNIX socket interface on Windows (broken by the TCP solver patch in 1.57); bumped version number of default post-processing file formats to 1.3 (the only small modification is the handling of the end-of-string character for text2d and text3d objects in the ASCII format); new File->Rename menu; new colormaps+improved colormap handling; new color+min/max options in views; new GetValue() function to ask for values interactively in scripts; generalized For/EndFor loops in parser; new plugins (Annotate, Remove, Probe); new text attributes in views; renamed some shortcuts; fixed TeX output for large scenes; new option dialogs for various output formats; fixed many small memory leaks in parser; many small enhancements to polish the graphics and the user interface.

1.57 (Dec 23, 2004): generalized displacement maps to display arbitrary view types; the arrows representing a vector field can now also be colored by the values from other scalar, vector or tensor fields; new adaptive high order visualization mode; new options (Solver.SocketCommand, Solver.NameCommand, View.ArrowSizeProportional, View.Normals, View.Tangents and General.ClipFactor); fixed display of undesired solver plugin popups; enhanced interactive plugin behavior; new plugins (HarmonicToTime, Integrate, Eigenvectors); tetrahedral mesh file reading speedup (50% faster on large meshes); large memory footprint reduction (up to 50%) for the visualization of triangular/tetrahedral meshes; the solver interface now supports TCP/IP connections; new generalized raise mode (allows one to use complex expressions to offset post-processing maps); upgraded Netgen kernel to version 4.4; new optional TIME list in parsed views to specify the values of the time steps; several bug fixes in the Elliptic mesh algorithm; various other small bug fixes and enhancements.

1.56 (Oct 17, 2004): new post-processing option to draw a scalar view raised by a displacement view without using Plugin(DisplacementRaise) (makes drawing arbitrary scalar fields on deformed meshes much easier); better post-processing

menu (arbitrary number of views+scrollable+show view number); improved view->combine; new horizontal post-processing scales; new option to draw the mesh nodes per element; views can now also be saved in "parsed" format; fixed various path problems on Windows; small bug fixes.

1.55 (Aug 21, 2004): added background mesh support for Triangle; meshes can now be displayed using "smoothed" normals (like post-processing views); added GUI for clipping planes; new interactive clipping/cutting plane definition; reorganized the Options GUI; enhanced 3D iso computation; enhanced lighting; many small bug fixes.

1.54 (Jul 03, 2004): integrated Netgen (3D mesh quality optimization + alternative 3D algorithm); Extrude Surface now always automatically creates a new volume (in the same way Extrude Point or Extrude Line create new lines and surfaces, respectively); fixed UNV output; made the "Layers" region numbering consistent between lines, surfaces and volumes; fixed home directory problem on Win98; new Plugin(CutParametric); the default project file is now created in the home directory if no current directory is defined (e.g., when double-clicking on the icon on Windows/Mac); fixed the discrepancy between the orientation of geometrical surfaces and the associated surface meshes; added automatic orientation of surfaces in surface loops; generalized Plugin(Triangulate) to handle vector and tensor views; much nicer display of discrete iso-surfaces and custom ranges using smooth normals; small bug fixes and cleanups.

1.53 (Jun 04, 2004): completed support for second order elements in the mesh module (line, triangles, quadrangles, tetrahedra, hexahedra, prisms and pyramids); various background mesh fixes and enhancements; major performance improvements in mesh and post-processing drawing routines (OpenGL vertex arrays for tri/quads); new Plugin(Evaluate) to evaluate arbitrary expressions on post-processing views; generalized Plugin(Extract) to handle any combination of components; generalized "Coherence" to handle transfinite surface/volume attributes; plugin options can now be set in the option file (like all other options); added "undo" capability during geometry creation; rewrote the contour guessing routines so that entities can be selected in an arbitrary order; Mac users can now double click on geo/msh/pos files in the Finder to launch Gmsh; removed support for FLTK 1.0; rewrote most of the code related to quadrangles; fixed 2d elliptic algorithm; removed all OpenGL display list code and options; fixed light positioning; new BoundingBox command to set the bounding box explicitly; added support for inexpensive "fake" transparency mode; many code cleanups.

1.52 (May 06, 2004): new raster ("bitmap") PostScript/EPS/PDF output formats; new Plugin(Extract) to extract a given component from a post-processing view; new Plugin(CutGrid) and Plugin(StreamLines); improved mesh projection on non-planar surfaces; added support for second order tetrahedral elements; added interactive control of element order; refined mesh entity drawing selection (and renamed most of the corresponding options); enhanced log scale in post-processing; better font selection; simplified View.Raise{X,Y,Z} by removing the scaling; various bug fixes (default postscript printing mode, drawing of 3D arrows/cylinders on Linux, default home directory on Windows, default initial file browser directory, extrusion of points with non-normalized axes of rotation, computation of the scene bounding box in scripts, + the usual

documentation updates).

1.51 (Feb 29, 2004): initial support for visualizing mesh partitions; integrated version 2.0 of the MSH mesh file format; new option to compute post-processing ranges (min/max) per time step; Multiple views can now be combined into multi time step ones (e.g. for programs that generate data one time step at a time); new syntax: #var[] returns the size of the list var[]; enhanced "gmsh -convert"; temporary and error files are now created in the home directory to avoid file permission issues; new 3D arrows; better lighting support; STL facets can now be converted into individual geometrical surfaces; many other small improvements and bug fixes (multi timestep tensors, color by physical entity, parser cleanup, etc.).

1.50 (Dec 06, 2003): small changes to the visibility browser + made visibility scriptable (new Show/Hide commands); fixed (rare) crash when deleting views; split File->Open into File->Open and File->New to behave like most other programs; Mac versions now use the system menu bar by default (if possible); fixed bug leading to degenerate and/or duplicate tetrahedra in extruded meshes; fixed crash when reloading sms meshes.

1.49 (Nov 30, 2003): made Merge, Save and Print behave like Include (i.e., open files in the same directory as the main project file if the path is relative); new Plugin(DecomposeInSimplex); new option View.AlphaChannel to set the transparency factor globally for a post-processing view; new "Combine Views" command; various bug fixes and cleanups.

1.48 (Nov 23, 2003): new DisplacementRaise plugin to plot arbitrary fields on deformed meshes; generalized CutMap, CutPlane, CutSphere and Skin plugins to handle all kinds of elements and fields; new "Save View[n]" command to save views from a script; many small bug fixes (configure tests for libpng, handling of erroneous options, multi time step scalar prism drawings, copy of surface mesh attributes, etc.).

1.47 (Nov 12, 2003): fixed extrusion of surfaces defined by only two curves; new syntax to retrieve point coordinates and indices of entities created through geometrical transformations; new PDF and compressed PostScript output formats; fixed numbering of elements created with "Extrude Point/Line"; use $GMSH_HOME as home directory if defined.

1.46 (Aug 23, 2003): fixed crash for very long command lines; new options for setting the displacement factor and Triangle's parameters + renamed a couple of options to more sensible names (View.VectorType, View.ArrowSize); various small bug fixes; documentation update.

1.45 (Jun 14, 2003): small bug fixes (min/max computation for tensor views, missing physical points in read mesh, "jumping" geometry during interactive manipulation of large models, etc.); variable definition speedup; restored support for second order elements in one- and two-dimensional meshes; documentation updates.

1.44 (Apr 21, 2003): new reference manual; added support for PNG output; fixed small configure script bugs.

1.43 (Mar 28, 2003): fixed solver interface problem on Mac OS X; new option to specify the interactive rotation center (default is now the pseudo "center of gravity" of the object, instead of (0,0,0)).

1.42 (Mar 19, 2003): suppressed the automatic addition of a ".geo" extension if the file given on the command line is not recognized; added missing Layer option for Extrude Point; fixed various small bugs.

1.41 (Mar 04, 2003): Gmsh is now licensed under the GNU General Public License; general code cleanup (indent).

1.40 (Feb 26, 2003): various small bug fixes (mainly GSL-related).

1.39 (Feb 23, 2003): removed all non-free routines; more build system work; implemented Von-Mises tensor display for all element types; fixed small GUI bugs.

1.38 (Feb 17, 2003): fixed custom range selection for 3D iso graphs; new build system based on autoconf; new image reading code to import bitmaps as post-processing views.

1.37 (Jan 25, 2003): generalized smoothing and cuts of post-processing views; better Windows integration (solvers, external editors, etc.); small bug fixes.

1.36 (Nov 20, 2002): enhanced view duplication (one can now use "Duplicata View[num]" in the input file); merged all option dialogs in a new general option window; enhanced discoverability of the view option menus; new 3D point and line display; many small bug fixes and enhancements ("Print" format in parser, post-processing statistics, smooth normals, save window positions, restore default options, etc.).

1.35 (Sep 11, 2002): graphical user interface upgraded to FLTK 1.1 (tooltips, new file chooser with multiple selection, full keyboard navigation, cut/paste of messages, etc.); colors can be now be directly assigned to mesh entities; initial tensor visualization; new keyboard animation (right/left arrow for time steps; up/down arrow for view cycling); new VRML output format for surface meshes; new plugin for spherical elevation plots; new post-processing file format (version 1.2) supporting quadrangles, hexahedra, prisms and pyramids; transparency is now enabled by default for post-processing plots; many small bug fixes (read mesh, ...).

1.34 (Feb 18, 2002): improved surface mesh of non-plane surfaces; fixed orientation of elements in 2D anisotropic algorithm; minor user interface polish and additions (mostly in post-processing options); various small bug fixes.

1.33 (Jan 24, 2002): new parameterizable solver interface (allowing up to 5 user-defined solvers); enhanced 2D aniso algorithm; 3D initial mesh speedup.

1.32 (Oct 04, 2001): new visibility browser; better floating point exception checks; fixed infinite looping when merging meshes in project files; various small clean ups (degenerate 2D extrusion, view->reload, ...).

1.31 (Nov 30, 2001): corrected ellipses; PostScript output update (better shading, new combined PS/LaTeX output format); more interface polish; fixed extra memory allocation in 2D meshes; Physical Volume handling in unv format; various small fixes.

1.30 (Nov 16, 2001): interface polish; fix crash when extruding quadrangles.

1.29 (Nov 12, 2001): translations and rotations can now be combined in extrusions; fixed coherence bug in Extrude Line; various small bug fixes and additions.

1.28 (Oct 30, 2001): corrected the 'Using Progression' attribute for tranfinite meshes to actually match a real geometric progression; new Triangulate plugin; new 2D graphs (space+time charts); better performance of geometrical transformations (warning: the numbering of some automatically created entities has changed); new text primitives in post-processing views (file format updated to version 1.1); more robust mean plane computation and error checks; various other small additions and clean-ups.

1.27 (Oct 05, 2001): added ability to extrude curves with Layers/Recombine attributes; new PointSize/LineWidth options; fixed For/EndFor loops in included files; fixed error messages (line numbers+file names) in loops and functions; made the automatic removal of duplicate geometrical entities optional (Geometry.AutoCoherence=0); various other small bug fixes and clean-ups.

1.26 (Sep 06, 2001): enhanced 2D anisotropic mesh generator (metric intersections); fixed small bug in 3D initial mesh; added alternative syntax for built-in functions (for GetDP compatibility); added line element display; Gmsh now saves all the elements in the mesh if no physical groups are defined (or if Mesh.SaveAll=1).

1.25 (Sep 01, 2001): fixed bug with mixed recombined/non-recombined extruded meshes; Linux versions are now build with no optimization, due to bugs in gcc 2.95.X.

1.24 (Aug 30, 2001): fixed characteristic length interpolation for Splines; fixed edge swapping bug in 3D initial mesh; fixed degenerated case in geometrical extrusion (ruled surface with 3 borders); fixed generation of degenerated hexahedra and prisms for recombined+extruded meshes; added BSplines creation in the GUI; integrated Jonathan Shewchuk's Triangle as an alternative isotropic 2D mesh generator; added AngleSmoothNormals to control sharp edge display with smoothed normals; fixed random crash for lighted 3D iso surfaces.

1.23 (Aug, 2001): fixed duplicate elements generation + non-matching tetrahedra faces in 3D extruded meshes; better display of displacement maps; fixed interactive ellipsis construction; generalized boundary operator; added new explode option for post-processing views; enhanced link view behavior (to update only the changed items); added new default plugins: Skin, Transform, Smooth; fixed various other small bugs (mostly in the post-processing module and for extruded meshes).

1.22 (Aug 03, 2001): fixed (yet another) bug for 2D mesh in the mean plane; fixed surface coherence bug in extruded meshes; new double logarithmic scale, saturate value and smoothed normals option for post-processing views; plugins are now enabled by default; three new experimental statically linked plugins: CutMap (extracts a given iso surface from a 3D scalar map), CutPlane (cuts a 3D scalar map with a plane section), CutSphere (cuts a 3D scalar map with a sphere); various other bug fixes, additions and clean-ups.

1.21 (Jul 25, 2001): fixed more memory leaks; added -opt command line option to parse definitions directly from the command line; fixed missing screen refreshes during contour/surface/volume selection; enhanced string manipulation functions (Sprintf, StrCat, StrPrefix); many other small fixes and clean-ups.

1.20 (Jun 14, 2001): fixed various bugs (memory leaks, functions in included files, solver command selection, ColorTable option, duplicate nodes in extruded meshes (not finished yet), infinite loop on empty views, orientation of recombined quadrangles, ...); reorganized the interface menus; added constrained background mesh and mesh visibility options; added mesh quality histograms; changed default mesh colors; reintegrated the old command-line extrusion mesh generator.

1.19 (May 07, 2001): fixed seg. fault for scalar simplex post-processing; new Solver menu; interface for GetDP solver through sockets; fixed multiple scale alignment; added some options + full option descriptions.

1.18 (Apr 26, 2001): fixed many small bugs and incoherences in post-processing; fixed broken background mesh in 1D mesh generation.

1.17 (Apr 17, 2001): corrected physical points saving; fixed parsing of DOS files (carriage return problems); easier geometrical selections (cursor change); plugin manager; enhanced variable arrays (sublist selection and affectation); line loop check; New arrow display; reduced number of 'fatal' errors + better handling in interactive mode; fixed bug when opening meshes; enhanced File->Open behavior for meshes and post-processing views.

1.16 (Feb 26, 2001): added single/double buffer selection (only useful for Unix versions of Gmsh run from remote hosts without GLX); fixed a bug for recent versions of the opengl32.dll on Windows, which caused OpenGL fonts not to show up.

1.15 (Feb 23, 2001): added automatic visibility setting during entity selection; corrected geometrical extrusion bug.

1.14 (Feb 17, 2001): corrected a few bugs in the GUI (most of them were introduced in 1.13); added interactive color selection; made the option database bidirectional (i.e. scripts now correctly update the GUI); default options can now be saved and automatically reloaded at startup; made some changes to the scripting syntax (PostProcessing.View[n] becomes View[n]; Offset0 becomes OffsetX, etc.); corrected the handling of simple triangular surfaces with large characteristic lengths in the 2D isotropic algorithm; added an ASCII to binary post-processing view converter.

1.13 (Feb 09, 2001): added support for JPEG output on Windows.

1.12: corrected vector lines in the post-processing parsed format; corrected animation on Windows; corrected file creation in scripts on Windows; direct affectation of variable arrays.

1.11 (Feb 07, 2001): corrected included file loading problem.

1.10 (Feb 04, 2001): switched from Motif to FLTK for the GUI. Many small tweaks.

1.00 (Jan 15, 2001): added PPM and YUV output; corrected nested If/Endif; Corrected several bugs for pixel output and enhanced GIF output (dithering, transparency); slightly changed the post-processing file format to allow both single and double precision numbers.

0.999 (Dec 20, 2000): added JPEG output and easy MPEG generation (see t8.geo in the tutorial); clean up of export functions; small fixes; Linux versions are now compiled with gcc 2.95.2, which should fix the problems encountered with Mandrake 7.2.

0.998 (Dec 19, 2000): corrected bug introduced in 0.997 in the generation of the initial 3D mesh.

0.997 (Dec 14, 2000): corrected bug in interactive surface/volume selection; Added interactive symmetry; corrected geometrical extrusion with rotation in degenerated or partially degenerated cases; corrected bug in 2D mesh when meshing in the mean plane.

0.996: arrays of variables; enhanced Printf and Sprintf; Simplified options (suppression of option arrays).

0.995 (Dec 11, 2000): totally rewritten geometrical database (performance has been drastically improved for all geometrical transformations, and most notably for extrusion). As a consequence, the internal numbering of geometrical entities has changed: this will cause incompatibilities with old .geo files, and will require a partial rewrite of your old .geo files if these files made use of geometrical transformations. The syntax of the .geo file has also been clarified. Many additions for scripting purposes. New extrusion mesh generator. Preliminary version of the coupling between extruded and Delaunay meshes. New option and procedural database. All interactive operations can be scripted in the input files. See the last example in the tutorial for an example. Many stability enhancements in the 2D and 3D mesh algorithms. Performance boost of the 3D algorithm. Gmsh is still slow, but the performance becomes acceptable. An average 1000 tetrahedra/second is obtained on a 600Mhz computer for a mesh of one million tetrahedra. New anisotropic 2D mesh algorithm. New (ASCII and binary) post-processing file format and clarified mesh file format. New handling for interactive rotations (trackball mode). New didactic interactive mesh construction (watch the Delaunay algorithm in real time on complex geometries: that's exciting ;-). And many, many bug fixes and cleanups.

0.992 (Nov 13, 2000): corrected recombined extrusion; corrected ellipses; added

simple automatic animation of post-processing maps; fixed various bugs.

0.991 (Oct 24, 2000): fixed a serious allocation bug in 2D algorithm, which caused random crashes. All users should upgrade to 0.991.

0.990: bug fix in non-recombined 3D transfinite meshes.

0.989 (Sep 01, 2000): added ability to reload previously saved meshes; some new command line options; reorganization of the scale menu; GIF output.

0.987: fixed bug with smoothing (leading to the possible generation of erroneous 3d meshes); corrected bug for mixed 3D meshes; moved the 'toggle view link' option to Opt->Postprocessing_Options.

0.986: fixed overlay problems; SGI version should now also run on 32 bits machines; fixed small 3d mesh bug.

0.985: corrected colormap bug on HP, SUN, SGI and IBM versions; corrected small initialization bug in postscript output.

0.984: corrected bug in display lists; added some options in Opt->General.

0.983: corrected some seg. faults in interactive mode; corrected bug in rotations; changed default window sizes for better match with 1024x768 screens (default X resources can be changed: see ex03.geo).

0.982: lighting for mesh and post-processing; corrected 2nd order mesh on non plane surfaces; added example 13.

Appendix E Copyright and credits

Christophe Geuzaine
<cgeuzaine at uliege.be>

and

Jean-Francois Remacle
<jean-francois.remacle at uclouvain.be>

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