# Gmsh

# Gmsh Reference Manual

The documentation for Gmsh 4.5.6 (development version)
A finite element mesh generator with built-in pre- and post-processing facilities

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# Short Contents

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# Obtaining Gmsh

The source code and various pre-compiled versions of Gmsh (for Windows, Mac and Unix) can be downloaded from http://gmsh.info. Gmsh is also directly available in pre-packaged form in various Linux and BSD distributions (Debian, 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 http://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 I [License], page 343). Further information about this license is available from the GNU Project webpage `http://www.gnu.org/copyleft/gpl-faq.html`. Detailed copyright information can be found in Appendix H [Copyright and credits], page 339.

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.

# 1 Overview

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 advanced visualization capabilities.

Gmsh is built around four modules: geometry, mesh, solver and post-processing. All geometrical, mesh, solver and post-processing instructions are prescribed either interactively using the graphical user interface (GUI) or in text files using Gmsh's own scripting language. Interactive actions generate language bits in the input files, and vice versa. A programming API is also available, for integrating Gmsh in your own C++, C, Python or Julia code: see Appendix D [Gmsh API], page 259. A brief description of the four modules is given hereafter.

## 1.1 Geometry: model entity creation

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, edges 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.

Gmsh's scripting language and the Gmsh API allow to parametrize all model entities. The entities can either be built in a "bottom-up" manner (first points, then curves, surfaces and volumes) or in a "Constructive Solid Geometry" fashion (solids on which boolean operations are performed). Both methodologies can also be combined. Finally, groups of model entities (called "physical groups") can be defined, based on the elementary geometric entities.

## 1.2 Mesh: finite element mesh generation

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. Gmsh implements several algorithms to generate such meshes automatically. All the 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. Every meshing step is constrained by a "size field" (also called "characteristic length 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 "fields" (for example related to the distance to some boundary, to a arbitrary scalar field defined on another mesh, etc.): see Section 6.3.1 [Specifying mesh element sizes], page 49. For each meshing step, all structured mesh directives are executed first, and serve as additional constraints for the unstructured parts.

## 1.3 Solver: external solver interface

Gmsh implements a ONELAB (http://onelab.info) server to pilot external solvers (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.

Examples on how to interface solvers are available in the source distribution (see utils/solvers). A full-featured solver interfaced in this manner is GetDP (http://getdp.info), a general finite elements solver using mixed finite elements.

Using the Gmsh API, Gmsh can also be embedded directly in your own solver, and ONELAB parameters can be used to interactively drive it. Examples on how to embed Gmsh in your solver, and build a custom graphical user interface to control it, are available in demos/api. See in particular custom_gui.py and custom_gui.cpp.

## 1.4 Post-processing: scalar, vector and tensor field visualization

Gmsh can load and manipulate multiple post-processing scalar, vector or tensor fields along with the geometry and the mesh. Such fields, together with visualization options, are called "post-processing views" (or simply "views"). Scalar views can be represented by iso-curves, iso-surfaces or color maps, while vector views can be represented by three-dimensional arrows or displacement maps. Post-processing functions include section computation, offset, elevation, boundary and component extraction, color map and range modification, animation, vector graphic output, etc. All the post-processing options can be accessed either interactively, through the input script files or through the API. Various operations on the

post-processing data can also be performed through plugins (see Section 8.2 [Post-processing plugins], page 82).

## 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 4.5 [User-defined macros], page 28, Section 4.6 [Loops and conditionals], page 29, and Section 4.7 [General commands], page 30). For more advanced geometries, using the Gmsh API (see Appendix D [Gmsh API], page 259) in the language of your choice (C++, C, Python or Julia) brings even greater flexibility, the only downside being that you need to either compile your code (for C++ and C) 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;

- parametrize these geometries. Gmsh's scripting language or the Gmsh API enable all commands and command arguments to depend on previous calculations (see Section 4.2 [Expressions], page 21, Section 5.1 [Geometry commands], page 37, and Appendix D [Gmsh API], page 259). Using the OpenCASCADE geometry kernel, Gmsh gives access to all usual constructive solid geometry operations;

- 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;

- generate 1D, 2D and 3D simplicial (i.e., using line segments, triangles and tetrahedra) finite element meshes (see Chapter 6 [Mesh module], page 47), with fine control over the element size (see Section 6.3.1 [Specifying mesh element sizes], page 49);

- create simple extruded geometries and meshes (see Section 5.1 [Geometry commands], page 37, and Section 6.3 [Mesh commands], page 49), 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 Chapter 7 [Solver module], page 75);

- 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 Chapter 8 [Post-processing module], page 77), can export plots in many different formats (see Section B.1 [General options list], page 169), and can generate complex animations (see Chapter 4 [General tools], page 21, and Section A.8 [t8.geo], page 151);

- run on low end machines and/or machines with no graphical interface. Gmsh can be compiled with or without the GUI (see Appendix C [Compiling the source code], page 253), and all versions can be used either interactively or directly from the command line (see Chapter 3 [Running Gmsh on your system], page 11);

- 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 3 [Running Gmsh on your system], page 11 and Appendix B [Options], page 169);

- and do all the above on various platforms (Windows, Mac and Unix), 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 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 E [Information for developers], page 313) to remedy the aforementioned (and all other) shortcomings!

## 1.7  Bug reports

Please file issues 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 the version of your operation system (see Section 3.3 [Command-line options], page 12 to see how to get this information).

See Appendix F [Frequently asked questions], page 315, and the bug tracking system to see which problems we already know about.

# 2 How to read this reference manual?

Gmsh can be used at three levels:

1. as a stand-alone application manipulated through its graphical user interface (GUI);

2. as a stand-alone script-driven application;

3. as a library.

You can skip most of this reference manual if you only want to use Gmsh at the first level (i.e., interactively with the GUI). Just read the next chapter (see Chapter 3 [Running Gmsh on your system], page 11) to learn how to launch Gmsh on your system, then go experiment with the GUI and the tutorial files (see Appendix A [Tutorial], page 137) provided in the distribution. Screencasts that show how to use the GUI are available here: http://gmsh.info/screencasts/.

The aim of the reference manual is to explain everything you need to use Gmsh at the second level, i.e., using the built-in scripting language. A Gmsh script file is an ASCII text file that contains instructions in Gmsh's built-in scripting language. Such a file is interpreted by Gmsh's parser, and can be given any extension (or no extension at all). By convention, Gmsh uses the '`.geo`' extension for geometry scripts, and the '`.pos`' extension for parsed post-processing datasets. Once you master the tutorial (read the source files: they are heavily commented!), start reading chapter Chapter 4 [General tools], page 21, then proceed with the next four chapters, which detail the syntax of the geometry, mesh, solver and post-processing scripting commands. You will see that most of the interactive actions in the GUI have a direct equivalent in the scripting language. If you want to use Gmsh as a pre- or post-processor for your own software, you will also want to learn about the non-scripting input/output files that Gmsh can read/write. In addition to Gmsh's native "MSH" file format (see Chapter 9 [File formats], page 113), Gmsh can read/write many standard mesh files, depending on how it was built: check the 'File->Export' menu for a list of available formats.

Finally, to use Gmsh at the third level (i.e., to link the Gmsh library with your own code), you will need to learn the Gmsh Application Programming Interface (API). This API is available in C++, C, Python and Julia, and is fully documented in Appendix D [Gmsh API], page 259.

## 2.1 Syntactic rules used in the manual

Here are the rules we tried to follow when writing this reference manual. Note that metasyntactic variable definitions stay valid throughout the manual (and not only in the sections 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.

# 3 Running Gmsh on your system

## 3.1 Interactive mode

To launch Gmsh in interactive mode, just double-click on the Gmsh icon, or type

```
> gmsh
```

at your shell prompt in a terminal. This will open the main Gmsh window, with a tree-like menu on the left, a graphic area on the right, and a status bar at the bottom. (You can detach the tree menu using 'Window->Attach/Detach Menu'.)

To open the first tutorial file (see Appendix A [Tutorial], page 137), select the 'File->Open' menu, and choose t1.geo. When using a terminal, you can specify the file name directly on the command line, i.e.:

```
> gmsh t1.geo
```

To perform the mesh generation, go to the mesh module (by selecting 'Mesh' in the tree) and choose the 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', 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[1].

To create a new geometry or to modify an existing geometry, select 'Geometry' in the tree. For example, to create a spline, select 'Elementary entities', 'Add', 'New' and 'Spline'. You will then be asked to select a list of points, and to type *e* to finish the selection (or *q* to abort it). Once the interactive command is completed, a text string is automatically added at the end of the current script file. You can edit the script file by hand at any time by pressing the 'Edit' button in the 'Geometry' menu and then reloading the model by pressing 'Reload'. 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.

Several files can be loaded simultaneously in Gmsh. When specified on the command line, the first one defines the active model and the others are 'merged' into this model. You can merge such files with 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 A.1 [t1.geo], page 137, you can type the following command:

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

In the Post-Processing module (select 'Post-Processing' in the tree), three items will appear, 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 small "remote-control" icons in 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.

---

[1] Nearly all the interactive commands have keyboard shortcuts: see Section 3.5 [Keyboard shortcuts], page 17, or select 'Help->Keyboard and Mouse Usage' in the menu. For example, to quickly save a mesh, you can press *Ctrl+Shift+s*.

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. Finally, 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 Appendix B [Options], page 169. A full list of options with their current values is also available in the 'Help->Current Options' menu.

## 3.2 Non-interactive mode

Gmsh can be run non-interactively in 'batch' mode, without GUI[2]. For example, to mesh the first tutorial in batch mode, just type:

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

To mesh the same example, but with the background mesh available in the file bgmesh.pos, type:

```
> gmsh t1.geo -2 -bgm bgmesh.pos
```

For the list of all command-line options, see Section 3.3 [Command-line options], page 12. In particular, any complicated workflow can be written in a .geo file, and this file can be executed as a script using

```
> gmsh script.geo -
```

The script can contain e.g. meshing commands, like Mesh 3;.

## 3.3 Command-line options

(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

-save       Save mesh, then exit

-o file     Specify output file name

---

[2] If you compile Gmsh without the GUI (see Appendix C [Compiling the source code], page 253), this is the only mode you have access to.

`-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 (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, pack, del3d, front3d, mmg3d, hxt (Mesh.Algorithm andMesh.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.CharacteristicLengthFactor)

`-clmin value`

> Set minimum mesh element size (Mesh.CharacteristicLengthMin)

`-clmax value`

> Set maximum mesh element size (Mesh.CharacteristicLengthMax)

`-clcurv value`

> Compute mesh element size from curvature, with given minimum number of elements per 2*pi radians (Mesh.CharacteristicLengthFromCurvature and Mesh.MinimumElementsPerTwoPi)

`-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`     Always listen to incoming connection requests (Solver.AlwaysListen)

`-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

`-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)

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

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

`-setnumber name value`
        Set constant or option number name=value

`-setstring name value`
        Set constant or option string name=value

`-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

## 3.4 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.

## 3.5  Keyboard shortcuts

(On Mac Ctrl is replaced by Cmd (the 'Apple key') 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`           Toogle x coordinate freeze in geometry creation mode

`y`           Toogle y coordinate freeze in geometry creation mode

`z`           Toogle 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+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+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 points

`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

# 4 General tools

This chapter describes the general commands and options that can be used in Gmsh's script files. By "general", we mean "not specifically related to one of the geometry, mesh, solver or post-processing modules". Commands peculiar to these modules will be introduced in Chapter 5 [Geometry module], page 37, Chapter 6 [Mesh module], page 47, Chapter 7 [Solver module], page 75, and Chapter 8 [Post-processing module], page 77, respectively.

If you plan to use Gmsh through its API (see Appendix D [Gmsh API], page 259) instead of the built-in scripting language, you can skip this chapter entirely.

## 4.1 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.

## 4.2 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.

### 4.2.1 Floating point expressions

Floating point expressions (or, more simply, "expressions") are denoted by the metasyntactic variable *expression* (remember the definition of the syntactic rules in Section 2.1 [Syntactic rules], page 9), 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 |
  real-option |
  Find(expression-list-item, expression-list-item) |
  StrFind(char-expression, char-expression) |
  StrCmp(char-expression, char-expression) |
  StrLen(char-expression) |
```

```
TextAttributes(char-expression<,char-expression...>) |
Exists(string) | Exists(string~{ expression }) |
FileExists(char-expression) |
StringToName(char-expression) | S2N(char-expression) |
GetNumber(char-expression <,expression>) |
GetValue("string", expression) |
DefineNumber(expression, onelab-options)
```

Such *expressions* 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 4.6 [Loops and conditionals], page 29), 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 4.3 [Operators], page 25. For the definition of *built-in-functions*, see Section 4.4 [Built-in functions], page 27. The various *real-options* are listed in Appendix B [Options], page 169. `Find` searches for occurrences of the first expression in the second (both of which can be lists). `StrFind` searches the first *char-expression* for any occurrence of the second *char-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 B.1 [General options list], page 169), 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 } |
  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 *expressions*, with a unit incrementation step. The third case also permits to create a list containing the range of numbers comprised between two *expressions*, 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 5.1.7 [Transformations], page 44, Section 5.1.5 [Extrusions], page 42 and Section 5.1.6 [Boolean operations], page 43).

The next two cases allow to retrieve entities in a given bounding box, or get the bounding box of a given entity. The last five cases permit to retrieve the mass or the center of mass of an entity, the coordinates of a given geometry point (see Section 5.1.1 [Points], page 37), 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
Appendix A [Tutorial], page 137. 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.

## 4.2.2 Character expressions

Character expressions are defined as:

    *char-expression* :
      "*string*" |
      *string* | *string*[ *expression* ] |
      Today | OnelabAction | GmshExecutableName |
      CurrentDirectory | CurrentDir | CurrentFileName
      StrPrefix ( *char-expression* ) |
      StrRelative ( *char-expression* ) |
      StrCat ( *char-expression* <,...> ) |
      Str ( *char-expression* <,...> ) |
      StrChoice ( *expression*, *char-expression*, *char-expression* ) |
      StrSub( *char-expression*, *expression*, *expression* ) |
      StrSub( *char-expression*, *expression* ) |
      UpperCase ( *char-expression* ) |
      AbsolutePath ( *char-expression* ) |
      DirName ( *char-expression* ) |
      Sprintf ( *char-expression* , *expression-list* ) |
      Sprintf ( *char-expression* ) |
      Sprintf ( *char-option* ) |
      GetEnv ( *char-expression* ) |
      GetString ( *char-expression* <,*char-expression*>) |
      GetStringValue ( *char-expression* , *char-expression* ) |
      StrReplace ( *char-expression* , *char-expression* , *char-expression* )
      NameToString ( *string* ) | N2S ( *string* ) |
      <Physical> Point|Curve|Surface|Volume { *expression* } |
      DefineString(*char-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` concate-
nate character expressions (`Str` adds a newline character after each string except the last).

`StrChoice` returns the first or second *char-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 pro-
vided). `UpperCase` converts the *char-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 *char-expression* is a format string that can contain floating point
formatting characters: `%e`, `%g`, etc.) The various *char-option*s are listed in Appendix B [Op-
tions], page 169. `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 *char-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.

Character expressions are mostly used to specify non-numeric options and input/output file
names. See Section A.8 [t8.geo], page 151, for an interesting usage of *char-expression*s in
an animation script.

List of character expressions are defined as:

```
char-expression-list:
  char-expression <,...>
```

### 4.2.3 Color expressions

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

```
color-expression:
  char-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 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 Appendix B [Options], page 169.

See Section A.3 [t3.geo], page 141, for an example of the use of color expressions.

## 4.3 Operators

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

*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. =, +=, -=, *=, /=

## 4.4  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*.

## 4.5  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`*` | `*`char-expression`*
>      Begins 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`    Ends the body of the current user-defined macro. Macro declarations cannot be imbricated.

`Call `*`string`*` | `*`char-expression`*` ;`
>      Executes the body of a (previously defined) macro named *string*.

See Section A.5 [t5.geo], page 145, 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!

## 4.6 Loops and conditionals

Loops and conditionals are defined as follows, and can be imbricated:

**For ( *expression* : *expression* )**
> Iterates 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* )**
> Iterates 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* }**
> Iterates 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* }**
> Iterates 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**   Ends 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**   Ends a matching `If` command.

See Section A.5 [t5.geo], page 145, for an example of `For` and `If` commands. Gmsh does not provide any `Else` (or similar) command at the time of this writing.

## 4.7  General commands

The following commands can be used anywhere in a Gmsh script:

*string* = *expression* ;
> Creates a new expression identifier *string*, or affects *expression* to an existing expression identifier. The following expression identifiers are predefined (hard-coded in Gmsh's parser):

Pi
> Returns 3.1415926535897932.

GMSH_MAJOR_VERSION
> Returns Gmsh's major version number.

GMSH_MINOR_VERSION
> Returns Gmsh's minor version number.

GMSH_PATCH_VERSION
> Returns Gmsh's patch version number.

MPI_Size
> Returns the number of processors on which Gmsh is running. It is always 1, except if you compiled Gmsh with ENABLE_MPI (see Appendix C [Compiling the source code], page 253).

MPI_Rank
> Returns the rank of the current processor.

Cpu
> Returns the current CPU time (in seconds).

Memory
> Returns the current memory usage (in Mb).

TotalMemory
> Returns the total memory available (in Mb).

newp
> Returns the next available point tag. As explained in Chapter 5 [Geometry module], page 37, 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 4.5 [User-defined macros], page 28) or general geometric primitives, when one does not know *a priori* which tags are already attributed, and which ones are still available.

newl
> Returns the next available curve tag.

news
> Returns the next available surface tag.

newv
> Returns the next available volume tag.

newll
> Returns the next available curve loop tag.

newsl
> Returns the next available surface loop tag.

newreg
> Returns the next available region tag. That is, newreg returns the maximum of newp, newl, news, newv, newll, newsl and all physical group tags[2].

---

[2] For compatibility purposes, the behavior of newl, news, newv and newreg can be modified with the Geometry.OldNewReg option (see Section B.2 [Geometry options list], page 199).

*string* = { };
> Creates a new expression list identifier **string** with an empty list.

*string* [] = { *expression-list* };
> Creates 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* };
> Affects 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* ;
> Adds and affects *expression* to an existing expression identifier.

*string* -= *expression* ;
> Subtracts and affects *expression* to an existing expression identifier.

*string* *= *expression* ;
> Multiplies and affects *expression* to an existing expression identifier.

*string* /= *expression* ;
> Divides and affects *expression* to an existing expression identifier.

*string* += { *expression-list* };
> Appends *expression-list* to an existing expression list or creates a new expression list with *expression-list*.

*string* -= { *expression-list* };
> Removes the items in *expression-list* from the existing expression list.

*string* [ { *expression-list* } ] += { *expression-list* };
> Adds and affects, 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* };
> Subtracts and affects, 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* };
> Multiplies and affects, 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* };
> Divides and affects, item per item, the right hand side *expression-list* to an existing expression list identifier. Parentheses can also be used instead of brackets.

*string* = *char-expression* ;
> Creates a new character expression identifier **string** with a given *char-expression*.

*string* `[] =` `Str(` *char-expression-list* `)` `;`

> Creates a new character expression list identifier **string** with a given *char-expression-list*. Parentheses can also be used instead of brackets.

*string* `[] +=` `Str(` *char-expression-list* `)` `;`

> Appends a character expression list to an existing list. Parentheses can also be used instead of brackets.

`DefineConstant[` *string* `= expression|char-expression <, ...>];`

> Creates a new expression identifier *string*, with value *expression*, only if has not been defined before.

`DefineConstant[` *string* `= {` *expression|char-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(` *char-expression* `, expression );`

> Sets the value a numeric ONELAB variable *char-expression*.

`SetString(` *char-expression* `, char-expression );`

> Sets the value a string ONELAB variable *char-expression*.

*real-option* `= expression;`

> Affects *expression* to a real option.

*char-option* `= char-expression;`

> Affects *char-expression* to a character option.

*color-option* `= color-expression;`

> Affects *color-expression* to a color option.

*real-option* `+= expression;`

> Adds and affects *expression* to a real option.

*real-option* `-= expression;`

> Subtracts and affects *expression* to a real option.

*real-option* `*= expression;`

> Multiplies and affects *expression* to a real option.

*real-option* `/= expression;`

> Divides and affects *expression* to a real option.

`Abort;`      Aborts the current script.

`Exit;`       Exits Gmsh.

`CreateDir` *char-expression* `;`

> Create the directory *char-expression*.

`Printf (` *char-expression* `<, expression-list> );`

> Prints a character expression in the information window and/or on the terminal. `Printf` is equivalent to the `printf` C function: *char-expression* is a format string that can contain formatting characters (`%f`, `%e`, etc.). Note that

all *expressions* are evaluated as floating point values in Gmsh (see Section 4.2 [Expressions], page 21), so that only valid floating point formatting characters make sense in *char-expression*. See Section A.5 [t5.geo], page 145, for an example of the use of `Printf`.

`Printf ( `*`char-expression`*` , `*`expression-list`*` ) > `*`char-expression`*`;`

Same as `Printf` above, but output the expression in a file.

`Printf ( `*`char-expression`*` , `*`expression-list`*` ) >> `*`char-expression`*`;`

Same as `Printf` above, but appends the expression at the end of the file.

`Warning|Error ( `*`char-expression`*` <, `*`expression-list`*`> );`

Same as `Printf`, but raises a warning or an error.

`Merge `*`char-expression`*`;`

Merges a file named *char-expression*. This command is equivalent to the 'File->Merge' menu in the GUI. If the path in *char-expression* is not absolute, *char-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( `*`char-expression`*` );`

Merges a BREP, STEP or IGES file and returns the tags of the highest-dimensional entities. Only available with the OpenCASCADE geometry kernel.

`Draw;`      Redraws the scene.

`SetChanged;`

Force the mesh and post-processing vertex arrays to be regenerated. Useful e.g. for creating animations with changing clipping planes, etc.

`BoundingBox;`

Recomputes 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`*` };`

Forces the bounding box of the scene to the given *expression*s (X min, X max, Y min, Y max, Z min, Z max).

`Delete Model;`

Deletes the current model (all model entities and their associated meshes).

`Delete Physicals;`
>     Deletes all physical groups.

`Delete Variables;`
>     Deletes all the expressions.

`Delete Options;`
>     Deletes the current options and revert to the default values.

`Delete` *string* `;`
>     Deletes the expression *string*.

`Print` *char-expression* `;`
>     Prints the graphic window in a file named *char-expression*, using the current
>     `Print.Format` (see Section B.1 [General options list], page 169). If the path in
>     *char-expression* is not absolute, *char-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* `;`
>     Suspends the execution of Gmsh during *expression* seconds.

`SystemCall` *char-expression* `;`
>     Executes a (blocking) system call.

`NonBlockingSystemCall` *char-expression* `;`
>     Executes a (non-blocking) system call.

`OnelabRun (` *char-expression* `<,` *char-expression* `> )`
>     Runs a ONELAB client (first argument is the client name, second optional
>     arguement is the command line).

`SetName` *char-expression* `;`
>     Changes the name of the current model.

`SetFactory(`*char-expression*`);`
>     Changes 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;`
>     Forces an immediate transfer from the old geometrical database into the new
>     one (this transfer normally occurs right after a file is read).

`NewModel;`
>     Creates a new current model.

`Include` *char-expression* `;`
>     Includes the file named *char-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
>     *char-expression* is not absolute, *char-expression* is appended to the path of the
>     current file.

## 4.8 General options

The list of all the general *char-option*s, *real-option*s and *color-option*s (in that order—check the default values to see the actual types) is given in Section B.1 [General options list], page 169. Most of these options are accessible in the GUI, but not all of them. When running Gmsh interactively, changing an option in the script file will modify the option in the GUI in real time. This permits for example to resize the graphical window in a script, or to interact with animations in the script and in the GUI at the same time.

# 5 Geometry module

Geometries can be constructed in Gmsh using different underlying CAD kernels. Selecting the CAD kernel in `.geo` files is done with the `SetFactory` command. 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.

The built-in CAD kernel (`SetFactory("Built-in")`) provides a simple CAD engine based on a bottom-up boundary representation approach: you need to first define points (using the `Point` command: see below), 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). The OpenCASCADE kernel (`SetFactory("OpenCASCADE")`) allows to build models in the same bottom-up manner, or by using a constructive solid geometry approach where solids are defined first. Boolean operations can then be performed to modify them.

These geometrical model entities are also referred to as "elementary entities" in Gmsh, and are assigned tags (strictly positive global identification numbers) when they are created:

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.

Elementary 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. Zero or negative tags are reserved by the system for special uses: do not use them in your scripts.

Groups of elementary entities can also be defined and are called "physical" groups. These physical groups cannot be modified by geometry commands: their only purpose is to assemble elementary entities into larger groups so that they can be referred to later as single entities. As is the case with elementary entities, each physical point, physical curve, physical surface or physical volume must be assigned a unique tag. See Chapter 6 [Mesh module], page 47, for more information about how physical groups affect the way meshes are saved.

## 5.1 Geometry commands

The next subsections describe all the available geometry commands in the scripting language. For the equivalent commands in the Gmsh API, see the `gmsh/model/geo` and `gmsh/model/occ` namespaces in Appendix D [Gmsh API], page 259.

Note that the following general syntax 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."

### 5.1.1 Points

`Point ( expression ) = { expression, expression, expression <, expression > };`
> Creates 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 6.3.1 [Specifying mesh element sizes], page 49, for more information about how this value is used in the meshing process.

Physical Point ( *expression* | *char-expression* <, *expression*> ) <+|->= { *expression-list* };

Creates 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 *char-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).

## 5.1.2 Curves

Line ( *expression* ) = { *expression*, *expression* };

Creates a straight line segment. The *expression* inside the parentheses is the line segment's tag; the two *expressions* inside the braces on the right hand side give tags of the start and end points of the segment.

Bezier ( *expression* ) = { *expression-list* };

Creates a Bezier curve. The *expression-list* contains the tags of the control points.

BSpline ( *expression* ) = { *expression-list* };

Creates 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* };

Creates a spline going through the points in *expression-list*. With the built-in geometry kernel this constructs a Catmull-Rom spline. With the OpenCAS-CADE kernel, this constructs a C2 BSpline. Creates a periodic curve if the first and last points are identical.

Circle ( *expression* ) = { *expression*, *expression*, *expression* <, ...> };

Creates a circle arc. The three *expressions* on the right-hand-side 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 additional *expressions* can be provided to define a full circle (4th expression is the radius) or a circle arc between two angles (next 2 expressions).

Ellipse ( *expression* ) = { *expression*, *expression*, *expression*, <, ...> };

Creates an ellipse arc. If four *expressions* 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;`

Creates 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 };`

Creates 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, and 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. Although Gmsh supports it, it is not recommended to specify multiple curve loops (or subloops) in a single `Curve Loop` command. (Curve loops are used to create surfaces: see Section 5.1.3 [Surfaces], page 39.)

`Wire ( expression ) = { expression-list };`

Creates a path made of curves. Wires are only available with the OpenCAS-CADE kernel. They are used to create `ThruSections` and extrusions along paths.

`Physical Curve ( expression | char-expression <, expression> ) <+|->= { expression-list };`

Creates 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 *char-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.

## 5.1.3 Surfaces

`Plane Surface ( expression ) = { expression-list };`

Creates 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`*` } >;`
>    Creates a surface filling. With the built-in kernel, the first curve loop should be
>    composed of either three or four curves. With the built-in kernel, 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).

`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`*` };`
>    Creates 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 >;`
>    Creates 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 con-
>    sistently (using negative tags to specify reverse orientation). (Surface loops are
>    used to create volumes: see Section 5.1.4 [Volumes], page 40.) With the Open-
>    CASCADE 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`*` | `*`char-expression`*` <, `*`expression`*`> ) <+|->= {`
`  `*`expression-list`*` };`
>    Creates 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 *char-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.

## 5.1.4 Volumes

`Volume ( `*`expression`*` ) = { `*`expression-list`*` };`
>    Creates 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* };

> Creates a sphere, defined by the 3 coordinates of its center and a radius. Additional expressions define 3 angle limits. `Sphere` is only available with the OpenCASCADE kernel.

Box ( *expression* ) = { *expression-list* };

> Creates 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* };

> Creates 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* };

> Creates 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* };

> Creates 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* };

> Creates 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* };

> Creates 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* | *char-expression* <, *expression*> ) <+|->= { *expression-list* };

> Creates 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 *char-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).

### 5.1.5 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 6.3.2 [Structured grids], page 67, to see how these commands can be extended in order to also extrude the mesh):

*extrude*:

`Extrude { expression-list } { extrude-list }`

> Extrudes all elementary entities (points, curves or surfaces) in *extrude-list* using a translation. The *expression-list* should contain three *expressions* giving the X, Y and Z components of the translation vector.

`Extrude { { expression-list }, { expression-list }, expression } { extrude-list }`

> Extrudes all elementary entities (points, curves or surfaces) in *extrude-list* using a rotation. The first *expression-list* should contain three *expressions* giving the X, Y and Z direction of the rotation axis; the second *expression-list* should contain three *expressions* 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 }`

> Extrudes 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 *expressions* giving the X, Y and Z components of the translation vector; the second *expression-list* should contain three *expressions* 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 *expressions* 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 }`

> Extrudes 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 }`

> Extrudes entities in *extrude-list* along the give wire. Only available with the OpenCASCADE geometry kernel.

`ThruSections { expression-list }`

> Creates surfaces through the given curve loops or wires. `ThruSections` is only available with the OpenCASCADE kernel.

`Ruled ThruSections { expression-list }`

> Creates 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 }`

> Fillets 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 4.2.1 [Floating point expressions], page 21, *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 B.2 [Geometry options list], page 199).

### 5.1.6 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* ` }`

Computes the intersection of the object and the tool.

`BooleanUnion { ` *boolean-list* ` } { ` *boolean-list* ` }`

Computes the union of the object and the tool.

`BooleanDifference { ` *boolean-list* ` } { ` *boolean-list* ` }`

Subtract the tool from the object.

`BooleanFragments { ` *boolean-list* ` } { ` *boolean-list* ` }`

Computes all the fragments resulting from the intersection of the entities in the object and in the tool, and makes all interfaces unique.

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 4.2.1 [Floating point expressions], page 21, *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 demos/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 };`
> Computes the intersection of the object and the tool and assign the result the tag *expression*.

`BooleanUnion { boolean-list } { boolean-list }`
> Computes the union of the object and the tool and assign the result the tag *expression*.

`BooleanDifference { boolean-list } { boolean-list }`
> Subtract the tool from the object and assign the result the tag *expression*.

Again, see demos/boolean for examples.

Boolean operations are only available with the OpenCASCADE geometry kernel.

### 5.1.7 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 }`
> Scales all elementary entities in *transform-list* by a factor *expression*. The *expression-list* should contain three *expressions* giving the X, Y, and Z coordinates of the center of the homothetic transformation.

`Dilate { { expression-list }, { expression, expression, expression } } { transform-list }`
> Scales all elementary entities in *transform-list* using different factors along X, Y and Z (the three *expressions*). The *expression-list* should contain three *expressions* giving the X, Y, and Z coordinates of the center of the homothetic transformation.

`Rotate { { expression-list }, { expression-list }, expression } { transform-list }`
> Rotates all elementary entities in *transform-list* by an angle of *expression* radians. The first *expression-list* should contain three *expressions* giving the X, Y and Z direction of the rotation axis; the second *expression-list* should contain three *expressions* giving the X, Y and Z components of any point on this axis.

`Symmetry { `*`expression-list`*` } { `*`transform-list`*` }`

> Transforms 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`*` }`

> Applies 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`*` }`

> Translates 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.) Returns 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.) Returns 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.) Returns 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.

with

```
transform-list:
  <Physical> Point | Curve | Surface | Volume
    { expression-list-or-all }; ... |
  Duplicata { <Physical> Point | Curve | Surface | Volume
    { expression-list-or-all }; ... } |
  transform
```

## 5.1.8 Miscellaneous

Here is a list of all other geometry commands currently available:

`Coherence;`

> Removes 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 B.2 [Geometry options list], page 199). With the OpenCASCADE geoemtry kernel, `Coherence` is simply a shortcut for a `BooleanFragments` operation on all entities.

`< Recursive > Delete { <Physical> Point | Curve | Surface | Volume {`
`expression-list-or-all }; ... }`

> Deletes 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 }; ... }`

> Deletes 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.

`< Recursive > Hide { <Physical> Point | Curve | Surface | Volume {`
`expression-list-or-all }; ... }`

> Hide the entities listed in *expression-list-or-all*, if `General.VisibilityMode` is set to `0` or `1`.

`Hide { : }`

> Hide all entities, if `General.VisibilityMode` is set to `0` or `1`.

`< Recursive > Show { <Physical> Point | Curve | Surface | Volume {`
`expression-list-or-all }; ... }`

> Show the entities listed in *expression-list-or-all*, if `General.VisibilityMode` is set to `0` or `1`.

`Show { : }`

> Show all entities, if `General.VisibilityMode` is set to `0` or `1`.

## 5.2  Geometry options

The list of all the options that control the behavior of geometry commands, as well as the way model entities are handled in the GUI, is given in Section B.2 [Geometry options list], page 199.

# 6 Mesh module

Gmsh's mesh module regroups several 1D, 2D and 3D meshing algorithms, all producing grids conforming in the sense of finite elements (see Section 1.2 [Mesh], page 5):

- 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 `Recombine` commands (see Section 6.3.2 [Structured grids], page 67, and Section 6.3.3 [Miscellaneous mesh commands], page 70). 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.SubdivisionAlgorihm` option (see Section B.3 [Mesh options list], page 208).

## 6.1 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[1]. Missing edges are recovered using edge swaps[2]. After this initial step several algorithms can be applied to generate the final mesh:

- The "MeshAdapt" algorithm[3] 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[4]. 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[5].

---

[1] 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.

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

[3] 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.

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

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

- Other experimental algorithms with specific features are also available. In particular, "Frontal-Delaunay for Quads"[6] is a variant of the "Frontal-Delaunay" algorithm aiming at generating right-angle triangles suitable for recombination; and "BAMG"[7] allows to generate anisotropic triangulations.

For very complex curved surfaces the "MeshAdapt" algorithm is the most robust. When high element quality is important, the "Delaunay-Frontal" algorithm should be tried. For very large meshes of plane surfaces the "Delaunay" algorithm is the fastest. 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[8].
- The "HXT" algorithm[9] is a new efficient and parallel reimplementaton of the Delaunay algorithm.
- Other experimental algorithms with specific features are also available. In particular, "MMG3D"[10] allows to generate anisotropic tetrahedralizations.

The "Delaunay" algorithm is currently the most robust and is the only one that supports embedded model entities, the `Field` mechanism to specify element sizes (see Section 6.3.1 [Specifying mesh element sizes], page 49) and the automatic generation of hybrid meshes with pyramids.

If your version of Gmsh is compiled with OpenMP support (see Appendix C [Compiling the source code], page 253), most of the meshing steps can be performed in parallel:

- 1D and 2D meshing is parallelized using a coarse-grain 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 Section 3.3 [Command-line options], page 12), or with the `General.NumThreads`, `Mesh.MaxNumThreads1D`, `Mesh.MaxNumThreads2D` and `Mesh.MaxNumThreads3D` options

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[6] 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.

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

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

[9] 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.

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

(see Section B.1 [General options list], page 169 and Section B.3 [Mesh options list], page 208).

## 6.2 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 Chapter 5 [Geometry module], page 37) through "physical groups".

By default in the MSH file format and in most other formats (see Chapter 9 [File formats], page 113), 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 element wether or not physical groups are defined, use the `Mesh.SaveAll` option (see Section B.3 [Mesh options list], page 208) or specify `-save_all` on the command line. In some formats (e.g. MSH2), setting `Mesh.SaveAll=1` discards all physical group definitions.

## 6.3 Mesh commands

The mesh module commands allow to modify the mesh element sizes and specify structured grid parameters. Certain mesh "actions" (i.e., "mesh the curves", "mesh the surfaces" and "mesh the volumes") can also be specified in the script files but are usually performed either in the GUI or on the command line (see Chapter 3 [Running Gmsh on your system], page 11, and Section 3.3 [Command-line options], page 12).

In the Gmsh API, the mesh commands are available in the `gmsh/model/mesh` module (see Appendix D [Gmsh API], page 259).

### 6.3.1 Specifying mesh element sizes

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

1. First, if the two options `Mesh.CharacteristicLengthFromPoints` and `Mesh.CharacteristicLengthExtendFromBoundary` are set (they are by default; see Section B.3 [Mesh options list], page 208), you can simply specify desired mesh element sizes at the geometrical points of the model (with the `Point` command: see Section 5.1.1 [Points], page 37). 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.CharacteristicLengthFromCurvature` is set (it is not by default), the mesh will be adapted with respect to the curvature of the model entities and the value of `Mesh.MinimumCirclePoints`, which gives the number of points per 2 Pi radians.

3. Finally, you can specify a general background mesh size, expressed as a combination of so-called mesh size fields:

   - 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 8.1 [Post-processing commands], page 78, and Chapter 9 [File formats], page 113) 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, in an iterative process of mesh adaptation). Warning: only parsed ('`.pos`') files can currently be used as background meshes ('`.msh`' files cannot be used, since the mesh used to define the field will be destroyed during the meshing process). (Note that you can also load a background mesh directly from the command line using the `-bgm` option (see Section 3.3 [Command-line options], page 12), or in the GUI by selecting 'Apply as background mesh' in the post-processing view option menu.)

- The `Min` field specifies the size as the minimum of the sizes computed using other fields.

- ...

The list of available fields with their options is given below. An example is available in Section A.10 [t10.geo], page 155.

The three aforementioned methods can be used simultaneously, in which case the smallest element size is selected at any given point. In addition, boundary mesh sizes (on curves or surfaces) are interpolated inside the enclosed entity (surface or volume, respectively) if the option `Mesh.CharacteristicLengthExtendFromBoundary` is set (it is by default).

All element sizes are further constrained in the interval [ `Mesh.CharacteristicLengthMin`, `Mesh.CharacteristicLengthMax` ] (which can also be provided on the command line with `-clmin` and `-clmax`). The resulting value is then finally multiplied by `Mesh.CharacteristicLengthFactor` (`-clscale` on the command line).

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

```
Mesh.CharacteristicLengthFromPoints = 0;
Mesh.CharacteristicLengthFromCurvature = 0;
Mesh.CharacteristicLengthExtendFromBoundary = 0;
```

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

Here are the mesh commands that are related to the specification of mesh element sizes:

`Characteristic Length { 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 = char-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).

Here is the list of all available fields with their associated options:

**Attractor**

> Compute the distance from the nearest node in a list. It can also be used to compute the distance from curves, in which case each curve is replaced by NNodesByEdge equidistant nodes and the distance from those nodes is computed. Attractor is deprecated: use Distance instead.
> Options:

> **EdgesList**
>
>> Tags of curves in the geometric model
>> type: list
>> default value: `{}`

> **FacesList**
>
>> Tags of surfaces in the geometric model (Warning, this feature is still experimental. It might (read: will probably) give wrong results for complex surfaces)
>> type: list
>> default value: `{}`

> **FieldX**     Id of the field to use as x coordinate.
>> type: integer
>> default value: `-1`

> **FieldY**     Id of the field to use as y coordinate.
>> type: integer
>> default value: `-1`

> **FieldZ**     Id of the field to use as z coordinate.
>> type: integer
>> default value: `-1`

> **NNodesByEdge**
>
>> Number of nodes used to discretized each curve
>> type: integer
>> default value: `20`

> **NodesList**
>
>> Tags of points in the geometric model
>> type: list
>> default value: `{}`

**AttractorAnisoCurve**

> Compute the distance from the nearest curve in a list. Then the mesh size can be specified independently in the direction normal to the curve and in

the direction parallel to the curve (Each curve is replaced by NNodesByEdge equidistant nodes and the distance from those nodes is computed.)
Options:

**EdgesList**

  Tags of curves in the geometric model
  type: list
  default value: `{}`

**NNodesByEdge**

  Number of nodes used to discretized each curve
  type: integer
  default value: `20`

**dMax**       Maxmium distance, above this distance from the curves, prescribe the maximum mesh sizes.
  type: float
  default value: `0.5`

**dMin**       Minimum distance, below this distance from the curves, prescribe the minimum mesh sizes.
  type: float
  default value: `0.1`

**lMaxNormal**

  Maximum mesh size in the direction normal to the closest curve.
  type: float
  default value: `0.5`

**lMaxTangent**

  Maximum mesh size in the direction tangeant to the closest curve.
  type: float
  default value: `0.5`

**lMinNormal**

  Minimum mesh size in the direction normal to the closest curve.
  type: float
  default value: `0.05`

**lMinTangent**

  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:

NRefine        Initial refinement level for the octree
               type: integer
               default value: `5`

gradientMax
               Maximun gradient of the size field
               type: float
               default value: `1.4`

hBulk          Size everywhere no size is prescribed
               type: float
               default value: `0.1`

nPointsPerCircle
               Number of points per circle (adapt to curvature of surfaces)
               type: integer
               default value: `55`

nPointsPerGap
               Number of points in thin layers
               type: integer
               default value: `5`

Ball           The value of this field is VIn inside a spherical ball, 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: `0`

VOut           Value outside the ball
               type: float
               default value: `0`

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
           hwall * ratio^(dist/hwall)
           Options:

AnisoMax   Threshold angle for creating a mesh fan in the boundary layer
           type: float
           default value: 10000000000

EdgesList
           Tags of curves in the geometric model for which a boundary layer
           is needed
           type: list
           default value: {}

ExcludedFaceList
           Tags of surfaces in the geometric model where the boundary layer
           should not be applied
           type: list
           default value: {}

FanNodesList
           Tags of points in the geometric model for which a fan is created
           type: list
           default value: {}

IntersectMetrics
           Intersect metrics of all faces
           type: integer
           default value: 0

NodesList
           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

hfar          Element size far from the wall
              type: float
              default value: 1

hwall_n       Mesh Size Normal to the The Wall
              type: float
              default value: 0.1

hwall_n_nodes
              Mesh Size Normal to the The Wall at nodes (overwrite hwall_n
              when defined)
              type: list_double
              default value: {}

ratio         Size Ratio Between Two Successive Layers
              type: float
              default value: 1.1

thickness
              Maximal thickness of the boundary layer
              type: float
              default value: 0.01

Box           The value of this field is VIn inside the box, VOut outside the box. 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: 0

              VOut      Value outside the box
                        type: float
                        default value: 0

              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`

Curvature

Compute the curvature of Field[IField]:

F = div(norm(grad(Field[IField])))
Options:

Delta       Step of the finite differences
            type: float
            default value: `0`

IField      Field index
            type: integer
            default value: `1`

Cylinder    The value of this field is VIn inside a frustrated cylinder, VOut outside. The
            cylinder is given 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: `0`

|         |                                                                                  |
|---------|----------------------------------------------------------------------------------|
| VOut    | Value outside the cylinder<br>type: float<br>default value: `0`                  |
| XAxis   | X component of the cylinder axis<br>type: float<br>default value: `0`            |
| XCenter | X coordinate of the cylinder center<br>type: float<br>default value: `0`         |
| YAxis   | Y component of the cylinder axis<br>type: float<br>default value: `0`            |
| YCenter | Y coordinate of the cylinder center<br>type: float<br>default value: `0`         |
| ZAxis   | Z component of the cylinder axis<br>type: float<br>default value: `1`            |
| ZCenter | Z coordinate of the cylinder center<br>type: float<br>default value: `0`         |

Distance  Compute the distance from the nearest node in a list. It can also be used to compute the distance from curves, in which case each curve is replaced by NNodesByEdge equidistant nodes and the distance from those nodes is computed. Options:

EdgesList

> Tags of curves in the geometric model
> type: list
> default value: `{}`

FacesList

> Tags of surfaces in the geometric model (Warning, this feature is still experimental. It might (read: will probably) give wrong results for complex surfaces)
> type: list
> default value: `{}`

FieldX  Id of the field to use as x coordinate.
> type: integer
> default value: `-1`

FieldY  Id of the field to use as y coordinate.
> type: integer
> default value: `-1`

FieldZ        Id of the field to use as z coordinate.
              type: integer
              default value: `-1`

NNodesByEdge
              Number of nodes used to discretized each curve
              type: integer
              default value: `20`

NodesList
              Tags of points 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    This field is an extended cylinder with inner (i) and outer (o) radiuseson both endpoints (1 and 2). Length scale is bilinearly interpolated betweenthese locations (inner and outer radiuses, endpoints 1 and 2)The field values for a point P are given by : $u = P1P.P1P2/||P1P2||$ $r = || P1P - u*P1P2 ||$ $Ri = (1-u)*R1i + u*R2i$ $Ro = (1-u)*R1o + u*R2o$ $v = (r-Ri)/(Ro-Ri)$ $lc = (1-v)*( (1-u)*v1i + u*v2i ) + v*( (1-u)*v1o + u*v2o )$ where $(u,v)$ in $[0,1]x[0,1]$
Options:

**R1_inner**    Inner radius of Frustum at endpoint 1
>      type: float
>      default value: 0

R1_outer    Outer radius of Frustum at endpoint 1
            type: float
            default value: 1

R2_inner    Inner radius of Frustum at endpoint 2
            type: float
            default value: 0

R2_outer    Outer radius of Frustum at endpoint 2
            type: float
            default value: 1

V1_inner    Element size at point 1, inner radius
            type: float
            default value: 0.1

V1_outer    Element size at point 1, outer radius
            type: float
            default value: 1

V2_inner    Element size at point 2, inner radius
            type: float
            default value: 0.1

V2_outer    Element 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: 1.455171629957881e-152

Gradient    Compute the finite difference gradient of Field[IField]:

F = (Field[IField](X + Delta/2) - Field[IField](X - Delta/2)) / Delta
Options:

Delta        Finite difference step
             type: float
             default value: `0`

IField       Field index
             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: `0`

**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[IField]:

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[IField] and d=Delta
Options:

Delta        Finite difference step
             type: float
             default value: `0.1`

IField       Field index
             type: integer
             default value: `1`

**LonLat**     Evaluate Field[IField] in geographic coordinates (longitude, latitude):

F = Field[IField](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

IField  Index 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 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 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[IField], with
      the gradients evaluated by finite differences:

      F = max(eig(grad(grad(Field[IField]))))
      Options:

      `Delta`   Step used for the finite differences
          type: float
          default value: `0`

      `IField`   Field index
          type: integer
          default value: `1`

Mean   Simple smoother:

      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[IField]
      Options:

      `Delta`   Distance used to compute the mean value
          type: float
          default value: `0.0003464101615137755`

      `IField`   Field index
          type: integer
          default value: `0`

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 use as x coordinate.
                      type: integer
                      default value: 746138744

Param      Evaluate Field IField in parametric coordinates:

           F = Field[IField](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: ""

           IField     Field index
                      type: integer
                      default value: 1

PostView   Evaluate the post processing view IView.
           Options:


           CropNegativeValues
                      return LC_MAX instead of a negative value (this option is needed
                      for backward compatibility with the BackgroundMesh option
                      type: boolean
                      default value: 1

IView          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.
           Options:

EdgesList
               Curve tags
               type: list
               default value: {}

FacesList
               Surface tags
               type: list
               default value: {}

IField         Field index
               type: integer
               default value: 1

RegionsList
               Volume tags
               type: list
               default value: {}

VerticesList
               Point 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 "SetOutside-Value" option is true).
            type: float
            default value: 0

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
        F = LCMin if Field[IField] <= DistMin,
        F = LCMax if Field[IField] >= DistMax,
        F = interpolation between LcMin and LcMax if DistMin < Field[IField] < DistMax
        Options:

DistMax     Distance from entity after which element size will be LcMax
            type: float
            default value: 10

DistMin     Distance from entity up to which element size will be LcMin
            type: float
            default value: 1

IField      Index of the field to evaluate
            type: integer
            default value: 0

LcMax       Element size outside DistMax
            type: float
            default value: 1

LcMin       Element size inside DistMin
            type: float
            default value: `0.1`

Sigmoid     True to interpolate between LcMin and LcMax using a sigmoid,
            false to interpolate linearly
            type: boolean
            default value: `0`

StopAtDistMax
            True to not impose element size outside DistMax (i.e., F = a very
            big value if Field[IField] > DistMax)
            type: boolean
            default value: `0`

## 6.3.2 Structured grids

Extrude { *expression-list* } { *extrude-list layers* }
            Extrudes both the geometry and the mesh using a translation (see Section 5.1.5
            [Extrusions], page 42). 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 cre-
ated 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 A.3 [t3.geo],
page 141, for an example.

For curve extrusions, the `Recombine` option will recombine triangles into quad-
rangles when possible. For surface extrusions, the `Recombine` option will re-
combine tetrahedra into prisms, hexahedra or pyramids.

Please note that, starting with Gmsh 2.0, region tags cannot be specified ex-
plicitly 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, ex-
truded volumes containing quadrangle-faced elements to structured or unstruc-
tured 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 simular 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 }`

> Extrudes both the geometry and the mesh using a rotation (see Section 5.1.5 [Extrusions], page 42). 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 }`

> Extrudes both the geometry and the mesh using a combined translation and rotation (see Section 5.1.5 [Extrusions], page 42). 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; > }**

Extrudes a boundary layer from the specified surfaces. If no view is specified, the boundary layer is created using gouraud-shaped (smoothed) normal field. 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.

**Transfinite Curve { *expression-list-or-all* } = *expression* < Using Progression | Bump *expression* >;**

Selects 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 6.3.1 [Specifying mesh element sizes], page 49). 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 > ;**

Selects 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`. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

**Transfinite Volume { *expression-list* } < = { *expression-list* } > ;**

Selects 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* ` } ;`
> Applies 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.

### 6.3.3 Miscellaneous

Here is a list of all other mesh commands currently available:

`Mesh ` *expression* ` ;`
> Generates *expression*-D mesh. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`RefineMesh;`
> Refines the current mesh by splitting all elements. If `Mesh.SecondOrderLinear` is set, the new nodes are inserted by linear interpolatinon. Otherwise they are snapped on the actual geometry. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`OptimizeMesh ` *char-expression* ` ;`
> Optimizes 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* ` < , ... > } };`
> Performs adaptive mesh generation. Documentation not yet available.

`RelocateMesh Point | Curve | Surface { ` *expression-list-or-all* ` };`
> Relocates 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* ` ;`
> Changes the order of the elements in the current mesh.

`PartitionMesh ` *expression* ` ;`
> Partitions the mesh into *expression*, using current partitioning options.

`Point | Curve {` *expression-list* `} In Surface {` *expression* `};`

>     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* `};`

>     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 sur-
>     face(s). This is only supported with the 3D Delaunay algorithm. This operation
>     triggers a synchronization of the CAD model with the internal Gmsh model.

`Periodic Curve {` *expression-list* `} = {` *expression-list* `} ;`

>     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* `} ;`

>     Force the mesh of the surface on the left-hand side (with boundary edges speci-
>     fied 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 sur-
>     face 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* `} ;`

>     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 ge-
>     ometrical 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
>     . This operation triggers a synchro-
>     nization of the CAD model with the internal Gmsh model.

`Periodic Curve | Surface {` *expression-list* `} = {` *expression-list* `} Rotate {`
*expression-list* `}, {` *expression-list* `},` *expression* `} ;`

>     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
>     . 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;`

Removes all duplicate mesh nodes.

`CreateTopology;`

Creates 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).

`CreateGeometry;`

Creates a parametrization for curves and surfaces that do not have one (i.e. discrete curves and surfaces represented solely by meshes, without an underlying CAD description).

`ClassifySurfaces {` *expression* `,` *expression* `,` *expression* `< ,` *expression* `> };`

Classify ("color") the 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;`

Renumbers the node tags in the current mesh in a contiunous sequence.

`RenumberMeshElements;`

Renumbers the elements tags in the current mesh in a contiunous sequence.

`< Recursive > Color` *color-expression* `{ <Physical> Point | Curve | Surface | Volume {` *expression-list-or-all* `}; ... }`

Sets 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.

`< Recursive > Hide { <Physical> Point | Curve | Surface | Volume {` *expression-list-or-all* `}; ... }`

Hides the mesh of the entities in *expression-list*, if `General.VisibilityMode` is set to `0` or `2`. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Hide { : }`

Hide the mesh of all entities, if `General.VisibilityMode` is set to `0` or `2`. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Recombine Surface {` *expression-list-or-all* `} < =` *expression* `>;`

Recombines 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* `;`
>   Forces the meshing algorithm per surface.

`MeshSizeFromBoundary Surface { ` *expression-list* ` } = ` *expression* `;`
>   Forces the mesh size to be extended from the boudnary, or not, per surface.

`Compound Curve | Surface { ` *expression-list-or-all* ` } ;`
>   Treats 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* ` } ;`
>   Reverses the mesh of the given curve(s) or surface(s). This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`ReorientMesh Volume { ` *expression-list* ` } ;`
>   Reorients the meshes of the bounding surfaces of the given volumes so that the normals point outward to the volumes. 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 ` *char-expression* `;`
>   Saves the mesh in a file named *char-expression*, using the current `Mesh.Format` (see Section B.3 [Mesh options list], page 208). If the path in *char-expression* is not absolute, *char-expression* is appended to the path of the current file. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`< Recursive > Show { <Physical> Point | Curve | Surface | Volume {` *expression-list-or-all* ` }; ... }`
>   Shows the mesh of the entities in *expression-list*, if `General.VisibilityMode` is set to `0` or `2`. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Show { : };`
>   Shows the mesh of all entities, if `General.VisibilityMode` is set to `0` or `2`. This operation triggers a synchronization of the CAD model with the internal Gmsh model.

`Smoother Surface { ` *expression-list* ` } = ` *expression* `;`
>   Sets 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.

## 6.4 Mesh options

The list of all the options that control the behavior of mesh commands, as well as the way meshes are displayed in the GUI, is given in .

# 7 Solver module

Solvers and other external codes can be driven by Gmsh through the ONELAB
interface (see `http://www.onelab.info`), which allows to have them share parameters
and modeling information.    To add a new external solver, you need to specify
its name (`Solver.Name0`, `Solver.Name1`, etc.)    and the path to the executable
(`Solver.Executable0`, `Solver.Executable1`, etc.).  The list of all the solver options is
given in Section B.4 [Solver options list], page 227. Examples on how to interface solvers
are available in the source distribution (in the utils/solvers directory).  A full-featured
solver interfaced in this manner is GetDP (`http://getdp.info`), a general finite element
solver using mixed finite elements.

Using the Gmsh API, you can also directly embed Gmsh in your own solver, and use
ONELAB for interactive parameter definition and modification.  See custom_gui.py and
custom_gui.cpp) for examples.

# 8 Post-processing module

Gmsh's 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), in native MSH files (ASCII or binary files with '.msh' extensions: see Chapter 9 [File formats], page 113), or in standard third-party formats.

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 `Force scalar` or `Force vector` options, or use `Plugin(MathEval)`: see Section 8.2 [Post-processing plugins], page 82.)

In Gmsh's jargon, 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 in a script or in the API) or globally (see the `PostProcessing.Link` option in Section B.5 [Post-processing options list], page 233).

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.

Although visualization is usually mostly an interactive task, Gmsh exposes all the post-processing commands and options to the user in its scripting language and through the API to permit a complete automation of the post-processing process (see e.g., Section A.8 [t8.geo], page 151, and Section A.9 [t9.geo], page 154).

The two following sections summarize all available post-processing commands and options. Most options apply to both 2D and 3D plots (colormaps, point/line sizes, interval types, time step selection, etc.), but some are peculiar to 3D (lightning, element selection, etc.) or 2D plots (abscissa labels, etc.). Note that 2D plots can be positioned explicitly inside the graphical window, or be automatically positioned in order to avoid overlaps.

Sample post-processing files in human-readable "parsed" format and in the native MSH file format are available in the tutorial directory of Gmsh's distribution ('.pos' and '.msh' files). The "parsed" format is defined in the next section (cf. the `View` command); the MSH format is defined in Chapter 9 [File formats], page 113.

## 8.1 Post-processing commands

This section describes the post-processing commands availanble in the scripting language. For the equivalent commands in the Gmsh API, see the `gmsh/view` module in Appendix D [Gmsh API], page 259.

`Alias View[`*expression*`];`

> Creates 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*`];`

> Creates 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;`

> Combines 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;`

> Combines 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;`

> Combines 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;`

> Combines 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;`

> Combines 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;`

> Combines 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*];**

Deletes (removes) the *expression*-th post-processing view. Note that post-processing view indices start at 0.

**Delete Empty Views;**

Deletes (removes) all the empty post-processing views.

**Background Mesh View[*expression*];**

Applies the *expression*-th post-processing view as the current background mesh. Note that post-processing view indices start at 0.

**Plugin (*string*) . Run;**

Executes the plugin *string*. The list of default plugins is given in Section 8.2 [Post-processing plugins], page 82.

**Plugin (*string*) . *string* = *expression* | *char-expression*;**

Sets an option for a given plugin. See Section 8.2 [Post-processing plugins], page 82, for a list of default plugins and Section A.9 [t9.geo], page 154, for some examples.

**Save View[*expression*] *char-expression*;**

Saves the *expression*-th post-processing view in a file named *char-expression*. If the path in *char-expression* is not absolute, *char-expression* is appended to the path of the current file.

**SendToServer View[*expression*] *char-expression*;**

Sends the *expression*-th post-processing view to the ONELAB server, with parameter name *char-expression*.

**View "*string*" { *string* < ( *expression-list* ) > { *expression-list* }; ... };**

Creates 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 A.4 [t4.geo], page 143), 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 9 [File formats], page 113, or use one of the standard formats like MED.

More explicitly, the syntax for a parsed **View** is the following

```
View "string" {
  type ( list-of-coords ) { list-of-values }; ...
  < TIME { expression-list }; >
  < INTERPOLATION_SCHEME { val-coef-matrix }
      { val-exp-matrix }
      < { geo-coef-matrix } { geo-exp-matrix } > ; >
};
```

where the 47 object *types* that can be displayed are:

```
                                type  #list-of-coords  #list-of-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 .

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 *expressions* in *list-of-coords* 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 *expressions* in *list-of-coords* 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 *list-of-values* can contain an arbitrary number of *char-expressions*. If the *char-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 *list-of-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 *list-of-coords*). 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}
};
```

## 8.2 Post-processing plugins

Post-processing plugins permit to extend the functionality of Gmsh's post-processing module. The difference between regular post-processing options (see Section B.5 [Post-processing options list], page 233) and post-processing plugins is that regular post-processing options only change the way the data is displayed, while post-processing plugins either create new post-processing views, or modify the data stored in a view (in a destructive, non-reversible way).

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 API, plugins are available in the `gmsh/plugin` module (see Appendix D [Gmsh API], page 259).

Here is the list of the plugins that are shipped by default with Gmsh:

`Plugin(AnalyseMeshQuality)`

Plugin(AnalyseMeshQuality) analyse all elements of a given dimension. According to what is asked, it computes the minimum of the Jacobian determinant (J), the IGE quality measure (Inverse Gradient Error) and/or the ICN quality measure (Inverse Condition Number). Statistics are printed and, if asked, a Pview is created for each measure. The plugin hides elements for which the measure mu > 'Hiding threshold', where mu is the ICN measure if asked otherwise the IGE measure if asked otherwise the Jacobian determinant.

J is faster to compute but gives information only on validity while the other measure gives also information on 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 article "Efficient computation of the minimum of shape quality measures on curvilinear finite elements" for details.)

Parameters:

- JacobianDeterminant = {0, 1}

- IGEMeasure = {0, 1}

- ICNMeasure = {0, 1}

- HidingThreshold = [0, 1]: Hides all element for which min(mu) is strictly greater than the threshold, where mu is ICN ifICNMeasure == 1, otherwise it is IGE if IGEMeasure == 1. If ICNMeasure == IGEMeasure == 0, nothing happens. If threshold == 0, hides all elements except invalid.

- DrawPView = {0, 1}: Creates a PView of min(J)/max(J), min(IGE) and/or min(ICN) according to what is asked. If 'Recompute' = 1, new PViews are created.

- Recompute = {0,1}: Should be 1 if the mesh has changed.

- DimensionOfElements = {-1, 1, 2, 3, 4}: If == -1, analyse element of the greater dimension. If == 4, analyse 2D and 3D elements. Numeric options:

`JacobianDeterminant`
> Default value: `0`

`IGEMeasure`
> Default value: `0`

`ICNMeasure`
> Default value: `0`

`HidingThreshold`
> Default value: `9`

`DrawPView`
> 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 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. Numeric options:

View        Default value: `-1`

`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 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 "negative" 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. For 1D cracks, 'NormalX', 'NormalY' and 'NormalZ' provide the reference normal of the surface in which the crack is supposed to be embedded. Numeric options:

`Dimension`
        Default value: `1`

                    `PhysicalGroup`
                              Default value: `1`

                    `OpenBoundaryPhysicalGroup`
                              Default value: `0`

                    `NormalX`    Default value: `0`

                    `NormalY`    Default value: `0`

                    `NormalZ`    Default value: `1`

`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 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 gen-
          erates hexahedra, quadrangles, lines or points depending on the values of 'Num-
          PointsU', '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 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 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 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 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: 4 |
| TargetError | |
| | Default value: 0 |
| 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 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: 4

TargetError
                Default value: 0

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 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 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 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 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 'Min-Val' != '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 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 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 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 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 cobination 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 com-
plement of the given physical groups.
'NameForResultChains': Post-processing view name prefix for the results.
'ApplyBoundaryOperatorToResults': Apply boundary operator to the result-
ing 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 instead
          of over space, starting at iteration i.If 'Visible' = 1, the plugin only integrates
          overvisible entities.

Plugin(Integrate) creates one new view. Numeric options:

`View`         Default value: `-1`

`OverTime`  Default value: `-1`

`Dimension`
                Default value: `-1`

`Visible`     Default value: `1`

## 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 views as there are time steps in 'View'. Numeric options:

`Value`         Default value: `0`

`ExtractVolume`
                Default value: `0`

`RecurLevel`
                Default value: `4`

`TargetError`
                Default value: `0`

`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 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.

Plugin(MathEval) creates one new 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

### 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 elments are considered.

Plugin(MeshVolume) creates one new 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 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. String options:
>
> `Type`        Default value: `"NodeData"`
>
> Numeric options:
>
> `NumComp`    Default value: `1`
>
> `Value`       Default value: `0`
>
> `ViewTag`    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 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 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 distribtion 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.)

The plugin creates the topology of the partitioned entities if 'CreateTopology' is set. 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
```

```
CreateTopology
            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.
Limitation - Unknown behaviour with curved meshes. 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 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 diffrent 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 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. Algorithm selects the old (0) or new (1) meshing algorithm.
>
> If 'View' < 0, the plugin is run on the current view.
>
> Plugin(Triangulate) creates one new view. Numeric options:
>
> Algorithm
> > Default value: `1`
>
> 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`

## 8.3 Post-processing options

General post-processing option names have the form '`PostProcessing.string`'. Options peculiar 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`' ($n = 0, 1, 2, \ldots$), *after the $n$-th view is loaded.*

The list of all post-processing and view options is given in Section B.5 [Post-processing options list], page 233. See Section A.8 [t8.geo], page 151, and Section A.9 [t9.geo], page 154, for some examples.

# 9  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 8.1 [Post-processing commands], page 78. Such "parsed" views do not require an underlying mesh, and can therefore be easier to use in some cases.)

## 9.1  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 Appendix D [Gmsh API], page 259 and Section E.1 [Source code structure], page 313 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 `$Nodes` section. Sections can be repeated in the same file, and post-processing sections can be put into separate files (e.g. one file per time step). Any section with an unrecognized header is simply ignored: you can thus add comments in a '`.msh`' file by putting them e.g. inside a `$Comments`/`$EndComments` section.

All the node, element and entity 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 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.

---

[1] If the numbering is not too sparse, Gmsh will still use a vector.

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).

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) ...
  ...
  surfaceTag(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) minX(double) minY(double) minZ(double)
    maxX(double) maxY(double) maxZ(double)
    numPhysicalTags(size_t) physicalTag(int) ...
    numBoundngSurfaces(size_t) surfaceTag(int) ...
  ...
$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(size_t) value(double) ...
      ...
   $EndNodeData

   $ElementData
      numStringTags(ASCII int)
      stringTag(string) ...
      numRealTags(ASCII int)
      realTag(ASCII double) ...
      numIntegerTags(ASCII int)
      integerTag(ASCII int) ...
      elementTag(size_t) value(double) ...
      ...
   $EndElementData

   $ElementNodeData
      numStringTags(ASCII int)
      stringTag(string) ...
      numRealTags(ASCII int)
      realTag(ASCII double) ...
      numIntegerTags(ASCII int)
      integerTag(ASCII int) ...
      elementTag(size_t) 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 9.2 [Node ordering], page 121 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 8.1 [Post-processing commands], page 78). 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:
"A scalar view"      the name of the view ("A scalar 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 Appendix D [Gmsh API], page 259).

- 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 re-worked for greater IO efficiency, with separation of entries by type and a block structure with predictable sizes.

## 9.2 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.

### 9.2.1 Low order elements

For all mesh and post-processing file formats, the reference elements are defined as follows.

```
    Line:                   Line3:          Line4:


        v
        ^
        |
        |
    0-----+-----1 --> u   0----2----1     0---2---3---1


    Triangle:               Triangle6:       Triangle9/10:         Triangle12/15:

    v
    ^                                                              2
    |                                                              | \
    2                       2                2                     9   8
    |'\                     |'\              | \                   |     \
    |  '\                   |  '\            7   6                 10 (14)  7
    |   '\                  5    '4          |     \               |        \
    |    '\                 |      '\        8  (9)  5             11 (12) (13) 6
    |     '\                |        '\      |         \           |          \
    0----------1 --> u      0-----3----1     0---3---4---1         0---3---4---5---1
```
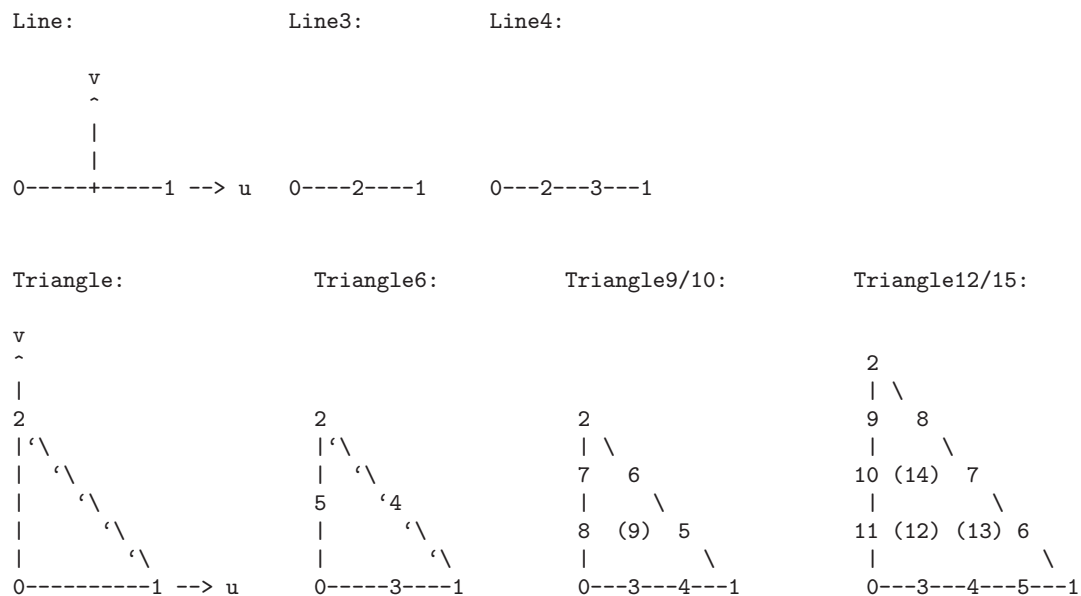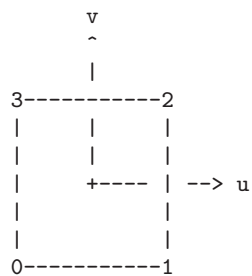
```
Quadrangle:              Quadrangle8:             Quadrangle9:

      v
      ^
      |
3-----------2            3-----6-----2            3-----6-----2
|     |     |            |           |            |           |
|     |     |            |           |            |           |
|     +---- | --> u      7           5            7     8     5
|           |            |           |            |           |
|           |            |           |            |           |
0-----------1            0-----4-----1            0-----4-----1
```
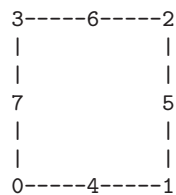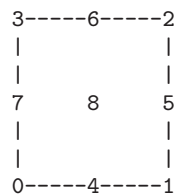
```
Tetrahedron:                              Tetrahedron10:

                  v
                   .
                 ,/
                /
             2                                 2
           ,/|'\                             ,/|'\
         ,/  |  '\                         ,/  |  '\
       ,/    '.   '\                     ,6    '.   '5
     ,/       |     '\                 ,/      8     '\
   ,/         |       '\             ,/        |       '\
  0-----------'.--------1 --> u     0--------4--'.--------1
   '\.         |      ,/             '\.       |      ,/
      '\.      |    ,/                  '\.     |    ,9
         '\.   '. ,/                      '7.   '. ,/
            '\. |/                           '\. |/
               '3                               '3
                 '\.
                   '  w
```
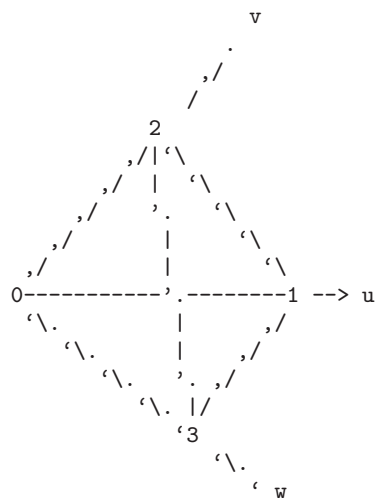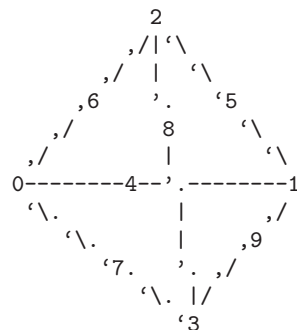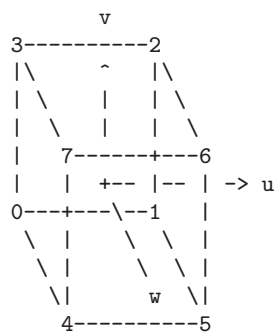
```
Hexahedron:              Hexahedron20:            Hexahedron27:

       v
3-----------2            3----13----2             3----13----2
|\     ^    |\           |\          |\           |\          |\
| \    |    | \          | 15        | 14         |15    24   | 14
|  \   |    |  \         9   \       11 \         9  \  20    11 \
|   \  |    |   \        |     \      |   \       |     \      |   \
|    7------+---6        |     7----19+---6       |     7----19+---6
|    | +-- |-- | -> u    |    |       |   |       |22 |  26   | 23|
0---+---\--1   |         0---+-8----1   |         0---+-8----1   |
 \   |   \  \  |          \   17       \   18      \  17    25 \  18
  \  |    \  \ |          10 |         12|         10 |  21     12|
   \ |     w  \|           \|           \|          \|          \|
    4---------5             4----16---5             4----16----5
```
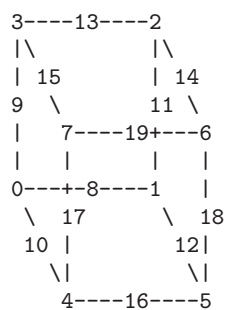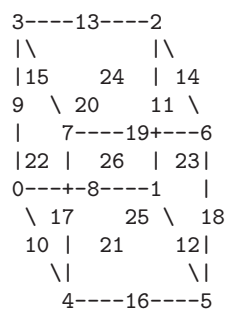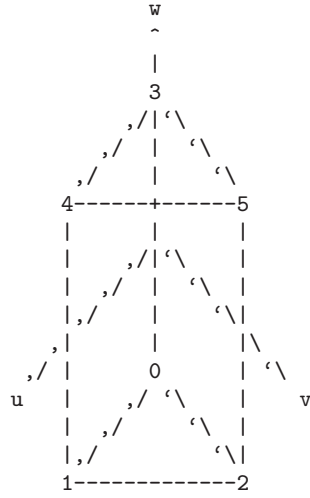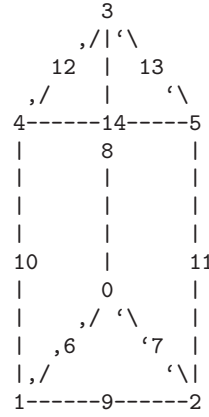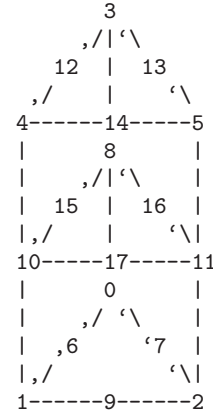
```
     Prism:                      Prism15:                    Prism18:

          w
          ^
          |
          3                           3                           3
        ,/|‘\                       ,/|‘\                       ,/|‘\
      ,/  |  ‘\                    12 |  13                   12  |  13
    ,/    |    ‘\                 ,/   |    ‘\                ,/   |    ‘\
   4------+------5              4------14-----5             4------14-----5
   |      |      |              |      8      |             |      8      |
   |    ,/|‘\    |              |      |      |             |    ,/|‘\    |
   |  ,/  |  ‘\  |              |      |      |             |   15 | 16   |
   |,/    |    ‘\|              |      |      |             |,/    |    ‘\|
   ,|     |     |\             10      |     11            10-----17-----11
 ,/ |     0     | ‘\           |       0      |            |      0      |
 u  |   ,/ ‘\   |   v          |     ,/ ‘\    |            |    ,/ ‘\    |
    | ,/     ‘\ |              |   ,6     ‘7  |            |   ,6     ‘7  |
    |,/        ‘\|             |,/          ‘\|            |,/          ‘\|
    1------------2             1------9------2             1------9------2


     Pyramid:                    Pyramid13:                  Pyramid14:

          4                           4                           4
        ,/|\                        ,/|\                        ,/|\
      ,/ .’|\                     ,/ .’|\                     ,/ .’|\
    ,/   | | \                  ,/   | | \                  ,/   | | \
  ,/     .’ | ‘.               ,/     .’ | ‘.               ,/     .’ | ‘.
 ,/      | ’.  \              ,7      | 12  \              ,7      | 12  \
,/      .’ w |   \           ,/      .’   |   \           ,/      .’   |   \
,/      | ^ |    \          ,/       9    |    11        ,/       9    |    11
0----------.’--|-3    ‘.    0--------6-.’----3    ‘.     0--------6-.’----3    ‘.
‘\         | | ‘\    \      ‘\        |      ‘\   \      ‘\        |      ‘\   \
 ‘\     .’  +----‘\ - \ -> v ‘5    .’       10   \       ‘5    .’ 13    10   \
  ‘\   |   ‘\    ‘\ \          ‘\  |          ‘\ \         ‘\  |          ‘\ \
   ‘\.’       ‘\    ‘\‘         ‘\.’            ‘\‘         ‘\.’            ‘\‘
    1---------------2           1--------8------2           1--------8------2
                ‘\
                u
```
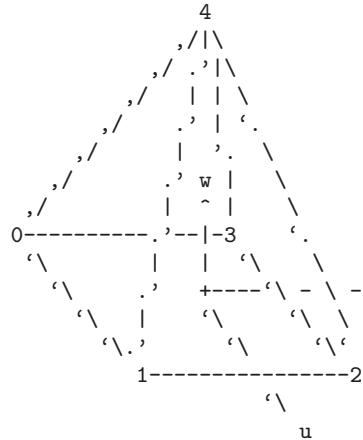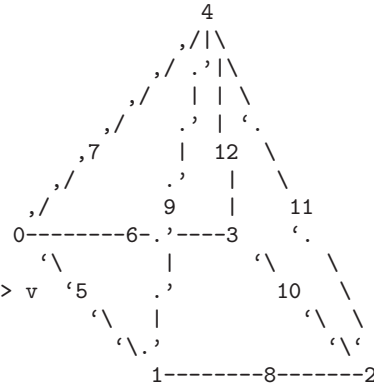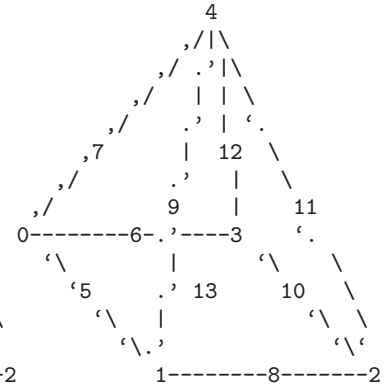
## 9.2.2  High-order elements

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.

## 9.3 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.

### 9.3.1 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 9.1 [MSH file format], page 113. 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
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 postive (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 postive (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 9.1 [MSH file format], page 113.

`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 9.2 [Node ordering], page 121.

`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 pro-
             vided

*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 spec-
             ify how to interpolate the data (they have the same meaning as in Section 8.1
             [Post-processing commands], page 78). 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, physical 99, elementary 2, nodes 1 2 3 4
2 3 2 99 2 2 5 6 3        quad #2: type 3, physical 99, elementary 2, nodes 2 5 6 3
$EndElements
$NodeData
1                       one string tag:
"A scalar view"           the name of the view ("A scalar 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 stan-
>       dard tags (the physical and elementary regions):

```
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);
}
```

## 9.3.2 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 9.1 [MSH file format], page 113. 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 postive (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 postive (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 postive 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 postive (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 .

### 9.3.3 POS ASCII file format (Legacy)

The POS ASCII file is Gmsh's old native post-processing format, now superseded by the format described in . 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

`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 co-ordinates (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.

### 9.3.4 POS binary file format (Legacy)

The POS binary file format is the same as the POS ASCII file format described in Section 9.3.3 [POS ASCII file format (Legacy)], page 131, 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  Tutorial

The following examples introduce new features gradually, starting with Section A.1 [t1.geo], page 137. The files corresponding to these examples are available in the tutorial directory of the Gmsh distribution. C++, C, Python or Julia versions of several of these tutorials are also available in the tutorial/c, tutorial/c++, tutorial/python and tutorial/julia directories.

To learn how to run Gmsh on your computer, see Chapter 3 [Running Gmsh on your system], page 11. Screencasts that show how to use the GUI are available on http://gmsh.info/screencasts/.

## A.1  t1.geo

```
// -----------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 1
//
//  Variables, elementary entities (points, curves, surfaces), physical groups
//  (points, curves, surfaces)
//
// -----------------------------------------------------------------------------

// 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 a characteristic length (lc) that sets
// the target element size at the point:

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

// The distribution of the mesh element sizes will then be obtained by
// interpolation of these characteristic lengths throughout the
// geometry. Another method to specify characteristic lengths 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' or 't19.geo' for complete examples based on
// OpenCASCADE, and 'demos/boolean' for more.
```

## A.2 t2.geo

```
// -----------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 2
//
//  Includes, geometrical transformations, extruded geometries, elementary
//  entities (volumes), physical groups (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};

// But Gmsh also provides tools to transform (translate, rotate, etc.)
// elementary entities or copies of elementary entities. For example, the point
// 3 can be moved by 0.05 to the left with:

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

// Note that there are no units in Gmsh: coordinates are just numbers - it's up
// to the user to associate a meaning to them. The resulting point can also be
// duplicated and translated by 0.1 along the y axis:

Translate {0, 0.1, 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]};), with list indexing starting at 0. Parentheses can also be used
// instead of square brackets, so that we could also write 'thirdlist() =
// {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, 0.13, lc};  Point(101) = {0.08, 0.3, 0.1, lc};
Point(102) = {0.08, 0.4, 0.1, lc}; Point(103) = {0., 0.4, 0.13, 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 characteristic length to
// some of the new points:

Characteristic Length {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.
```

## A.3 t3.geo

```
// -----------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 3
//
```

```
//  Extruded meshes, 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 t2.geo -setnumber angle 30' would define 'angle'
// before the 'DefineConstant', making 't2.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' 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 Options->For Current File'. To save the current options for all
// future Gmsh sessions use 'File->Save Options->As default'.
```

## A.4  t4.geo

```
// -----------------------------------------------------------------------------
//
//  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.DoubleClickedLineCommand = "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 }; }
```

## A.5 t5.geo
```
// ----------------------------------------------------------------------------
//
```

```
//  Gmsh GEO tutorial 5
//
//  Characteristic lengths, 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 characteristic
// lengths on the command line with the '-clscale' option (or with
// 'Mesh.CharacteristicLengthFactor' 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.

// 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 'newl', 'newll, 'news', 'newsl' and 'newv' select new curve,
  // curve loop, surface, surface loop and volume tag.
  //
  // 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.

  l1 = newll; Curve Loop(l1) = {c5,c10,c4};
  l2 = newll; Curve Loop(l2) = {c9,-c5,c1};
  l3 = newll; Curve Loop(l3) = {c12,-c8,-c1};
  l4 = newll; Curve Loop(l4) = {c8,-c4,c11};
  l5 = newll; Curve Loop(l5) = {-c10,c6,c3};
  l6 = newll; Curve Loop(l6) = {-c11,-c3,c7};
  l7 = newll; Curve Loop(l7) = {-c2,-c7,-c12};
  l8 = newll; 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 identification numbers 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 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; // 2D algorithm set to Frontal-Delaunay
Mesh.Algorithm3D = 1; // 3D algorithm set to Delaunay

// 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;
```

## A.6 t6.geo

```
// -----------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 6
//
//  Transfinite meshes
//
// -----------------------------------------------------------------------------

// Let's use the geometry from the first tutorial as a basis for this one:
Include "t1.geo";

// 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 = newl; Line(l1) = {1, p1};
l2 = newl; Line(l2) = {p1, p2};
l3 = newl; 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;
```

## A.7  t7.geo

```
// -----------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 7
//
//  Background mesh
//
// -----------------------------------------------------------------------------
```

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

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

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

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

## A.8  t8.geo

```
// -----------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 8
//
//  Post-processing, scripting, animations, options
//
// -----------------------------------------------------------------------------

// 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-%02g.gif", num2);
    // Print Sprintf("t8-%02g.ppm", num2);
    // Print Sprintf("t8-%02g.jpg", num2);
  EndIf

EndFor

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

  // with whirlgif:
  /*
  System "whirlgif -minimize -loop -o t8.gif t8-*.gif";
  */

  // with mpeg_encode (create parameter file first, then run encoder):
  /*
  Printf("PATTERN I") > "t8.par";
  Printf("BASE_FILE_FORMAT PPM") >> "t8.par";
  Printf("GOP_SIZE 1") >> "t8.par";
  Printf("SLICES_PER_FRAME 1") >> "t8.par";
  Printf("PIXEL HALF") >> "t8.par";
  Printf("RANGE 10") >> "t8.par";
  Printf("PSEARCH_ALG EXHAUSTIVE") >> "t8.par";
  Printf("BSEARCH_ALG CROSS2") >> "t8.par";
  Printf("IQSCALE 1") >> "t8.par";
  Printf("PQSCALE 1") >> "t8.par";
  Printf("BQSCALE 25") >> "t8.par";
  Printf("REFERENCE_FRAME DECODED") >> "t8.par";
  Printf("OUTPUT t8.mpg") >> "t8.par";
  Printf("INPUT_CONVERT *") >> "t8.par";
  Printf("INPUT_DIR .") >> "t8.par";
  Printf("INPUT") >> "t8.par";
  tmp = Sprintf("t8-*.ppm [01-%02g]", frames);
  Printf(tmp) >> "t8.par";
  Printf("END_INPUT") >> "t8.par";
  System "mpeg_encode t8.par";
  */

  // with mencoder:
  /*
  System "mencoder 'mf://*.jpg' -mf fps=5 -o t8.mpg -ovc lavc
          -lavcopts vcodec=mpeg1video:vhq";
  System "mencoder 'mf://*.jpg' -mf fps=5 -o t8.mpg -ovc lavc
          -lavcopts vcodec=mpeg4:vhq";
```

```
    */

    // with ffmpeg:
    /*
    System "ffmpeg -hq -r 5 -b 800 -vcodec mpeg1video
            -i t8-%02d.jpg t8.mpg"
    System "ffmpeg -hq -r 5 -b 800 -i t8-%02d.jpg t8.asf"
    */
  EndIf

EndFor
```

## A.9 t9.geo

```
// -----------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 9
//
//  Post-processing plugins (levelsets, sections, annotations)
//
// -----------------------------------------------------------------------------

// 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;
```

## A.10 t10.geo

```
// -----------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 10
//
//  General 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].NodesList = {5};
Field[1].NNodesByEdge = 100;
Field[1].EdgesList = {2};

// 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
//
// LcMax -                              /------------------
//                                     /
//                                    /
//                                   /
// LcMin -o---------------/
//        |              |        |
//      Point        DistMin DistMax
Field[2] = Threshold;
Field[2].IField = 1;
Field[2].LcMin = lc / 30;
Field[2].LcMax = 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].NodesList = {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;

// 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->Fields' in the 'Mesh' module.

// Finally, let's use the minimum of all the fields as the background mesh 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.CharacteristicLengthFromPoints' is set, the mesh size specified
//    at geometrical points;
// 3) if 'Mesh.CharacteristicLengthFromCurvature' is set, the mesh size based on
//    the curvature and 'Mesh.MinimumCirclePoints';
```

```
// 4) the background mesh field;
// 5) any per-entity mesh size constraint.
//
// This value is then constrained in the interval
// ['Mesh.CharacteristicLengthMin', 'MeshCharacteristicLengthMax'] and
// multiplied by 'Mesh.CharacteristicLengthFactor'.  In addition, boundary mesh
// sizes (on curves or surfaces) are interpolated inside the enclosed entity
// (surface or volume, respectively) if the option
// 'Mesh.CharacteristicLengthExtendFromBoundary' is set (which is the case by
// default).
//
// When the element size is fully specified by a background mesh (as it is in
// this example), it is thus often desirable to set

Mesh.CharacteristicLengthExtendFromBoundary = 0;
Mesh.CharacteristicLengthFromPoints = 0;
Mesh.CharacteristicLengthFromCurvature = 0;

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

## A.11 t11.geo

```
// -----------------------------------------------------------------------------
//
//  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;
```

## A.12 t12.geo

```
// -----------------------------------------------------------------------------
//
//  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.CompoundCharacteristicLengthFactor' 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};
```

## A.13 t13.geo

```
// -----------------------------------------------------------------------------
//
//  Gmsh GEO tutorial 13
//
//  Remeshing 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
```

```
angle = DefineNumber[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 = DefineNumber[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.

// 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;
```

## A.14  t14.geo

```
// -----------------------------------------------------------------------------
//
//  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 characteristic length
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};

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) = {1};

// Four "terminals" of the model
Physical Surface(70) = {36};
Physical Surface(71) = {44};
Physical Surface(72) = {52};
Physical Surface(73) = {60};

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

// Complement of the domain surface respect to the four terminals
bnd[] -= {36, 44, 52, 60};
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.
```

## A.15  t15.geo

```
// -----------------------------------------------------------------------------
//
//  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;
Characteristic Length {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 = newl;
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 = newll;
Curve Loop(ll) = {l+1:l+4};
s = news;
Plane Surface(s) = {ll};
Surface{s} In Volume{1};
```

## A.16 t16.geo

```
// -----------------------------------------------------------------------------
//
//  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 small pratical issues for e.g. setting mesh sizes at points, or
// identifying boundaries.

// To identify point 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:
Characteristic Length{ PointsOf{ Volume{:}; } } = lcar1;

// Override this constraint on the points of the five spheres:
Characteristic Length{ 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};
Characteristic Length{ p() } = lcar2;

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

## A.17  t17.geo

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

// Characteristic lengths 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) = {-1, -1, 0, 2, 2};

// 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;
```

## A.18 t18.geo

```
// -----------------------------------------------------------------------------
//
//  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};
Characteristic Length {:} = 0.1;
Characteristic Length {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.

// 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 some a non-uniform mesh size constraint (again to check results
// visually):
Characteristic Length { PointsOf{ Volume{vin()}; }} = 0.1;
p() = Point In BoundingBox{2-eps, -eps, -eps, 2+eps, eps, eps};
Characteristic Length {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 i
  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
```

## A.19 t19.geo

```
// -----------------------------------------------------------------------------
//
//  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 = DefineNumber[ 1, Min 0.1, Max 3, Step 0.01, Name "Parameters/Turn" ];
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:
Mesh.CharacteristicLengthFromCurvature = 1;

// And we set the minimum number of elements per 2*Pi radians:
Mesh.MinimumElementsPerTwoPi = 20;

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

# Appendix B  Options

This appendix lists all the available options. 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 lists 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 lists 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 Options->For Current File' (cf. "Saved in: -" in the lists below).

To reset all options to their default values, use the 'Restore default options' button in 'Tools->Options->General->Advanced', or erase the `General.SessionFileName` and `General.OptionsFileName` files by hand.

All the options can be manipulated through the Gmsh API through the `gmsh/option` namespace (see Appendix D [Gmsh API], page 259).

## B.1  General options list

`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: 4.5.6-git-c72008761; License: GNU General Public License; Build OS: MacOSX-sdk; Build date: 20200328; Build host: Christophes-MacBook-Pro.local; Build options: 64Bit ALGLIB Ann Bamg Blas[veclib] Blossom Cairo Cgns DIntegration Dlopen DomHex Fltk GMP Gmm Hxt Hxt3D Jpeg Kbipack Lapack[veclib] MathEx Med Mesh Metis Mmg3d Mpeg Netgen ONELAB ONELABMetamodel OpenCASCADE OpenCASCADE-CAF OpenGL OpenMP[usr/local] OptHom Parser Plugins Png Post QuadTri Solver TetGen/BR Voro++ Zlib; FLTK version: 1.4.0; OCC version: 7.4.1; MED version: 4.0.0; Packaged by: geuzaine; Web site: http://gmsh.info; Issue tracker: https://gitlab.onelab.info/gmsh/gmsh/issues"`

       Saved in: `-`

`General.BuildOptions`

       Gmsh build options (read-only)

       Default value: `"64Bit ALGLIB Ann Bamg Blas[veclib] Blossom Cairo Cgns DIntegration Dlopen DomHex Fltk GMP Gmm Hxt Hxt3D Jpeg Kbipack Lapack[veclib] MathEx Med Mesh Metis Mmg3d Mpeg Netgen ONELAB ONELABMetamodel OpenCASCADE OpenCASCADE-CAF OpenGL OpenMP[usr/local] OptHom Parser Plugins Png Post QuadTri Solver TetGen/BR Voro++ 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, 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.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: `"4.5.6-git-c72008761"`
> Saved in: -

`General.WatchFilePattern`
>Pattern of files to merge as they become available
>Default value: `""`
>Saved in: -

`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.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.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.HighResolutionPointSizeFactor
    Point size factor when using high-resolution OpenGL graphics
    Default value: 2
    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

      Set (maximum) number of threads (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)each time you quit Gmsh?
        Default value: `0`
        Saved in: `General.SessionFileName`

`General.SaveSession`

        Automatically save session specific information in General.SessionFileName
        each time you quit Gmsh?
        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 Mac OS X?
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 during processing (0: no information)
> 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`

`Print.ParameterCommand`
> Command parsed when the print parameter is changed
> Default value: `"Mesh.Clip=1; View.Clip=1; General.ClipWholeElements=1;`
> `General.Clip0D=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.Width`

> Width of printed image; use (possibly scaled) current width if < 0)
> Default value: `-1`
> Saved in: `General.OptionsFileName`

## B.2 Geometry options list

`Geometry.DoubleClickedPointCommand`

> Command parsed when double-clicking on a point
> Default value: `""`
> Saved in: `General.OptionsFileName`

`Geometry.DoubleClickedLineCommand`

> Command parsed when double-clicking on a line
> Default value: `""`
> Saved in: `General.OptionsFileName`

`Geometry.DoubleClickedSurfaceCommand`

> Command parsed when double-clicking on a surface
> Default value: `""`
> Saved in: `General.OptionsFileName`

`Geometry.DoubleClickedVolumeCommand`

> Command parsed when double-clicking on a volume
> Default value: `""`
> 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
> OpenCASCADE default bahavior)
> Default value: `""`
> Saved in: `General.OptionsFileName`

`Geometry.AutoCoherence`

> Should all duplicate entities be automatically removed with the built-in geom-
> etry 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.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.HighlightOrphans

>    Highlight orphan entities (lines connected to a single surface, etc.)?
>    Default value: 0
>    Saved in: General.OptionsFileName

Geometry.LabelType

>    Type of entity label (0: description, 1: elementary entity tag, 2: physical group tag)
>    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.Lines

>    Display geometry curves?
>    Default value: 1
>    Saved in: General.OptionsFileName

`Geometry.LineNumbers`
> Display curve labels?
> Default value: `0`
> Saved in: `General.OptionsFileName`

`Geometry.LineSelectWidth`
> Display width of selected curves (in pixels)
> Default value: `3`
> Saved in: `General.OptionsFileName`

`Geometry.LineType`
> Display curves as solid color segments (0), 3D cylinders (1) or tapered cylinders (2)
> Default value: `0`
> Saved in: `General.OptionsFileName`

`Geometry.LineWidth`
> Display width of lines (in pixels)
> Default value: `2`
> 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 edge subdivisions between control points when displaying curves
> Default value: `40`
> 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 Open-CASCADE kernel
>   Default value: `0`
>   Saved in: `General.OptionsFileName`

`Geometry.OCCFixSmallFaces`
>   Fix small faces when importing STEP, IGES and BRep models with the Open-CASCADE kernel
>   Default value: `0`
>   Saved in: `General.OptionsFileName`

`Geometry.OCCImportLabels`
>   Import labels and colors when importing STEP models with the OpenCAS-CADE 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.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 OpenCAS-CADE kernel

Default value: `0`

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.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.Points`
>     Display geometry points?
>     Default value: `1`
>     Saved in: `General.OptionsFileName`

`Geometry.PointNumbers`
>     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.OrientedPhysicals`
>     Use sign of elementary entity in physical definition as orientation indicator
>     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.SurfaceNumbers`
> 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.VolumeNumbers
          Display volume labels?
          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.Lines`
> 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: {255,255,0}
> 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`

## B.3 Mesh options list

`Mesh.Algorithm`
> 2D mesh algorithm (1: MeshAdapt, 2: Automatic, 5: Delaunay, 6: Frontal-Delaunay, 7: BAMG, 8: Frontal-Delaunay for Quads, 9: Packing of Parallelograms)
> Default value: `6`
> Saved in: `General.OptionsFileName`

`Mesh.Algorithm3D`
> 3D mesh algorithm (1: Delaunay, 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
> 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.BoundaryLayerFanPoints`
> Number of points (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.CharacteristicLengthExtendFromBoundary`
> Extend computation of mesh element sizes from the boundaries into the interior
> (for 3D Delaunay, use 1: longest or 2: shortest surface edge length)
> Default value: `1`
> Saved in: `General.OptionsFileName`

`Mesh.CharacteristicLengthFactor`
> Factor applied to all mesh element sizes
> Default value: `1`
> Saved in: `General.OptionsFileName`

`Mesh.CharacteristicLengthMin`
> Minimum mesh element size
> Default value: `0`
> Saved in: `General.OptionsFileName`

`Mesh.CharacteristicLengthMax`
> Maximum mesh element size
> Default value: `1e+22`
> Saved in: `General.OptionsFileName`

Mesh.CharacteristicLengthFromCurvature
          Automatically compute mesh element sizes from curvature
          Default value: 0
          Saved in: General.OptionsFileName

Mesh.CharacteristicLengthFromPoints
          Compute mesh element sizes from values given at geometry points
          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.CompoundCharacteristicLengthFactor
          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.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.FlexibleTransfinite`

> Allow transfinite constraints to be modified for Blossom or by global mesh size factor
> Default value: `0`
> Saved in: `General.OptionsFileName`

`Mesh.NewtonConvergenceTestXYZ`

> Force inverse surface mapping algorithm (Newton-Raphson) to converge in real coordinates (experimental)
> 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.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
> 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.HighOrderPrimSurfMesh`

        Try to fix flipped surface mesh elements in high-order optimizer?

        Default value: `0`

        Saved in: `General.OptionsFileName`

`Mesh.HighOrderDistCAD`

        Try to optimize distance to CAD 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.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.LineNumbers`
> 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 default)
> Default value: `0`
> Saved in: `General.OptionsFileName`

`Mesh.MaxNumThreads2D`
> Maximum number of threads for 2D meshing (0: use default)
> Default value: `0`
> Saved in: `General.OptionsFileName`

`Mesh.MaxNumThreads3D`
> Maximum number of threads for 3D meshing (0: use default)
> 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.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.MinimumCirclePoints
          Minimum number of nodes used to mesh circles and ellipses
          Default value: `7`
          Saved in: `General.OptionsFileName`

Mesh.MinimumCurvePoints
          Minimum number of points used to mesh curves other than lines, circles and
          ellipses
          Default value: `3`
          Saved in: `General.OptionsFileName`

Mesh.MinimumElementsPerTwoPi
          Minimum number of elements per 2 * Pi radians when the mesh size is adapted
          to the curvature

Default value: `6`
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.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.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.Normals`

        Display size of normal vectors (in pixels)

        Default value: `0`

        Saved in: `General.OptionsFileName`

`Mesh.NumSubEdges`

        Number of edge subdivisions when displaying high-order elements

        Default value: `2`

        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.Points`
>  Display mesh nodes (vertices)?
>  Default value: `0`
>  Saved in: `General.OptionsFileName`

`Mesh.PointNumbers`
>  Display mesh node labels?
>  Default value: `0`
>  Saved in: `General.OptionsFileName`

`Mesh.PointSize`
>  Display size of mesh nodes (in pixels)
>  Default value: `4`
>  Saved in: `General.OptionsFileName`

`Mesh.PointType`
>  Display mesh nodes as solid color dots (0) or 3D spheres (1)
>  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.Trihedra`
>  Display mesh trihedra?
>  Default value: `1`
>  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.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.IgnorePeriodicity`

        Ignore alignment of periodic boundaries when reading the mesh in MSH2 format (used by ParaView plugin)

        Default value: `0`

        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.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.SaveAll`

> Save all elements, even if they don't belong to physical groups
> 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.SaveTopology`

> Save model topology in MSH2 output files (this is always saved in MSH3)
> Default value: `0`
> Saved in: `General.OptionsFileName`

`Mesh.SaveParametric`

> Save parametric coordinates of nodes
> Default value: `0`
> Saved in: `General.OptionsFileName`

`Mesh.SaveGroupsOfElements`

> Save groups of elements for each physical group (for INP mesh format)
> Default value: `1`
> Saved in: `General.OptionsFileName`

`Mesh.SaveGroupsOfNodes`

> Save groups of nodes for each physical group (for UNV, INP and Tochnog mesh formats). For the INP format, a negative value will save a group of node for each entity of dimension = (-Mesh.SaveGroupsOfNodes)
> 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 representation of surfaces (currently only used with the OpenCASCADE kernel)

Default value: `0.35`

Saved in: `General.OptionsFileName`

`Mesh.StlLinearDeflection`

Maximum linear deflection when creating STL representation of surfaces (currently only used with the OpenCASCADE kernel)

Default value: `0.01`

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.SurfaceNumbers`
> 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-08`
> Saved in: `General.OptionsFileName`

`Mesh.Triangles`
> Display mesh triangles?
> Default value: `1`
> 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.VolumeNumbers`

> 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.Points`

> Mesh node color
> Default value: `{0,0,255}`
> Saved in: `General.OptionsFileName`

`Mesh.Color.PointsSup`

> 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`

## B.4 Solver options list

`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`

## B.5 Post-processing options list

`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.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`

`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)
>   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.ForceComponents > 0)
>   Default value: `0`
>   Saved in: `General.OptionsFileName`

`View.ComponentMap1`

> Forced component 1 (if View.ForceComponents > 0)
> Default value: `1`
> Saved in: `General.OptionsFileName`

`View.ComponentMap2`

> Forced component 2 (if View.ForceComponents > 0)
> Default value: `2`
> Saved in: `General.OptionsFileName`

`View.ComponentMap3`

> Forced component 3 (if View.ForceComponents > 0)
> Default value: `3`
> Saved in: `General.OptionsFileName`

`View.ComponentMap4`

> Forced component 4 (if View.ForceComponents > 0)
> Default value: `4`
> Saved in: `General.OptionsFileName`

`View.ComponentMap5`

> Forced component 5 (if View.ForceComponents > 0)
> Default value: `5`
> Saved in: `General.OptionsFileName`

`View.ComponentMap6`

> Forced component 6 (if View.ForceComponents > 0)
> Default value: `6`
> Saved in: `General.OptionsFileName`

`View.ComponentMap7`

> Forced component 7 (if View.ForceComponents > 0)
> Default value: `7`
> Saved in: `General.OptionsFileName`

`View.ComponentMap8`

> Forced component 8 (if View.ForceComponents > 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) or 3D cylinders (1)
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: `0.01`
>    Saved in: `General.OptionsFileName`

`View.TensorType`

>    Tensor display type (1: Von-Mises, 2: maximum eigenvalue, 3: minimum eigen-
>    value, 4: eigenvectors, 5: ellipse, 6: ellipsoid, 7: frame)
>    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`

# Appendix C  Compiling the source code

Stable releases and source snapshots are available from http://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 detailed information on how to run CMake).

Each build can be configured using a series of options, to selectively enable optional modules or features. Here is the list of CMake options:

ENABLE_3M
> Enable proprietary 3M extension (default: OFF)

ENABLE_ACIS
> Enable ACIS geometrical models (experimental) (default: ON)

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 (required for meshing) (default: ON)

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_CXX11

>   Enable C++11 (default: ON)

ENABLE_C99

>   Enable C99 (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_FLTK

>   Enable FLTK graphical user interface (requires mesh/post) (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 (required by GUI) (default: ON)

ENABLE_METIS

>   Enable Metis mesh partitioner (default: ON)

ENABLE_MMG3D

>   Enable MMG3D 3D anisotropic mesh refinement (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: OFF)

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 firld (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 files) (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_QUADTRI
> Enable QuadTri structured meshing extensions (default: ON)

ENABLE_REVOROPT
> Enable Revoropt (used for CVT remeshing) (default: OFF)

ENABLE_SLEPC
> Enable SLEPc eigensolvers (default: OFF)

ENABLE_SOLVER
> Enable built-in finite element solvers (required for compounds) (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_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_WRAP_JAVA
> Enable generation of Java wrappers for private API (default: OFF)

ENABLE_WRAP_PYTHON
> Enable generation of Python wrappers for private API (default: OFF)

ENABLE_ZIPPER
        Enable Zip file compression/decompression (default: OFF)

The wiki (<https://gitlab.onelab.info/gmsh/gmsh/wikis/Gmsh-compilation>) contains more detailed instructions on how to compile Gmsh, including the compilation of common dependencies.

# Appendix D  Gmsh API

The Gmsh Application Programming Interface (API) allows you to integrate the Gmsh library in your own application. C++, C, Python and Julia versions of several of the `.geo` tutorials from Appendix A [Tutorial], page 137 are available in the tutorial/c, tutorial/c++, tutorial/python and tutorial/julia directories. Other API examples are available in the demos/api directory.

By design, the Gmsh API is purely functional, and only uses elementary types from the target language. Currently supported languages are C++, C, Python and Julia. 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

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 E.1 [Source code structure], page 313):

- 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/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 their dimension and by a *tag*: a strictly positive identification number. *Physical groups* are collections of model entities and are 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. 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 9.1 [MSH file format], page 113), 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 9.1 [MSH file format], page 113) or independent from any model (*list-based* data, as stored in parsed POS files: cf. Section 8.1 [Post-processing commands], page 78). 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`, and in C to `gmshModelGeoAddPoint`. 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.

## D.1 Namespace `gmsh`: top-level functions

`gmsh/initialize`

> Initialize Gmsh. 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

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[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.

app. If `readConfigFiles` is set, read system Gmsh configuration files (gmshrc and gmsh-options).

Input:      (`argc = 0`), `argv = []`, `readConfigFiles = True`

Output:     -

Return:     -

`gmsh/finalize`

Finalize Gmsh. This must be called when you are done using the Gmsh API.

Input:      -

Output:     -

Return:     -

`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`

Output:     -

Return:     -

`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`

Output:     -

Return:     -

`gmsh/write`

Write a file. The export format is determined by the file extension.

Input:      `fileName`

Output:     -

Return:     -

`gmsh/clear`

Clear all loaded models and post-processing data, and add a new empty model.

Input:      -

Output:     -

Return:     -

## D.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 reference manual.
>
> Input:      `name`, `value`
>
> Output:     -
>
> Return:     -

`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 reference manual.
>
> Input:      `name`
>
> Output:     `value`
>
> Return:     -

`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 reference manual.
>
> Input:      `name`, `value`
>
> Output:     -
>
> Return:     -

`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 reference manual.
>
> Input:      `name`
>
> Output:     `value`
>
> Return:     -

`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.option" or "category[num].option". Available categories and options are listed in the Gmsh reference manual, with the "Color." middle string removed.
>
> Input:      `name, r, g, b, a = 0`
>
> Output:     -
>
> Return:     -

**gmsh/option/getColor**

Get the `r`, `g`, `b`, `a` value of a color option. `name` is of the form "category.option" or "category[num].option". Available categories and options are listed in the Gmsh reference manual, with the "Color." middle string removed.

Input:      `name`

Output:   `r`, `g`, `b`, `a`

Return:    -

## D.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`

Output:   -

Return:    -

**gmsh/model/remove**

Remove the current model.

Input:      -

Output:   -

Return:    -

**gmsh/model/list**

List the names of all models.

Input:      -

Output:   `names`

Return:    -

**gmsh/model/getCurrent**

Get the name of the current model.

Input:      -

Output:   `name`

Return:    -

**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`

Output:   -

Return:    -

**gmsh/model/getEntities**

Get all the entities in the current model. 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) integer pairs.

Input:     `dim = -1`

Output:    `dimTags`

Return:    -

**gmsh/model/setEntityName**

Set the name of the entity of dimension `dim` and tag `tag`.

Input:     `dim`, `tag`, `name`

Output:    -

Return:    -

**gmsh/model/getEntityName**

Get the name of the entity of dimension `dim` and tag `tag`.

Input:     `dim`, `tag`

Output:    `name`

Return:    -

**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) integer pairs.

Input:     `dim = -1`

Output:    `dimTags`

Return:    -

**gmsh/model/getEntitiesForPhysicalGroup**

Get the tags of the model entities making up the physical group of dimension `dim` and tag `tag`.

Input:     `dim`, `tag`

Output:    `tags`

Return:    -

**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`, `tag`

Output:    `physicalTags`

Return:    -

`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`.

Input:     `dim`, `tags`, `tag = -1`

Output:    -

Return:    integer value

`gmsh/model/setPhysicalName`

Set the name of the physical group of dimension `dim` and tag `tag`.

Input:     `dim`, `tag`, `name`

Output:    -

Return:    -

`gmsh/model/getPhysicalName`

Get the name of the physical group of dimension `dim` and tag `tag`.

Input:     `dim`, `tag`

Output:    `name`

Return:    -

`gmsh/model/getBoundary`

Get the boundary of the model entities `dimTags`. 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`, `combined = True`, `oriented = True`, `recursive = False`

Output:    `outDimTags`

Return:    -

`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`, `ymin`, `zmin`, `xmax`, `ymax`, `zmax`, `dim = -1`

Output:    `tags`

Return:    -

`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`, `tag`

Output:      `xmin`, `ymin`, `zmin`, `xmax`, `ymax`, `zmax`

Return:      -

### gmsh/model/getDimension
Get the geometrical dimension of the current model.

Input:       -

Output:      -

Return:      integer value

### 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`, `tag = -1`, `boundary = []`

Output:      -

Return:      integer value

### gmsh/model/removeEntities
Remove the entities `dimTags` of the current model. If `recursive` is true, remove all the entities on their boundaries, down to dimension 0.

Input:       `dimTags`, `recursive = False`

Output:      -

Return:      -

### gmsh/model/removeEntityName
Remove the entity name `name` from the current model.

Input:       `name`

Output:      -

Return:      -

### gmsh/model/removePhysicalGroups
Remove the physical groups `dimTags` of the current model. If `dimTags` is empty, remove all groups.

Input:       `dimTags = []`

Output:      -

Return:      -

### gmsh/model/removePhysicalName
Remove the physical name `name` from the current model.

Input:      name

Output:     -

Return:     -

**gmsh/model/getType**

>  Get the type of the entity of dimension `dim` and tag `tag`.

> Input:      `dim`, `tag`

> Output:     `entityType`

> Return:     -

**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`, `tag`

> Output:     `parentDim`, `parentTag`

> Return:     -

**gmsh/model/getPartitions**

>  In a partitioned model, return the tags of the partition(s) to which the entity belongs.

> Input:      `dim`, `tag`

> Output:     `partitions`

> Return:     -

**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 pairs of u, v parametric coordinates on the surface, concatenated: [p1u, p1v, p2u, ...]). Return triplets of x, y, z coordinates in `points`, concatenated: [p1x, p1y, p1z, p2x, ...].

> Input:      `dim`, `tag`, `parametricCoord`

> Output:     `points`

> Return:     -

**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 pairs of 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 derivate with respect to u and v: [d1ux, d1uy, d1uz, d1vx, d1vy, d1vz, d2ux, ...].

Input:      `dim`, `tag`, `parametricCoord`

Output:    `derivatives`

Return:     -

### 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 pairs of u, v parametric coordinates on the surface, concatenated: [p1u, p1v, p2u, ...]).

Input:      `dim`, `tag`, `parametricCoord`

Output:    `curvatures`

Return:     -

### 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`, `parametricCoord`

Output:    `curvatureMax`, `curvatureMin`, `directionMax`, `directionMin`

Return:     -

### gmsh/model/getNormal

Get the normal to the surface with tag `tag` at the parametric coordinates `parametricCoord`. `parametricCoord` are given by pairs of u and v coordinates, concatenated: [p1u, p1v, p2u, ...]. `normals` are returned as triplets of x, y, z components, concatenated: [n1x, n1y, n1z, n2x, ...].

Input:      `tag`, `parametricCoord`

Output:    `normals`

Return:     -

### gmsh/model/getParametrization

Get the parametric coordinates `parametricCoord` for the points `points` on the entity of dimension `dim` and tag `tag`. `points` are given as triplets of x, y, z coordinates, concatenated: [p1x, p1y, p1z, p2x, ...]. `parametricCoord` returns the parametric coordinates t on the curve (if `dim` = 1) or pairs of u and v coordinates concatenated on the surface (if `dim` = 2), i.e. [p1t, p2t, ...] or [p1u, p1v, p2u, ...].

Input:      `dim`, `tag`, `points`

Output:      `parametricCoord`

Return:      -

**gmsh/model/setVisibility**

Set the visibility of the model entities `dimTags` to `value`. Apply the visibility setting recursively if `recursive` is true.

Input:      `dimTags`, `value`, `recursive = False`

Output:      -

Return:      -

**gmsh/model/getVisibility**

Get the visibility of the model entity of dimension `dim` and tag `tag`.

Input:      `dim`, `tag`

Output:      `value`

Return:      -

**gmsh/model/setColor**

Set the color of the model entities `dimTags` 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`, `r`, `g`, `b`, `a = 0`, `recursive = False`

Output:      -

Return:      -

**gmsh/model/getColor**

Get the color of the model entity of dimension `dim` and tag `tag`.

Input:      `dim`, `tag`

Output:      `r`, `g`, `b`, `a`

Return:      -

**gmsh/model/setCoordinates**

Set the `x`, `y`, `z` coordinates of a geometrical point.

Input:      `tag`, `x`, `y`, `z`

Output:      -

Return:      -

## D.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`

Output:      -

Return:        -

**gmsh/model/mesh/partition**

Partition the mesh of the current model into `numPart` partitions.

Input:         `numPart`

Output:        -

Return:        -

**gmsh/model/mesh/unpartition**

Unpartition the mesh of the current model.

Input:         -

Output:        -

Return:        -

**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). If `force` is set apply the optimization also to discrete entities. If `dimTags` is given, only apply the optimizer to the given entities.

Input:         `method`, `force = False`, `niter = 1`, `dimTags = []`

Output:        -

Return:        -

**gmsh/model/mesh/recombine**

Recombine the mesh of the current model.

Input:         -

Output:        -

Return:        -

**gmsh/model/mesh/refine**

Refine the mesh of the current model by uniformly splitting the elements.

Input:         -

Output:        -

Return:        -

**gmsh/model/mesh/setOrder**

Set the order of the elements in the mesh of the current model to `order`.

Input:         `order`

Output:        -

Return:       -

**gmsh/model/mesh/getLastEntityError**

Get the last entities (if any) where a meshing error occurred. Currently only populated by the new 3D meshing algorithms.

Input:        -

Output:    `dimTags`

Return:       -

**gmsh/model/mesh/getLastNodeError**

Get the last nodes (if any) where a meshing error occurred. Currently only populated by the new 3D meshing algorithms.

Input:        -

Output:    `nodeTags`

Return:       -

**gmsh/model/mesh/clear**

Clear the mesh, i.e. delete all the nodes and elements.

Input:        -

Output:    -

Return:       -

**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`, `tag = -1`, `includeBoundary = False`, `returnParametricCoord` `= True`

Output:    `nodeTags`, `coord`, `parametricCoord`

Return:       -

**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`, `tag = -1`, `returnParametricCoord = True`

Output:     nodeTags, coord, parametricCoord

Return:     -

**gmsh/model/mesh/getNode**

Get 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

Output:     coord, parametricCoord

Return:     -

**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, coord, parametricCoord

Output:     -

Return:     -

**gmsh/model/mesh/rebuildNodeCache**

Rebuild the node cache.

Input:      onlyIfNecessary = True

Output:     -

Return:     -

**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, tag

Output:     nodeTags, coord

Return:     -

**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`, `tag`, `nodeTags`, `coord`, `parametricCoord = []`

Output:     -

Return:     -

### 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:     -

### 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`, `tag = -1`

Output:     -

Return:     -

### 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`, `tag = -1`

Output:     `elementTypes`, `elementTags`, `nodeTags`

Return:     -

### gmsh/model/mesh/getElement

Get the type and node tags of the element with tag `tag`. 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`

Output:     `elementType`, `nodeTags`

Return:       -

**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 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`, `y`, `z`, `dim = -1`, `strict = False`

Output:      `elementTag`, `elementType`, `nodeTags`, `u`, `v`, `w`

Return:       -

**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`, `y`, `z`, `dim = -1`, `strict = False`

Output:      `elementTags`

Return:       -

**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`, `x`, `y`, `z`

Output:      `u`, `v`, `w`

Return:       -

**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`, `tag = -1`

Output:      `elementTypes`

Return:       -

**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, order, serendip = False |
|---------|-------------------------------------|

| Output: | - |
|---------|---|

| Return: | integer value |
|---------|---------------|

`gmsh/model/mesh/getElementProperties`

Get the properties of an element of type elementType: its name (elementName), dimension (dim), order (order), number of nodes (numNodes), coordinates of the nodes in the reference element (nodeCoord vector, of length dim times numNodes) and number of primary (first order) nodes (numPrimaryNodes).

| Input:  | elementType |
|---------|-------------|

| Output: | elementName,  dim,  order,  numNodes,  nodeCoord, numPrimaryNodes |
|---------|-------------------------------------------------------------------|

| Return: | - |
|---------|---|

`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.

| Input:  | elementType, tag = -1, task = 0, numTasks = 1 |
|---------|-----------------------------------------------|

| Output: | elementTags, nodeTags |
|---------|-----------------------|

| Return: | - |
|---------|---|

`gmsh/model/mesh/preallocateElementsByType`

Preallocate data before calling getElementsByType with numTasks > 1. For C and C++ only.

| Input:  | elementType, elementTag, nodeTag, tag = -1 |
|---------|--------------------------------------------|

| Output: | elementTags, nodeTags |
|---------|-----------------------|

| Return: | - |
|---------|---|

`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, tag, elementTypes, elementTags, nodeTags

Output:      -

Return:      -

**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, elementType, elementTags, nodeTags

Output:      -

Return:      -

**gmsh/model/mesh/getIntegrationPoints**

Get the numerical quadrature information for the given element type `elementType` and integration rule `integrationType` (e.g.     "Gauss4" for a Gauss quadrature suited for integrating 4th order polynomials). `integrationPoints` contains the u, v, w coordinates of the G integration points in the reference element: [g1u, g1v, g1w, ..., gGu, gGv, gGw]. `integrationWeigths` contains the associated weights: [g1q, ..., gGq].

Input:       elementType, integrationType

Output:      integrationPoints, integrationWeights

Return:      -

**gmsh/model/mesh/getJacobians**

Get the Jacobians of all the elements of type `elementType` classified on the entity of tag `tag`, at the G integration points `integrationPoints` given as concatenated triplets of 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 integration 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 integration point: [e1g1, e1g2, ... e1gG, e2g1, ...]. `points` contains for each element the x, y, z coordinates of the integration 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`.

Input:       elementType, integrationPoints, tag = -1, task = 0, numTasks = 1

Output:      jacobians, determinants, points

Return:    -

**gmsh/model/mesh/preallocateJacobians**

Preallocate data before calling `getJacobians` with `numTasks > 1`. For C and C++ only.

Input:    `elementType, numIntegrationPoints, jacobian, determinant, point, tag = -1`

Output:    `jacobians`, `determinants`, `points`

Return:    -

**gmsh/model/mesh/getBasisFunctions**

Get the basis functions of the element of type `elementType` at the integration points `integrationPoints` (given as concatenated triplets of coordinates in the reference element [g1u, g1v, g1w, ..., gGu, gGv, gGw]), for the function space `functionSpaceType` (e.g. "Lagrange" or "GradLagrange" for Lagrange basis functions or their gradient, in the u, v, w coordinates of the reference element). `numComponents` returns the number C of components of a basis function. `basisFunctions` returns the value of the N basis functions at the integration points, i.e. [g1f1, g1f2, ..., g1fN, g2f1, ...] when C == 1 or [g1f1u, g1f1v, g1f1w, g1f2u, ..., g1fNw, g2f1u, ...] when C == 3.

Input:    `elementType, integrationPoints, functionSpaceType`

Output:    `numComponents, basisFunctions`

Return:    -

**gmsh/model/mesh/getBasisFunctionsForElements**

Get the element-dependent basis functions of the elements of type `elementType` in the entity of tag `tag`at the integration points `integrationPoints` (given as concatenated triplets of coordinates in the reference element [g1u, g1v, g1w, ..., gGu, gGv, gGw]), for the function space `functionSpaceType` (e.g. "H1Legendre3" or "GradH1Legendre3" for 3rd order hierarchical H1 Legendre functions or their gradient, in the u, v, w coordinates of the reference elements). `numComponents` returns the number C of components of a basis function. `numBasisFunctions` returns the number N of basis functions per element. `basisFunctions` returns the value of the basis functions at the integration points for each element: [e1g1f1,..., e1g1fN, e1g2f1,..., e2g1f1, ...] when C == 1 or [e1g1f1u, e1g1f1v,..., e1g1fNw, e1g2f1u,..., e2g1f1u, ...]. Warning: this is an experimental feature and will probably change in a future release. If `numTasks > 1`, only compute and return the part of the data indexed by `task`.

Input:    `elementType, integrationPoints, functionSpaceType, tag = -1, task = 0, numTasks = 1`

Output:    `numComponents, numFunctionsPerElements, basisFunctions`

Return:    -

**gmsh/model/mesh/preallocateBasisFunctions**

Preallocate data before calling `getBasisFunctionsForElements` with `numTasks > 1`. For C and C++ only.

| Input:  | `elementType`, `numIntegrationPoints`, `functionSpaceType`, `tag` `= -1` |
|---------|--------------------------------------|
| Output: | `basisFunctions` |
| Return: | - |

**gmsh/model/mesh/getKeysForElements**

Generate the `keys` for the elements of type `elementType` in the entity of tag `tag`, for the `functionSpaceType` function space. Each key 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`, `functionSpaceType`, `tag = -1`, `returnCoord =` `True` |
|---------|--------------------------------------|
| Output: | `keys`, `coord` |
| Return: | - |

**gmsh/model/mesh/getNumberOfKeysForElements**

Get the number of keys by elements of type `elementType` for function space named `functionSpaceType`.

| Input:  | `elementType`, `functionSpaceType` |
|---------|--------------------------------------|
| Output: | - |
| Return: | integer value |

**gmsh/model/mesh/getInformationForElements**

Get information about the `keys`. `infoKeys` returns information about the functions associated with the `keys`. `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:  | `keys`, `elementType`, `functionSpaceType` |
|---------|--------------------------------------|
| Output: | `infoKeys` |
| Return: | - |

**gmsh/model/mesh/precomputeBasisFunctions**

Precomputes the basis functions corresponding to `elementType`.

| Input:  | `elementType` |
|---------|--------------------------------------|
| Output: | - |
| Return: | - |

**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`.

Input:      `elementType, tag, fast, primary, task = 0, numTasks = 1`

Output:     `barycenters`

Return:     -

**gmsh/model/mesh/preallocateBarycenters**

Preallocate data before calling `getBarycenters` with `numTasks > 1`. For C and C++ only.

Input:      `elementType, tag = -1`

Output:     `barycenters`

Return:     -

**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`.

Input:      `elementType, tag = -1, primary = False, task = 0, numTasks = 1`

Output:     `nodeTags`

Return:     -

**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`.

Input:      `elementType, faceType, tag = -1, primary = False, task = 0, numTasks = 1`

Output:     `nodeTags`

Return:     -

**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`, `tag`

Output:     `elementTags`, `partitions`

Return:     -

## gmsh/model/mesh/setSize

Set a mesh size constraint on the model entities `dimTags`. Currently only entities of dimension 0 (points) are handled.

Input:      `dimTags`, `size`

Output:     -

Return:     -

## 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`) and "Bump" (refinement toward both extremities of the curve).

Input:      `tag, numNodes, meshType = "Progression", coef = 1.`

Output:     -

Return:     -

## 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, arrangement = "Left", cornerTags = []`

Output:     -

Return:     -

## 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, cornerTags = []`

Output:     -

Return:     -

## 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.

Input:      `dim, tag`

Output:     -

Return:     -

**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`, `tag`, `val`

Output:     -

Return:     -

**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`, `tag`, `val = True`

Output:     -

Return:     -

**gmsh/model/mesh/setAlgorithm**

Set the meshing algorithm on the model entity of dimension `dim` and tag `tag`. Currently only supported for `dim == 2`.

Input:      `dim`, `tag`, `val`

Output:     -

Return:     -

**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`, `tag`, `val`

Output:     -

Return:     -

**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`, `tags`

Output:     -

Return:     -

**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. Currently only available with the OpenCASCADE kernel, as it relies on the STL triangulation.

Input:       `tag`

Output:      -

Return:      -

**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 be part of the boundary of the entity `inTag`, whose mesh will conform to the mesh of the embedded entities.

Input:       `dim`, `tags`, `inDim`, `inTag`

Output:      -

Return:      -

**gmsh/model/mesh/removeEmbedded**

Remove embedded entities from the model entities `dimTags`. if `dim` is >= 0, only remove embedded entities of the given dimension (e.g. embedded points if `dim` == 0).

Input:       `dimTags, dim = -1`

Output:      -

Return:      -

**gmsh/model/mesh/reorderElements**

Reorder the elements of type `elementType` classified on the entity of tag `tag` according to `ordering`.

Input:       `elementType`, `tag`, `ordering`

Output:      -

Return:      -

**gmsh/model/mesh/renumberNodes**

Renumber the node tags in a continuous sequence.

Input:       -

Output:      -

Return:      -

**gmsh/model/mesh/renumberElements**

Renumber the element tags in a continuous sequence.

Input:       -

Output:      -

Return:      -

**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`, `tags`, `tagsMaster`, `affineTransform`

Output:     -

Return:     -

**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`.

Input:      `dim`, `tag`

Output:     `tagMaster`, `nodeTags`, `nodeTagsMaster`, `affineTransform`

Return:     -

**gmsh/model/mesh/removeDuplicateNodes**

Remove duplicate nodes in the mesh of the current model.

Input:      -

Output:     -

Return:     -

**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.`, `tag = -1`

Output:     -

Return:     -

**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 edges 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`.

Input:      `angle`,    `boundary = True`,    `forReparametrization = False`, `curveAngle = pi`

Output:     -

> Return:      -

`gmsh/model/mesh/createGeometry`

> Create a parametrization for discrete curves and surfaces (i.e. curves and surfaces represented solely by a mesh, without an underlying CAD description), assuming that each can be parametrized with a single map.
>
> Input:       -
>
> Output:      -
>
> Return:      -

`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).
>
> Input:       -
>
> Output:      -
>
> Return:      -

`gmsh/model/mesh/computeHomology`

> Compute a basis representation for homology spaces after a mesh has been generated. 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 homology computation is given in a list of physical group tags `subdomainTags`; if empty, absolute homology is computed. The dimensions homology bases to be computed are given in the list `dim`; if empty, all bases are computed. Resulting basis representation chains are stored as physical groups in the mesh.
>
> Input:       `domainTags = []`, `subdomainTags = []`, `dims = []`
>
> Output:      -
>
> Return:      -

`gmsh/model/mesh/computeCohomology`

> Compute a basis representation for cohomology spaces after a mesh has been generated. 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 cohomology computation is given in a list of physical group tags `subdomainTags`; if empty, absolute cohomology is computed. The dimensions homology bases to be computed are given in the list `dim`; if empty, all bases are computed. Resulting basis representation cochains are stored as physical groups in the mesh.
>
> Input:       `domainTags = []`, `subdomainTags = []`, `dims = []`
>
> Output:      -
>
> Return:      -

`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`

Return:     -

## D.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.

Input:      `fieldType, tag = -1`

Output:     -

Return:     integer value

`gmsh/model/mesh/field/remove`

Remove the field with tag `tag`.

Input:      `tag`

Output:     -

Return:     -

`gmsh/model/mesh/field/setNumber`

Set the numerical option `option` to value `value` for field `tag`.

Input:      `tag, option, value`

Output:     -

Return:     -

`gmsh/model/mesh/field/setString`

Set the string option `option` to value `value` for field `tag`.

Input:      `tag, option, value`

Output:     -

Return:     -

`gmsh/model/mesh/field/setNumbers`

Set the numerical list option `option` to value `value` for field `tag`.

Input:      `tag, option, value`

Output:     -

Return:     -

`gmsh/model/mesh/field/setAsBackgroundMesh`
    Set the field `tag` as the background mesh size field.

    Input:        `tag`

    Output:       -

    Return:       -

`gmsh/model/mesh/field/setAsBoundaryLayer`
    Set the field `tag` as a boundary layer size field.

    Input:        `tag`

    Output:       -

    Return:       -

## D.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, y, z, meshSize = 0., tag = -1`

    Output:       -

    Return:       integer value

`gmsh/model/geo/addLine`
    Add a straight line segment 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, endTag, tag = -1`

    Output:       -

    Return:       integer value

`gmsh/model/geo/addCircleArc`
    Add a circle arc (strictly smaller than Pi) between the two points with tags `startTag` and `endTag`, 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, centerTag, endTag, tag = -1, nx = 0., ny = 0., nz = 0.`

    Output:       -

    Return:       integer value

`gmsh/model/geo/addEllipseArc`

> Add an ellipse arc (strictly smaller than Pi) between the two points `startTag` and `endTag`, 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, centerTag, majorTag, endTag, tag = -1, nx = 0., ny = 0., nz = 0.`
>
> Output:　　-
>
> Return:　　integer value

`gmsh/model/geo/addSpline`

> Add a spline (Catmull-Rom) curve 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, tag = -1`
>
> Output:　　-
>
> Return:　　integer value

`gmsh/model/geo/addBSpline`

> Add a cubic b-spline curve 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, tag = -1`
>
> Output:　　-
>
> Return:　　integer value

`gmsh/model/geo/addBezier`

> Add a Bezier curve 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, tag = -1`
>
> Output:　　-
>
> Return:　　integer value

`gmsh/model/geo/addCompoundSpline`

> Add a spline (Catmull-Rom) 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, numIntervals = 5, tag = -1`

Output:     -

Return:     integer value

**gmsh/model/geo/addCompoundBSpline**

Add a b-spline 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`, `numIntervals = 20`, `tag = -1`

Output:     -

Return:     integer value

**gmsh/model/geo/addCurveLoop**

Add a curve loop (a closed wire) formed by the curves `curveTags`. `curveTags` should contain (signed) tags of model enties 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. Return the tag of the curve loop.

Input:      `curveTags`, `tag = -1`

Output:     -

Return:     integer value

**gmsh/model/geo/addPlaneSurface**

Add a plane surface 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`, `tag = -1`

Output:     -

Return:     integer value

**gmsh/model/geo/addSurfaceFilling**

Add a surface filling the curve loops in `wireTags`. 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`, `tag = -1`, `sphereCenterTag = -1`

Output:     -

Return:     integer value

**gmsh/model/geo/addSurfaceLoop**

Add a surface loop (a closed shell) formed by `surfaceTags`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the shell.

Input:      surfaceTags, tag = -1

Output:     -

Return:     integer value

**gmsh/model/geo/addVolume**

Add a volume (a region) 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, tag = -1

Output:     -

Return:     integer value

**gmsh/model/geo/extrude**

Extrude the model entities dimTags by translation along (dx, dy, dz). Return extruded entities in outDimTags. If numElements is not empty, also extrude the mesh: the entries in numElements give the number of elements in each layer. If height is not empty, it provides the (cumulative) height of the different layers, normalized to 1. If dx == dy == dz == 0, the entities are extruded along their normal.

Input:      dimTags, dx, dy, dz, numElements = [], heights = [], recombine
            = False

Output:     outDimTags

Return:     -

**gmsh/model/geo/revolve**

Extrude the model entities dimTags by 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 numElements is not empty, also extrude the mesh: the entries in numElements give the number of elements in each layer. If height is not empty, it provides the (cumulative) height of the different layers, normalized to 1.

Input:      dimTags, x, y, z, ax, ay, az, angle, numElements = [], heights =
            [], recombine = False

Output:     outDimTags

Return:     -

**gmsh/model/geo/twist**

Extrude the model entities dimTags by 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 numElements is not empty, also extrude the mesh: the entries in numElements give the number

of elements in each layer. If `height` is not empty, it provides the (cumulative) height of the different layers, normalized to 1.

Input:     dimTags, x, y, z, dx, dy, dz, ax, ay, az, angle, numElements = [], heights = [], recombine = False

Output:    outDimTags

Return:    -

### gmsh/model/geo/translate
Translate the model entities `dimTags` along (`dx`, `dy`, `dz`).

Input:     dimTags, dx, dy, dz

Output:    -

Return:    -

### gmsh/model/geo/rotate
Rotate the model entities `dimTags` of `angle` radians around the axis of revolution defined by the point (`x`, `y`, `z`) and the direction (`ax`, `ay`, `az`).

Input:     dimTags, x, y, z, ax, ay, az, angle

Output:    -

Return:    -

### gmsh/model/geo/dilate
Scale the model entities `dimTag` by factors `a`, `b` and `c` along the three coordinate axes; use (`x`, `y`, `z`) as the center of the homothetic transformation.

Input:     dimTags, x, y, z, a, b, c

Output:    -

Return:    -

### gmsh/model/geo/mirror
Mirror the model entities `dimTag`, with respect to the plane of equation `a` * x + `b` * y + `c` * z + `d` = 0.

Input:     dimTags, a, b, c, d

Output:    -

Return:    -

### gmsh/model/geo/symmetrize
Mirror the model entities `dimTag`, 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, a, b, c, d

Output:    -

Return:    -

`gmsh/model/geo/copy`

Copy the entities `dimTags`; the new entities are returned in `outDimTags`.

Input:      `dimTags`

Output:     `outDimTags`

Return:     -

`gmsh/model/geo/remove`

Remove the entities `dimTags`. If `recursive` is true, remove all the entities on their boundaries, down to dimension 0.

Input:      `dimTags`, `recursive = False`

Output:     -

Return:     -

`gmsh/model/geo/removeAllDuplicates`

Remove all duplicate entities (different entities at the same geometrical location).

Input:      -

Output:     -

Return:     -

`gmsh/model/geo/splitCurve`

Split the model curve of tag `tag` on the control points `pointTags`. Return the tags `curveTags` of the newly created curves.

Input:      `tag`, `pointTags`

Output:     `curveTags`

Return:     -

`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.

Input:      -

Output:     -

Return:     -

## D.7 Namespace `gmsh/model/geo/mesh`: built-in CAD kernel meshing constraints

`gmsh/model/geo/mesh/setSize`

Set a mesh size constraint on the model entities `dimTags`. Currently only entities of dimension 0 (points) are handled.

Input:      `dimTags`, `size`

Output:     -

Return:     -

**gmsh/model/geo/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`) and "Bump" (refine-
ment toward both extremities of the curve).

Input:      `tag`, `nPoints`, `meshType = "Progression"`, `coef = 1.`

Output:     -

Return:     -

**gmsh/model/geo/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 "Alter-
nateRight". `cornerTags` can be used to specify the (3 or 4) corners of the
transfinite interpolation explicitly; specifying the corners explicitly is manda-
tory if the surface has more that 3 or 4 points on its boundary.

Input:      `tag`, `arrangement = "Left"`, `cornerTags = []`

Output:     -

Return:     -

**gmsh/model/geo/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`, `cornerTags = []`

Output:     -

Return:     -

**gmsh/model/geo/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.

Input:      `dim`, `tag`, `angle = 45.`

Output:     -

Return:     -

**gmsh/model/geo/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`, `tag`, `val`

Output:     -

Return:        -

**gmsh/model/geo/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, tag, val = True`

Output:       -

Return:        -

**gmsh/model/geo/mesh/setAlgorithm**

Set the meshing algorithm on the model entity of dimension `dim` and tag `tag`. Currently only supported for `dim == 2`.

Input:        `dim, tag, val`

Output:       -

Return:        -

**gmsh/model/geo/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, tag, val`

Output:       -

Return:        -

# D.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, y, z, meshSize = 0., tag = -1`

Output:       -

Return:       integer value

**gmsh/model/occ/addLine**

Add a straight line segment 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, endTag, tag = -1`

Output:      -

Return:      integer value

### gmsh/model/occ/addCircleArc

Add a circle arc between the two points with tags `startTag` and `endTag`, with center `centerTag`. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the circle arc.

Input:       `startTag, centerTag, endTag, tag = -1`

Output:      -

Return:      integer value

### gmsh/model/occ/addCircle

Add a circle of center (`x`, `y`, `z`) and radius `r`. 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. Return the tag of the circle.

Input:       `x, y, z, r, tag = -1, angle1 = 0., angle2 = 2*pi`

Output:      -

Return:      integer value

### gmsh/model/occ/addEllipseArc

Add an ellipse arc between the two points `startTag` and `endTag`, 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, centerTag, majorTag, endTag, tag = -1`

Output:      -

Return:      integer value

### gmsh/model/occ/addEllipse

Add an ellipse of center (`x`, `y`, `z`) and radii `r1` and `r2` along the x- and y-axes respectively. 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. Return the tag of the ellipse. Note that OpenCASCADE does not allow creating ellipses with the major radius (along the x-axis) smaller than or equal to the minor radius (along the y-axis): rotate the shape or use `addCircle` in such cases.

Input:       `x, y, z, r1, r2, tag = -1, angle1 = 0., angle2 = 2*pi`

Output:      -

Return:      integer value

### gmsh/model/occ/addSpline

Add a spline (C2 b-spline) curve 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, tag = -1`

Output:     -

Return:     integer value

**gmsh/model/occ/addBSpline**

Add a b-spline curve of degree `degree` 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, tag = -1, degree = 3, weights = [], knots = [],`
            `multiplicities = []`

Output:     -

Return:     integer value

**gmsh/model/occ/addBezier**

Add a Bezier curve 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, tag = -1`

Output:     -

Return:     integer value

**gmsh/model/occ/addWire**

Add a wire (open or closed) 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, tag = -1, checkClosed = False`

Output:     -

Return:     integer value

**gmsh/model/occ/addCurveLoop**

Add a curve loop (a closed wire) formed by the curves `curveTags`. `curveTags` should contain tags of curves forming a closed loop. Note that an OpenCAS-CADE 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, tag = -1`

Output:     -

Return:     integer value

`gmsh/model/occ/addRectangle`

Add a rectangle 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, y, z, dx, dy, tag = -1, roundedRadius = 0.`

Output:    -

Return:    integer value

`gmsh/model/occ/addDisk`

Add a disk with center (`xc`, `yc`, `zc`) and radius `rx` along the x-axis and `ry` along the y-axis. If `tag` is positive, set the tag explicitly; otherwise a new tag is selected automatically. Return the tag of the disk.

Input:      `xc, yc, zc, rx, ry, tag = -1`

Output:    -

Return:    integer value

`gmsh/model/occ/addPlaneSurface`

Add a plane surface 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, tag = -1`

Output:    -

Return:    integer value

`gmsh/model/occ/addSurfaceFilling`

Add a surface filling the curve loops in `wireTags`. 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.

Input:      `wireTag, tag = -1, pointTags = []`

Output:    -

Return:    integer value

`gmsh/model/occ/addSurfaceLoop`

Add a surface loop (a closed shell) 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 to build a shell made of surfaces that share geometrically identical (but topologically different) curves.

Input:      `surfaceTags, tag = -1, sewing = False`

Output:    -

Return:    integer value

`gmsh/model/occ/addVolume`

Add a volume (a region) 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`, `tag = -1`

Output:    -

Return:    integer value

`gmsh/model/occ/addSphere`

Add a sphere of center (`xc`, `yc`, `zc`) and radius `r`. 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, yc, zc, radius, tag = -1, angle1 = -pi/2, angle2 = pi/2,`
           `angle3 = 2*pi`

Output:    -

Return:    integer value

`gmsh/model/occ/addBox`

Add a parallelepipedic box 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, y, z, dx, dy, dz, tag = -1`

Output:    -

Return:    integer value

`gmsh/model/occ/addCylinder`

Add a cylinder, 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, y, z, dx, dy, dz, r, tag = -1, angle = 2*pi`

Output:    -

Return:    integer value

`gmsh/model/occ/addCone`

Add a cone, 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, y, z, dx, dy, dz, r1, r2, tag = -1, angle = 2*pi |
| Output: | -                                                    |
| Return: | integer value                                        |

### gmsh/model/occ/addWedge

Add a right angular wedge, 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. Return the tag of the wedge.

|         |                                        |
|---------|----------------------------------------|
| Input:  | x, y, z, dx, dy, dz, tag = -1, ltx = 0. |
| Output: | -                                      |
| Return: | integer value                          |

### gmsh/model/occ/addTorus

Add a torus, 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). Return the tag of the wedge.

|         |                                        |
|---------|----------------------------------------|
| Input:  | x, y, z, r1, r2, tag = -1, angle = 2*pi |
| Output: | -                                      |
| Return: | integer value                          |

### gmsh/model/occ/addThruSections

Add a volume (if the optional argument makeSolid is set) or surfaces 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. If the optional argument makeRuled is set, the surfaces created on the boundary are forced to be ruled surfaces.

|         |                                                      |
|---------|------------------------------------------------------|
| Input:  | wireTags, tag = -1, makeSolid = True, makeRuled = False |
| Output: | outDimTags                                           |
| Return: | -                                                    |

### gmsh/model/occ/addThickSolid

Add a hollowed volume 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, excludeSurfaceTags, offset, tag = -1 |
| Output: | outDimTags                                       |
| Return: | -                                                |

gmsh/model/occ/extrude

> Extrude the model entities `dimTags` by translation along (`dx`, `dy`, `dz`). Return extruded entities in `outDimTags`. If `numElements` is not empty, also extrude the mesh: the entries in `numElements` give the number of elements in each layer. If `height` is not empty, it provides the (cumulative) height of the different layers, normalized to 1.
>
> Input:     dimTags, dx, dy, dz, numElements = [], heights = [], recombine = False
>
> Output:    outDimTags
>
> Return:    -

gmsh/model/occ/revolve

> Extrude the model entities `dimTags` by 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 `numElements` is not empty, also extrude the mesh: the entries in `numElements` give the number of elements in each layer. If `height` 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.
>
> Input:     dimTags, x, y, z, ax, ay, az, angle, numElements = [], heights = [], recombine = False
>
> Output:    outDimTags
>
> Return:    -

gmsh/model/occ/addPipe

> Add a pipe by extruding the entities `dimTags` along the wire `wireTag`. Return the pipe in `outDimTags`.
>
> Input:     dimTags, wireTag
>
> Output:    outDimTags
>
> Return:    -

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`. Remove the original volume if `removeVolume` is set.
>
> Input:     volumeTags, curveTags, radii, removeVolume = True
>
> Output:    outDimTags
>
> Return:    -

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`, `curveTags`, `surfaceTags`, `distances`, `removeVolume` `= True`

Output:    `outDimTags`

Return:    -

### gmsh/model/occ/fuse

Compute the boolean union (the fusion) of the entities `objectDimTags` and `toolDimTags`. 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`, `toolDimTags`, `tag = -1`, `removeObject = True`, `removeTool = True`

Output:    `outDimTags`, `outDimTagsMap`

Return:    -

### gmsh/model/occ/intersect

Compute the boolean intersection (the common parts) of the entities `objectDimTags` and `toolDimTags`. 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`, `toolDimTags`, `tag = -1`, `removeObject = True`, `removeTool = True`

Output:    `outDimTags`, `outDimTagsMap`

Return:    -

### gmsh/model/occ/cut

Compute the boolean difference between the entities `objectDimTags` and `toolDimTags`. 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`, `toolDimTags`, `tag = -1`, `removeObject = True`, `removeTool = True`

Output:    `outDimTags`, `outDimTagsMap`

Return:    -

`gmsh/model/occ/fragment`

Compute the boolean fragments (general fuse) of the entities `objectDimTags` and `toolDimTags`. 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`, `toolDimTags`, `tag = -1`, `removeObject = True`, `removeTool = True`

Output:     `outDimTags`, `outDimTagsMap`

Return:     -

`gmsh/model/occ/translate`

Translate the model entities `dimTags` along (`dx`, `dy`, `dz`).

Input:      `dimTags`, `dx`, `dy`, `dz`

Output:     -

Return:     -

`gmsh/model/occ/rotate`

Rotate the model entities `dimTags` of `angle` radians around the axis of revolution defined by the point (`x`, `y`, `z`) and the direction (`ax`, `ay`, `az`).

Input:      `dimTags`, `x`, `y`, `z`, `ax`, `ay`, `az`, `angle`

Output:     -

Return:     -

`gmsh/model/occ/dilate`

Scale the model entities `dimTag` by factors `a`, `b` and `c` along the three coordinate axes; use (`x`, `y`, `z`) as the center of the homothetic transformation.

Input:      `dimTags`, `x`, `y`, `z`, `a`, `b`, `c`

Output:     -

Return:     -

`gmsh/model/occ/mirror`

Apply a symmetry transformation to the model entities `dimTag`, with respect to the plane of equation `a * x + b * y + c * z + d = 0`.

Input:      `dimTags`, `a`, `b`, `c`, `d`

Output:     -

Return:     -

`gmsh/model/occ/symmetrize`

Apply a symmetry transformation to the model entities `dimTag`, 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`, `a`, `b`, `c`, `d`

Output:     -

Return:     -

### gmsh/model/occ/affineTransform

Apply a general affine transformation matrix `a` (16 entries of a 4x4 matrix, by row; only the 12 first can be provided for convenience) to the model entities `dimTag`.

Input:      dimTags, a

Output:     -

Return:     -

### gmsh/model/occ/copy

Copy the entities `dimTags`; the new entities are returned in `outDimTags`.

Input:      dimTags

Output:     outDimTags

Return:     -

### gmsh/model/occ/remove

Remove the entities `dimTags`. If `recursive` is true, remove all the entities on their boundaries, down to dimension 0.

Input:      dimTags, recursive = False

Output:     -

Return:     -

### gmsh/model/occ/removeAllDuplicates

Remove all duplicate entities (different entities at the same geometrical location) after intersecting (using boolean fragments) all highest dimensional entities.

Input:      -

Output:     -

Return:     -

### gmsh/model/occ/healShapes

Apply various healing procedures to the entities `dimTags` (or to all the entities in the model if `dimTags` is empty). Return the healed entities in `outDimTags`. Available healing options are listed in the Gmsh reference manual.

Input:      dimTags = [],    tolerance = 1e-8,    fixDegenerated = True,
            fixSmallEdges = True,    fixSmallFaces = True,    sewFaces =
            True, makeSolids = True

Output:     outDimTags

Return:     -

`gmsh/model/occ/importShapes`

        Import BREP, STEP or IGES shapes from the file `fileName`. The imported entities are returned in `outDimTags`. 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`, `highestDimOnly = True`, `format = ""`

        Output:   `outDimTags`

        Return:    -

`gmsh/model/occ/importShapesNativePointer`

        Imports an OpenCASCADE `shape` by providing a pointer to a native Open-CASCADE `TopoDS_Shape` object (passed as a pointer to void). The imported entities are returned in `outDimTags`. If the optional argument `highestDimOnly` is set, only import the highest dimensional entities in `shape`. For C and C++ only. Warning: this function is unsafe, as providing an invalid pointer will lead to undefined behavior.

        Input:     `shape`, `highestDimOnly = True`

        Output:   `outDimTags`

        Return:    -

`gmsh/model/occ/setMeshSize`

        Set a mesh size constraint on the model entities `dimTags`. Currently only entities of dimension 0 (points) are handled.

        Input:     `dimTags`, `size`

        Output:   -

        Return:    -

`gmsh/model/occ/getMass`

        Get the mass of the model entity of dimension `dim` and tag `tag`.

        Input:     `dim`, `tag`

        Output:   `mass`

        Return:    -

`gmsh/model/occ/getCenterOfMass`

        Get the center of mass of the model entity of dimension `dim` and tag `tag`.

        Input:     `dim`, `tag`

        Output:   `x`, `y`, `z`

        Return:    -

`gmsh/model/occ/getMatrixOfInertia`

        Get the matrix of inertia (by row) of the model entity of dimension `dim` and tag `tag`.

| Input:  | dim, tag |
| ------- | -------- |
| Output: | mat      |
| Return: | -        |

**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.

| Input:  | - |
| ------- | - |
| Output: | - |
| Return: | - |

## D.9 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, tag = -1 |
| ------- | -------------- |
| Output: | -              |
| Return: | integer value  |

**gmsh/view/remove**

Remove the view with tag `tag`.

| Input:  | tag |
| ------- | --- |
| Output: | -   |
| Return: | -   |

**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           |
| ------- | ------------- |
| Output: | -             |
| Return: | integer value |

**gmsh/view/getTags**

Get the tags of all views.

| Input:  | -    |
| ------- | ---- |
| Output: | tags |
| Return: | -    |

`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 to specify data in several sub-sets.

Input:      `tag, step, modelName, dataType, tags, data, time = 0.`,
            `numComponents = -1, partition = 0`

Output:     -

Return:     -

`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, step`

Output:     `dataType, tags, data, time, numComponents`

Return:     -

`gmsh/view/addListData`

Add list-based post-processing data to the view with tag `tag`. `dataType` identifies the data: "SP" for scalar points, "VP", for vector points, etc. `numEle` gives the number of elements in the data. `data` contains the data for the `numEle` elements.

Input:      `tag, dataType, numEle, data`

Output:     -

Return:     -

`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.

Input:      `tag`

Output:     `dataType, numElements, data`

Return:     -

`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 posi-
tive use it (and remove the view with that tag if it already exists), otherwise
associate a new tag. Return the view tag.

Input:      `refTag, copyOptions = False, tag = -1`

Output:     -

Return:     integer value

`gmsh/view/copyOptions`

Copy the options from the view with tag `refTag` to the view with tag `tag`.

Input:      `refTag, tag`

Output:     -

Return:     -

`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, how, remove = True, copyOptions = True`

Output:     -

Return:     -

`gmsh/view/probe`

Probe the view `tag` for its `value` at point (`x, y, z`). 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 `value` if `gradient` is set. Probes with a
geometrical tolerance (in the reference unit cube) of `tolerance` if `tolerance`
is not zero. Return the result from the element described by its coordinates if
`xElementCoord`, `yElementCoord` and `zElementCoord` are provided.

Input:      `tag, x, y, z, step = -1, numComp = -1, gradient = False,`
            `tolerance = 0., xElemCoord = [], yElemCoord = [], zElemCoord`
            `= []`

Output:     `value`

Return:     -

`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, fileName, append = False`

Output:     -

Return:     -

## D.10  Namespace `gmsh/plugin`: plugin functions

**gmsh/plugin/setNumber**

Set the numerical option `option` to the value `value` for plugin `name`.

Input:      `name`, `option`, `value`

Output:    -

Return:    -

**gmsh/plugin/setString**

Set the string option `option` to the value `value` for plugin `name`.

Input:      `name`, `option`, `value`

Output:    -

Return:    -

**gmsh/plugin/run**

Run the plugin `name`.

Input:      `name`

Output:    -

Return:    -

## D.11  Namespace `gmsh/graphics`: graphics functions

**gmsh/graphics/draw**

Draw all the OpenGL scenes.

Input:      -

Output:    -

Return:    -

## D.12  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:    -

**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.`

Output:      -

Return:      -

### 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:      -

### 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 = ""`

Output:      -

Return:      -

### gmsh/fltk/lock

Block the current thread until it can safely modify the user interface.

Input:       -

Output:      -

Return:      -

### gmsh/fltk/unlock

Release the lock that was set using lock.

Input:       -

Output:      -

Return:      -

### 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:      -

### gmsh/fltk/isAvailable

Check if the user interface is available (e.g. to detect if it has been closed).

Input:       -

Output:     -

Return:     integer value

**gmsh/fltk/selectEntities**

Select entities in the user interface. If `dim` is `>= 0`, return only the entities of the specified dimension (e.g. points if `dim == 0`).

Input:      `dim = -1`

Output:     `dimTags`

Return:     integer value

**gmsh/fltk/selectElements**

Select elements in the user interface.

Input:      -

Output:     `elementTags`

Return:     integer value

**gmsh/fltk/selectViews**

Select views in the user interface.

Input:      -

Output:     `viewTags`

Return:     integer value

## D.13 Namespace `gmsh/onelab`: ONELAB server functions

**gmsh/onelab/set**

Set one or more parameters in the ONELAB database, encoded in `format`.

Input:      `data, format = "json"`

Output:     -

Return:     -

**gmsh/onelab/get**

Get all the parameters (or a single one if `name` is specified) from the ONELAB database, encoded in `format`.

Input:      `name = "", format = "json"`

Output:     `data`

Return:     -

**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, value`

Output:     -

Return:      -

**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`, `value`

Output:      -

Return:      -

**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`

Output:      `value`

Return:      -

**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`

Output:      `value`

Return:      -

**gmsh/onelab/clear**

Clear the ONELAB database, or remove a single parameter if `name` is given.

Input:       `name = ""`

Output:      -

Return:      -

**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 = ""`, `command = ""`

Output:      -

Return:      -

## D.14 Namespace `gmsh/logger`: information logging functions

**gmsh/logger/write**

Write a `message`. `level` can be "info", "warning" or "error".

Input:       `message`, `level = "info"`

Output:      -

Return:      -

**gmsh/logger/start**
Start logging messages.

Input:       -

Output:      -

Return:      -

**gmsh/logger/get**
Get logged messages.

Input:       -

Output:      `log`

Return:      -

**gmsh/logger/stop**
Stop logging messages.

Input:       -

Output:      -

Return:      -

**gmsh/logger/getWallTime**
Return wall clock time.

Input:       -

Output:      -

Return:      floating point value

**gmsh/logger/getCpuTime**
Return CPU time.

Input:       -

Output:      -

Return:      floating point value

# Appendix E  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 C [Compiling the source code], page 253 (see also Appendix F [Frequently asked questions], page 315).

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.

## E.1  Source code structure

Gmsh's code is structured in several subdirectories, roughly separated between the four core modules (Geo, Mesh, Solver, Post) and associated utilities (Common, Numeric) on one hand, and the graphics (Graphics) and interface (Fltk, Parser, api) code on the other.

The geometry module is based on a model class (Geo/GModel.h), and abstract entity classes for geometrical points (Geo/GVertex.h), curves (Geo/GEdge.h), surfaces (Geo/GFace.h) and volumes (Geo/GRegion.h). Concrete implementations of these classes are provided for each supported CAD kernel (e.g. Geo/gmshVertex.h for points in Gmsh's built-in CAD kernel, or Geo/OCCVertex.h for points from OpenCASCADE). All these elementary model entities derive from Geo/GEntity.h. Physical groups are simply stored as integer tags in the entities.

A mesh is composed of elements: mesh points (Geo/MPoint.h), lines (Geo/MLine.h), triangles (Geo/MTriangle.h), quadrangles (Geo/MQuadrangle.h), tetrahedra (Geo/MTetrahedron.h), etc. All the mesh elements are derived from 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 (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 (Post/PView.h) and abstract data containers (derived from Post/PViewData.h). Data can be either mesh-based (Post/PViewDataGModel.h), in which case the view is linked to one or more models, or list-based (Post/PViewDataLis.h), in which case all the relevant geometrical information is self-contained in the view.

## E.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`.

## E.3  Adding a new option

To add a new option in Gmsh:

1. create the option in the `CTX` class (Common/Context.h if it's a classical option, or in the `PViewOptions` class (Post/PViewOptions.h) if it's a post-processing view-dependent option;

2. in 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 Common/Options.cpp (and add the prototype in Common/Options.h);

4. optional: create the associated widget in Fltk/optionWindow.h;

# Appendix F  Frequently asked questions

## F.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 or Julia 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 I [License], page 343 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 Appendix D [Gmsh API], page 259). See [Copying conditions], page 3 for the licensing constraints.

5. Where can I find more information?

   http://gmsh.info is the primary location to obtain information about Gmsh. There you will for example find the complete reference manual, a bug tracking database and a searchable archive of the Gmsh mailing list (gmsh@onelab.info).

## F.2  Installation problems

1. Which OSes does Gmsh run on?

   Gmsh runs on Windows, Mac OS X, 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 C [Compiling the source code], page 253 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.

## F.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 Mac OS X) 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 option).

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 A.8 [t8.geo], page 151 or demos/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.

## F.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 unrolled geometry in another file (e.g. with gmsh file.geo -0), 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. 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).

4. 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. demos/boolean/import.geo.

5. 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. While it can indeed export a limited subset of geometrical entities created by other CAD kernels, it's there only for debugging purposes. If you want to modify a STEP model, see the previous question.

6. 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.

7. 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.

## F.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 demos/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 A.1 [t1.geo], page 137) for a detailed description and some examples.

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 Planes' 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 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 for example demos/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 for example demos/api/faces.cpp.

## F.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 Chapter 7 [Solver module], page 75.

2. Can I launch Gmsh from my solver (instead of launching my solver from Gmsh) in order to monitor a solution?

The simplest (but rather crude) approach if to re-launch Gmsh everytime you want to visualize something (a simple C program showing how to do this is given in utils/misc/callgmsh.c).

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 solver option panel (or run gmsh with the `-listen` command line option), and Gmsh will always listen for your program on the `Solver.SocketName` socket.

Using the Gmsh API, you can also directly embed Gmsh in your own solver, and use ONELAB for interactive parameter definition and modification. See custom_gui.py and custom_gui.cpp) for examples.

## F.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->Cut Map' 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 A.8 [t8.geo], page 151 or demos/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 Planes'.

    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 G  Version history

4.5.6 (March 30, 2020): better calculation of OCC bounding boxes using STL; API tutorials; small bug fixes.

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.

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.

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.

* 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.

* 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.

* 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.

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.

* Incompatible API changes: changed type of node and element tags from int to
  size_t to support (very) large meshes; changed logger/start,
  mesh/getPeriodicNodes and mesh/setElementsByType.

4.1.5 (February 14, 2019): improved OpenMP parallelization, STL remeshing, mesh
partitioning and high-order mesh optimization; added classifySurfaces in API;
bug fixes.

4.1.4 (February 3, 2019): improved ghost cell I/O; added getGhostElements,
relocateNodes, getElementType, getElementFaceNodes, getElementEdgeNodes
functions in API; small improvements and bug fixes.

4.1.3 (January 23, 2019): improved quad meshing; new options for automatic
full-quad meshes; save nodesets also for physical points (Abaqus, Tochnog); new
getPartitions, unpartition and removePhysicalName functions in API; small bug
fixes.

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.

4.1.0 (January 13, 2019): improved ONELAB and Fltk support in API; improved renumbering of mesh nodes/elements; major code refactoring.

* 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) 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.

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; added color and visibility handling in API; small bug fixes.

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 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 H  Copyright and credits

Code contributions to Gmsh have been provided by David Colignon (colormaps),
Emilie Marchandise (old compound geometrical entities), Gaetan Bricteux (Gauss
integration and levelsets), Jacques Lechelle (DIFFPACK export), Jonathan
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Pascale Noyret (MED mesh IO), Pierre Badel (root finding and minimization), Ruth
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the sources for more information. If we forgot to list your contributions please
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# Syntax index

## H

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